Web Lines: Walker on Web Handling

2003-2014

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WEB PROPERTIES AND MECHANICS

Who Likes Film? – Jan 2005

Customers like films because they are cool. Films can be clear, thin, shiny, clean, and elastic. Product designers like films because they are functional. Films can improve a product's break strength, tear resistance, and gas barrier performance. Process people like films because…wait. Do process people like films?

Ask a process person whether he or she likes to run films or papers and many will answer "paper." The first run of a thin film on a line designed for paper will be fraught with waste—waste from scratching, winding, and wrinkling. Yikes! Maybe process people don't like films. But since customers and product designers like films, process people better figure out a way to deal with the challenges of film processing.

In many cases, films tend to be flimsy compared to the paper product they replace. Films can be as stiff as paper, but many have lower elastic modulus, especially if heated. Generally, films are smoother and tend to announce abrasion like scratches in a car's paint. On the positive side, films are less sensitive to moisture (except nylon film), and their high tear resistance (for most films) means less web breaks.

How do these differences translate into process challenges?

Film Challenge #1: Films will have more scratching and other slip-related problems. The very film properties we like in product design come back to haunt us in film handling. Nonporous means air is trapped between the web and roller. Low tension means less driving force to squeeze air out. Smooth surfaces provide less "tread" and quicker onset of lubrication.

To add to these problems, many films have naturally lower initial coefficients of friction to roller surfaces. When rollers do slip, the smooth surface and low hardness of films will abrade quickly and call attention to even the most subtle scratch.

Solution #1: Counter to the initial fear a rough roller surface will create more scratching, it will not. Slip is the cause of scratching, not roughness. Fight the anti-slip battle in two ways: Use textured or grooved rollers to maintain traction, and improve idler roller performance to spin more easily.

Film Challenge #2: Films will have more winding and wound roll problems, such as core crushing, blocking winding-induced bagginess, and telescoping. The telescoping problems are related to the same factors that cause increased slip and scratching defects.

High tension defects are more common because films tend to have a greater tourniquet effect in winding. Since films form wound rolls with relatively hard radial stiffness, there is little hoop tension relief from radial compression. Film rolls are rarely described as "squeezably soft." The reduced radial compression also will create more diameter difference in rolls after slitting, causing problems with lock shaft and shared nip winding.

Optimize tension, tension taper, and winding nip loads. Shorten roll length or increase cores size to reduce roll diameter and stress buildup. Use individual winding nips and differential winding to compensate for post-slitting diameter variations.

Film Challenge #3: Films will have more wrinkling and creasing problems. Films are not inherently more prone to wrinkles and creases, but since films usually are thinner and baggier than the material they replace, they will be relatively more prone to wrinkling.

Understand your wrinkle causes. Improve equipment alignment. Apply anti-wrinkle web path geometry and spreading rollers.

Film Challenge #4: Films will have more tension control problems. In an initial run of a new film, you may find your tension control system is sluggish, having trouble both running low enough tension and having too much tension variation. A film with lower thickness and modulus has a lower spring constant than the product it replaces.

Solution #4: Running thin films may require you to upgrade your tension feedback system, whether transducer or dancers, to work in a lower range with less noise or hysteresis. You also may need to re-tune the tension control loop gain to adjust for the lower web spring constant.

Do process people like films? Let's say they enjoy the challenges of films. If you learn to run films and overcome their process hurdles, you will gain the benefits your customers want and a competitive advantage in process knowledge. Now there's something to like about films.

The Long and the Short of Web Bending – Sept 2003

Bending a web is like bending a pencil or a wire. A little bending is no problem, but if you go too far, something will get bent out of shape or break.

Bending is defined as deforming a web by shifting it left or right relative to its centerline. Last month's column was about twisting, but relative to twisting, bending is much more hazardous to a web's health. For the same amount of roller misalignment, bending will create far greater stress variations than the same amount of twisting (perhaps 100x higher) and lead to problems much sooner.

To understand bending, try this simple experiment. Go in the kitchen and grab the boxes of aluminum foil, wax paper, and cling wrap. Cut out a strip of each about a foot long and 1–2 in. wide.

Start with the cling wrap. Hold the strip between your hands and tension it a little bit, say 1–2 lbs of tension. Feel how much it elongates (strains) under tension. Now turn one or both of your hands a few degrees to bend the web in its plane. See how far you have to misalign the ends of the cling wrap to make one side go slack.

Next, try the wax paper. Tension it, feel the elongation, bend it, and watch for slackness. You should notice two things. First, it didn't elongate much. Second, a small misalignment will make one side go slack.

Finally, let's try the aluminum foil. Tension it, feel the elongation, bend it…oops. I'm guessing you just ripped it.

What did you learn? Different webs respond differently to tension. Low-modulus webs, like the cling wrap, have high elongations at low tension. The more elongation or strain a web has decreases its sensitivity to misalignment.

Of these webs, which is strongest? There's no doubt aluminum is stronger than any paper or plastic. So why did the aluminum break so easily? The answer lies in how bending creates crossweb tension variations.

When you bend a web, you are trying to force it into a new shape, one that is longer on one side than the other. The web will do its best to deform to the new shape, stretching on the long side and relaxing on the short side. The cling wrap, with its high elongation, can conform easily to a new shape. The paper and foil, with much lower elongations, are less conforming, and at even small angles, their short side will become loose.

When the short side goes loose, the tension from that side doesn't evaporate; it shifts, increasing the tension on the long side. As the bending angle increases, the tension is carried by a narrower and narrower lane of web on the long side. When you focus a load over an extremely small area, you get high stress. In the case of the aluminum foil, the concentrated edge stress was above the critical break stress. Besides breaking a web, misaligned rollers will cause web shifting or wrinkles.

So why bend a web? Most bending is unwanted, but since we can't align equipment perfectly, some amount will happen. With proper attention to machine design, bending can be held low enough to avoid problems.

The Oklahoma State Univ. Web Handling Research Center has published several papers on when misalignment causes wrinkling. You'll find that modeling of bending and wrinkling is quite complex, but thankfully, there is commercially available software to do this math for you.

You don't need these advanced models to know how to solve most bending problems. Design your equipment so you can measure and maintain good alignment. For most processes, I recommend holding alignment to better than 2 mils/ft of width. For stretchy webs, roller alignment isn't as critical. You can't avoid bending your web, but a little understanding will help you bend without breaking.

Bending: Don't Get Bent Out of Shape – Feb 2007

Bending a web is like bending a pencil or a wire. A little bending is no problem, but if you go too far, something will get bent out of shape or break.

Bending is defined as deforming a web by shifting it left or right relative to its centerline. Last month's column was about twisting, but relative to twisting, bending is much more hazardous to a web's health. For the same amount of roller misalignment, bending will create far greater stress variations than the same amount of twisting (perhaps 100x higher) and lead to problems much sooner.

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Twisting: Twist and Shout – Jan 2007

A wrinkle is the web's equivalent of a shout—stop it, you're hurting me! To avoid your web shouting at you, think about how to apply uniform tension across it.

Most converting equipment is designed with uniform tensioning in mind by ensuring all rollers are cylindrical and parallel to a tight tolerance. The two most common exceptions to our uniform tension plan are twists and bends. If a web twists or bends too much, it will "feel" excessively high shear, compressive or tensile stresses, and it will shout at you to stop it in the voice of buckling, wrinkles, creases, bagginess, or web breaks.

Twisting is defined as deforming a web by rotating it about its centerline. Bending is defined as deforming a web by shifting it left or right relative to its centerline. For a given misalignment, bending will create far greater stress variations than the same degree of twisting (perhaps 100x higher) and lead to problems much sooner. (I'll cover bending in more detail next month.)

Twisting a long, narrow web would turn it into a helix. Twisting doesn't add tension to a web, it just shifts it around. Twisting usually is thought of as pure or symmetrical twisting where both web edges will tighten and the center gets looser. Pure twisting, with perfect left-to-right symmetry, will not induce any lateral web motion. In reality, most twisting is at least slightly asymmetrical, leading to one edge tightening more than the other and possible lateral shifting.

If twisting creates undesired tension variations and possible lateral shifts, why would we do it? Twisting is inherent in two of the most common (and useful) mechanisms of web guiding. A correctly installed displacement guide uses twisting in both the entry and exit spans. A 90-deg wrapped steering guide, the most common geometry, uses twisting in the exit span.

Twisting is used to compensate for web bagginess, such as having an end-pivot roller upstream of a nip point. Twisting is used in some simple in-line folding processes, either twisting one-half of a web 180 deg to the other half or rotating both sides 90 deg to folded contact.

In handling multiple narrow slit strands over long distances, twisting can be a useful trick to create a more compact machine layout. Bowed rollers, with their curved axis of rotation, inherently will have a small amount of web twisting.

Twisting is surprisingly gentle relative to bending. Where a typical converting process (handling 1-mil thick, 50-in.-wide polyester over a 50-in. span at 1 PLI) likely will wrinkle if the rollers are misaligned by 3 mils/ft of width, the same web likely will have no problem with a twist 100x greater or 300 mils/ft.

What is the most you can twist without problems? Traditionally, I've seen several sources that say the maximum recommended twist is the angle where the web center tension goes to zero. Assuming a pure twist and parabolic crossweb tension profile, the web edges will see a three-fold tension increase. For many thicker webs, this maximum twist or minimum span calculation is fine, but for many thin products, this criterion is too liberal.

Dr. Keith Good of Oklahoma State Univ. presented a nice paper on web twisting and wrinkles at the Fifth Intl. Conference on Web Handling (1999). He showed by theory and experiment that thin films will buckle and wrinkle at twisting angles smaller than the slack center condition.

Twist and shout? The traditional calculation of web twisting may lead you to designing and installing a wrinkle generator. Be conservative when doing the twist with your web, or your boss will be shouting about too much waste.

TENSION CONTROL

Why Tension? – Feb 2005

What is the first step of most converting processes? Tensioning the web.

When a slitter operator splices in a new jumbo roll, the smart ones will back tension the newly spliced web, taking out the slack. For more automated lines, before a line goes to "run" mode, I like to see a brief "tension" or "stall" mode, where the follower drives will pull the slack out of the web from unwind to rewind.

Why is tensioning such a crucial first step? What are the benefits of a well-tensioned web? What is the right amount of tension for your product? Don't slack off now...keep reading for these answers and more.

Why tension the web? It's mostly a matter of control. Letting the web loose is like taking your dog off leash. Some dogs will behave themselves and some will chase a rabbit into the woods. It's the same with webs. Some webs will behave themselves, especially if they have enough stiffness through modulus, thickness, width, and small curvature. Too many webs react like rabbit-frenzied dogs or sheets hanging in the wind to be left untensioned.

Tensioning the web in spans and over rollers gives stiffness and straightness not necessarily inherent in the web. Tension-induced stiffness will reduce lateral bending and shifting and improve a web's ability to resist wrinkling temptations.

How much tension is right?

Too much tension is easy to define. Don't pull so hard you will break or yield the web. Don't run at 90% of a web's break point and figure a 10% safety factor is enough. Roller misalignment, roller diameter variations, and web bagginess all are capable of create extreme crossweb tension variations.

Since these cross-web factors easily can create lanes of tension 3x–5x higher than the average tension, normally I recommend using a tension setpoint of 10–20% of the web's yield or break point. Think about how a web's break or yield stress may vary in your process. Heating polymer films will depress their elastic modulus and yield points. Drying paper and poor edge quality will mean breaks at lower tensions.

Too little tension is more difficult to define; it varies by your process needs. If your web needs to go through nipped rollers or lie flat through slitting, you should tension the web enough to pull out the web bagginess. In long horizontal spans, tension is needed to reduce excessive catenary sag. Tension is needed to overcome idler roller force demands, such as roller drag, inertia, and any web-roller bonding forces.

These roller factors really start adding up (or subtracting) when you have a zone with ten or more rollers. There is a minimum tension needed at every undriven roller to keep it turning. Having more than enough driving force from tension, traction coefficient, and wrap angle to overcome a roller's opposing forces is what I call the Traction Safety Factor.

How will uniform tension benefit coating and laminating? Most coating processes are a precise metering of another material onto the surface of the moving web. It's obvious that good speed control is required to get the right ratio of web to coating, but the importance of uniform tensioning often is missed. A web can have perfect, slip-free bond to a coating backup roller but still have web control coating variations. If the incoming web is tensioned to 1% elongation, a 20% tension swing equals to a 0.2% speed change and coating variation in the final product.

Proper tension control at laminating is hard to see while the web is running, but curly, scroll-forming samples will show quickly when the proper laminating strain matching is messed up.

How important is tensioning and winding?

Tensioning each wrap as it goes onto the roll creates the internal pressure and friction that is just right to hold the roll together. Too little tension and the roll package easily falls apart or sags excessively. Too much tension and the core or roll's inner layers are crushed. Too much torque applied to the center of the roll, and the whole thing may begin to shift tangentially like a giant clock spring, leading to crepe buckles or telescoping.

Whether center or surface winding, tension doesn't have to do all the work in creating roll tightness. If you have a loaded nip roller, a significant amount of roll tightness can be created by the nip-induced tension independent of handling tension. Why tension? To control lateral position and keep the web flat; to avoid breaking, yielding, wrinkling, and scratching; to have quality coating and laminating; and to make good rolls.

My advice to all converters: Don't be slackers—keep your web tensioned and don't let go.

What is the Right Tension? – Dec 2009

Of all the questions about web handling, the most-asked question has to be: “What is the right web handling tension for my product?” This is a great question and one of the first things that needs to be determined to design tensioning, rollers, and structural elements of a converting process.

If you conduct a poll on tension across the converting industry, the leading vote-getter among tensions likely will be 1 PLI or 1 lb/linear in. of width. (This means a 50-in.-wide web runs at 50 lb total tension, a 12-in. web runs at 12 lb, and so on).

If you tally up this imaginary poll, you will find 80% of webs run between 0.3 and 3.0 PLI, and 95% of processes are happy between 0.1 and 10 PLI. But survey results or rules of thumb will only get you so far and must have some origin in engineering. Why would 1 PLI be right for you? When should you consider going up or down from the starting point?

The engineering root of the “right tension” for your web starts with the mechanical properties of your web. Most webs can be considered elastic, meaning they will snap back to their original dimensions when tension is removed.

Find the yield or break points in terms of stress and strain from tensile-elongation testing. Find the yield point (or break point in brittle webs) of your product. Define this “bad” tension in PLI/product, psi, or strain, and stay below it.

Most tensile-elongation tests are completed under reasonably controlled temperature and humidity with well-cut samples. Beware of process factors that can change your product's yield or break point dramatically.

Yield stress drops when heating thermoplastic webs, when super-heating foils, and when paper moisture content is high. Break points drop with poor slit edge quality or when edges are nicked or damaged. Poor splices may break or fail much sooner than the web itself.

Once you find the damage tension or elongation, where should you set your process tension? A good starting point is 10%-20% of damaging condition or a 10:1 or 5:1 safety factor.

Why is such a large safety factor needed? It's not that your tension control system will have wild variations from the tension set point (though a 20% swing from set point isn't unusual). The problem is variations from average tension in both the machine and crossweb direction.

Tensions in a web line vary like temperatures in a home. Tension will vary crossweb from roller misalignment, roller diameter variations, web bagginess, and misaligned splices. Tension will vary in the machine direction from gravity or roller drag and inertia losses. Feel free to live closer to the danger point with a lower safety factor if you have a narrow web, low bagginess, well-aligned/low-drag/low-mass rollers, or a limited number of rollers in a tension zone.

There are many cases where your process or problem solution means going to higher or lower than normal tension. Use low tension to let wrinkles slide out and reduce excessive wound roll tightness. Use high tension to avoid scratching and slip, pull out wrinkles, and increase roll tightness. Go lower or higher tension to match strains at laminating. Look out for processes like nipping or coating that can put extreme stresses or drags on your web.

For laminate webs comprised of many layers, you should consider the yield or break point of each layer. It doesn't matter if the polyester film survives tensioning if the metallized coating on it cracks and crazes into an esthetic or nonfunctional mess. Like many web handling problems, think about the strain or stretch that causes problems and set tensions to avoid over-stretching.

So what is the right tension? As with most simple questions, the answer is complicated, but there is an answer. Start with tensile-elongation testing; be sure to look at not just the break data but also yield points. A proper tension safety factor will ensure the web will get through your process no worse for wear (or tension).

A Look at Stress – Sept 2003

Do you work well under pressure?

How you react is dependent on the level of pressure or stress exerted on you. How your product reacts to pressures or stresses also will depend on the stress level it feels.

Typically, we think about external loads as applied force with units of pounds (or newtons). However, to predict a material's response, all external loads must be converted to pressures and stresses in units of pounds per square inch (or pascals, 1 psi = 6.9 kPa).

Pressures and stresses, whether 10 or 10,000 psi, are not an intuitive variable to most people. We all may be able to imagine what a hit from a 250-lb linebacker would feel like, but what about 250 psi? Answer: That same linebacker standing on your big toe. Let's take a tour through increasing pressure events to improve our intuition.

Less than 1 psi — This is like a pat on the back or someone pulling your leg. In either case, the pounds applied are less than the cross-section area in square inches.

A tensioned web pulled over a cylinder generates low pressure. These pressures are so low that modest velocities of air can offset the tensioned web's pressure, such as on air turns or the top layer of a winding roll.

1-10 psi — Standing flat-footed, the floor will feel this pressure under your shoes. Gently pulling your dog away from the fire hydrant, the leash will feel this in tensile stress. Pressures and tensions in this range will begin to exert a cooperative force on something.

The pressure under a low-level winding or laminating nip will average 1-10 psi. This level of tension is created in an untensioned, hanging loop of web.

10-100 psi — Basketballs and car tires are at the low end of this range. Pulling your finger enough to crack your knuckle or hanging by one arm will create this level of average tensile stress.

Winding nips that significantly increase roll tightness or moderately high laminating or coating nips create this pressure in their footprint. The internal layer-to-layer pressure in paper rolls usually will be at the low end of this range, while films and low modulus materials will be at the high end.

100-1,000 psi — At this point you are deforming solids significantly, except the highest-modulus materials. One to three people hanging from a rope will create this level of tensile stress.

This is the typical range of most web handling tension. A paper calender or film embossing nip likely creates this level of footprint pressure. Exerting 100 PLI nip load over a 0.5-in. MD contact length will create 200 psi nip pressure.

1,000-10,000 psi — A compressed oxygen cylinder will hold 2,000 psi. Great safety precautions are taken in handling these tanks since, potentially, they are explosive. When you break off a sales tag, you create this level of tension in that small string of plastic.

To create this level of pressure, you are exerting a load over an increasingly small area. To average 5,000 psi in a nip would require 500 PLI over a 0.1-in. contact length, best achieved with a steel-on-steel nip. The low end of this range is high tension for papers and films.

Greater than 10,000 psi — These stresses require seriously high load and miniscule contact areas. You are crushing and breaking stuff. When you stomp on a beer can or use scissors, you are creating the level of stress to fracture and buckle solid materials.

Paper supercalenders greatly change the quality of paper using this solid deforming pressure (and temperature). All slitting or cutting methods are designed to create these stresses in the web, whether from the sharp edge of shear or razor blade or the tips of a crosscut knife.

We have to be from the planet Krypton to go any further. To better understand the stresses in a web's life, remember to think about area supporting an external force. The difference ranges from a pat on the back to Superman's handshake.

What is a Tension Zone and How Many are Needed? – Jan 2010

Tension and speed control are the two most fundamental purposes of any web handling system. Speed control is easy for most people to understand, since they practice speed control every time they press the accelerator or brake in their car, but tension control is not as intuitive.

To make things more complicated, where a web line typically has one speed set point, there may be two, three, or even 15 tension set points in a line. For each of these tension set points, it may not be obvious how or where they are controlling tension.

When talking about multiple tension set points, the term “tension zone” usually is used to answer the “where?” question. But what exactly is a tension zone?

A tension zone is a section of a web line between any two torque or speed controlling devices where the tension is set by design or by control. Torque or speed controlling devices typically include motors, clutches, and brakes.

To count the number of tension zones in your process, start at the unwind. Follow the web path through the system, and count the number of times the web wraps a roller (winding cores count as a roller here) that is connected to a motor, clutch, or brake.

The number of tension zones will be the total number of speed and torque contact points minus one. If you have a braked unwind, one drive roller, and a clutched windup, you have three speed or torque controlling devices and two tension zones (three minus one is two). If you have a driven unwind, five driven rollers, and a driven winder, you have six tension zones.

Why is there one less tension zone than speed and torque controllers? It takes two devices to pull on the web and create tension.

The Zen koan asks, “What is the sound of one hand clapping?” The Zen converter asks, “What is the tension of one drive pulling?” The answer to both is nothing. Just as you can't clap without one hand opposing another, you can't tension a web without one device pulling against another.

Each tension zone will have one device controlling tension. In a braked unwind, the brake torque divided by the roll's radius sets the unwinding tension. (We are ignoring mechanical torque losses and inertial effects here.)

Question | If we have X number of devices and (X-1) of tension zones, what is the function of the extra device?

Answer | It is the process pacer or master speed controller and therefore doesn't care about tension.

If you use this definition to count the number of tension zones in your process, don't be surprised to find you have more tension zones than the equipment control panel or operator's manual says there are. The most common “undocumented” tension zones are the short section of web between two speed controlled rollers, rollers that are considered in speed ratio or draw control and may or may not be adjustable by an operator.

Some examples of undocumented tension zones include the following:

In a printing press, the backup rollers are all speed controlled and set a nearly 1:1 speed ratio.

In a section where multiple rollers are driven with one motor, such as an S-wrap pull roller, or the driven rollers in the middle of a slitter/rewinder.

When driven properly, these sections are easily ignored, but when the surface speed ratios are off by improper gearing or unintended diameter changes, understanding that these are tension zones can help diagnose and solve a problem.

Since many webs are sensitive to speed changes as small as one tenth of one percent, documenting each tension zone, no matter how small, and keeping them in control is as important as the known and obvious tension zones.

Mapping Your Way to Better Tension Control

Web handling defects often can be traced back to a specific location in your web line. Web tension at that location is always a prime factor in understanding defects. Just like a road map is a useful tool to help understand where we are and how we got there, a tension control map describes how tension is created and controlled at every point in a web line.

To map a line's tension control, we will create two documents: a tension control device diagram and a tension zone table.

Start with a web line elevation drawing. If one isn't available, we will need to create one. This drawing doesn't have to have every roller or span, but we will want to lay out the general web path and show the location of tension control elements.

Take notes during a web line tour. Mark all the drive points and tension feedback devices on the elevation diagram. Web drive points include rollers or belts coupled to motors, clutches, or brakes. Tension feedback devices include tension transducer rollers and dancer systems. A dancer is usually a pneumatically loaded roller but also may use a vacuum box or web sag sensor.

Start at the beginning. For roll-to-roll processes, start at the unwind. If the web line starts with a film, paper, or nonwoven maker, then start at the first point where web tension is applied.

Follow the web. Walk the complete web line, following the web around every turn. If the web ducks into an oven, underground, or overhead, find where it comes out and what the web does while out of sight. The tour ends when the web is accumulated in a winding roll or no longer carries tension.

This diagram, showing drive points and feedback devices, is the first part of the tension control map.

Create the tension zone table. A tension zone is the section of web controlled between two driven points. The tension zone table should have four columns for the zone name, the input and output drive points, and the zone's control method. The first tension zone will be between the first and second drive points. Continue the table with a row for each zone. The total number of tension zones is one less than the number of drive points.

Identify the tension control method used in each zone. Start at the pacer roller. (If needed, ask the controls group which drive point is the pacer.) All the tension zones will cascade upstream or downstream away from the pacer.

For each zone, identify which of three control options is employed (tension, torque, or draw control). A closed loop tension controlled zone, the most common, would have a transducer or dancer between the input and output drive points. Torque control zones would have a clutched or braked drive point with no tension feedback. Draw control is defined as controlling two consecutive drive points by speed without tension feedback.

Review the tension control map with the web line design groups. When complete, don't hide the map; post it for everyone to see and use.

Creating the map is the first step in understanding your web line and thinking about ways to improve it. The tension control map will prove a valuable tool in problem solving, training, and line-to-line comparisons.

A good map may not keep your tension on course, but it should help put you on the road to improvement.

Well Done Tension – Sept 2002

I'm in love with a new gadget that makes cooking easier. It's the electronic temperature probe. These have been available for manufacturing applications for years, but now are inexpensive enough that you can find them in most kitchen stores.

I use mine for both oven cooking and out on the grill. The probe gives me a continuous readout of the meat's status. When the meat hits the temperature equal to medium rare or well done, the direct temperature measurement tells me. For chicken, the probe provides confidence the inside temperature has killed off bacteria without overcooking.

My father is from the old school of grilling. Over years of experience, he knows just the right burner setting or quantity of charcoal. He knows how many minutes to cook per side based on thickness and cut of meat. His method works great for him, but without his skill and knowledge it's difficult to reproduce. My direct measurement method easily allows me to repeat perfect grilling time after time.

Cooking is possible without temperature measurement. Clearly more fuel equals hotter temperatures. But without temperature measurement, we are simply adjusting an input variable with no feedback. Most ovens measure air temperature and reasonably infer that it is a good indicator of the cooking conditions. Indirect measurement is better than no measurement, but still not as reliable as direct measurement.

In cooking steaks, I know what I like and direct measurement lets me get there repeatedly.

I'm also in love with an old gadget that makes web handling easier. It's the tension-measuring roller. There are a couple old designs and some new technology, but measuring web tension via roller shaft load is not new.

I think tension-measuring rollers should be used in all web line tension zones. Tension measurement provides continuous readout of the web's running tension. When does the dancer air pressure create the desired tension? The direct tension measurement shows it.

Is measuring web tension important? Like cooking temperature, there's an optimal tension for different webs and processes. Setting tension correctly matches the strains to make curl-free laminate. Balancing the web tensions across driven rollers reduces the chance to slip and lose speed control. Pulsing tension will indicate eccentricities or transmission problems that create coating bar marks. Direct measurement of tension easily allows you to repeat perfect web handling time after time (or at least show when you've got it).

Tensioning a web is possible without tension measurement. Clearly more brake torque, higher dancer pressure, or more machine draw will increase tension. However, running a web line without tension measurement is like cooking without temperature measurement.

Web handling, unlike cooking, doesn't always provide immediate feedback. Did that roll wind with the right tightness? In cooking we eat our results and know immediately if we have over-cooked the steak. In web handling, we may have over-tensioned a roll or scratched yards of product, but we won't be eating the bad results until our customers send it back. This delayed feedback can lead to a lot of burnt steaks (bad rolls).

In web handling, I know what I like and web tension measurement lets me get there repeatedly. Use direct measurement in cooking and web handling for great steaks and webs well done.

Dancer Rollers: Trust But Verify – Nov 2006

In last month's tension quiz, I gave out five points if your process had a calibrated tension transducer roller. Those of you with dancer rollers might have wondered why you didn't get any points. Why am I "dissing" dancers?

I like to know my web's tension, and dancer rollers don't tell you what the tension is or how much it varies. A dancer roller is not truly a tension feedback device. It doesn't rise or fall because the tension is too high or too low. Dancers respond to errors in the speed ratio of the input and output web drives.

Besides not telling you what your tension is and how much it's varying, the other big disadvantage of a dancer roller is that it will create tension variations. Every dancer roller has some resistance to motion, including friction and inertia (both translational and rotational). Tension decreases while accumulating and increases while dispensing.

So why are dancers popular? Dancers can accumulate or dispense, keeping tension variations low during speed-varying events such as out-of-round rolls, accelerating, uncoordinated drives, turret winder indexing, and transitions of zero speed splicers. In a dancer-controlled tension zone, if the input web speed is 0.2 in./sec (1 fpm) faster than the output, the dancer will accumulate the difference, collecting 1 in. of web for every second the speed differential exists. If a 0.2-in./sec speed differential occurs in a transducer roller zone, the web quickly will become slack or the tension will spike high.

Every time I see a dancer without a transducer roller in the same zone, I immediately start to calculate the web tension from geometry and air pressure. In many processes, the control panel may say you are setting the web tension, but in a dancer zone, all it really is controlling is the air pressure to the dancer assembly cylinders. You believe the control panel display for dancer tension if you trust the equipment designers and programmers.

Here are the easy steps to estimate how the air pressure supplied to a dancer roller system creates web tension:

Calculate the total area of the air cylinder(s) (e.g., 5 in.2 times 2 cylinders is 10 in.2

Calculate the total air cylinder force output at 10 psi of air pressure (e.g., 10 psi x 10 in.2 = 100 lbf).

Multiply this value by the dancer arm length and divide by the distance from the air cylinder to the pivot point (e.g., in this diagram, the leverage ratio is 1:2, so the effective cylinder force at the roller is 100 lbf x 0.5 = 50 lbf).

For vertical dancers, add the roller's weight to the leverage cylinder load (e.g., if the roller weight is 30 lbf, the combined roller load on the web is 30 lbf + 50 lbf = 80 lbf).

For 180-deg wrapped, the two webs pull against the one roller, so web tension will be half of the combined roller load (80 lbf/2 = 40 lbf).

As you change the air pressure supplied to the dancer roller, the tension will be found by T=(5P+30)/2, so for 30 psi the tension would be 90 lbf and 70 psi would create 190 lbf of tension. How are dancer rollers like the old Soviet Union? I'm with President Ronald Reagan on this one. "Trust but verify."

A Wealth of Accumulators

A good accumulator should be like money in the bank — easy to deposit and readily available to withdraw when you need it. A web accumulator is like a bank, a safe place to keep extra web in a buffer between two sections of a web line running temporarily at differing speeds.

Most accumulators are found at either end of a web line, buffering between the main constant speed process, such as coating or printing, and the stop-start processes of splicing at the winders. For intermediate stop-start processes, such as non-rotary stamping or heat sealing, you will need two accumulators — one each to buffer the input and output speed differentials. Accumulators also can be used just for threading up a long web path tank or oven process.

Accumulators store anywhere from a few inches to hundreds of feet of web by moving one or more rollers relative to other fixed position rollers, increasing or decreasing the length of the web path between points A and B. A dancer roller system is a small web accumulator designed to collect and dispense web tension control delays. While a dancer system usually moves just one roller, most accumulators will move two, five, or tens of rollers to create the required path length differential.

To calculate the required storage capacity of your accumulator, multiply line speed times the sum of deceleration (or acceleration) time and the required time at zero speed. If you need to stop an unwinder running at 100 fpm with a deceleration time of six seconds and require 30 seconds to make a splice, then you need an accumulator with 60 feet of storage (100 fpm × 0.6 minutes). This accumulation could be met with a six-roller accumulator in which each roll translates five feet, accumulating and dispensing ten feet of web each.

If you increase your line speed, your accumulator size must increase proportionally. When the calculated accumulator size becomes unreasonable, you have two options:

Reduce the accumulation times further with faster accel/decel rates and shorter zero-speed processes (such as automatic splicing);

Avoid accumulation altogether and upgrade to an at-speed splicing system or rotary process.

Regarding accumulator design options, most favor vertical over horizontal motion to avoid problems of catenary sag. Linear motion is more common than pivoting, though this leads to many problems of misalignment, wander, and wrinkling during their translation.

Try to include mechanical design features that will hold a tight alignment during translation. For dispensing buffers, wait until just prior to the dispensing need before filling the buffer to minimize time of running with the long accumulated web spans.

Some accumulators have an ease of threading feature in which the bottom rollers are able to rise above (and between) the top rollers. This allows a simple manual threading, using the accumulator's motion to create the complicated serpentine web path.

Controlwise, most accumulators are simply multiroller dancer systems, loading the web with the combined forces of gravity and pneumatic loads with position feedback to close the tension loop. More sophisticated systems drive the accumulator position, using feed-forward to position the accumulator relative to input and output process speeds, and using a dancer or tension roller to close the tension loop.

Accumulators with a large number of rollers may see scratching or width-variation-induced wrinkling during the tension swing from drag and inertia. Both low inertia rollers and reducing line speed just prior to splicing will help.

The correctly designed accumulator should be like a bank in another aspect: Both should give back your deposit with at least equal the value from when you put it in.

Drawing Conclusions: Part 1 – May 2005

In planning the tension control for any web line, there are only three options: tension control, torque control, and draw control. Between any two rollers or rolls controlled by a motor, brake, or clutch, you have to select one of these three choices.

The most advanced of these options is closed loop tension control. Torque control is the easiest option when tension is created by a brake or clutch. The third option, draw control, is the open loop alternative to tensioning the web between two speed-controlled rollers.

What is draw control?

Draw control is simple. Any time you drive the web with two or more rollers, you have draw. Each driven roller can have its own motor or share a motor using a timing belt, chain, or line shaft. Driven rollers in draw control work as a team. They speed up together, slow down together, and they don't necessarily care what the web is doing. Remember, draw is a machine property. The web goes along for the ride.

What determines draw in converting equipment?

In many machines, the draw is a fixed value. The machine designers determine the draw by selecting gear ratios and roller diameters. Many slitter/rewinders and line-shafted presses drive two or more rollers with one motor. Each driven roller's rpm is determined by motor speed and the gear ratio of the motor to the rollers. The rpm turns in to a surface speed depending on the roller's circumference.

Some machines have a programmable draw, allowing you to dial in the ratio or percent draw between driven sections. Closed loop tension control using pacer and follower driven rollers also will use draw, but the draw will be moving up and down to satisfy the tension trim control loop.

What is the relationship between machine draw and web strain?

Draw is a machine characteristic. Often it is confused with strain, which is a web property. Draw and strain both can be described in percent, but where strain is always relative to zero strain; draw can be relative to any initial speed. An untensioned 10-in. web sample stretched 0.1 in. has a strain of 1%. Given two driven rollers, if the first is driven at 100 fpm and the second at 101 fpm, this is a draw of 1%. For larger draws, it is more common to talk about a draw ration. If two sections are driven at 100 fpm and 300 fpm, such as in length orienting film, the draw ratio is 3:1.

How does draw control create strain?

Here's the crazy part about draw control. As simple as it is to design, how it creates strain and the corresponding tension is confounding. Let's see if I can demystify it.

Imagine a machine section with two driven rollers, the first at 100 fpm and the second at 101 fpm. The draw is 1%. What will be the steady-state web strain in this draw zone?

If you run an elastic web through these two rollers, you would be correct to assume the web will be stretched 1%. Yes, but stretching 1% doesn't mean the web has 1% strain.

The initial condition is critical to knowing the final strain. If I stretch a relaxed rubber band 10%, the strain is 10%. But if I stretch it another 10%, the strain will be 20%. Draw control is a similarly additive process. The draw or stretching will modify the entering condition.

Asking you to predict strain from draw is a trick question. I can't estimate the draw zone strain unless I give you three values: the speeds of both roller and the strain of the entering web. So let me ask the fair question. Let's say the entering web is strained 0.5%. Now can you tell me the tension? Hmmm. It starts at 0.5%, we stretch it 1% more for total of 1.5% strain. Correct? Yes, 1.5% strain is the anticipated steady strain in the draw zone.

That was a qualified "yes." I chose my words carefully. To truly know draw zone strain, we need even more information. Why? Because draw zones have a time constant that determines how quickly the draw conditions will get to steady state or respond to changes in upstream strain or roller speeds.

Drawing Conclusions: Part 2 – Jun 2005

The principles of draw control usually create a good deal of confusion. Let's pick up where we left off in my last column and see if we can move from drawing confusions to draw control conclusions.

I set out a scenario where I asked you to predict the web's strain in a draw zone. I eventually gave out three data points: the web speed at roller #1, the web speed at roller #2, and the strain of the web at roller #1. This info is enough to determine the system's eventual steady-state condition, but without knowing the initial strain in the draw zone and the time the system has been running, this still isn't enough information to know the draw zone web strain.

How are draw zones time-dependent? The draw zone's time constant is equal to the web length between the first and last draw-controlled rollers divided by the web speed. When any condition in the draw zone changes, it takes 3x the time constant to move 95% of the way to the new steady-state condition.

For example, a printing press with 50 ft of web from the first to last print station and running at 200 fpm has a the time constant of 15 sec (50 ft/200 fpm). If the input web tension (and strain) is changed, it will take 45 sec for the change to feed through the system.

I've seen operators chasing their tails after changing the infeed tension. They try to keep the multi-station press in registration before the draw zone reaches a steady state. At 45 sec, this isn't a long wait, but if the press is running at low speed, say 50 fpm, then you have an agonizing 3-min wait before you see the registration return.

This time delay is the biggest negative of draw zones. Where closed loop tension control and open loop torque control will get to their steady state quickly, draw zones take time. This is like waiting for the hot water to get to the shower head in the morning. Your shower would continue to act like a draw zone if the hot and cold knobs adjusted the flow 30 ft. away. Each adjustment would require purging the entire pipeline before you felt the new temperature.

Draw zones also are poor in handling slack webs. Since web strains and draw zone percentages often are less than 1%, if the slackness in a draw zone is 5% of the zone length, it will be some time before the excess material is purged.

Why is draw control used? Draw is a great way to limit or control the stretch of your web. For nonwoven, crepe paper, and low-modulus films, applying too much tension will stretch the product beyond its elastic limit. Even high-modulus materials such as polyester or steel will be best handled in draw control when their temperature weakens their mechanical properties.

If you have a series of driven rollers, think about the draw of each roller relative to the first driven roller—what I would call the total draw. Having a small 0.5% stretch between driven rollers doesn't seem like much until you do it ten times for a 5% stretch that yields or breaks your web.

What creates tension variations in a draw zone? Asking this question may be missing the point, since draw control usually is intended to control strain, not tension. But since draw control is used in tension control, it's worth talking about how strain becomes tension.

All the variables reviewed so far (speeds, initial strains, time) will lead you to the draw zone's web strain. To find tension, multiply the strain by the web's modulus. Is the modulus constant? It would be nice to say "yes," but material properties change from moisture, temperature, cross-linking, strain rates, and the big wildcard—viscoelasticity. In many processes, the web's response to strain will be predictably elastic, but be on the lookout for unusual mechanical properties and the resulting drawing confusion.

What are the most common applications of draw control? Small draws are common for any multi-roller driven sections (presses, slitters, small-wrap over rollers, and unnipped pull rollers) and for low-modulus or easily yielding webs. Large draws are used for film orienting and for separation after sheeting.

I hope I've cleared up some of the most common misconceptions and confusion of draw control. Draw your own conclusions on whether draw control is right for you.

Do You Have a Need for Speed? – Oct 2008

Faster, faster, faster. As you reach the designed capacity of your existing process, before buying new equipment, most converters will ask if they simply can increase speed to get more capacity and profitability. In an effort to increase profits everywhere, here is a checklist of what to consider as you think about moving to higher process speeds.

How fast can you drive a roller or roll? Theoretically, there is no limit to how fast you can drive a roller or roll. (Don't you brace yourself anytime a point starts with the word “theoretically”?) Motor speeds typically are maxed out at 1,750 or 2,000 rpm, but line speed is rpm times roll or roller circumference and can be magnified with gearboxes or pulley-belt systems to get as much surface speed as you want.

As you move to extreme rpms, you will need to bulk up your bearings, couplings, rollers, and other components to handle the speed increase. Just as an automobile can be designed to set land-speed records, a web line can be beefed up to meet just about any challenge. However, you likely already have a web line, one that was designed for a given maximum speed. Simply changing the gear ratio doesn't mean your line will function properly at high speeds any more than turning your '65 Chevy Impala into a hot rod will survive your drag racing dreams.

In the paper industry, where speeds of 5,000, even 12,000 fpm are not unusual, critical speeds of all rotating elements must be addressed. Most web handling processes never will need to consider the critical speed of a roller, winding shaft, or core, but if you do, balance and deflection play strongly into what speed a rotating element will begin to whip and uncontrollably vibrate or buckle. You don't ever want to see your rollers or cores beyond their critical speed because they will actually explode.

So far, we've addressed equipment issues; what about the web?

Air drag may create too much tension drop. Baggy webs may begin to flutter and tear apart like a flag in a hurricane. Entrained air pulled along by the moving web, roller, or winding roll will grow beyond the web or roller roughness. Too much air lubricates web-roller contact, reducing the traction to drive the web and idler rollers or hold the winding roll together. Too much air entrained in the winding roll will bleed out slowly over roll storage time and turn a tightly wound roll into a loose structure impossible to transport or unwind.

Beyond the web-only issues, the more likely limit to increasing speed will be your processes. Your extrusion or coating system is limited in pound or volume per hour. Your drying or curing process requires time, so your process doesn't have enough length-to-speed ratio to get the job done. Heating, cooling, and moisturizing all may be time or length-to-speed limited.

Web handling systems and components also may be speed averse. Web guides will have increasing following error as lateral offset occurs over a short time. Rubber-covered rollers generate heat due to hysteresis and need convective cooling, so high speed turns rubber coverings into goo. Clutches, brakes, and differential winding shafts generate heat proportional to the differential speed. At high speeds, these components won't have enough convective cooling, leading to thermal expansion and failure.

The last consideration is operational issues. With increasing speed, unwinding rolls run out faster; winder roll transfers happen more frequently; start-up and winder indexing waste will increase; quality sampling inspection will see a smaller percent of your product; and 100% inspection systems will have to work harder.

Beware of the plan to increase speed, because as the old joke says: We're losing money, but we'll make up for in it volume.

A Rant from Tim Walker – Dec 2011

Dear Equipment Builders,

I am writing to file a formal complaint.

Would you buy a car in which, instead of speed, the dashboard displayed only fuel consumption or motor rpms? When the police officer pulled you over for speeding, you could say: "I was only burning 0.12 gallons per mile," or "My motor was only turning at 150 rpms."

This would be great if we all drove the exact same car, but the relationship between gas consumption and rpms will differ from car to car to truck to tractor. That's why the dashboard reads miles per hour.

But, my dear equipment supplier, when you get out of your car and get to the office or shop floor and build your winder, slitter, or nipped process, this concept of displaying the process variable that is critical to running successfully seems to get lost. Please, please, could you please help me understand how your equipment creates force in winding and nipping processes?

What am I specifically talking about? Winder torque set by air pressure, winder torque set by motor amps, winding contact rollers controlled by air pressure, unwind brakes controlled by air pressure, unwind brakes controlled by amps, nipped roller controlled by air pressure, and anything controlled by a mysterious percent or zero to ten knob.

You know who you are, giving me an operator control panel with pressure gauges and motor currents. That is so 1970s. When I ordered the equipment, we talked about my winding tensions in force and nipped processes in terms of nip load (pounds or pounds per width, maybe kilograms or newtons). With our requests, you made some calculations to figure motor or clutch size and air cylinder diameters and leverages. It was all engineered with a force of tension, level of torque, or force of nipping.

But then when you were done with your calculations and sized all the appropriate components, well…you closed your file. Then, when it was time to design the operator panel, you somehow spaced out that forces and torques were ever considered. You gave me this knob or display for air pressure or current. To this, I sarcastically say—thanks so much. That makes everything so perfectly unclear.

So I now have two winders: one from supplier A we bought in the 1980s and one from supplier B we bought in the 1990s. We also have two slitters, one from supplier C and one from supplier D. How am I supposed to explain to my operators that 40 psi and 10 amps are the same when you move from one machine to another? Wouldn't it have been nicer if you would have done the math for us and provided either an operator control panel that controls winding tension and nipping in terms of force, not air pressure and motor amps?

What is the motive for this? I don't think it is just laziness or ignorance. In some cases, at least 20 and 30 years ago, it was a cost decision. Adding a multiplier to make a display proportional to load was cost prohibitive. Though that doesn't explain why your operations manual couldn't have included a chart or equation to let us work out the air pressure to load relationship or what torque you expect from that motor current setting. Was it that you didn't want your equipment supplier competitors to know? If so, they followed your lead and didn't give us the operator panel we need either.

What? You'd like to make it up to me? Okay. Can you make the following pledge? From this day forward, every machine I make will include one of the following:

A display, graph, or equation of what torque or tension I expect from the motor or clutch amps or air pressure

A display, graph, or equation of what force I expect from nipped process air pressures

Now, that wasn't so hard, was it? I'm not hard to please. Umm, one more thing: Could you send me this info for the slitter I bought In 1987?

Web Tension: A Pop Quiz

Today's column is a pop quiz on web tensioning. Feel free to work as a team on the answers. If you score poorly, don't worry, but it's worth your while to do your homework and work toward getting the answer right.

Step 1: What is your web's tension? (5 points and possible 5 points extra credit)

What is your web's tension? Hands down, this is the most important web tensioning question, but surprisingly few will have the answer. If you have a calibrated tension sensing roller in your process, congratulations, give yourself 5 points. However, if you control your process with torque from a brake or clutch, if you control tension with a dancer roller, if you control tension with a speed ratio, if you set tension in percent of anything, or you set it by air pressure, mark down 0 points, but I'll give you a chance for partial or extra credit.

Options for extra credit: Have you calibrated your clutch or brake, or used a force gauge to measure the performance of your clutch, brake, differential shaft, or dancer roller? (3 points) Have you calculated the likely change in web tension from your speed ratio or draw setting from web thickness, width, and modulus? (2 points)

Step 2: How does your product react to tension? (5 points)

Do you know your product's break or yield point in terms of tension and elongation? (2 points) Do you use this data to set your product's web handling tension, running your products with tension proportional to their width, thickness, and modulus, web's spring constant, yield point, or break point? (2 points)

Super special extra credit: Have you measured your product's modulus as a function of temperature, moisture, or strain rate, or have you measured the effective modulus of your coated or laminated product? (1 point)

When anyone asks me what the right tension for their product is, I send them off looking for modulus, yield, and break data. My advice is always to start with a tension of 10%-20% of the product's trouble point, which is usually yield or break. Think of tension in terms of stress and strain. In general, tension will double each time you double the width, thickness, or modulus. There is a diminishing need to increase tension proportionally as the product has natural stiffness, so a tenfold thickness increase likely won't need a tenfold tension increase.

Step 3: Bonus round (possible 10 points)

Do you prefer unnipped or vacuum drive rollers over nipped drive rollers? (1 point) Have you used the belt equation to figure the tension ratio of an unnipped roller? (1 point) Have you measured friction of your various webs to the drive roller surface to estimate the tension change that would cause slip? (1 point)

Does your winder and unwind tension control include inertia compensation (where the drive tuning is adapted to changes in width, diameter, and density)? (1 point)

Do you minimize the use of dancer rollers, only using them between drive points with anticipated relative speed variations? (1 point) Have you designed your dancers to have minimum friction, inertia, and pneumatic hysteresis? (1 point)

For speed-controlled tension loops, do all your drives share a line speed reference from the pacer or lead section? (1 point)

When writing specs for new equipment, especially winders, do you take time to calculate your minimum and maximum torque requirements? (1 point) Do you include torque to accelerate or decelerate large rollers or wound rolls? (1 point) If your torque range (max/min) is more than 30, do you figure how to make concessions to reach a reasonable torque range, including taper tension? (1 point)

REPORT CARD

0-5	Summer school anyone?
6-10	Better bring an apple for the teacher!
11-15	Most excellent.
15-20	Your web likes you.
>20	Certified web tensioning guru.

ROLLER DESIGN

The Great Span Debate: Part 1 – Mar 2009

What is the best span length? How far apart should rollers be? Is there a good rule of thumb on span length, such as "span lengths should be less than one (or one and a half) web widths?"

Whether this rule sounds good to you will depend on the webs with which you work. For a 60-in.-wide web, one roller every 60 in. or one every web width seems reasonable.

For paper or polypropylene film makers working with widths that can be more than 20 ft, having a roller every 20 ft is not reasonable. For narrow web handling, such as 2-in. wide tapes, it would be ridiculous to require a roller every 2 in.

There are at least half a dozen things that come to mind in the great span length debate. Let's review the checklist to figure out what span length is right for you.

Costs (since rollers don't grow on trees)

A 3-in.-dia roller can cost from $5-$10/in. of width. A 6-in.-dia roller will run closer to $20/in. ($40 if you want stainless steel).

If you need to transport the web 100 ft through an oven, ten 70-in. rollers will cost $14,000. The debate whether span lengths should be every 10 ft or every 2.5 ft (equal to 2× or one-half of a 60-in. web width) is a $42,000 question.

Roller costs, just like any piece of equipment, don't stop at the purchase price. Rollers have to be aligned. Their bearings and surface need to be maintained. When the webs break, each roller needs to be rethreaded. When slimed, each roller has to be cleaned. Suddenly this simple question is more complicated.

Ergonomics and Safety

Rollers in close proximity always should be considered a safety hazard. In some cases, a guardable nip point can be two rollers as far as 6 in. apart.

For ease of threading, roller spacing should start at 4 in. between roller-roller and roller-machine surfaces, unless process or space limitations trump this goal.

Gravity

Most CAD drawings of web lines show rollers and webs as circles with tangential connecting lines. Real webs will sag and flutter from gravity, web bagginess, and roller misalignment.

Gravity is most obvious and significant as spans are closer to horizontal, when it causes catenary sag (the same as the sag of high tension power lines between poles).

In a 20-ft span, a 1-mil polyester web at 1 PLI will sag 0.75 in. A 10-mil polyester web would sag ten times more or require 10 PLI tension to get back to 0.75-in. of sag.

Sag will increase directly with span length squared and inversely with tension. If you start adding loads onto your web, such as the mass of a wet coating or the force of air impingement, then the deflections will increase proportionally.

In vertical spans, the effects of gravity are often negligible. The tension in a web rising vertically will increase by the web span's weight as it rises from the bottom to the top of a vertical span (or drop the same amount in falling vertical spans). For a 10-mil thick polyester rising 20 ft, the tension change will be only 0.12 PLI — hardly worth talking about.

Bagginess and Misalignment

If either of these imperfections drives the web to slackness — look out. In a 50-in. span, just 0.040 in. of excess length or misalignment will allow the web to deviate from the web's plane by 1-in. That's less than a 0.1% error. Close spacing of rollers is required to prevent contact when passing through slots, a tunnel, or to avoid other non-moving elements.

Span length debate so far: Short spans are expensive; extremely short spans are hazardous; and long spans lead to flutter and out-of-plane problems. Next month we'll cover traction, tension, guiding, wrinkling, and spreading.

The Great Span Debate: Part 2 – Apr 2009

Here a roller, there a roller, everywhere a roller-roller. That may make an entertaining toddler's song, but it isn't a good strategy for web line design.

Last month, in The Great Span Length Debate | Part 1 we debated roller spacing (a.k.a. web span length) relative to cost, safety, out-of-plane deviations from gravity, bagginess, and misalignment. Let's continue the debate.

Traction

The length of span has no significant effect on web-to-roller traction. Longer spans don't increase the friction coefficient, tension, wrap angle, lubrication, or roughness/grooving. If sequential rollers are wrapped in over-under-over-under, more rollers will create larger wrap angles per roller. In arched or flat dryers where a series of rollers are all on one side of the web, more rollers means less wrap angle per roller. For rollers with less than two degrees of wrap, a one degree change can be the difference between stick and slip, but roller performance is the more likely solution to slip problems.

Air Turns

It is rarely a good idea to have an air turn controlling a long span, especially a long entering span. A web is perfectly happy to wrap helically around an air turn (which we like in a web flip) or shift back and forth violently (which we rarely enjoy). Prevent this with a roller (usually on the non-air turn side) as close as possible to the air turn's entrance and good air turn alignment.

Air Flotation

Whether using Coanda or impingement nozzles, the longest spans in converting are in well-designed air flotation ovens, but this special case falls outside the great span debate.

Tension Control

Span length is usually a non-factor in tension control. Total length increases a draw system's response time, and more rollers will increase MD tension variations within the zone, but neither specifically changes if any individual span is long or short. Short spans in and out of dancer or load cell rollers will increase the system mass-spring harmonic frequency and reduce the likelihood of problems in below 1,000 fpm speeds.

Guiding

Long spans are better. Long spans get more correction for a given angle change. Long spans have greatly reduced tension variations from bending and twisting, especially if a longer translation span means misalignment angles are smaller.

Wrinkling

This is the Catch-22 of span lengths. Longer spans are less sensitive to shear wrinkles from misalignment or diameter variations. Short spans are less sensitive to tracking wrinkles from deflection, baggy-center webs, or crowned winding rolls. I lean toward short spans in wrinkle-sensitive webs since good equipment design can prevent misalignment and diameter variations but can't stop baggy webs.

Spreading

Spreaders can spread more with less force if entry spans are long. Exit spans should be short to reduce post-spreader tracking and immediately upstream of your critical process if the spreading is for anti-wrinkle benefits.

Slitting

Short spans in and out of slitting are best to minimize slit quality problems of a web that flutters or sags away from the ideal cut point.

Winding

Of all the span problems I see over and over, lack of span control at winding is the most common. Old paper winders insensitive to wrinkling are ill-prepared to winding film product. Old turret winders that lose their optimized entry span control during indexing are a major cause of waste worldwide.

It's cheating, but true, to say the answer to the great span debate is “it depends,” but clearly it does. Here's my educated gut feeling on spacing transport rollers. I am comfortable with 1-6-in. web spans up to 6 ft, 24-80-in. up to 8 ft, and ultra-wide 100-200-in. webs with spans to 15 ft. I think you can double these lengths for purely vertical spans, since gravity doesn't pull the web out of plane.

When Roller Fight, Webs Lose: The Importance of Roller Alignment

A tram is a coal bin with wheels. If you want your coal bin to stay on its tracks, you must keep the two axles parallel. If they are not parallel, the front and back wheels will fight each other, leading to a derailment and a coal catastrophe.

Tram is used to describe parallelism in any direction, though most often in the horizontal plane or the plane of the web. Tramming is the action of measuring and setting good parallelism. If you want your web line to stay on track, keep your rollers and equipment sections parallel. If sequential rollers are not parallel, the upstream and downstream rollers will fight each other. When rollers fight, the web loses, leading to misalignment maladies such as wrinkles, tracking error, deformation, breakage, or process variations.

Measuring level — the alignment in the vertical direction — is the first step in tramming. You likely have used a carpenter's level to put up a shelf or hang a picture. For your web process, upgrade to a mechanic's precision level that features a V groove to rest the cylindrical topside of a roller and graduated lines to measure level errors in mils per foot.

Measuring tram — the alignment in the horizontal plane — is more difficult since we don't have gravity to guide us. There are at least five options for measuring tram, including tramming sticks, gauge blocks, pi tapes, optical transits, and laser-based systems. The first three are inexpensive and should be in every web handler's toolbox.

The web-tracking error from roller misalignment will be directly proportional to the error angle times the upstream web span length. A 10-mil/ft misalignment will shift the web about 7 mils for every foot of span length. This “rule of thumb” will overestimate tram-related tracking errors for wide, thick, short span, and high-modulus webs.

The tension variations from tram error are directly proportional to the side-to-side strain change and the web's modulus and thickness. A 10-mil edge-to-edge tram error over a 10-in. span will cause a 0.1% strain change. Multiplying the strain change by modulus (500 kpsi for bond paper or polyester film) produces a 500-psi tension variation or 0.5 PLI for every mil of thickness.

The tram error required to wrinkle a web is a far more complex calculation. Wrinkle analysis starts by assessing whether a roller has enough traction to hold a wrinkle. Next, the web, span, and tension values combine to determine the web's stiffness or resistance to buckling. Most web-tension-span combinations have no problem with an alignment error of 5-10 mil/ft. For wrinkle-sensitive materials (think thin and stiff), I recommend an alignment target of 2 mil/ft of width. I think this is a reasonable and measurable target.

Alignment is more difficult in pivoting assemblies, such as winders, nips, and dancer rollers. Start by ensuring the pivot axis is aligned, design the pivoting arms to translate this alignment, and then ensure the roller is square. Poor alignment at winding leads to crossweb wound-in tension variations and wrinkling. Nip pressure is extremely sensitive to misalignment. A compliant nip roller forgives some degree of misalignment, helping to reduce pressure variations.

How often should my equipment be leveled and trammed? I don't advocate a regular, all-out alignment preventive maintenance plan. Let the process or web tell you when you need to improve your alignment. Wrinkles, coating variations, winding variations, and edge flutter all will beg for improved alignment when they need it. Instead of spending your time and money on periodic alignment, invest in equipment design that holds good alignment. Beef up framework to prevent deflection. Drill and pin your roller or bearing blocks to prevent shifting in bolt hole clearance. Change over to split cap blocks, allowing rollers to be removed and installed without losing alignment.

Good roller alignment is the first step in successful web handling. Watch your web — it will tell you when it is caught in a roller battle of misalignment. Keep your process on track by ensuring roller alignment through design, measurement, and maintenance.

Support Your Rollers

Most of us like to feel we are well-supported, i.e., secure and stable. A roller isn't that different.

How should a roller be supported or attached to your equipment? To answer this question, let's review your roller support needs and your options to meet these needs.

Aligned | Rollers should be parallel to each other. Each roller must be installed and measured to be level (perpendicular to gravity) and trammed (perpendicular to a machine's centerline), usually to less than 2 mils/ft error. (Stretchier, thicker, and narrower webs are less sensitive to misalignment than this.) Even rollers that will be intentionally misaligned should begin with a known parallel reference position.

Rigid | Rollers should hold their position and alignment through tension and process changes and over the life of the equipment.

Serviceable | Rollers should be designed so they can be removed for maintenance and reinstalled back into their alignment position with reasonable ease.

Machine builders attempt to meet these three needs through two general approaches. Which approach is used often depends on whether the equipment's structure will include two thick steel plates, usually called side frames, on either side of the web path.

To mount a series of rollers between two side frames, the builder will clamp the two plates together and bore all the roller positioning holes as a set. When the side frames are separated and spanned by rollers, in theory, the rollers should automatically be parallel since the holes are spaced identically in each frame.

The bored holes may be quite accurate, but in all bored side frame cases, something must be press fit into the holes that then holds the shaft. This is what will make or break this approach.

Shaft-holding options include: 1) bearings, 2) shoulder bolts, or 3) engineered plugs that function as large shoulder bolts. In inexpensive equipment or wrinkle-insensitive products, this method is good enough. The engineered plug approach can work quite well, especially if it includes split caps and some minor alignability.

When you don't have bored side frames, there are two other options to connect rollers to any horizontal or vertical surface: flange mounts (where the shaft holder bolts to the side frames parallel to the roller shaft) and pillow block mounts (where the shaft holder is bolted down in a direction perpendicular to the roller shaft). Flange and pillow block mounts can be well or poorly executed, depending on the details of their execution.

Flange and pillow block mounts may be an all-in-one design with an integrated standard bearing and a Zerk fitting. Though these are great for many shaft applications, overly greased bearings often have higher rotational drag than I'd like to see in my idler rollers.

If the live shaft roller has an exceptionally long shaft or journal (something that should be avoided), having spherical bushings to capture the bearing can avoid detrimental torsional bearing loads from shaft bending.

I'm a fan of split cap pillow block mounts. The pillow block mount is the easiest to level and tram in independent steps. The split cap feature is the best for easy removal and reinstallation of a roller without losing alignment.

And one last point on alignment of these shaft holders: If you'd like to keep your alignment over time, don't rely on the bolt friction to hold things in place; take the time to drill and pin the roller mounts securely in place.

If you are a person who enjoys living on the edge, you may find roller support options a boring topic. For you thrill seekers, I have two words: cantilevered rollers. But that will have to wait for a future column.

Q&A on Roller Deflection

Here are five frequently asked questions about roller deflection with my responses. Next month, we'll talk more about deflection, but instead of rollers, we'll discuss deflection at winding and slitting.

WHAT IS ROLLER DEFLECTION?

A roller remains cylindrical but no longer straight. This is not the deflection of crushing a pop can, more like bending a garden hose. A roller supported from one side only (cantilevered) will deflect by increasing amounts moving away from the supported end. A roller supported from both ends will have maximum deflection at the center of the roller.

WHAT CAUSES ROLLER DEFLECTION?

Gravity, tension, nip loads, and intentional bowing, such as a curved axis spreader roller, all cause roller deflection.

HOW IS ROLLER DEFLECTION MEASURED?

Deflection angle caused by gravity is easy to measure with a precision level. For cantilevered rollers, measure the level on the outboard side of the roller with no load and after hanging a weight equal to web tension at the center of the roller. For dual-end supported rollers, measure the level at the left, center, and right positions under no load and with a weight equal to web tension.

Alternatively, use a dial indicator to measure the magnitude of deflection between a reference point and the roller surface. Measure total deflection for low and high loads or tensions.

HOW MUCH ROLLER DEFLECTION IS A PROBLEM?

For cantilevered rollers, the deflection and alignment specs should be the same. My default is less than 2 mils/ft of width or about 2 mm/m. For lower elastic modulus (stretchier) products, you can relax this to 5 mils/ft. For dual-end supported rollers, the troublesome deflection is more difficult to pin down.

Nipping systems are the most sensitive to deflection for two reasons:

They have load many times higher than gravity or tension.

They control many critical processes that are sensitive to gap or engagement variations.

A well-designed nipped roller system will have larger-diameter rollers, rubber-covered rollers, or both to compensate for the pressure variations that would be created by high roller deflections.

It is more difficult to recommend universal deflection specification dual-end supported unnipped rollers. My first instinct is to set a similar specification as roller alignment — keep roller deflection to less than 2 mils/ft of width. However, there is at least one condition in which roller deflection below this specification may cause you troubles, namely wrinkles.

Most of you likely know about bowed rollers (a.k.a. curved-axis or Mount Hope, a brand of Xerium Technologies) and how they are used to spread a web. A bowed roller should be approached in the same manner as a bow and arrow. If you are on the inside of the bow and you shoot an arrow you are safe. If you are on the outside of the bow, receiving the arrow — not so safe.

The same is true with webs. A web approaching a deflecting or bowed roller from the inside of the bow will be encouraged to spread or flatten, but a web approaching a deflecting or bowed roller from the outside of the bow will be encouraged to gather or wrinkle.

Imagine a roller deflection from gravity (let's ignore web tension). If you approach a deflection roller from above, the web will come at the bow from the inside and be encouraged to spread. However, if you approach a gravity-deflection roller from below — look out — this web comes at the outside of the bow and is looking the arrow in the eye or encouraged to gather and wrinkle.

This is the tricky part of deflection — same roller, but depending on the direction from which it enters, above or below, totally different results.

HOW CAN ROLLER DEFLECTION PROBLEMS BE ELIMINATED?

Here are three ways to solve roller deflection problems:

Eliminate the load that causes deflection | Less weight, less tension and wrap angle, less nip load.

Beef up the roller to resist deflection | Larger diameter, tiffer materials, thicker cylinder walls, narrower widths.

Optimize your process to reduce the effects of deflection | Avoid long rising vertical spans into rollers.

Idler Roller Bearings: Living the Good Long Life

Most bearings are designed for a hard life, expecting to end up on a drive shaft of a high-speed motor with a heavy load. Some bearings, however, end up with a relatively cushy job in the relatively light-duty life as the bearing in an idler roller on a coating line or slitter/rewinder.

NOTE

If you run an extremely high-tension web, like steel or an extra-thick paper product, you likely never think about roller drag, so stop here.

People look at me funny when I say you should be able to put in an idler roller and never replace the bearing. To convince yourself of this, get out your favorite engineering handbook and calculate the life expectancy of your bearing based on process rpms and the load from roller weight and web tension.

You likely will find an expected life of 10 or even 100 years. These bearing life expectancies may seem unreasonable, but they are achievable if you consider a few real-world factors. Tend to these five factors and you too may see bearings lasting a decade or more.

SIZE

What is the right size idler bearing? The easy answer is the bearing needs to have an inner diameter bigger than your shaft and outer diameter smaller than the roller's shell. On the plus side, larger idler shafts will have less deflection, but larger bearings will have longer expected life but also more friction, especially in greased, contact seal bearings.

Some idlers eliminate the need for large inner diameters by eliminating the through shaft. A small diameter stub shaft can reduce bearing diameter greatly, but the tradeoff is life. I think ¾ in. is the place to start on bearing inner diameter unless your idlers are running under extremely light loads.

LUBRICANTS

From a low-drag point of view, no lubricant is best, but a bearing with no lubricant will fail quickly. The answer is to use either of the following options.

Use 5%-25% fill with a light oil lubricant.

Avoid petroleum-based lubricant altogether and opt for a PTFE-based, low-viscosity lubricant.

For low-tension web handling, just say no to Zerk fittings on idler rollers. A Zerk fitting doesn't mean a roller will have too much thick grease inside, but I've never met a Zerk fitting that doesn't eventually have a date with the pump-pump-pump of a grease gun.

SEALS

Contact seals add to idler roller friction, yet with no seals, dust and debris will get in and destroy a bearing. Labyrinth seals, where any particle must travel a tortuous route to get to the balls in the bearing, are the preferred answer. Some low-drag bearings use a lubricated felt seal to block contamination.

ENVIRONMENT

The top environmental questions for bearings are heat, humidity (or lack thereof), ozone (near corona treaters), and contamination (such as near slitting). Sufficient lubrication, non-petroleum lubricants, and labyrinth seals are the answer.

LOADS

Bearings are good at supporting loads perpendicular to their axis of rotation, but the real world may exert loads in other directions. Undesired side loads may result from an over-muscled roller assembly or from a shell's thermal expansion. Excessive radial loads may come from thermal expansion differences between high thermal expansion of aluminum shells and relative-to-low-expanding steel bearings.

Twisting loads are generated from misalignment of the bearing outer and inner race, usually from overly small shafts. A bearing in a spherical bushing mount can minimize this, or you can use basic engineering to model the shaft and shell deflection and keep the bearing angle mismatch to a minimum (usually less than ¼ deg).

I would like to thank Cal Couillard of Componex (www.componex.net) and Pete Eggen of Webex (www.webexinc.com) for their valuable discussion in preparing for this column. I expect, like me, either of them would welcome a call from you to discuss your unique idler roller bearing challenges.

The Spin on Idler Roller Testing

It's an election year, so I'd like to join the political pundits and offer some spin of my own, but my spin will be free of political opinions. Instead, I'll be giving you my spin on free-spinning rollers.

Not every converter needs to consider improving idler roller performance. If you have a high-tension process, giving up a few pounds to your idler rollers is okay. If you have a scratch-insensitive product, a few rollers that fail to spin may not affect your yields. But not all converters are so lucky.

If you have a low-tension process, you can't afford to give up much tension to your idler rollers. If you have rollers where the available traction is marginal, such as extra-low tension, low wrap angle, low web-to-roller COF, or a reduced traction coefficient due to air lubrication, then keep reading.

Before we can talk about improving idler rollers, we need to measure their performance. There are three tests I recommend: break-away drag, at-speed, and spin-down testing.

Break-away testing is the simplest test and something that comes naturally, like kicking the tires of a new car. With the web out of the machine, reach out and spin an idler roller, noting the ease or difficulty in getting the roller started. If you want to quantify this value, use a small spring scale and measure the surface force required to move the roller at creep speed.

At-speed testing answers the question, "Are your idler rollers turning at line speed?" You can use a contact or noncontact tachometer. Using a noncontact tachometer eliminates the concern the measurement load will slow the roller down, but it will take more work on your part, requiring you to attach a small piece of reflective tape to the side of your roller. You also will need to know the roller's diameter, so you can convert rpms to speed in feet or meters per minute.

Many people feel at-speed testing — comparing the speed of your idler rollers to speed of your web or to a non-slipping roller such as a nipped or vacuum-assisted driven roller — is the acid test. If the roller isn't slipping, what could be wrong? That's the same thinking the captain of the Titanic had just before that unsuspected iceberg. At-speed tests will measure failure but won't tell you if you are living on the edge.

Spin-down testing is more complicated, but it will give you a sense of your safety factor for slipping idlers. The spin-down test tools are simple: a stopwatch, a tachometer, and some way to accelerate the roller (I recommend a rubber wheel on a cordless screwdriver).

The spin-down test is a balance of the roller's inertia, wanting to keep the roller spinning and the bearing drag trying to decelerate the roller. The spin-down test itself is simple: 1) Drive the roller to a given speed; 2) measure the roller speed; 3) note the speed and start the stop watch; and 4) measure the time until the roller stops. Long times indicate free-turning rollers (or high inertia).

You can use spin-down times to compare a set of nearly identical rollers, but the real value of this test is a few calculations away. Calculate the roller's rotational inertia from function of diameter, wall thickness, width, and density. Calculate deceleration in radians per second-squared from the spin-down speed and time. Multiply inertia by deceleration, and you get bearing torque. Divide by radius to get surface force of the bearing drag. Compare this surface force to the available traction (COF, tension force, and wrap angle), and you will know quickly if there are any idler bearing icebergs in your process.

In July we will cover the key factors in idler roller bearings that will reduce bearing drag without sacrificing bearing life.

TRACTION

Get a Grip: Driving Your Web

In my October 2007 column, "In Search of Tension Isolation," I myth-busted the belief that a high traction driven roller can completely isolate one tension zone from another. However, the subtle effect of web transport should not sway you from designing all driven rollers with traction sufficient to support your apparent or actual tension differential between tension zones.

If your driven pacer roller slips, you lose control of line speed. If your driven follower rollers slip, you lose tension control. As if losing speed and tension control isn't bad enough, slipping rollers of any kind lead to loss of lateral control and scratched webs.

Most roll-to-roll web processes have at least one driven roller, commonly called the pacer or master roller, that controls process speed. A basic web line of unwind, pacer, and winder creates two tension zones: one controlled by the unwind and one by the winder. If the unwinding and winding tensions are about the same, it doesn't require much pacer roller traction to keep the web from slipping and to maintain speed control and tension separation.

As processes get more complicated, additional intermediate driven rollers may be required to allow each process step to have its own unique optimized tension. As a web process gets more rollers or moves to lower tensions, more driven rollers may be added to reduce the percentage of tension lost to roller drag and inertial torques. Each added driven roller creates another tension zone and another point where traction capacity needs to be greater than the apparent or actual tension differential.

Many coating lines have four tension zones controlling unwinding tension, tension into coating, tension in the drying process, and winding tension, respectively. The four zones are separated by (see how I avoid the verb "isolated" here) three intermediate driven sections.

The options for driving a web between tension zones include the following:

UNNIPPED ROLLERS

Simple, usually with a larger wrap angle and high traction surface (rubber with a roughness or groove pattern). These are my first choice, since they are highly tolerant of baggy webs. The belt equation defines their traction capacity, stating that the tension ratio (not absolute differential) must be less than the natural log e to the power of the wrap angle (in radians) times the coefficient of traction. Unnipped rollers aren't helpful when input or output tension goes to zero, since that is an unsupportable infinite tension ratio.

VACUUM-ASSISTED UNNIPPED ROLLERS (OR BELTS)

A great option for driving with limited wrap angle. A high traction surface, like rubber, gives vacuum rollers especially strong traction. Surprisingly, these rollers can partially air lubricate at high speeds if they are too smooth and the grooves or holes are too far apart.

NIPPED ROLLERS

My third choice, since they are notorious for wrinkling baggy webs. Nipping rollers should be larger than other rollers to minimize deflection-associated problems. They do provide a reliable traction capacity directly proportional to nipping force and traction coefficient, and they are good at preventing air lubrication.

TENTERS (OR STENTERS)

Edge-only gripping systems using clips or needles. These usually are reserved for film or textile heated processes.

Each driven section should have sufficient traction capacity to handle the apparent or actual tension differential. In many applications, actual tension differentials are unknown either because tension isn't measured or is measured so many rollers away from the driven roller that the actual tension differential varies greatly from the measured valued due to drag and inertial losses or additions.

In any case, get a grip and choose an option that will have more than the traction capacity you think you will need.

Do You Want Nips With That? Part 1 – Apr 2011

"No nips, please." To qualify this statement, I just want to get rid of unnecessary nips, especially for preventing slip on tension controlling drive rollers.

"But," you say, "if I don't have nips, my drive rollers slip, and I can't control tension." Okay, I believe you, but let me ask these questions:

Do you understand the tension differential across your drive rollers?

Are you sure you can't support this differential without a nip roller?

If you know you can't with your process as is, are you sure you can't change either your tension set points or your idler roller-related tension losses to reduce your need for drive roller differential and traction? You may find that you have two or three scenarios, some with high tension differentials, such as during rapid accelerations. You may find your nips are needed during acceleration, but they can be opened once steady line speed is reached.

Q

WHY ARE NIP ROLLERS A POPULAR CHOICE TO CREATE DRIVE ROLLER FRICTION?

A Mainly, nips are simple to understand — pinch it, pull it. We can relate to nipped rollers — they create friction just like tires on the road. Nipped rollers are even able to pull when web tension on one side is zero, such as during machine threading.

Nipping two rollers together with 400 lb of load combined with a 0.25 web-to-roller coefficient of friction (COF) creates 100 lb of traction. The high pressure between nipped rollers will reject and compress air entrained by the moving web and roller, maintaining traction without worry of lubrication, even on fairly smooth web-roller combinations. It's only when wrinkling at your nipped rollers — from your baggy webs or roller deflection — that you wonder about the alternative to nipped rollers.

Q

WHAT ARE THE ALTERNATIVES TO MEET DRIVEN ROLLER TRACTION NEEDS WITHOUT NIPPING?

A The first choice for driven roller traction should always be an unnipped, high friction, grooved or textured, high wrap angle roller. To make an unnipped roller meet your needs, you may have to do three things you don't want to do:

You need to restrain your tension differential.

You have to think exponentially.

You have to design to avoid air lubrication.

An unnipped roller creates tension by the capstan. The capstan equation calculates the maximum tension ratio of high-to-low tension across a wrapped cylinder.

To calculate the maximum ratio of any roller, raise Euler's number, e (2.7183), to the power of COF times the wrap angle in radians. For example, if your COF is 0.25 and your wrap angle is 3.14 radians (180 deg), the maximum high-to-low tension ratio without slipping is more than 2:1.

A ratio of 2:1 is sufficient for many applications, but why stop there? If you have a rubber-covered roller and a higher wrap angle, for example COF of 0.6 and a wrap of 200 deg, the non-slipping tension ratio is more than 8:1.

The Achilles' heel of the unnipped roller is air lubrication. You may measure web-to-roller COF as 0.3 or 0.6, but the true coefficient of traction (COT) may drop when entrained air exceeds the combined surface roughness of web and roller.

However, don't let fear of air lubrication keep you hip-deep in nip-related waste. Even subtle roughness or grooving easily keeps your web-to-roller at high traction levels.

It's easy to see why nipped rollers are naturally more popular than unnipped rollers. Nipping is simple. Who wants to worry about estimating true tensions, calculating exponentials, and avoiding air lubrication? Answer: Anyone who wants to enjoy the profits of wrinkle-free processes. Maybe that's you.

Unnipped rollers made easy: more wrap, more friction, more roughness, less wrinkles.

"Do you want nips (and wrinkle waste) with that?" No, thank you.

Do You Want Nips With That? Part 2 – May 2011

"No nips, please." I need a button that says this. Every day, dumpsters and truckloads around the converting world are filled with waste generated due to unnecessary nipped rollers. Nipped rollers are a double-edged sword, creating high pressure for value-adding processing that quickly turn into value-subtracting wrinkling machines.

Nip-related waste may be your web supplier's fault (excessive bagginess), or your equipment supplier's fault (undersized rollers or poor choices in entering span length and pre-nip wrap angle), or your own fault (uneven nipping or deflection-excessive loads). However, the worst sin of nipping is the unnecessary nip. The nip that isn't there doesn't create waste.

You may not be able to get rid of your need for nip pressure in your value-adding processes, but the nips I'd like to see avoided are the ones used to create friction on driven pull rollers. To avoid these nips, we have to understand why they are used and how they can be bypassed or removed without upsetting our tension control.

To wean you of "tension isolation" nips, we have to answer four questions:

Why do we have driven rollers in our process?

How much friction or traction is required at each roller to avoid slip and maintain tension control?

Why are nip rollers a popular choice to create drive roller friction?

What are the alternatives to meet driven roller traction needs without nipping?

I touched on some of these answers in my January 2008 column, "Get a Grip: Driving Your Web" (pffc-online.com/web_handling/grip_driving_web_0101). However, in that column I don't think I went far enough to persuade you to give up your nipped drive rollers or help you to understand how to do it.

Why do we have driven rollers in our process? Driven rollers control process speed and local tension or draw ratio.

At least one of your driven rollers is the lead section of your process with the important job of controlling line speed. Beside the lead section, all the other driven points of your process are follower pull rollers in charge of local process tension or draw ratio.

How many driven rollers your process has may be due to the need for local process-specific tensions or to make up for tension losses of undriven roller drag and inertia.

How much traction does a drive roller need? Drive roller traction needs to be greater than the tension differential between the incoming and outgoing webs. If not, the drive roller will slip, losing control of tension or speed.

Figuring your tension differentials may be more difficult than you would think. The true tensions in the spans just before and after the driven roller may differ significantly from the values displayed on the operator control panel.

Getting to the real input and output tensions requires some work. For load cell feedback, we need to confirm their calibration. For dancer rollers, we need to confirm the tension required to counter the dancer's force.

For draw control processes, it can be quite challenging but not impossible to estimate the process tension from upstream tension, draw ratio, and web mechanical properties. Most importantly, if there are a number of rollers or a process between the feedback roller and the drive roller, you have to consider the losses or gains in tension from drag and inertia.

The goal of all this work is to understand and estimate the real tension differential needed at every drive roller. In next month's column, we continue on the nip-free path and discuss why nips are so popular and how to reduce our dependence on them.

In Search of Tension Isolation

Bigfoot, the Loch Ness Monster, the Yeti. These are but a few of the world's myths. In web handling, one of the myths told most frequently is that of the independent tension zone, protected from other tension zones by the protective powers of the tension isolation. Like most myths, we want to believe, but alas, scientific reason is the myth buster.

What do people imagine when they use the term "tension isolation"? It is the belief that two tension zones are independent of each other if the friction of the web on the "isolating" driven roller is greater than the tension differential between the two zones.

I totally agree with the goal that each pull roller should have traction greater than the anticipated tension differential. It's good to avoid pull roller slip since slipping pacers lead to unknown web speed, and slipping followers lead to uncontrolled tensions. Though the sufficient drive roller friction prevents slip, it is incorrect to say the non-slipping pull roller provides tension isolation where the tension in one zone is totally independent of another.

The myth of tension isolation stems from our understanding of statics. Imagine a large brick sitting on a table with two ropes tied to it. The brick's weight and the COF of the two materials create an available frictional force between the brick and the table.

To slide the brick, you have to pull on one rope with enough force to overcome this friction. If you pull on both ropes in opposing directions, the frictional force will isolate the tensions of the two ropes as long as the rope tension differential is lower than the available friction.

The myth-buster lies in the difference between static and dynamic cases. In a web line, the moving web carries tension information with it as it passes from one tension zone to another, even without slippage.

The tension in any zone is determined by the strain or stretch of the web entering the zone plus or minus the change in strain in the zone. If a web enters a zone controlled at either end by driven rollers in a 1:1 ratio, the tension zone doesn't alter the strain of the web, and the tension in the zone is the same as the entering web.

If the tension zone has a positive or negative speed ratio (or draw), it would increase or decrease the tension, respectively. But the tension in any zone is not independent of the upstream tension, since tensioning of elastic webs always will start with what is the upstream tension and go up or down from there.

The myth of tension isolation is busted when the upstream tension is altered, and no matter how high the pull roller friction may be, this new baseline tension will enter the tension zone as the web moves through the system.

This concept is known as strain transport. The strain of the web is a property that moves with the web as it enters and exits a tension zone.

For draw controlled processes, this concept of strain transport is critical to understanding your process (see "Drawing Conclusions," my columns of May and June 2005). In closed-loop or torque-controlled zones, the system will adjust quickly for any upstream tension changes, making it seem as if tension isolation is true, but any monitor of process speeds would show how upstream tensions feed through the system.

With the tension isolation myth busted, the list of usual suspects for some defects, such as coating variations, must grow to include anything that changes upstream tension.

Limitations of Vacuum Pull Rollers

I love vacuum pull rollers (VPRs). When it comes to driving a web without slipping and scratching or to knowing you have control of the tension differential from one zone to another, a vacuum pull roller can't be beat. They are especially great when you can't or don't want to touch one side of the web.

I was going to write this month's column about my love for vacuum pull rollers (this could have been my Valentine's Day column to VPRs), but after a quick web search, I realized Pete Eggen of Webex Inc., Neenah, WI, wrote a wonderful pro-VPR column, "Get a Grip on Your Web," in the November 2009 issue of PFFC.

Pete's column did a great job covering the what, how, and why of VPRs. To read the article, visit http://pffc-online.com/web_handling/tension/paper-grip-on-web-1109.

What is there left to say about VPRs? As with anything you love, if you remove your rose-colored spectacles, you are able to see even your true love has faults. Here's a list of some the limitations and disadvantages of VPRs.

VPRs cost more | A VPR is a special roller, similar to a heated or chilled roller, but instead of pumping water or oil through the roller, a VPR has an advanced pneumatic system to create a desired internal negative pressure without excessive leakage or flow volume. It's not as sophisticated as a low vacuum processing chamber, but it has its own sealing and pressure control challenges. This adds up to a roller that is much more expensive than a nipped or unnipped pull roller, both in upfront and operating costs.

VPRs don't like dirt and dust | The extra traction of a VPR comes from suctioning the web down to the roller, but like any vacuum cleaner, a VPR isn't smart enough to know what or what not to suck up. This means debris, dust, and anything airborne or on the web may be sucked onto or into the VPR, clogging up the system, reducing its effective traction, and fouling the internal seals and pneumatics.

VPRs are noisy | Like any pneumatic system, air flow and fans are noisy. Good designs will reduce noise, but a VPR always will be noisier than a non-vacuum roller.

VPRs should be a tailored fit | The problems with dust and noise can be reduced by adjusting the VPR's effective vacuum area to match both the web width and roller wrap angle. However, this will add to the complexity and cost of the system, especially if you need to run varied web widths.

VPR holes may mark your web or coating | Some VPRs are simply perforated cylinders with large holes to expose the web to the negative internal pressure. However, large holes will cause dimples, impressions, or wrinkles in thinner webs or sensitive coatings.

VPRs may promote wrinkles | First, since VPRs are intended to have high traction and most wrinkles are dependent on good traction, VPRs with even slight misalignment or diameter variations will create wrinkles quickly. Some VPRs avoid large holes instead by using a screen sleeve, exposing the vacuum pressure over a finer, less-likely-to-dimple pattern. However, screen sleeves that are unsecured, except at the roller's ends, are known to balloon outward slightly at high rotation speeds. This turns your VPR into a high traction crowned roller, which is an excellent web wrinkler.

VPRs won't work in a vacuum | This one shouldn't be a surprise. VPRs develop force by the difference in atmospheric pressure from their fan-induced low internal pressure. If you take away atmospheric pressure, you can't have a pressure differential to hold the web down.

A Slippery Answer to Web Scratching

What percent slippage in idler roller speed relative to web speed is required to create scratches?

Answer #1: Zero percent slip.

Scratches are a form of abrasive wear. Abrasive wear occurs any time two surfaces are pressed together and then slid relative to each other. Each material will give up something.

The softer material, usually the web, will have the more obvious loss of material. Over time, the web abrading the rollers, especially rubber-covered rollers, also will be apparent. Scratching is promoted by surface irregularities and debris — both acting as stress concentrators — increasing the local abrasion event (the scratch).

For scratch-sensitive products, every effort should be made to ensure idler rollers are not slipping. I advise scratch-sensitive converters to implement an idler roller maintenance plan.

Recently I completed a project for a client in which we analyzed the performance of more than 300 idlers on a coater. Using the "spin-down" test and timing the deceleration rate of a freely spinning roller, we could find the "bad actors" and calculate a Traction Safety Factor (TSF), an indicator of how close each roller is to slipping.

The TSF is the ratio of driving torque (wrap*tension*COF*radius) to drag torque (bearing drag torque and inertial torque). The result: Bad idlers are repaired, and marginally driven rollers are modified with more wrap, higher friction, or better bearings. Also, an idler roller minimum performance is identified to ensure new rollers meet an appropriate standard. This approach nearly can eliminate scratch defects.

For answer #2, we need to look at things on a micro-scale.

A tensioned web is elongated a small amount (web strain = tensile stress/modulus). As the web goes around a driven pull roller, moving from one tension to another, the web's strain will change. The moving web will contact the roller with the strain proportional to the upstream tension. But the web strain needs to make a transition to the downstream tension, and it does this while on the roller. For many webs, the change in strain from tension extremes is less than 1%, but the roller does not move with the web, creating a slip and abrasion condition.

The belt equation (a.k.a. the band-brake or capstan equation) defines the critical wrap angle where the strain transition will begin. During the entire critical angle wrap on the downstream side of the roller, there will be "micro-slip." Does this cause scratching? On a microscopic scale, this abrasion probably is detectable, but to the naked eye, this "micro-slip" is not a problem.

Micro-slip happens on every roller, not just tension-isolating pull rollers. The drag of driving an idler creates a small tension change in the web, so there always is a small web strain change in the final wrap of the roller and micro-slip.

Answer #2: Slip less than web strain is okay.

Lastly, when surfaces in an engine or bearing need to slip, but wear is undesirable, what do we do? We lubricate them.

You can't pour oil on every roller (unless you're in the steel industry), but high-speed web handling has a natural lubricant — air. It is possible to have massive slip, even a stopped roller, and not scratch the web. Air lubrication is promoted by large diameter, high speeds, low tensions, and smooth surfaces (both roller and web).

Answer #3: Up to 100% slip may be okay (if properly lubricated).

In summary, my slippery answers to acceptable roller slip — zero, a percent less than web strain, and 100% slip — all may be okay. Those are my answers and I'm sticking to them. I hope I haven't left you scratching your head on this one.

Recipe for Scratching

This month we're having another session of "Do the Opposite." I'm going to tell you how to make great scratches. The solution to stopping scratches is to "Do the Opposite." Eliminate these factors, even just one, and your scratches will be gone.

There are five prerequisites to create a scratch or abrasive wear. All five are required to create the scratch. Let's review them.

CONTACT

The web must be touching something — roller, any nonmoving equipment, or itself — in the winding or unwinding roll.

Do the opposite: If you don't touch the web, you can't scratch it. Eliminate unnecessary rollers. Use air turns or air floatation nozzles in place of rollers. Use air or fluid to fully lubricate the web/roller interface. For narrow and stiff webs, use an undercut or dumbbell-shaped roller that makes contact only at the web edges. Use a tenter or edge nips to hold the web.

FORCE

The web must be pushing against the scratch-causing surface with sufficient force.

Do the opposite: The normal load or pressure is created by the tension web pull over a radius. Reduce pressure of contact by decreasing web tension or increasing roller radius. Reduce tension in a scratch-sensitive area by reducing the roller diameter in that area. For example, if the coated center of a web is most important, machine a profile into all coated-side contact rollers to have smaller diameter in the middle and carry most of the web tension at the uncoated edges.

RELATIVE MOTION

Two surfaces with matched surface speeds may cause a gouge or pick out, but they are unlikely to cause a scratch.

Do the opposite: Ensure the traction available is greater than the traction demand. Increase available traction with larger wrap angle, high tension, and higher coefficient of traction. Prevent lubrication by increasing roughness, increasing porosity, or increasing surface texture or grooving. Decrease the traction demand with low drag bearing performance, reducing roller inertia, minimizing acceleration rates, and reducing tension differentials across driven rollers.

STRESS CONCENTRATION

Solid materials react to stress or force exerted over an area. High stress, which is easier to get when the area is small, is needed to cause abrading and scratching. Debris, burrs, or other surface imperfections act to focus normal forces as concentrators of available forces into high stress.

Do the opposite: Eliminate dust and debris particles from the incoming web, roller surfaces, and process environment. Specify and inspect the incoming web for cleanliness. Prevent roller slippage and associated debris generation. Design processes and equipment for cleanliness by eliminating debris sources or isolating the web from them. Ensure roller surfaces are even and free of burrs.

RELATIVE HARDNESS

When abrasive wear occurs, it is usually the softer surface that loses more material. Diamonds are the top of the hardness scale and usually will cut or abrade anything else.

Do the opposite: The first four factors will lead to some nice scratching, with more severe scratching on the softer of the two rubbing surfaces. Change from steel or aluminum rollers to rubber-covered rollers, or wrap the rollers with a softer material such as masking tape, cheesecloth, fabric, or paper.

In my experience, the top factor in stopping scratches is to stop relative motion by using rough or textured roller surfaces. Many converters wrongly associate high roller roughness with more likelihood of scratching. Roughness without relative motion does not create scratching. Rough or textured roller surfaces include micro-grooving, dimpled tape, plasma sputtering, and many roller wrap options, such as fabric or cheesecloth.

Follow this plan and you will have the opposite of scratched webs: happy customers.

Five Questions and Answers on Web-Roller Lubrication

Lubrication occurs when a gas or liquid separates or reduces the contact between two surfaces. Lubrication is used intentionally to reduce wear and increase the life of your car's engine. However, unintended lubrication between your tires and the road can be a bad thing. Water, oil, or snow can separate tires from the road, causing loss of driving, braking, and steering control.

Air lubrication is used intentionally to prevent web contact on air turns. However, unintended air lubrication on rollers and in the winding roll may be a bad thing. Air lubrication needs to be understood and controlled to prevent loss of web tension, guiding, and winding control.

Following is a Q&A primer on air lubrication in web handling.

What problems are caused by air lubrication?

Lubrication reduces the force to drive idler rollers, leading to scratching and debris. Driven roller lubrication breaks down the first assumption of tension control, that the roller speed equals the web speed. When a coater's pacer roller slips, the web speed is uncontrolled, creating coating thickness variation. Lack of friction due to lubrication will increase laterally shifting and position error at web guides and winding rolls. Excessive wound-in air may form “soft roll” defects associated with air's departure over time.

What determines when air lubrication occurs?

Rollers and winding rolls lubricate when the entrained air layer thickness is greater than the combined surface roughness. The entrained air layer thickness increases with larger radius, higher speed, and lower tension. Smooth surfaces lubricate quickly, like films on chromed rollers and winding smooth webs. Porous webs — where air can escape through the web — will see little, if any, lubrication. Web widths of 1 in. or less will see some edge escape effects. Most lubrication problems start above 300 fpm, but smooth surfaces and low tension can air lubricate as slowly as 50 fpm.

How can I tell if I have air lubrication?

The signs of air lubrication are idlers dropping below web speed and driven rollers not maintaining tension set points or deviating from line speed. For undriven rollers, measure the force to hold the roller stopped (please think safety). On driven rollers, run experiments to find the tension differential that causes slip. You have measurable lubrication if this force or differential is lower at higher speeds and lower tensions. At winding, the telltale sign is shifting in the outside layers of the building roll. Air lubrication should be suspected when shifted layers increase with larger diameter, higher speed, lower tension, and smoother products.

How is air lubrication prevented?

For unnipped rollers, surface roughness or texture is the simplest way to prevent lubrication. Don't drive with bald tires, and don't handle webs with overly smooth rollers. Since the air layers are usually less than 0.005 in. thick, a roller roughness feature of 0.010-0.015 in. is a sufficient tread. Nips are effective at eliminating air lubrication but may create additional problems. Vacuum pull rollers eliminate air lubrication without the problems associated with nips. At winding, pack rollers are effective air squeegees, greatly reducing the air entering the roll.

When is air lubrication good?

Traction is required to hold in wrinkles; thus, lubrication reduces wrinkling sensitivity. Air entrained in winding rolls helps to fill the valleys of crossweb caliper variation.

Understanding air lubrication can help you prevent the detrimental effects (scratching, tension, and tracking control problems) and take advantage of the beneficial effects (less wrinkling and less caliper-sensitive winding).

Are You Rough Enough?

Rough necks, rough language, rough drafts, and golf balls in the rough. Smooth operator, smooth as a baby's bottom, smooth sailing, and smooth moves. Smooth gets all the good press. Rarely is rough an admirable quality.

What is the better roller surface to prevent web scratching, smooth or rough? Many people will opt for smooth, but in fact, this is the wrong direction.

If we want to scratch something or "rough it up," we grab something that has high roughness (and usually hardness, too). We know if we push the hard, rough object against the to-be-scratched object and work the surfaces back and forth against each other, the soft material will begin to wear down.

This is all true, but roughness is a secondary factor. Abrasive wear occurs anytime you push two materials together and slide them relative to each other. Whether smooth or rough, you'll get scratching.

In web-roller contact, the key to eliminating scratches is to prevent the relative motion. Keep the roller surface turning at web speed. You can lie down on a bed of nails and you won't scratch yourself—just don't slide on it.

Why are rougher surfaces better at eliminating scratches? Roughness prevents traction loss from air lubrication. As long as the combination of tension, wrap angle, and traction coefficient can apply enough torque to overcome roller drag and inertial torque—no scratches. But as you want to run faster, with lower tension, or with larger radius, you will be more prone to air lubrication.

A simplified model of air lubrication (from work at the Oklahoma State Univ. Web Handling Research Center) says the lubrication of a surface begins when the entrained air layer height is equal to the combined roughness of the web and roller surfaces and reaches full lubrication (zero traction) when the air layer is triple this height.

Increasing roller roughness can prevent traction loss at increasing web speed to tension ratios. Since air layer goes up direct with radius, you need more roughness for larger rollers. The curves on this graph include this by plotting traction losses as a function of Ra to radius ratio.

If you run 300 fpm at 1 pli tension, an Ra of 32 micro-inches/in. of roller radius would be fully lubricated, but an Ra of 64/in. of radius would only have lost about 20% of its initial traction. A 4-in.-dia roller may be fully lubricated if the Ra was only 64 but likely will still have good traction with an Ra of 125.

These traction loss curves are conservative with no consideration of web roughness, edge effects, web porosity, or uneven tension across the web, but it's clear that a little roughness shouldn't rub you the wrong way.

Next month: More on roller surface options.

If Not Rough, How About Groovy?

Last month I presented the cases for rough over smooth in preventing slip and scratching problems (see "Are You Rough Enough?"). Even though rough surfaces have a bad reputation, rough is better than smooth to fight lubrication from air or liquid lubrication. But is rough the best solution?

Creating a rougher roller surface from machining or bead blasting is effective and inexpensive, but rough surfaces do have drawbacks. Rough surfaces can prove difficult to clean, both from snagging your cleaning cloths and collecting crud in their deeper valleys. The reduced contact area can be good for release properties but bad for heat transfer. The machined and blasted rough surface profiles get much of their peak-to-valley difference from a limited number of peaks. Even a small amount of wear or applying a thin, hard coat will reduce their Ra and lubrication-preventing powers significantly. Creating a specific Ra value from machining or blasting may be difficult to repeat from lot to lot or supplier to supplier.

So, how else can you fight an air or liquid lubrication beside simple roughening techniques? For a quick change in roller roughness, try a roller wrap. By far the most popular choice is masking tape. Masking tape is inexpensive, has a low tack adhesive that is removed easily (if you don't leave it exposed to UV light too long or bake it on), and it conforms easily to the roller's surface. Masking tape also creates two levels of roughness from both the tape roughness and the ridges or grooves of the tape thickness.

Other popular choices for roller wraps include fabrics (including cheesecloth and sailcloth); netting (including pantyhose); abrasive tapes (such as emery cloth or safety walk tread); cork; and embossed rubber tape.

Roller wraps have some drawbacks. They can wear or fall off, sending bits of debris out the door with your product. Wraps may insulate any desired heat transfer or create more (or less) electrostatic charging or dissipation. Acknowledging these drawbacks, roller wraps remain a quick, inexpensive solution.

For a long-term solution with consistent performance, add grooves or ridges to your roller. Ridges and grooves are cut into your roller materials, whether steel, aluminum, or rubber, and can be hard-coated without changing their performance significantly.

Any grooved or ridged surface is defined by four variables: pitch, depth, width, and angle. Whether a cut pattern is a groove or a ridge depends on what percentage of the surface is raised or recessed. Grooved surfaces are far more common, since a web can span a small gap without much deflection, but even the narrowest ridge can wrinkle a thin web.

To prevent lubrication, I look for a fine groove pattern, with a 10–20 pitch (grooves per inch). I've found at this pitch, a groove depth of 5 mils/in. of radius (same for groove depth) works to prevent air lubrication in even extremely high speed-to-tension ratios. I've seen rollers with big grooves and small pitch. The big grooves seem more than adequate to channel away unwanted air, but the distance between grooves, even at 1 in., is too far for air to travel in the short contact time on the roller, reducing the expected benefit.

What groove angle is best? Axial grooves can be noisy; annular hoop grooves may catch and hold wrinkles. Chevron pattern grooves are a good choice, and diamond patterns are the most popular.

Consider a car tire. Grooving or tread, not roughness, is the engineered solution to prevent lubrication. Grooved rollers are also a well-engineered solution.

Optimizing Traction

Rollers are the hands of web handling — the hands we use to grip the web to meet our goals for web speed, position, and flatness. To be able to position the web, we need to "get a grip," creating the frictional force between the web and each roller. How much grip or traction do we need?

There's a famous children's story about a girl named Goldilocks and three bears. As the girl explores the vacant bears' home, everything seems to fall into one of three categories: "too much," "too little," or "just right." I'd like you to apply this same approach to determining the optimal "grip" for your web line.

Before we can talk about too much or too little grip, we need to review the factors that determine total web-to-roller traction. A good first estimate of web-to-roller traction is:

Friction = Tension × Wrap Angle × Friction Coefficient

In this equation, friction and tension are in units of force (lbf, N, or kgf), wrap angle is in radians, and coefficient of friction (COF) is dimensionless.

It can be surprising there are no width or radius factors in this equation. The normal force is found by multiplying web pressure by roller wrap area. Increasing area by radius or width is offset by a proportional decrease in pressure ($P=T/RW$), canceling each other out.

This is not to say width and radius are not important to web traction optimization. Friction will increase with width, since tension typically is set proportional to web width. Radius can be an important variable, especially with high-speed processes where air lubrication increases proportional to radius.

The four main factors that determine total traction are tension per unit width, width, wrap, or COF. We could adjust any of these in our effort to find "just right" grip; however, width usually is fixed for the given product and tension may be fixed for a process requirement. This leaves wrap angle and COF as the main optimizing variables to adjust in our goal of finding a grip that is "just right."

The most common sign of "too little" grip is web scratching, from an idler roller not turning at web speed or from a driven roller unable to isolate a zone-to-zone tension differential. Too little grip also will be observed as poor tracking, guiding, or wound roll alignment. Increasing traction variables prevents these defects (such as more wrap angle or more tension).

How will we know when we have "too much" traction? The top hazard associated with "too much" grip is web wrinkling. High traction by itself does not cause wrinkles, but enough friction to hold the web in a buckled form is a prerequisite for wrinkling. Wrinkles first appear on high-wrap angle, high-friction rollers.

Also, wider, higher-friction webs are more prone to wrinkles. Reducing wrap angles and lowering web-to-roller friction often can prevent wrinkles. However, if traction is lowered too far, we can be back to the "too little" traction problems.

"Just right" traction is between "too little" and "too much," between web slip and web wrinkling. Sometimes this window is wide open, especially for wrinkle-insensitive materials. Other times, this window seems to be closed. Reducing roller drag and inertial torques will lower the "too little" traction criteria. Optimizing spans, tension, and product design will open up the "too much" traction wrinkle sensitivity.

By understanding the optimized window between these two extremes we, too, can enjoy the pleasures of "just right."

Friction Circles on a Winter's Day

Doing doughnuts — this was the term my high school friends called the art of driving around in snow-covered parking lots, spinning your back tires during a hard turn to get your car to fishtail in a circle. We thought we were James Garner on the Rockford Files. The onset of front wheel drive ruined one of life's simple pleasures.

Little did we know "doing doughnuts" was an educational endeavor that helped us better understand a curious, yet practical, mechanism in web handling — the friction circle.

The friction circle is a common term among racing enthusiasts. In racing, it describes the combination of conditions that will lead to a spinout in the third turn.

As your car races down the straightaway, the only way your tires will slip is if you try to accelerate or brake too much. If the inertial load is greater than the tire-to-road traction, you will slip relative to the road. With experience, you learn quickly to control how much gas or brake to apply without slipping.

"Brake before the turn" is good advice given to new drivers. Why? Why should it matter whether you brake while driving straight or while turning? The answer lies in the friction circle. When you are turning, there is another demand on the friction between your tires and the road — centrifugal force.

A moving object will travel in a straight line unless acted upon by an outside force. To redirect your car, you will use the traction or friction forces between the tires and road to overcome centrifugal force. If you try to turn too fast or on too sharp a radius, you will spin out.

If you coast through a turn, you can make a tighter radius without slipping than if you accelerate or brake while in the turn. The friction circle is the combined limit of friction available to be used in any direction. If your 4,000-lb car creates 1,000 lb of friction, you can use that to accelerate or brake and offset centrifugal forces in a turn, but if the combination of these exceeds 1,000 lb, you will slip.

The limit is actually the vector sum of the applied forces, so you will be able to support 700 lb of load in perpendicular directions but not much more.

How does the friction circle apply to web handling? The friction circle applies any time you are trying to use web-to-roller (or web-to-web) traction in the machine and transverse directions at the same time.

Following are three cases in which the friction circle explains what may otherwise seem inexplicable web behavior.

Case 1: A steering style web guide uses web-to-roller traction in the transverse direction to create the bending force that redirects the web, but it also uses traction in the machine direction to overcome roller bearing and inertial drag. I've had clients tell me "the steering roller slips before the other idler rollers." Since a steering roller has more lateral traction demand, it will have less traction available to overcome the machine-direction loads and therefore slip before similar non-steering rollers.

Case 2: To hold a wrinkle, the roller must exert forces laterally on the buckled web. Rollers with wrinkles also need traction to oppose machine-direction drag. If the roller machine-direction load increases, the wrinkles will disappear just before the roller slips. A roller on the fine edge of slipping will have difficulty holding in a wrinkle. This phenomenon is a powerful anti-wrinkle tool when properly applied.

Case 3: Early last year (February and March), I wrote columns on cinching, where the winding roll's torque capacity is exceeded. The friction circle concept explains why cinching typically is accompanied by telescoping. When the machine-direction applied torque consumes all roll's internal traction, there is nothing left to hold the roll laterally.

I expect you wondered how I was going to get from doing doughnuts in my high school parking lot to a useful principle of web handling, but there it is. Think about the friction circle this winter next time your traction-control braking system kicks in on that snow-covered road.

AIR FLOTATION

Whatever Floats Your Web

Why float a web? If you can float your web over a stationary plate or cylinder, you've got something simpler than a roller. But if floating your web requires a complex air flow control system, you're getting into something not just more complex than a roller but more expensive, noisier, and less stable. So again, why float a web?

Because air floating can do things a roller can't. The most common reason to float a web is to change its direction without touching it, such as turning the wet or sticky side in a drying or curing oven. The next most common reason is to make a right-angle turn of your machine centerline. You also can stabilize your web from flutter with air or induce lateral shape stiffening to prevent curl or wrinkles in long spans.

A right-angle turn bar usually is a perforated cylinder set at a 45-deg angle to the machine centerline. The web enters the turn bar, wraps the cylinder through 180 deg, and exits on a parallel plane, one diameter higher or lower than it entered, now traveling at a right angle from whence it came.

To visualize this, fold a strip of paper to form a right-angle "L" and stick your pen in at the 45-deg fold point. Right-angle turns are used to flip a web (using two turn bars), to make a U-turn in your process, or to bring a web in or out from a winder set perpendicular to a line's main centerline. (Don't try this with a roller. Webs don't like to travel helically around rollers.) The problem with a nonlubricated turn bar is the tension increase from friction. In some applications, you can use natural lubrication, something you get when the entrained air by the moving web and roller is greater than the roughness or textures of their surfaces (see "Web Lines," February 2006).

To float your web, do the opposite of all my nonlubricating advice: Think smooth, large radius, and low tension. In web handling, usually we calculate air lubrication on a spinning roller, but the web alone can entrain enough air to float on a nonmoving cylinder or curved plate.

If self-lubricating isn't enough air, you can add more with a forced air system. Simply pump some air into a perforated cylinder or plate, run the web over it, and immediately you will notice a drop in sliding friction. When the air flow is small, I like to call these air-greased surfaces. The intention is to reduce friction, but air-greased surfaces still may have some contact and are not appropriate for a scratch-sensitive product.

If you want to ensure noncontact, you must work a little harder. To establish a controlled float height, think about the web's opposing tension and air leakage. The pressure to float a web is equal to the tension (in force per width) divided by the radius of curvature. Several calculations later—considering the air escape velocity, total flow, supply pressure, pressure drop—you will have an engineered, guaranteed-to-almost-never-contact air turn.

To reduce out-of-plane web flutter, mount a flat plate parallel to a web span. Why does this work? Put two plates of glass together, then try to pull them apart. It's not necessarily adhesion fighting you; it's the low-pressure vacuum you create by trying to expand the low volume of air between the glass plates. This same effect inhibits web motion from a close proximity plate.

The Coanda effect is another form of air float stabilizing. If you blow air parallel to the web, it will create pressure that opposes the web if it tries to move perpendicular to the air flow. Air foil nozzles use the Coanda effect.

Lastly, you can induce crossweb stiffness with air. Staggered air nozzles in an over-under-over configuration commonly are used in long, contact-free spans of air floatation dryers. The air-induced shape increases lateral stiffness, preventing the web from curling or wrinkling.

Except for nonvacuum processes, your web is going to interact with the air around it. Use these tricks, and float your web to your advantage.

Blow Away Your Roller

What can reverse the direction of your web without touching it? What can redirect a web's running angle or inclination with the tension losses of roller drag or inertia?

What can turn your web process centerline at a right angle? How can you take a running web and flip the bottom side up while maintaining the same process center line?

How can you unwind and wind horizontally, yet run your process with the web running on end vertically? How can you measure the tension in a web — even the crossweb tension variations — without touching it?

There are two answers to these questions.

Travel to an alternate universe and break the traditional laws of physics.

Use an air turn, also known as an air turn bar or air reverser.

An air turn is a cylindrical element with either a slotted, perforated, or porous surface combined with an air supply. In design, the air turn has much in common with air hockey tables and hovercraft.

All three supply a constant velocity of air to create enough cushion pressure over a working area to offset a load. The air hockey table lifts the light plastic puck; the hovercraft lifts the ship and its cargo; and an air turn offsets the pressure of web tension over a radius.

The pressure needed to offset tension is easy to calculate; it's the tension in force per width divided by the air turn's effective radius (P=T/R). If you are running a web at 1 PLI (lb/in.) over a 10-in. dia air turn, the pressure under the web will be 0.2 psi (1 PLI/5-in. radius).

You can see that this is a low pressure that should be fairly easy to create with blowing air. From this equation, you can see that it will take more pressure to offset higher tension or air turns with a smaller radius.

In designing air turns, there are two approaches:

Partial lubrication for reduced friction contact

Full lubrication to a target non-contacting float height

The air hockey table is an example of a partially lubricating design. The goal is low friction, but occasional contact between the puck and table will happen.

I've seen many partially lubricated air turns — what I considered an air-greased bar. They are usually smaller in diameter (less than 6 in.) and feature a sparse hole pattern (e.g., ⅛-in. hole for every 4 sq in.), and the air supply is via a constant speed fan (or more expensively, supplied with plant air!). These work great for many cases, but don't expect them to handle your optical film scratch-free or float a PSA product sticky side in.

A fully lubricated air turn requires a bit more engineering. Besides calculating the cushion pressure to offset tension, a fully lubricated air turn will consider the following:

The height the web will float above the curved surface without contact

Supplying sufficient volume of air to make up for the escape of air from the entry, exit, and side leakage

Performing the first two functions with acceptable insensitivity to crossweb tension variations from misalignment or web bagginess

Accounting for the diameter and float height in the elevation change with the entry to exit rollers

Supplying the air from an independent blower and motor system

Using a 180-deg wrapped air turn will reverse the web's direction from north to south, east to west, or up to down without the contact, drag, and inertia of a roller. By far the most common application of air reversing air turns is in drying ovens, in which an air turn can reduce the footprint of an oven and avoid the problems of a hot roller.

Don’t Flip Out, It’s Just a Web Flip

The first time you see a web flip, you will wonder if you are looking at an M.C. Escher drawing. Escher was famous for his castles where you could walk on stairs mounted on the walls and ceiling - where up was up in the X, Y, and Z directions.

People go this way and that way, ways that seem unnatural. There is something fun and disturbing about losing your sense of orientation in this art.

Web flips are Escheresque. The web goes this way, then that way - ways that seem to be unnatural.

Web flips are fun and disturbing. They are especially disturbing if your web scratches, crashes, or wrinkles during one.

The purpose of a web flip is to - as the name implies - flip the web from side A up to side B up without reversing direction. (The easy way to flip a web is turn around a roller, but then you reverse from heading north to south.)

Web flips are added to dual coating or multi-station printing processes to provide the following two options:

bypassing the web flip and putting two coatings on one side of the web

using the web flip to coat on both sides

A web flip system includes three parts:

the first web turn bar

a return roller (or rollers)

a second turn bar

By the time a web leaves the web flip system, it will have traveled in at least three different directions. Follow the web path in the top view and end view schematic of a web flip system as shown above.

The web enters traveling east with side A up, shown in blue.

The web helically wraps the first air bar and exits with a 90-deg turn heading south, now with side B up, shown in green.

The web wraps a roller (or rollers) for 180 deg and heads back north, with side A up again.

After another 90-deg turn on the second air bar, the web leaves the system, again traveling east, but now with side B up.

Fun and disturbing, right?

WHERE DO WEB FLIPS RUN INTO PROBLEMS?

There are several chances to mess up this system. If the air turn has insufficient supply air or a low pressure drop, the web easily may touchdown or crash into the turn, especially with a baggy web or if the air turn is poorly aligned.

If you try to force the web to make a 90-deg turn with improper geometry, the result will be severe crossweb tension variations, or worse yet, wrinkling and web breaks.

These are two common mistakes that lead to improper geometry:

If the turn bar is installed off of 45 deg, it will create a short web path on one side and a long one on the other.

Less obvious is the problem created if the elevation change from web paths 1 to 2 or 3 to 4 don't account for the air turn diameter and the air flotation height. If not, the air turn will be wrapped more or less than 180 deg and will over- or under-shoot a true 90-deg turn.

The last point on web flips is the same as any air turns: Avoid long spans into the air bar. However, unlike Escher drawings, web flips are real, and once installed correctly, they can run smoothly in your converting operations.

NIPPED ROLLERS / LAMINATING

Under Pressure (Revisited...and Revised) – Apr 2007

If I have any repeating theme to understanding web handling, it is to follow the stresses and strains. In nipped processes, you need to follow the compressive stress (aka pressure).

What is the pressure in your nip? How does one set of nips compare to another? What if you change roller diameters, rubber hardness, or covering thickness? If you want to double the pressure in the nip, how much do you need to turn up the load?

Most nipped processes aren't run with the actual nipping pressure in mind. It is rare for anyone to try and calculate the actual force per area that the web endures within the nip contact zone. Instead, most nips are run based on air pressure to loading air cylinders or how many turns of a screw are just right.

When I want to understand something on an engineering level, I usually dig into my past Proceedings from the Intl. Conference on Web Handling (IWEB). For this column, I'm digging into a good paper from the 2001 IWEB by Dr. Keith Good titled "Modeling Rubber Covered Nip Rollers in Web Lines."

In this paper, three things can be put together to answer most of the questions I posed in paragraph two. First, there is a review of classic Hertzian contact equations relating indentation and contact length of two cylinders. Second, the paper cites a few authors of past research showing how pressure varies in the machine direction through footprint contact length. Third, Dr. Good graphs out data from his experiments confirming a strong correlation to the theoretical equations.

Almost teasingly, this paper shows the trend between nip load (in force per width) and rubber indentation, but not pressure. As with many academic papers, either intentionally or not, some work is "left to the student."

Sometimes a set of what-if scenarios is better than looking at a complex equation. The table is for nipping steel and 60 Shore A rubber-covered rollers of equal diameters. The tables below show average pressure. In Hertzian contact, the maximum pressure at the center of the nip footprint will be 4/p times higher than the average, or 27% more.

Average Pressure vs. Diameter and Covering Thickness

	Pressure vs. ConstantIndentatin (Indentation=10 mils)		Pressure vs. Load (Load/Width=10 lbf/in.)		
	Diameter (in.)		Diameter (in.)		
3	6	12	3	6	12
0.2539 psi	39 psi	39 psi	11 psi	8 psi	7 psi
0.5020 psi	20 psi	20 psi	17 psi	13 psi	11 psi
1.0010 psi	10 psi	10 psi	25 psi	21 psi	17 psi

Durometer is 60 Shore A (or IRHD). For Compliant Roller on Steel Roller of Equal Diameter

From these two tables you can see that nip pressure for a fixed indentation or engagement, the pressure is a strong function of rubber covering thickness, but independent of roller diameter. For a given indentation (10 mils), larger diameter nips will have a longer footprint and residence time, but the pressure is constant. It is also interesting to see at a fixed nip load (10 PLI), there is an interaction of covering thickness and diameter on pressure. If you run your nipped process by load, which many people do, a lab machine with a 0.25-in. of rubber on a 3-in. roller will create the same pressure as a production machine with 0.5 in. of rubber on a 12-in. roller.

Rubber modulus is an exponential function of hardness, so small changes can have a big effect. For a given penetration, the force and pressure will go up directly with modulus. If you hold penetration constant, but decrease hardness by 10 Shore A, the force and pressure will drop 43%. If you increase hardness, they will go up 76%.

If you combine the equations for load per width and contact length, you find that average pressure goes up as a function of load per width to the two-thirds power. Doubling load per width only increases pressure by 60%. If you want double the pressure, increase the load by 2.8x.

If after all this you are interested in the jumbo equations, please contact me and I'll send them to you.

How To Control Roller Nips – Aug 2010

If you want to compress something, you always have two choices. You can use either one of the following options:

Put it in a vise or C-clamp and slowly turn the screws until it compresses to the desired dimension (but let the force or pressure be whatever happens).

Pile weights over a given area to compress it (but not control the final dimension).

There is no right answer that fits every need for compression. You might choose to control the compression distance when you are looking to control the final dimension; when the spring constant of your system is consistent; or you want some tactile feedback to the compression that you can "feel" (such as the hand torque required to turn the screw).

You might choose pressure control when you know that your system spring constant will change over time; you want to avoid excessive loads; or you want to take the need for skill out of the repeatability of the compression.

Nipped rollers, used in many processes, rely on high pressure created by rolling a web between two pinching rollers. In nipping roller systems, you have the same choices:

Control the nip pressure adjusting the indentation, gap, or footprint.

Control the force pushing two rollers together, usually through a combination of roller weight and external load delivered by pneumatic or hydraulic cylinders.

In my June 2007 column "Under Pressure" (http://pffc-online.com/mag/paper_pressure_brighter_look/index.html), I reviewed the variables that determine the relationship between either rubber cover engagement or rubber roller nip load (in units of force per width) and pressure; however, I didn't make an argument as to which is better. Again, there is no one answer that fits all nip systems.

My first preference, whenever possible, is to design a system in which one of the two rollers is sufficiently large to avoid significant deflection and make the other roller nip from above using only its weight. The advantage that gravity loading has over end loading is that the force is applied uniformly across the nip's width just like your process probably needs. Any method — engagement or force loading — that relies on controlling a nip system by squeezing down on the roller's shaft or journal ends has to convert the outboard point loads into a uniform, evenly distributed central load. This will always mean deflection and the many problems associated with crossweb nip pressure variations.

Choose gap, engagement, or footprint if your goals are one of the following:

You are looking for the least expensive design to push two rollers together.

You want to control thickness, such as metering a coating or calendaring rubber or similar webs.

You like that feeling the same resistance in turning the screw knobs on either side of your nipping roller let's you know that the left-right loading is uniform.

However, if there are other sources of resistance to screwing a nip shut, you may be fooling yourself that you have uniformity. The greatest argument against engagement control is that the same setting (such as three turns after contact or a micrometer-measured motion) may create different results over time when rubber coverings wear or harden. Also, engagement loaded nips will fluctuate more with diameter, product thickness, and roller eccentricity variations.

I will almost always recommend controlling nip load with force delivered by pneumatic cylinders. Load control creates a nip pressure largely independent of product thickness and roller covering variations. Sized right, they prevent overzealous operators from damaging your nip rollers. Cylinder pressure can be set from a computer hooked to an I/P (current to pressure) converter, allowing recipe control of your process.

There are still applications in which thumb screws are the right choice, but you can avoid unintentional web torture by setting your nip with either gravity or pneumatic load.

Mission: Detect Nip Variations – Sep 2010

"Good morning, Mr. Phelps. Many converting processes rely on uniform nip pressure to create a uniform product (and satisfied customer) independent of crossweb position. However, our best agents have been foiled in finding an inexpensive method to infiltrate the dangerous combat zone between nip rollers. Your mission, should you decide to accept it, is to determine a repeatable, yet inexpensive methodology to assess whether any nipped process meets our goal of crossweb uniformity or has fallen to the forces of variations."

Nipped processes are under assault from many evil forces trying to thwart our best efforts at providing consistent uniform nip pressures. The perfect nip system has cylindrical, nondeflecting, aligned rollers pressing evenly on uniform webs and coatings without temperature variations.

However, the perfect nip is a rarity. All efforts for uniform nipping are threatened by diameter variations from wear or poor machining, deflection from gravity and end-loading, misalignment or uneven loading from nipping mechanisms or gap control, uneven thickness in webs and coatings, and uneven thermal expansion from poorly designed heating or cooling rollers and uneven product thermal loading.

With a goal of measuring what happens between two nipped rollers, there are many options available to you ranging from more than $40,000 to less than 25¢.

There are two approaches to measuring nip uniformity. The more difficult and expensive option is measuring pressure between the rollers using a resistive, capacitance, or strain-based sensor. The far simpler option is to measure the machine direction contact length, also known as the nip's footprint length. A forensic pathologist can estimate your weight from your footprint by modeling the combination of your shoe size, footprint depth, and compressibility of the ground. A web handling pathologist can estimate nip load from roller material and geometry and by measuring the contact length between nipping cylinders.

For small indentations, the footprint length will increase proportional to the load (in force per width) raised to the 1.5 power. A 20% footprint contact length increase reveals a 31% load change. A 50% or 100% footprint change represents an 84% or 183% load change. If you have a 3x footprint variation, you have a greater than 5x load variation.

How do you measure nip variations for 25¢? With tape! This method works best if one of your rollers is fairly smooth and you can see through the tape so you can easily identify where there are entrapped air bubbles between the tape and roller or a bubble-free wetted contact. I have found many polypropylene splicing tapes work well. Follow these steps:

With the nip open, carefully place several strips of thin splicing tape on one of the nipping rollers without pressing out the bubble trapped between the tape's adhesive and the roller.

Rotate the tape to the nip contact zone and close the nip with the desired nip load.

Open the nip and rotate the sample out of the contact zone.

Now measure the machine direction length of the "wetted" contact area where the bubbles have been pressed out.

Plot the footprint length versus crossweb position and check for uniformity.

Repeat the test at different loads to ensure your system provides uniformity at all your typical process conditions.

If you want to go further with this data, use the contact length model discussed in my past column on nip mechanics or my PFFC column archive page.

If you wondered who Mr. Phelps is, you will have to search the web for old "Mission: Impossible" episodes. This column will self-destruct in five seconds.

Deflecting Nip Roller Problems? – Apr 2006

X 'em out! Nipped rollers are vital to many web processes, including coating, laminating, embossing, calendaring, and winding. Two nipped rollers have a lot more of something than a single roller will ever have—pressure.

Is this pressure nice and uniform across the web? Not likely. It would be if we had perfectly cylindrical rollers applying the same load over each inch of width, and the web was perfectly flat. Anyone out there with this perfect process, you can stop reading now.

Nip rollers often have compliant coverings to forgive many imperfections. An elastomer covered roller will reduce pressure variations from thick and thin lanes in the web, roller diameter variations, cover hardness or modulus variations, and the big one: roller deflection.

What causes nip roller deflection? All rollers are noodles. They may be 12-in.-dia steel noodles, but they will bend like noodles when torqued.

If you set a solid steel cylinder on a flat plate, it doesn't deflect. The nip load is created by gravity pulling uniformly across the cylinder. If you want more nip load than the roller weight provides, you have to get a bigger roller, stack rollers, or apply an external force.

For more nip load, most people apply extra load to the roller by pressing down on either end of the roller's shaft. This indirectly applied load will create a torque, leading to bent noodles. Since larger solid cylinders are heavy and expensive, we often choose a smaller diameter, hollow cylinder as our nip roller and have to live with the result, which is more deflection.

The deflections are small, maybe just a few thousandths of an inch. But even with compliant nips, a deflection of 0.005 in. may create a crossweb variation of 5–40 PLI in nip load.

How can you compensate for nip roller deflection? Using stiffer rollers and compliant covers are the first line of defense. Crowning one of the rollers is a popular solution. But the most overlooked option is to skew the axes of the nipped rollers, creating an X-nip.

In a typical nip with the web wrapping a steel roller and compliant nip, skew the unwrapped roller. Skewing the roller axes allows the deflecting rollers to stay in contact, reducing crossweb pressure variations. An X-skew of 0.2 in. between two 4-in.-dia rollers can compensate for 5 mils of deflection.

When I suggest X-skewing, most people worry that this misalignment will create web handling problems. Yes, it might. I'd prefer to keep the roller parallel, but you're the one who tried to save money and put in nipped rollers that are too small. We're just trying to improve on a bad situation.

You may have X-nips and not know it. The X-nip effect can create huge pressure variations in steel-steel nips. Think about the pressure variations of X-nips. The X-factor can help or hurt, but be in control of whether or not to put the X on your product.

Who's Driving This Nip? – Dec 2008

What is the best way to drive a set of nipped rollers? Two rollers and two drive options (driven or not) lead to four options.

To make this discussion a little easier, I will assume the two-roller nipping system includes one hard steel roller and one rubber-covered steel roller.

Option 1 | Both Rollers Are Idling

This option is probably the least common from what I've seen. There are two problems with an idling nip set. First, idling nips steal tension from the web to overcome drag from bearings, inertia, and rubber hysteresis, not to mention whether your nips are used as part of a drag-creating process, such as calendering, embossing, or metering viscous fluids.

Second, since idling nips steal tension from the web, they should be set at high nipping loads to create enough friction to transfer this tension to the rollers without slippage, though large wrap angles, tensions, and friction coefficients can reduce the friction needed from nipping. Artificially high nip load to meet friction needs are ripe problems, including rubber roller wear and deflection.

Option 2 | Drive the Rubber Roller, Idle the Steel Roller

I won't say that this is a dumb idea, but there are better ideas. The biggest problem with driving a rubber roller is that the rubber's surface speed is a function of nip load and rubber indentation. A first estimate of this effect is that a driven rubber nip will increase web speed equal to about one quarter of the percent maximum indentation of the rubber covering.

For example, for every 10-mil indentation change you make to a half-inch thick rubber covering, the web speed will change 0.5% (¼ × 10 mils/0.5 in. = 0.5%). For stiff webs, such as many papers and polyester film, this is a massive speed change and potential source of a tension upset or induced web-roller slip. If the driven rubber roller is in closed loop tension control, then this small percent speed change is easily handled within a standard tension trimming. But if this roller is operating in speed ratio control or is the pacer of your process, a half-percent speed change is likely a big deal.

Option 3 | Drive the Steel Roller, Idle the Rubber Roller

This is by far the most common option in rubber-steel nip systems used in tension control, coating, and laminating. The steel roller's indentation is insignificant, so surface speed is independent of nip load. The rubber roller is driven by either the steel roller contact outside the web (for thin webs) or through the product (for thicker webs). Either way, the motor can provide the torque needed to overcome bearing, inertia, rubber hysteresis, and process drags.

Option 4 | Drive Both the Steel and Rubber Rollers

At first, this seems to be a belt-and-suspenders plan, but there are some scenarios in which it makes sense. As mentioned under Option 3, for thicker webs, the rubber roller will be driven by the steel roller, but this force is transmitted through your web. When the rubber-turning resistance is high and your product's sensitivity to shear stress is low (such as with thick adhesives or nonwovens), driving the rubber roller is a good idea.

Once we decide to drive both rollers, we create more questions (and some answers). Should the two rollers be driven by one motor via gears or a timing belt? Yes, this is quite common in printing where the nip is lubricated with ink.

Should the two rollers have independent speed control? Rarely, since it is difficult to figure out how to speed match them, especially through nip load adjustments.

Should one or both rollers be driven in torque mode? Yes, clutching the rubber roller is a good advanced design with great process flexibility.

Driving steel rollers is rarely a problem, but the driving plan, like most rubber roller topics, is complicated, but not illogical.

Web Length per Roller Revolution=?– Oct 2010

When a roller rotates, how much web does it feed forward per revolution? At first, the answer seems obvious: It feeds forward a length of web equal to the circumference of the roller or Pi (3.14) times the roller diameter. However, this answer is correct only to 99%.

If you want to accurately estimate the feed rate, you need to consider other factors, including the effects of web thickness, web tension, nipping compression, and rubber covering elongations.

Answering this question depends on how sensitive you or your customers (and their lawyers) are to small errors in actual length and how it will be measured. Are you going to measure the web while it is still under tension? Or do you need to consider the length of the web under no tension, such as total length of cut sheets?

Product thickness effects will make you underestimate the web feed per revolution. A web bending around a roller will have different lengths depending on whether you measure the side of the web away from or in contact with the roller.

The effective feeding diameter of a web on a roller is the roller diameter plus the web thickness. For thin webs, this is a small error, but for thicker webs on small rollers, this can become a +0.1-0.3% error.

Web tension will make you overestimate/underestimate the web feed per revolution. If you feed 1,000 in. of web stretched by tension 0.5%, you will have pushed only 995 in. of untensioned web. You are better off sending an overage proportional to the strain of web tension.

When solid nipped rollers rotate, how much web do they feed forward per revolution? This question opens up one of the biggest cans of worms in web handling. Read on if you dare.

If you set the solid nipping rollers of a home pastamaker to a gap less than the dough thickness, the dough will compress as it passes between the nips. If the dough is incompressible, the volume must be constant, and any loss of thickness must be offset by an increase in width or length.

Except for small edge effects, there is no place for dough to move laterally, so the thickness change in a nipped system will mostly become a length change, forcing the web to double its length for a halving of its thickness.

Will the nipped rollers push more or less web per revolution than a wrapped roller? It depends on whether the web recovers from the nipping action. If you are feeding a highly elastic web, like rubber, the web will immediately contract back to its original length once it leaves the nip point. Therefore, your feed length will be less than the roller.

If you are feeding a viscous or deformable web, like soft cookie dough, you will see little or no snap back after leaving the nip point, and web length will be close to the roller circumference.

When a rubber nip system rotates, how much web does it feed forward? This is the real can of worms. The rubber will react like an elastic web pinched between two solid rollers, stretching in the nip zone and snapping back in the unnipped condition.

For the web pinched between the stretching rubber and the rigid metal surface, which will control the web elongation? Since most webs will have a higher coefficient of friction to rubber than hard metals, it is likely the rubber roller will determine how much web is fed forward.

The first estimate of the speed difference between a steel and rubber-covered roller is proportional to the covering indentation divided by four times the covering thickness. For a 20-mil indentation of a 0.5-in. covering, the rubber roller will turn 1% slower than the rigid roller of equal diameter.

Of course there are more worms in our can. Special rubber rollers made of hard skin on a compressible interior may have no or opposite speed differential. If the web slips against any roller, all bets are off on how much web is fed forward per revolution.

Reduce Web Nip Problems – Feb 2004

Web handling is about transport and delivery, getting from point A to point B, without damaging the product. It is relatively easy to move a web across a free span or over an unnipped roller, but getting into and through a nip can be a show stopper for many processes or products. As a web handler, you should consider nips your tough customers.

Nips are the most threatening point in a process for man or web. A nip's power to crush and pull endangers body parts. The nature of a nip's threat to a web is different. Nips are intended to pressure and pull a web. The source of most nip-web problems is cross-web variations in either the nip or the web. Process nips are used to meter material uniformity. In extrusion or coating, the nip is expected to redirect and smooth out the fluid polymer or solution to a uniform cross-web thickness and flow rate. This assumes uniform nip geometry and pressure and the uniform web.

Uniformity is like perfection: always desired but seldom delivered. Once again, we have the recurring theme in web handling of dealing with imperfection (a.k.a. making the silk purse from the sow's ear). By following a few tips, you can optimize your web-nip interactions:

Minimize nip pressures

Excessive forces lead to deflection and wear. Determine what is needed for the process. Don't assume that more is better; usually, it is not.

Increase nip system stiffness

Start with sufficient roller diameters, shell thicknesses, and material strengths. Continue good stiffness into the nip loading structure, framework, and loading system.

Use tension to create a uniform web

Baggy webs and nips don't play well together. Use enough tension to pull the bagginess out of the web. The metering nature of a nip wants to feed a uniform length of web over all cross-web lanes. Any untensioned baggy lanes will accumulate any excess length upstream of the nip until it folds over and passes through as a wrinkle.

Avoid 0-deg entry angles to reduce wrinkles

Even a small wrap angle of 5-10 deg will create a shape-stiffening benefit to prevent tracking and shear wrinkles.

Avoid 90-deg wrap angles to avoid wrinkles

End-loaded nip deflections can turn a cylinder into a banana. Wrapping a nip roller with near zero or 180 deg of wrap orients the entry span perpendicular to any deflections, avoiding “negative bow” tracking wrinkles.

Make nip load independent of web tension

Most nip systems move a nipping roller into a fixed roller. The nip pressure is created by controlling the two rollers' relative position through load or engagement. If you are working with a single web, avoid wrapping the loading roller. Engagement or negative gap controlled nips are insensitive to tension and wrap angles. For load-controlled nips, use low or 180-deg wrap angles to make nip load independent of tension.

Minimize entry span length to reduce wrinkles

Free web spans are controlled by the downstream roller. Nips are notorious for subtle non-uniformities that create tracking or shear wrinkles. Both of these wrinkle mechanisms are less likely with shorter spans.

Adjustable rollers can save the day

When high web stiffness prevents pulling out web bagginess with web tension, consider installing an adjustable roller upstream of the nip. Though a skewing roller can compensate only for left-right variations, this tool can be a web-saver, getting bad webs to run wrinkle-free through a nip. If you use an adjustable roller, make sure to include a position indicator, allowing you to move back to a trammed and level position.

Keep away from nips

No discussion of nip points is complete without reviewing safety. Coating, laminating, winding, and slitting nips are all hazardous pinch points and should be guarded to prevent human access. There are standard OSHA guidelines to nip guarding based on access slot gaps and their distance from the nip point.

Don't use nips

The nip that isn't there can't damage the web. If at all possible, design a process that doesn't require nips. For wrinkle-sensitive webs, tensioning nips should be replaced with S-wrap or vacuum pull rollers.

Nips are required for many processes, but they have unintended potential for web handling disasters. Follow these nip tips for successful web handling, not web mangling.

Can This Lamination Be Saved? – Sep 2004

Delaminating — undesired separation within a multilayer product — is a major problem for many converters.

Laminate products are a marriage of two or more layers with combined properties not found in any individual layer. Delamination is the breakup of this marriage when outside forces exceed the ties that bind.

If coatings are counted as layers, almost all converted products could be considered laminates. As I refer to laminates in this column, I'm generally thinking about substrate layers and stiffer and thicker coated layers. For a laminate to work, we usually want the layers to stay together. But, look out! There are forces at work to undermine the marriage of your laminate layers.

Products with intentionally low laminate bonds will be more susceptible to unintended delamination. For example, label stock will need more care in processing to avoid an early breakup, since ease of delamination is a desired end-customer feature.

Many laminating processes create a product with weak initial bond strength, sometimes called "green strength." Often a laminate bond involves curing, whether chemical or added by outside energy, developing a stronger bond over time. Therefore, the most important period to deter delamination is just after initial bonding.

In web handling, the excitement usually happens at the web-roller interface. Going around a roller should be an elastic experience. When your flat web is forced around the cylinder of a roller, the curved shape will impose tensile and compressive stresses on the outer and inner surfaces, respectively. These stresses are proportional to the product thickness divided by the roller radius.

Many web processes have specifications for minimum bending radius or roller diameter, aimed at avoiding curvature-induced stresses beyond a product's elastic limits. However, for laminates, you may need to set a larger minimum roller diameter, since the forces to cause delamination may be well short of elastic limits.

As a laminate wraps around a roller, the layers respond with a through-thickness stress and strain change. At the interface, the inside is attempting to elongate while the outside layer is trying to contract. This mechanical opposition creates a shear force at the bond point. If the shear load is greater than the laminate bond, the laminate will split apart.

When two webs are transported over the same roller, there is a natural tendency for the top web to have greater velocity. Assuming no slip, the average web speed going around a roller is determined by the roller revolutions per minute and the circumference of the center line of the web. When two webs wrap a roller together, the small difference in the centerline circumference will create a significant long-term length variation.

For example, two 1-mil webs will have a 1-mil radial centerline difference and a 0.006-in. feed length variation per roller revolution. This doesn't seem like much, but at 100 fpm on a 4-in.-dia roller, this adds up to 0.6 in./min of extra material in the bottom web.

When two webs have low or no bond, this extra material will pile up on the floor, wrap on the roller, or fold over in a crossweb wrinkle — all undesired outcomes. If a laminate has high bond strength, the two layers will act as one, the top web will stretch, the bottom will contract, and there will be no delamination or feed rate variations.

Here are four tips to avoid roller curvature and feed rate-induced delamination:

Move to large-diameter rollers. The curvature-induced delaminating stresses go down inversely proportional to diameter.

Avoid rollers until bond strength increases. If you postpone roller curvature until green strength goes up, you may avoid delamination.

Increase tension. The pressure created by the outer web's tension will add to the laminate bond force, increasing the resistance to delaminate.

Use lateral or low-angle spiral-ridged rollers. Roller ridges may not prevent delamination, but they can burp through small feed variations, preventing the catastrophe of web wrinkling or wrapping rollers.

Get Out of the Scroll Business – Mar 2005

Whatever happened to scrolls? Scrolls were good business until about 200 A.D. when the book came along. What is it about books that made them better than scrolls? With scrolls, you'd be reading along, look up and wave at someone, and whoops, your scroll would curl back up and you'd lose your place. You could use a couple of rocks to hold your scroll open. With books, you didn't need rocks; they stayed open. Curl killed the scroll.

Curl will kill your product, too. Curled sheets and label stock will jam a printer or copier. Curled book covers are unattractive and prone to damage. Curled sticky tapes will stick to themselves before they get to where you want them.

How do webs end up curly? Let's go over the top causes and consider how to eliminate them.

Yielding from stress of a tight radius. Any time you form a flat sheet into a curved shape, whether winding a roll, going over to a roller, or dragging over a bar, you will induce stress and strain change through the thickness of the web. The inside of the curved web will go into or move toward compression. The web's outside will see increased tension. In many cases, the web springs back with no induced curl, but there are limits.

The amount of stress change from forming a curve is directly proportional to the web thickness divided by the radius of curvature.

Take a sheet of paper. Roll it up into a 5-in.-dia cylinder and unroll it. There is probably no evidence of induced curl. Take the same sheet and roll it into a 0.5-in.-dia cylinder. Now let go. I bet it turned curly on you. The tighter radius curvature created enough stress on the paper's outside edge to cause it to yield. Try this with thicker and thinner paper and you will see that thicker papers will curl at a larger radius of curvature.

Stop curvature-induced curl by (A) not forming your flat web into small-radius curves; or (B) reversing the process, forming a curve in the opposite direction. Option B is known as decurling.

Strain mismatch in laminate. Rule #1 in laminating is to match the strains of web A and B. If we laminate two materials with different strains, they will relax unequally when tension is removed, resulting in curl to the overly strained side. Set the tensions of the pre-laminate webs to have equal strains, so when tension is removed you get equal recover and maintain flatness.

Moisture variations in paper products. Papers will grow with increased moisture content. I've seen bond paper shrink 0.5% in width as it dries. If you coat and dry on a paper substrate, you will drive moisture out of both the coating and the paper. If you then laminate the dry paper before it can return to normal moisture content, you are asking for a curled product. The key to scroll-free paper products is controlling moisture by re-moisturizing either before or after laminating.

Expansion or contraction from temperature. Films and foils will expand with temperature. Laminating to a hot film or foil is the opposite of laminating to dry paper. After laminating, the film or foil moves to room temperature, and you are now entering Scroll-ville.

Density changes in film or coatings. As a coating dries, it may shrink, pulling the web toward the drying side. Freshly made polymer films may shrink subtly in the first few hours after quenching as the polymer chains try to alleviate internal residual stresses. For the more powerful density change of a thick coating, web tension stiffening can prevent machine direction curl but not the more common problems of cross-web curl. The induced machine-direction curvature of arc or air flotation ovens may provide the shape stiffening needed to fight cross-web curl.

Laminate bond develops while curved. If you want to form a curved hull on a sailboat, you soak the wood in water, shape it, and then bond it in place. Converters try to avoid this by bonding the web in the flat footprint of a nip or the flatness of a web span. If a product with poor green strength is transported over a small-radius roller too soon after laminating, the layers may slide and bond in the curved shape. Avoid this curly fate by avoiding small-radius turns until your bond is strong.

Curls are okay for cocker spaniels, ribbon bows, and building biceps, but flat is where it's at for converted products.

Shifty Answers to Nip-Induced Tracking – Nov 2008

Nipping rollers are used in many value-adding processes in web converting — roll coating, laminating, embossing, calendering, high-speed winding, and more. Imperfect nips, where the load is uneven, can create process variations, but they also may induce a lateral shifting of your web, leading to misalignment or wrinkling.

Before I can tell you about how uneven left-right nip loads will induce lateral tracking of your web, I must get on my anti-nip soapbox. The nip that isn't there will not shift your web (or wrinkle it).

In my experience, nips and webs are a volatile combination (baggy webs, in particular, and all webs are baggy to some degree). Nips should be avoided whenever possible. Nips are required for many processes (listed above), but nips are the last choice for creating friction.

Please choose large wrap angles on high-friction rollers or vacuum-suction rollers over nips if you need simple high friction. (Okay, I'm getting off my anti-nip soapbox now.)

How does a nip roller induce lateral shifts in your web? If you have left-right nip load variations, higher on one side than the other, which way will the web go? Do we know the answer?

Some work completed by the Web Handling Research Center (WHRC) at Oklahoma State Univ. sheds some light on these questions. The nip-induced lateral tracking phenomenon needs to be assessed in several steps.

Q1 | How does the nip create cross-web tension variations?

Q2 | Which way will the torque, created by the tension variations, bend the web?

Q3 | Will the web bending create a curvature as it enters the nip roller, violating the parallel entry rule (see “Web Lines,” August 2003, p20)?

Q4 | Does the nip have sufficient traction to bend the web to obey the parallel entry rule?

In the most predictable setup, the WHRC experiments showed, for a rubber-rubber nip, the web will track to the high nip load side. In these tests, the answers to the four questions above are as follows:

A1 | The rubber in the nip speeds up proportional to the nip load. If one side of a nip roller set has more load than the other, that side pulls the web faster than the other side, creating more tension on the high nip load side.

A2 | The high tension side torques the entering web span and may cause it to bend away from the high tension side. The web's first response is to move away from the high nip load side.

A3 | The web bending from the tension variations presents a web at an angle that violates the parallel entry rule, so if there is good traction, the web will spiral back toward the high nip load side, similar to how webs with good tracking will track to the large diameter side of a tapered roller.

A4 | Traction? You bet. This is a nip. Nips usually have an abundance of traction. Putting it all together, in a controlled experiment, the web will move to the high load side of a set of nipping rollers.

Bonus question | Will the web always track to the high load side of a nipped roller system?

Answer | Not necessarily. A slipping nip, such as a nip grabbing an oiled metal web, may shift the web away from the high load side.

Real-world nips include many complications to the simplified WHRC experiments. One or both rollers may be steel. High nip loads may create web-rubber slippage when the nip's rubber cover stretches many times more than a stiff web can.

If the web wraps either roller prior to the nip point, what effects will friction and deflection have? What if there is a big tension change across the nip that induces slippage?

As usual, questions about web shifting may get answers that are equally shifty.

Take The Laminator Quiz – Oct 2011

Someone asked me a couple years ago, after auditing their lamination process, "What is the ideal laminator design?" I always love these simple questions that open up a giant can of worms. There are many things I like and do not like in laminator design. To see where your laminator ranks relative to my ideals, take the following quiz.

For each Yes answer, award your laminator the points for that question.

1. Is your nip guarded and accident free? Yes = 20 pts.

2. Is your nip entry point well-lit and easily viewable? 3 pts.

3. Do you control pre-laminating tensions of input webs to match elastic strains? 10 pts.

4. Do you control downstream tension to a set point nearly equal to the sum of the input tensions (allowing you to run low nip loads without slipping)? 4 pts.

5. (a) If your nip is controlled by supply pressure (either pneumatic or hydraulic), do you know the relationship of pressure to nip load force? or (b) If your nip is controlled by open or overlap gapping, do you have a procedure to measure the gap and set it repeatedly? 10 pts.

6. If you have a rubber roller in your nip system, do you know the maximum indentation of the rubber at your typical process condition? 5 pts.

7. Do you avoid large wraps on rubber nip rollers? 3 pts.

8. When your product is in the nip, do you know if there is contact between the rollers outside the width of your product? 3 pts.

9. Have you measured cross nip footprint length or pressure to check for nip uniformity at typical process loads? 3 pts.

10. Do you know if either of your nip rollers is crowned and, if so, by how much and what profile? 3 pts.

11. Have you ever estimated nip footprint pressure by dividing total load force by effective area (width x footprint)? 5 pts.

12. Does your nip close in a pivoting motion (as opposed to a linear motion), and do you know if your moving nip roller is self-aligning to the non-moving roller or holds its own alignment? 3 pts.

13. If your nip is pressure loaded, do you use flow control to limit the nip closing speed, and does it open during long stop times? 3 pts.

14. Do you consider thermal and hygroscopic expansion coefficients in your laminating process, and do you know the Poisson's ratios of your laminated materials? 3 pts.

15. Does your web exit the nip tangentially, not wrapping either of the nipping rollers after the nip point? 3 pts.

16. (a) Is your laminator driven, and if there is one steel and one rubber covered roller, is the steel roller the driven one? and (b) If you drive both rollers, is one driven in torque mode? 3 pts.

17. If your product is wrinkle-sensitive, is the last roller prior to the nip point: (a) a spreader roller, (b) does it form a short pre-nip span, and (c) does it create a small wrap angle on the nip roller? 5 pts.

18. Have you measured or estimated nipping roller deflection from end loading and avoid entering the nipped roller with 90-deg wrap angles (avoiding deflection-induced wrinkles)? 5 pts.

19. Do you set pre-laminate tension high enough to pull out product bagginess? 3 pts.

20. For cambered or skewed webs, do you have an adjustable roller upstream of the nip point to tighten one side or the other, and does this roller have a trammed or zero position indicator? 3 pts.

Scoring:

0-50 points = Ummm, what's the opposite of ideal?

50-70 points = You are making the grade, but maybe summer school would help you.

70-90 points = Your laminator is close to greatness.

90-100 points = Wow! I'm impressed.

If you have any questions about why I like any of these questions answered "Yes," please contact me. Maybe there is another column to focus on some key issue listed here.

LATERAL POSITION CONTROL / GUIDING

Going with the Parallel Flow – Aug 2003

Parallel flow usually is a good thing. In driving your car down the road, if you and the other drivers agree to keep parallel to the lines in the road, things go smoothly. If you have a small error in the angle of your front tires relative to the road, you will begin to track laterally, increasing your error with every revolution. If you observe your error, you can shift your tire angle in the opposite direction and track back to your lane.

From this we learn a good rule of driving: Keep your tires turning parallel to the direction you wish to travel. Parallel tracking is a good thing.

What causes problems with parallel tracking in driving? The first condition may seem obvious, but the car must be moving. The lateral shift of parallel tracking requires the tires to rotate to move the car relative to the road.

Second, to move the car in a new direction requires external force acting on the car. The force required to overcome momentum comes from the traction between the tires and the road. Traction forces are available proportional to the car's weight and tire-to-road traction coefficient. If the traction is too low, such as under icy conditions, the tires may point in a new direction, but the force required to redirect the car is unavailable.

In web lines, parallel flow still is a good thing. In tracking a web through a web line, if we keep the web parallel to the machine centerline, things go smoothly. If there is a small error in the angle of a roller relative to the web angle, every revolution will attempt to track the web laterally. If we observe this error, we can realign our rollers or install an automatic web guide. In either case, we would redirect the web back to the intended lateral position.

From this we learn a good rule of web tracking: Keep your rollers turning parallel to the machine centerline. Parallel tracking is a good thing.

Why does the moving web tend toward parallel flow? The web reacts to the direction of the roller's surface. Imagine pouring water onto a spinning roller. Which direction will the water fly off? It will fly off parallel to the direction of the roller's rotation, perpendicular to the axis of rotation. The force vectors of a roller always will be parallel to its rotation.

How does a web interact with a spinning roller? You can learn a little about web-roller tracking while sitting at your desk. Take a tape dispenser and a pencil. Pull out some tape from the roll without cutting it off, and start winding the leading edge around your pencil. Rotate your pencil, winding on the pencil "core" while the tape dispenser provides back tension. If you hold the pencil perpendicular (a.k.a. normal) to the dispenser, you should be winding a relatively well-aligned roll of tape on your pencil.

(Note: This effect commonly is described as normal entry to the roller's axis of rotation. However, as we apply this rule to other situations, I believe there will be less confusion if we describe the web's entry as parallel to direction of the roller's surface motion.)

What happens if you tilt the pencil away from perpendicular entry by a small degree? As you continue to wind, you will notice the web will track laterally, attempting to align parallel to the pencil's rotation.

As with driving, parallel flow in web handling depends on both motion and traction. If you stop rotating your pencil, nothing much happens. Traction is important since redirecting with the parallel entry rule bends the web.

Bending a web, like bending a cantilevered beam, requires an external force to create this mechanical deformation. If a roller doesn't have enough grip on the web, it will not be able to exert the force needed to bend the web to parallel entry.

How much force is required for the web to obey the parallel entry rule? I'll try to answer that question next month as we continue to go with the parallel flow of web and rollers.

Your Guide to Web Guiding Part I Lateral Registration Needs – Mar 2010

Web guiding done right is easy to forget. The principles of web guiding are well understood. With good decisions in the design phase of a process and a couple adjustments at startup, many automatic guides are in the "set it and forget it" mode.

To help more processes into the good guiding groove, review this four-part series, which starts this month with "What is lateral registration, and where do you need it?"

Lateral registration is the left-right or crossweb relative positioning of two or more features of your web or equipment. To most people, registration is something used in printing and packaging to align one print or die-cut pattern to another. In these cases, registration has both machine and crossweb direction components.

Webs without machine direction patterns still need lateral registration. Whereas printing and die-cutting may have tolerances of ±3-10 mils (thousandths of an inch), most other lateral registration needs have much lower tolerance (but equally important).

Let's review the most common needs and ranges of lateral registration:

Rollers

This seems like a simple one, but the web should stay on the face of the rollers and not track over the end of the roller. For most idler rollers, this is usually 2 in. or more. For a 58-in.-wide web, the rollers typically would be 62 in. wide or greater. This gives you ±2 in. of lateral shifting without tracking off roller, assuming the rollers are centered on the machine centerline, which often they are not.

If you want to see how good your tracking is, try to run a 61.5-in. web on your 62-in. rollers. I think you will find ±0.25 in. of clearance isn't enough.

Equipment Slots

The entrance and exits of most oven, curing, dip tank, or vacuum processes require the web to pass through a slot designed to minimize the leakage of gas, heat, or radiation. Slots may be either generous (±1 in. or more) or tight (I've seen slots with less than 1 mm clearance).

Air Nozzles, Turns, and Flips

Tracking off the edge of any forced-air web handling device usually leads to crashing into a stationary object and web breaks. All air nozzles, turns, and flips should have the same lateral buffer as rollers (±2 in. or more), unless they are preceded by a well-tuned web guide.

Coating and Laminating

Most coating processes coat something short of full web width, leaving a small uncoated margin at the edge of the web. If the web tracks off more than this margin of error, usually between 1/10-½ in., the coating will go onto the back-up roller or someplace where it shouldn't be, again often leading to web breaks. Lamination processes apply one web to another (and may include a coated layer), again with some tolerance to misalignment, beyond which creates waste.

Winding Core and Sidewall

The winding should be centered on the core or at least not hanging over the core's end. For flush cores, where the web and core width are essentially the same, there always will be a slight error in lateral position. (I consider less than 50 mils to be well aligned.)

More challenging is a roll's layer-to-layer alignment with an ideal sidewall having the shine of a phonograph record. When making a roll for internal use, many wound rolls do not have or need this level of perfection, they just need sidewall alignment that is not easily damaged in shipping or handling. However, whether for internal or external customers, a good-looking roll sidewall, like a fresh coat of paint, will always sell better and lead to happier customers.

Now that we know our guiding needs, we can move on over the next three months to understand why our web isn't where we want it, what force is required to bring it back, and where automatic guiding is needed.

Your Guide to Web Guiding Part II Lateral Motion Causes – Apr 2010

Where is your web? In the machine direction, hopefully, it is continuously running between your upstream and downstream processes. But where is it laterally?

Last month, we reviewed all the needs for lateral positioning of the web, including requirements ranging from fairly loose (staying on the rollers) to quite tight (winding a roll with the side as nice as a phonograph record).

Why isn't the web in the right lateral position? There are two strong forces that promote centerline tracking. First, tension will tend to pull a bad web straight. Second, the web tracking rule promotes centerline tracking on well aligned rollers in traction with the web (see "Going with the Parallel Flow," PFFC, August 2003, p20, or visit www.pffc-online.com/web_lines). Even with these two strong effects, our webs wander.

If you've been reading "Web Lines" for some time, you will notice my usual modus operandi of problem solving here. Attempted remedies should be based on at least a guess of what causes a problem.

Having a list of common causes makes this step easier. I group lateral errors in web position into four categories, each with several common causes.

Lateral Errors in Initial Positioning | Many webs start off in the wrong place. The original sin of lateral error is unwinding. Is the web centered on the core? Is the core centered on the unwinder? Is the unwinder centered on the machine centerline? An automatic unwind guide can put much of these concerns to rest.

The next biggest sin is threading. When you thread up a line from scratch, invariably, you put the web slightly off center of where it wants to run. In many paper processes, the transition from threaded to running position will break the web. Avoid this problem by threading with less breakable webs (thicker webs or films) and avoid losing your tensioned, threaded web position at reasonable costs.

Lateral Errors in Web Transport | The five big causes that shift the web are misalignment, diameter variations, web camber/bagginess, uneven nipping, and interaction of the web to air or fluid flow. All of these are minimized by reducing variations.

Align your rollers (to less than 200 micro-radians). Machine rollers to cylindricity. Reject overly baggy or cambered webs, and use tension to pull out the rest. Ensure nip loading is uniform side to side, size nip rollers for low deflection, and approach nip points from a low angle relative to loading or deflecting plane. Ensure fluid flow is perpendicular to the web and return flow is uniformly distributed.

Lateral Errors in Automatic Guiding | Automatic web guides are meant to reduce lateral errors, but like a broken car or drunk driver, they can be the cause of a problem as well. Ensure automatic guides have the appropriate range, gain, rigidity, and correction rate. Get the geometry right, especially in steering-type guides. Ensure edge, center, or line guides can detect your web; are close to the guide they work with; and work to reduce, not increase, the work of downstream guides within the same process.

Lateral Errors in Winding | Before blaming the winding process, always check to see if the source of wound roll shifting is from upstream handling. Winding is susceptible to all the problems of web transport (see above), but also: width recovery from in-roll tension losses, core shifting from equipment misalignment, deflection, or loss of grip between cores and shafts.

Beyond this list, perfect handling and perfect winders will still see shifted layers if care is not taken to control air lubrication (usually prevented with nipped winding) and cinching (see "Belt Tightening Gone Bad," PFFC, February 2003, p24, and March 2003, p20, or www.pffc-online.com/web_lines).

Resolving or reducing lateral errors has the secondary (maybe primary) benefit of eliminating bending-induced wrinkles. Next month we will address an important aspect of bending, guiding, steering, and wrinkling: How much force is required to bend a web?

Your Guide to Web Guiding Part III Force Is Needed to Shift a Web – May 2010

When your web isn't where you want it to be, you have two choices: You can be happy where it is, or you can try to move it to where you want it. If you decide you want to move it, then you should understand that this doesn't happen for free.

Why do we want to bend a web? The most obvious need is in web guiding. Though you may be surprised to find most web guides don't need to bend a web, steering guides do need to bend the web reliably to put it in the right position.

Why would you not want to bend a web? In most cases, we want our web running on machine centerline, so we mostly don't want to bend a web. We also don't like one of the web's responses to bending — wrinkling. Since webs don't like to bend, when they do, the applied bending forces generate internal shear and compressive stresses that may lead to wrinkling.

Do we want sufficient forces applied to the web to bend them? It seems that we do and we don't. We like good steering, but we don't want wrinkling. My philosophy is mostly that good traction — the source of the force for web bending — is a good thing.

What you don't want is a web that is unpredictable. Insufficient web-roller traction leads to a web that may be in transition from stick to slip, creating a wandering web.

If you want to bend a beam, you have to push on it. If you aren't strong enough or your beam is stiff, you won't be able to bend it much.

If you want to bend a web, your rollers will need to push on it. That push is delivered by web-to-roller traction. If you don't have enough traction or your web and geometry are stiff, you won't be able to bend your web as far as you would like to bend it.

If you try to bend a beam with a rectangular cross-section, the physics of bending are straightforward. The lateral force required to bend a beam goes up with the stiffness, which is a function of the elastic modulus and cross-sectional geometry and how much you want to bend it.

The force to bend a beam also will go up inversely with how long the beam is, making longer beams much easier to bend. For a rectangular cross-section, it is also much easier to bend something along the smaller dimension (webs are much easier to bend around a roller than laterally or widthwise).

In webs, since webs are beams, all this is still true. A higher modulus web takes more force to move. A thicker web takes more force to move. Moving a web more takes more force. But the biggest effect in how hard a web is to move is the width-to-length ratio. The force to move a web increases by the width-to-length ratio to the third power.

If you double a web's width, the force to move it increases eight times. If you double the length of web you are trying to bend, the force to bend it drops eight times.

Example

Take a 12-in. (150-mm)-wide web of paper or polyester (modulus of 500 kpsi/3.4 GPa) 2 mils (50 microns) thick at 1 lb/in. (175 N/m) tension. Use a 90-deg wrapped roller with a friction coefficient of 0.25.

If you try to bend this web just 40 mils (1 mm) in a 20-in. (0.5-m) span, no problem. But try to bend this same web ⅛ in. (3 mm), and you won't have enough web-roller friction to do it. The web will bend as far as the friction available allows (just shy of 0.1 in. or 2.5 mm).

If you increase the width fivefold (to 60 in. or 1.5 m), the force to bend will go up 125 times, but web-roller friction will go up only five times. You won't get the web to move very far (about 4 mils or 0.1 mm). If you want to bend a wide web, either go long (spans) or forget stable steering.

Your Guide to Web Guiding Part IV Do You Need an Auto Web Guide? – Jun 2010

Does every web process need an automatic web guide? Maybe two? If I was in sales for a web guide supplier, I would say, “Of course!” and “How about three?”

Yet, even though I am not in web guide sales, my answer isn't much different. Almost every web line will benefit from at least one web guide.

In my days as a corporate web handling engineer, one of the ways I found out about all the web processes that were under development in my company was to talk to the web guide sales reps. Why this worked was somewhat unique, but it might be true at your company. First, unlike other products, most of our web guides were purchased from only one of two suppliers. Second, almost all new equipment purchases had to go through our central engineering group. So to find out what new web processes were going into my company, all I had to do was ask the web guide sales reps to whom they were talking when they visited, and I had the inside scoop on almost all of the company's new web process plans.

But not all. There are a few web processes that sneak by without automatic web guides. Some may truly need web guides but will start their lives without one (and likely get one later when they misbehave and have too much waste).

But who doesn't need an automatic web guide? It is a short list.

Slit To Position

What is the world's best web guide? Slitting. You will never know the absolute position of a web edge better than you do immediately after a slitting knife. You don't need an automatic web guide if your input product is sufficiently wider than your final product.

If your input rolls have lateral alignment better than your target width plus a minimum trim width (both sides), you can eyeball the input roll position and trim to the final position. I recommend keeping things short and sweet after the final width and positioning trim.

The shorter the process and more attentive your operators, the more likely this will work for you. However, as you look to improve yields by reducing trim widths, you will find this guideless approach is harder and harder to do without losing your trims, and you likely will install an automatic web guide.

Hard To Guide

If your product or process makes web guiding impossible or difficult to guide, then by default, you may not be able to guide your web even if you want to. When is guiding difficult?

If your web is stiff — a combination of thick, wide, high modulus, and short spans — it will be tough to bend or twist. (See last month's column on the force to bend a web.) Besides not having the frictional force to move your web, guiding may damage, wrinkle, yield, or break it.

Though this may mean no web guide for you, it doesn't take you off the automatic guide sales reps' radar. You may be a candidate for chase guiding in which you move your process to follow the web instead of moving the web to your process. (This may sound like holding the light bulb and turning the room, but it makes sense if your light bulb is gigantic and the room is easy to spin.)

Easy To Guide/Too Many To Guide

If you have 100 webs, then the price of 100 automatic web guides is cost-prohibitive. Luckily, when you have 100 webs, they usually are also easy to guide.

The opposite of the hard-to-guide web — a web that is narrow, flexible, and has long spans — may be guided with the passive guiding methods of crowned roller, taper and flanged roller, or guided through dual flanges, combs, or other physical restraints. The easy, but too-many-to-guide processes include post-slitting processes (such as level winding many rolls) and processes with multiple narrow input rolls, such as paper core winding.

I don't expect this column will put any automatic web guide sales reps out of business. The automatic web guide is an important tool in many web processes, but it is nice to know when you do or don't need one.

Your Guide to the Right Web Guide – Apr 2008

Webs are blind — they don't know where they are going. With a well-aligned roller, sufficient tension, and good traction, the web has a tendency to track down the centerline of a machine. However, web and machine are not perfect and many processes occasionally lose tension or traction, so centerline tracking can't be assumed. Enter the automatic web guide, the seeing-eye dog of the converting industry.

All converting processes have some left-right tolerance of web position. The first goal in web guiding is to get the unwinding roll aligned to the roller or centerline of the machine. This usually can be done manually by eyeballing where the unwinding roll is placed on the unwind chuck or shaft.

After hitting the first roller, the left-right tolerance of web position may get more challenging. Does the web align to the coating head? To trim knives? To the laminator? To the winder core? To the other layers in a winding roll? If you worry about your blind and imperfect web going astray, select an automatic guide to meet your needs.

There are three main points where guiding is needed:

at unwinding;

at an intermediate point in your process;

at winding.

There are four options for automatic web guides:

A. unwind sidelay;

B. displacement;

C. steering;

D. rewind sidelay.

For each guiding need, there are at least two good options to meet your needs. For unwind guiding, first consider E, none of the above.

If your input roll alignment is good and you manually align to a centerline reference mark, there is no need for an automatic unwind guide. However, if you have telescoped input rolls or want to start your process with accurate lateral position, choose either A or B. Both sidelay unwinding and displacement guides are nearly foolproof options. Once set up properly, it is easy to forget these guides are even there because they usually perform their function without fail.

An unwind sidelay guide has the simplest web path but requires a larger actuator to move the unwind and unwinder. A displacement guide immediately downstream of the unwind adds slightly to the web path but guides with a smaller actuator and without shifting the unwinding roll or unwinder. For intermediate guiding, the first choice is a displacement guide.

Steering guides should be reserved for one application: to guide a long span, such as the web exiting an oven. Steering guides are a tempting choice, since their design appears to take up less space than a displacement guide, requiring only one moving roller. But don't do it. Steering guides, by far, are the source of many more guiding headaches than the other options.

Steering guides with short entry spans are wrinkle generators. Steering guides need to be designed carefully for the correct spans, wrap angles, traction, and pivot radius or they will fail to perform as anticipated. For long spans, they are the best. If you have a short span, consider yourself warned.

For winder guiding, choose either a displacement guide immediately upstream of the winder or sidelay. A winder sidelay guide isn't really a web guide but a web chaser or winder guide, placing your winder in front of the web wherever it may wander, much like a baseball catcher chases wild pitches.

The best winder guiding is a sixth option: slitting. No automatic web guide will ever beat the exactness of the web's edge position immediately after slitting. When the side of a wound roll looks like a phonograph record, it is almost certainly from winding immediately after slitting.

The right automatic guide installed properly is a wonderful thing. It is a tireless, faithful, often forgotten key to your operation.

Pitch and Catch Guiding – Feb 2010

If you are like me, you find yourself thinking about spring as a way to cope with long winter days. For many, spring means baseball.

A good way to combine your baseball daydreams with your converting operation is to think about web guiding. Unwind and winder guiding systems, often called sidelay guides, are like baseball pitchers and catchers.

An unwind sidelay guide is like a baseball pitcher. A pitcher's goal is to throw a strike, to brush the batter, or to pitch the ball to a target.

An unwind sidelay guide has the same goal: to unwind the web in a lateral position relative to the machine centerline, usually centered on the machine centerline, but sometimes intentionally off-center. For a pitcher, the reference is home plate, a fixed target. For an unwind sidelay guide, the target is a fixed web sensor, either a single edge sensor or a set of web centering sensors.

It is a misnomer to call a rewind sidelay guiding system a web guide, since it doesn't guide the web at all. The motion of a rewind sidelay guide instead chases the web, guiding the winder to the correct position to catch the web.

A rewind sidelay guide is like a baseball catcher. The catcher doesn't care whether the pitch is a strike, inside, or outside. A catcher has to go find the ball where it is and be in position to catch the ball in his glove.

A rewind sidelay guide doesn't care where the web is. It simply detects the web's position and shifts so the web lands on the core in the right position.

The components of unwind and rewind sidelay guiding systems are nearly identical. The motion of sidelay unwind and rewind web guides is similar, a simple left-right sliding on linear rails. Both mount the winder/unwinder on linear slides and shift the unwinding or winding roll laterally with a linear actuator, either a motor or hydraulic cylinder. Both have a web edge or center sensor. The difference between unwind and rewind sidelay guiding is in the sensor motion and location.

An unwind sidelay sensor is stationary, serving as a target to where the web should run versus machine centerline. The sensor should be placed at the upstream end of the span, between the last shifting roller and the first fixed roller.

A rewind sidelay sensor moves with the shifting of the rewinding core. The sensor usually is mounted on an arm that moves with the sidelay platform and detects the web position at the downstream end of the span between the last two fixed rollers. This position isn't always critical, but it attempts to isolate the incoming web's position from the sidelay motion.

Sidelay guides at both unwinds and rewinds are nearly foolproof once installed properly. Unlike the other common web guide (steering and displacement), the motion of sidelay guides does not involve any misalignment of rollers. There is no twisting of the web and bending is minimized. Since twisting and bending are minimized, they don't need long span length in the correction spans (many times less than a web width).

The biggest potential drawbacks to sidelay guides when compared to displacement and steering style guides are inertial or structural limitations. To be able to shift an entire winder and massive roll, sidelay guides will need much larger actuators.

Since sidelay systems typically move an entire winder stand and a massive roll, they inherently will have more backlash and flexure. Even with these potential limitations, sidelay web guides are the key to starting and ending most converting processes on the right track.

I highly recommend you ask your boss if you can take a field trip to study the fundamentals of sidelay guiding. Maybe the peanuts and Cracker Jack can go on your expense account.

Displacement vs. Steering: Battle of the Web Guides – Jun 2011

In today's match, we have two well-known web guides ready to square off and try to finally decide which is the top web guide.

In one corner — weighing in at what is usually two rollers in a pivoting frame — is the displacement guide (also known as the offset pivot, a positive displacement, or a tabletop guide). In the other corner — sleek and trim in what is usually a single roller on a unique arcing motion — the steering guide.

Both of these famous guides have a long history of being the “right” guide for intermediate corrections of lateral web position. These two mighty guides long ago dismissed the slow, wanna-be end-pivoting roller with their speedy and stable performances.

Let's put these two top guide candidates through some battle scenarios and see if we can crown a champion.

Space | In a tight location, the displacement guide wins hands down. The displacement guide's twist-displace-twist action without web bending (pulling a web in its width direction) can fit in tight locations with spans as short as one-half to one web width.

When a steering guide is shoe-horned into a tight location with short spans, it reacts like a cornered wild boar. In short spans, a steering guide can only make minimum lateral shifts before the force to bend exceeds the traction available or the guide becomes a shear wrinkle factory.

Traction | Steering guides can struggle with traction. Like any roller, they need traction to overcome bearing drag and inertia losses, but they also need lateral traction to bend the web left or right.

Like a race car in a turn, when there isn't enough traction, they lose control. Displacement guides win the traction battle with their easy twisting of the web.

Wrinkling | Bending will create wrinkles at much smaller angles of correction that twisting, so displacement guides would seem to win this one, but steering guides can magnify their correcting angles with long entry spans. Even considering the span multiplying effect, displacement guides will have far fewer wrinkles.

Ease of Setup | A steering guide with one 90-deg wrapped roller seems easier to set up than the two-roller displacement guide, but each system has four rollers that need to be properly set with wrap angle and span lengths to work their best. However, steering guides need to be tuned to the entry span length, need to avoid the strange unstable steering geometry, and by far, get installed incorrectly more often by a 20:1 ratio.

Rate and Range Limits | Both guides can correct as fast as their actuators will move them. Both can be designed for large correction ranges. This one is a tie.

Upstream Corrections | The correction of a displacement guide occurs between the two rollers in the frame (or during the wrap of one large roller in single-roll displacement guides). A steering guide can exert its influence of a long, long entry span. This is where the steering guide excels.

If you have a long process span, such as an oven, you have two choices:

Wait until the web exits the oven and correct the web with a displacement guide.

Install a steering guide as the first roller at the end of the long oven span.

The displacement guide will be happy to let your web crash into the side of the oven. A steering guide will start correcting at the first error during startup and work to bend the web in the oven back to centerline. A steering guide has its limits, but it will open the non-crashing window of your long span process.

The winner? If you have anything other than a long-span correction need, the displacement guide easily wins “top guide” honors. However, if you are worried about a long span, the steering guide will do what no other guide can — limit the lateral shifting upstream and put the web on centerline downstream.

Steering Directions Made Simple – Jul 2004

Steering and displacement guides are the two most popular forms of intermediate guiding.

Steering guides appear simpler, since they are often a single actuating roller. Don't be fooled. Thinking a single-roller steering guide is simpler than a two-roller displacement guide is like thinking a unicycle is easier to ride than a bicycle. Simple in design does not always mean simple in use.

Steering guides are web benders. If the web is off target laterally, the steering guide will shift a roller to bring the web back to the desired position. Steering guides use the parallel entry principle, which I've covered in many of my past columns.

If you want to apply the "unicycle of web guiding," let's see if we can keep you from crashing with a few practical guidelines.

Use steering guides only for long-span corrections. When a steering roller is angled out of parallelism, it will displace the web laterally proportional to the misalignment angle multiplied by the upstream span length.

To create a significant lateral shift, a steering roller must have either a large misalignment angle or a long multiplying span length. (A steering span is considered long when the distance from the steering roller to the upstream roller is more than three web widths in length.) Attempting to bend a short span with a steering guide creates several problems, including lateral slippage, wrinkling, and tension variations.

Good traction is critical to good steering. Web bending isn't free. Just like bending a beam, we need to apply a lateral force to the web. The web bending force comes from web-to-roller traction (a function of traction coefficient, wrap angle, and tension). Remember, air lubrication can reduce traction, so strongly consider a rough or textured roller for your steering guide.

Long-span steering requires less traction. A shorter span is stiffer and requires more force to bend, so a short-span steering guide will fail from traction loss sooner.

Short-span steering often will create wrinkles. For most rollers, we take great effort to ensure parallelism, since we know misaligned rollers create large crossweb tension variations and wrinkles. To keep your steering guide from being a wrinkle factory, use a long entry span.

Install steering rollers with a 90-deg wrap with the pivot plane perpendicular to the exit span. We want to steer the web in the entry span, not the exit span. These wrap and pivot plan guidelines will set up the steering guide to bend upstream and twist downstream of the steering roller, creating the least post-guide error.

Occasionally, steering guides are installed with two pivoting rollers and an exit span parallel to the pivot plane. This almost always leads to trouble. The exit span bending will create wrinkles (if the span is short) or post-guide error (if the span is long).

Avoid under- or over-steering by tuning your steering guide to the span geometry. A steering guide roller's actuation includes both lateral translation and misaligning rotation. The translation carries the web to the new position as fast as the actuator will move.

The rotation is coordinated with the translation to make the web happy in the new position (satisfying the parallel entry principle). The wrong ratio of translation to rotation will cause a poor dynamic response.

Test your steering guide for under- or over-steering. This is a hard to explain without a picture but easy to test for. Draw a line where the web runs on your steering roller. In manual mode, shift the roller 1 in. to the left. If the web moves more than 1 in., you are over-steering; less than 1 in. is under-steering. Adjust the pivoting geometry until the web and roller move together.

With a little more space, I'd tell you about the benefits of good traction on the roller upstream of a steering roller, that steering guides are great as the first roller at the exit of an air flotation oven, and that in most cases you'd be better off using a displacement guide, but that may be too much backseat advice.

Contact me if you'd like to learn more, I'll try not to steer you wrong.

Strand Tracking Problems on Your Slitter/Rewinder – May 2002

A slitter/rewinder has two goals: Divide the web into strands (slitting); and create uniform individual rolls (winding). This plan has three potential pitfalls: bad slitting, bad winding, and bad strand tracking.

Strand tracking is the forgotten pitfall. In this column I will present the most common sources of slit-to-wind tracking problems.

Slitting knife axial runout

Sometimes things aren't straight out of the starting blocks. This isn't really a tracking problem, but the result is the same: wound rolls with shifted layers. To check for this, use a dial indicator to determine if the slitting knives shift laterally during rotation or under load. You would expect this to show up as a slit width variation, but knives — especially stacked sets — can run out as a set, creating wander without width change.

Neighboring strand contact

Two slit strands running side by side on a transport roller have the potential to jump one atop the other. Once one strand rides up on a neighboring strand, the apparent diameter variation will cause it to track over more. If the strands are wound side by side and overlapped entering the winding rolls, the result is a big mess.

Slackness from web bag

All webs have some nonuniformity in their cross-web length. If the length variations are greater than the web strain from tension, some of the slit strands may become slack immediately after slitting. The lack of stiffness and traction caused by low tension will allow the web to wander.

Slackness from winding accumulation

Lock bar winding is sensitive to roll-to-roll diameter variations. Without differential winding, where winding rolls can turn at different rotational rates, thinner strands may lead to smaller diameter roll buildup and less web accumulation. The result is slack web and related web wander.

Wander from web skew

Strand length variations do not have to be greater than strain to cause tracking problems. Strands with one side longer than the other will have a tendency to track toward their tight edge (with good traction). Changes in strand skew and traction over time will create wander.

Web roller attraction

Both adhesive and electrostatic forces, if present, must be overcome to peel a web from a roller. If the forces are two high or variable, the result will be wrapped rollers at worst, or tracking variability at best.

Tracking from roller or winding roll diameter variation

The cylindricity of the downstream roller can cause a web to track to the large diameter side. A winding roll with noncylindrical profile will create the same effect, pulling the web to the larger diameter side. Pack and gap rollers at winding are used to eliminate this problem, but many slitter/rewinders do not have this design option.

Tracking from roller or winding roll alignment

The normal entry rule defines how a web will track to enter a downstream roller perpendicular to its axis of rotation. In this same manner, a misaligned or deflecting core or winding shaft will redirect the web's lateral position.

By understanding these mechanisms, you can avoid them. The result will be less waste for you and straighter rolls for your customers.

In this column we only addressed lateral shifting on the way to the winding point. We'll save web shifting after entering the wound roll for another column.

WRINKLING AND SPREADING

The Signs of Shear Wrinkle – Aug 2004

Your web is talking to you. Not out loud but in a form of sign language. It's saying, “Oh, I'm shifting to the right (or left) in this span,” or “Ouch, I'm shifting so much I'm wrinkling on this roller.”

What does the sign language of the web look like? It's not spoken with finger and hand gestures but with troughs and wrinkles. Since troughs and wrinkles aren't standardized terms, a quick review of their definitions will help me translate the web's sign language.

A trough is the buckled, out-of-plane web in a span between rollers. Troughs usually are spaced in wavelengths of 1-3 in. crossweb, running mostly in the machine direction but may be angled off 5-20 deg. Some people refer to troughs as soft wrinkles, since they usually don't leave a permanent mark in the web.

A wrinkle is formed when a web buckles while wrapping a roller. Wrinkles usually form one or two at a time with the cross-sectional shape of a bunched-up inchworm. They may hold a steady position on a roller or form on one side and travel laterally like a moving wave. Wrinkles commonly will leave a permanent mark in the web (known as a crease or hard wrinkle) or may even create small rips in paper webs. Wrinkles come in many forms (I covered tracking-type wrinkles earlier this year, see May '04, p26).

Of the many wrinkle causes, shear stress wrinkles are the most studied, due to their widespread waste and the ease of creating them in a lab.

Shearing probably creates images of cutting hair or slitting webs, but it also should make you think about troughing, buckled webs, and wrinkles.

The term “shear wrinkles” implies a shearing or scissoring action. The shearing action of scissors or shear knives develops when one blade pushes down while the other pushes up. Unlike compressive stresses, the up and down forces don't oppose each other directly but are exerted along different planes of the material. The unfortunate matter caught in the middle will be sheared.

Shear wrinkles are caused by web bending and the resulting stresses, whether the bending is created by misaligned rollers, one-side diameter variations, or a lateral shift from an abrupt web guide.

Getting back to translating the web's sign language, let's read the sign language of a single sheet of paper and scale that up to translating our moving web's signs.

Place a sheet of paper on your desktop running away from you (imagine the web centerline runs from 6:00 to 12:00 on an imaginary clock face. Holding the near side of the web fixed, slide the far side slightly toward 1:00. What happens? With even the slightest shift toward 1:00, you should see troughs and buckles forming in the sheet. These troughs will run from 7:00 to 1:00. If you slide the web back, the troughs should go away. If you slide the far web edge in the other direction, toward 11:00, you will see troughs form with an orientation of 5:00 to 11:00.

To create a shear wrinkle in a moving web, twist a roller out of alignment in the plane of a web span. A little misalignment will create a small amount of bending and shear, creating subtle troughing. More misalignment will create larger troughs. With even more misalignment and web bending, the buckled, trough-shaped web will travel over the downstream roller, forming a wrinkle and crease defect. Note: A clockwise misalignment in the downstream roller will create a clockwise troughing or creasing.

The combination of conditions that creates a wrinkle (tension, span length and width, traction, and web thickness, modulus, and uniformity) is a complex engineering problem, but it is predictable with advanced web wrinkling models.

If you see clockwise-angled troughs or wrinkles in your process, understand the web is telling you, “Oh, I'm shifting to the right in this span.” Learn these signs. By combining these web signals with an understanding of what shifts the web, you can determine the correct course of action to correct the problem. The web's sign language will not provide the quantitative feedback of lasers, levels, Pi tapes, or transits, but these signs should be your first diagnostic signal when facing shear wrinkles.

With a little practice, you should see more of the best web signal, “Ah, that's better; I'm right on track.”

Plotting Shear Wrinkles – Sep 2011

The combined conditions of when roller misalignment is bad enough to wrinkle a web is a complicated mechanism. You have to combine concepts of roller misalignment, web buckling, and web-to-roller traction. As with any engineering challenge, you can use both experiment and mathematical methods to advance your understanding. The advanced modeling techniques are amazing, but some simple experiment techniques can be a great starting point (and you don't need a fast computer or advance modeling aptitude).

For the single span shear wrinkle test, you need the following:

1) A web line where you know web tension and speed (just about any load-cell controlled zone is a good candidate).

2) A section of the web path with three rollers where the second of the three rollers has a wrap angle of 90 deg, preferably with the first span at least half a web width long, but all spans lengths can prove interesting.

3) A good coefficient of traction on the first of the three rollers, which you can get with a rubber covering or tacky tape wrap. This will make the span more wrinkle-sensitive and prevent our experiment from having interactions between spans.

4) A mechanism to misalign the #2 roller parallel to the entering web, inducing bending in the entry span and twisting in the exit span. Sliding on a pillow block may be good enough, but a fine adjust linear actuator, turnbuckle, or bolt adjustment would be great.

5) A dial indicator, micrometer, or some other way to measure the amount of roller misalignment, and know when it is back to the aligned position.

Just add your web—some you are willing to damage—and you are ready to wrinkle. Start with a known web, speed, and tension, and the rollers aligned. Now misalign the #2 roller, bending the web between rollers 1 and 2 until a wrinkle forms. The shear wrinkle should form on roller #2, forming initially on the loose side of the bending span then walking to the tight side. At this point, you should have a continuous diagonal crease generator.

If you run paper or another brittle material, you may have broken your web. (Consider yourself warned.) Repeat the test at different tensions. Make a table of the minimum roller misalignment to make a wrinkle at each tension. Now you can make a shear wrinkle plot.

The graph is an example of a shear wrinkle plot and includes data from wrinkling narrow and wide thin polyester. The shear wrinkle plots usually graph tension (or strain) on the X-axis and misalignment on the Y-axis. The typical shape of the isolated span shear wrinkles tests will resemble a Nike swoosh. At extremely low tension, it can be difficult to wrinkle when there is insufficient web-roller traction to bend the web or hold the web in the buckles form on the roller. For moderate to high tension, tension stiffening makes the web less wrinkle-sensitive due to tension stiffening.

The data and line on the bottom show a more sensitive wide and thinner web. You might expect thinness is the cause of this sensitivity, but the greater width is the more important factor.

Repeat this experiment with different webs, rollers, web speeds, and span lengths. Before you know it, you will have a number of contour plots showing which of your web and process conditions are the most sensitive to wrinkling.

How Much Misalignment Is Trouble? Part 1 – Jan 2009

Most converting equipment suppliers and manufacturers take care to ensure the rollers of their machines are aligned. Designing for good alignment, machining and assembling to close tolerances, measuring to ensure alignment, and periodically rechecking roller parallelism all cost money, so we ought to think about what we are getting for our money.

Some products gain more from precise alignment, while other products quite likely are insensitive to misalignment. How do we know what the alignment specification goal should be for a specific product?

My general rule of thumb on converting equipment alignment calls for targeting a parallelism of 2 mils/ft. This converts to about 0.2 mils/in. or mm/m, 0.01 degrees, or 0.7 seconds of a degree.

It's a small angle, usually imperceptible to the naked eye. You will find equipment aligned to this specification is achievable, measurable, and will eliminate unwanted roller-induced wrinkles, lateral shifting, and edge flutter in most webs.

What problems will occur if roller alignment is only accurate to 10 mils/ft? Three big problems result from roller misalignment:

Lateral shifting;
Loose edges;
Shear wrinkles.

In my previous column of April 2004, "When Rollers Fight, Webs Lose," I provided more details on the definitions of level and tram and gave some examples of lateral shifts from misalignment. (Find this column on the web at www.pffc-online.com/mag/paper_rollers_fight_webs/index.html).

In short spans, the tracking from roller misalignment will be as imperceptible as the roller misalignment. In long spans, a misalignment of 10 mils/ft will shift by 7-10 mils/ft of web span length. In a 10-ft span, the web will shift 70-100 mils, a noticeable but not earth-shattering amount.

Whether a roller misalignment causes the short side of the web span to go slack is dependent on the strain or stretch in the web. To drive an edge of the web into slackness, the misalignment of two rollers in a web span needs to be two times the stretch in the web.

In this case, the tension in the centerline of the web will not change, but one edge will lose all its tension and the other edge will stretch to double the average tension and strain. Since each span has two rollers that potentially can be misaligned, the critical alignment of any one roller is equal to the strain of the web.

Low modulus materials, such as most nonwoven and softer films, will stretch more that 1% under web tension, so a roller needs greater misalignment to relax this elongation out of the web to a point where looseness would occur. A 1% misalignment in a 2-ft span is about 0.25-in. or 50 mils/ft for a 60-in. web width.

Higher modulus materials (such as polyester films, many papers, and all foils) will have a much lower tolerance for how much misalignment causes edge looseness and associated problems of out-of-plane sagging or flutter. A 2-ft span of 1-mil polyester tensioned at 1 PLI (lbs/in. of width) is stretched about 0.2% or 100 mils. In longer spans, it will take more misalignment to create a slack edge.

This absolute misalignment to induce a slack edge is independent of width, but viewed on a mils per foot basis, wider products are more sensitive. As web width reaches 50-100 in., the 100-mil error converts to 25 or 10 mils/ft.

In aluminum foil, elongation from tension is lower yet, 0.01%. A 2-ft span needs only 5 mils of misalignment to loosen an edge, just 1 mil/ft for a 60-in. wide product. Unless you are running aluminum foil or extremely wide, it looks like 10 mils/ft should be just fine for many processes.

Next month we'll continue to drill down into the complexity of what is an unacceptable roller misalignment. We'll provide more real numbers of how much misalignment will wrinkle a web based on stiffness, width, and span lengths.

How Much Misalignment Is Trouble? Part 2 – Feb 2009

Shear wrinkles are the most common wrinkle mechanism, forming a diagonal crease and appearing to walk across rollers like an inch worm. The way to create a shear wrinkle is to increase the misalignment of a well-wrapped roller until shear stresses within the bending web lead to buckling and a gathered wrinkling web on the misaligned roller. Shear wrinkles have three prerequisites:

a mechanism that causes the web to bend between span, usually roller misalignment, but other possibilities include roller diameter variations or web lateral shifting;

sufficient friction to bend the web;

sufficient friction to hold the web in a buckled, wrinkled shape on the roller.

Roller misalignment by itself will not wrinkle a web without sufficient friction to meet the second and third requirements. If a roller has low friction or traction relative to the web due to low tension, lubricated traction, or a small wrap angle, wrinkles are less likely to form. If the web span is difficult to bend, such as short spans or thicker, wider webs, wrinkles may not form. Since total friction is proportional to web width, narrow webs may not have sufficient friction to meet the third requirement.

I always recommend including roller alignment in any equipment specification, usually advising 2 mils/ft of width. However, in many cases your web is insensitive to 2 mils/ft of misalignment.

The graphs show for various web widths (the X-axis) how much misalignment (the Y-axis) is required to create a shear wrinkle. Any roller with misalignment below the curve would be wrinkle free. Each case is analyzed at the theoretical worst case when span length is 40% of web width.

The first graph shows three materials, each at 1-mil thickness and 1 PLI. For example, at 60 in. wide, the critical misalignment for PE, PET, and aluminum is 5, 2, and <1 mil>

The second graph is for three cases of PET shear wrinkles starting with 1 mil and 0.5 PLI but also showing the effect of moving to 0.5-mil thickness or 1 PLI tension. Increasing the tension of 1-mil PET from 0.5 to 1 PLI almost doubled the critical misalignment, showing the benefit of tension stiffening. Keeping constant stress or strain, you can see 1-mil PET at 1 PLI is less wrinkle sensitive than 0.5-mil PET at 0.5 PLI, showing the benefit of increasing thickness. It is often stated wrinkle sensitivity goes up or down with thickness-cubed based on untensioned beam theory; this is clearly not accurate for tensioned thin-shell buckling.

These graphs give insight into critical variables, but don't use these curves to justify loosening your roller alignment spec to less than 2 mils/ft. Why not? Wrinkle causes rarely come one at a time. If you combine other contributors, such as imperfect webs, deflecting rollers, tension variations, and roller deflection, you'll find a 5x or 10x safety factor in roller alignment is the only good approach to a wrinkle-free process.

Tracking Wrinkles: Part 1 – May 2004

When traffic is heavy on a multi-lane freeway, staying in your lane is critical. We trust the other drivers in the cars next to us will stay in their lanes. The evenness of the road and the driver-controlled alignment of the tires promote parallel flow. If the cars on either side of you diverge, there is no problem. But if they begin to converge — look out. A fender bender is imminent.

Think about your web similarly. Imagine the wide web as a series of strips. We trust each strip of the web will stay in its lane. The uniform tension and dimensions of the web and straightness and alignment of the rollers promote parallel flow. If the strips diverge or spread, no problem. But if the strips converge — look out. A web bender or wrinkle is imminent.

What makes a web move off track or shift lanes? This concept is crucial in understanding web behavior, both good and bad. I would like to be able to give you a short, simple statement to answer this question, but I can't. I've heard some say "the web moves to the tight side." Do not listen to them; this is an oversimplification.

There are three primary mechanisms that can cause a web to shift laterally: roller misalignment, roller diameter variations, and web bagginess.

Any of these tracking mechanisms can create a web wrinkle. If the entire web tracks too far to one side, it will create a shear wrinkle. If both sides of the web track to the center, it will create a tracking wrinkle. It is the tracking wrinkle I will emphasize in this and next month's columns.

Misalignment tracking is dependent on the parallel entry rule (see PFFC "Web Lines," August and September 2003). The displacement of the web bonded by traction to a roller controls the bending of the upstream web span. With good traction, the web angle entering a roller will align parallel to the roller's surface motion.

Misalignment tracking occurs any time the web or roller angle differs from machine direction. Straight webs on straight and aligned rollers will have minimal lateral motion or position changes. If either the roller or web angles are shifted, the web will track to resolve the angle differences.

Roller bending is the most common source of tracking wrinkles. A bent roller has a consistent diameter but a continuously changing angle of rotation across its width, similar to a bowed anti-wrinkle roller. When the bowed roller is oriented pointing downstream, it is a powerful spreader. However, if the bow orientation points upstream, it is an equally powerful wrinkler.

Though a bowed roller should never be installed backward intentionally, there are several common conditions that create this undesired orientation. When a roller's length-to-diameter ratio is high, like a noodle, the roller may have excessive deflection due to gravity. Approaching a sagging roller from above will create a tracking wrinkle.

Noodle-like rollers also will deflect due to web tension. Tension-deflected rollers and large wrap angles align to create tracking wrinkles. Even the stockiest roller may see significant bending when end-loaded as a nip roller. Again, if the entry span is oriented parallel to the bending, the nip deflection will create tracking wrinkles.

The more mysterious misalignment wrinkles are created by the web. Extremely subtle angle errors in the web on perfectly aligned and cylindrical rollers will create tracking wrinkles. Web angle errors are created by web width expansion effects, usually due to heat, moisture, or tension changes. As a foil or film enters a roller-supported oven, the heating process will cause thermal expansion in the initial web spans.

Looking at either web edge, the web's angle will be slightly outward. As this outward angle approaches an aligned roller, the web and roller angles will disagree, causing each edge to move inward, forming a tracking wrinkle. The same effect occurs in moisturizing dry paper or necking recovery of a web moving from high to low tension.

Next month we will stay onboard the tracking wrinkle express, covering the important issues of web-roller traction, diameter variations, and web bagginess.

Tracking Wrinkles: Part 2 – Jun 2004

The easiest way to explain roller diameter variation tracking is to walk you through the chain of events.

Diameter variations create web strain variations. The tensioned web will attempt to form to the roller's shape. The average web strain will not change, but the web will stretch more in large-diameter lanes and relax in small-diameter lanes.

Strain variations create web tension variations. Elastic materials have a direct relationship between stress and strain. Multiply the strain change by the material's elastic modulus to get the induced tensile stress change.

Roller-induced tension variations exert a torque on the web span. A torque is a force at a distance. As tension varies across the web width, the difference in the centerline of web tension upstream versus downstream applies a bending moment to the web.

Torque will bend or curve a web. If you apply a torque to the end of a pencil, you will see it change from straight to curved. Torque applied to the web does the same thing, though the curvature may be too small to see.

A curved web will violate the parallel entry rule. Without lateral tracking, the induced web curvature has an entry angle that is not parallel to the downstream roller. If there is poor traction, the slipping web need not obey the parallel entry rule. Result: The web will track to the small-diameter lane.

With good traction, the web curvature will displace laterally to the large-diameter side. To satisfy the parallel entry rule, the downstream head of the bent web will shift relative to the upstream tail. Result: The web will track to the large-diameter lane.

Yikes. Rube Goldberg designed less complicated chains of events.

Looking at the details of this chain of events, you can find some important tidbits to help you understand how diameter variations create or don't create tracking wrinkles.

Diameter variations should be viewed as percent change, not absolute. A 20-mil change is significant on a 4-in.-dia roller, but less so on a 20-in.-dia roller. For predictable web behavior, think about diameter variations that are on the same order of magnitude as the web's strain. If the diameter change is too dramatic, say 5%, it is more than the web can conform to, and you are guaranteeing a slip condition.

Bending a web isn't free, it requires force. The web often is limited by a roller's available friction force. This is one reason why rollers with small wrap angles and friction rarely wrinkle: The roller can't exert enough force on the web to create or hold it in a wrinkled shape.

The last tracking wrinkle source is web bagginess or length variations.

The wrinkle mechanism is similar to tracking wrinkles from pre-roller width expansion. Baggy or nonuniform webs have subtle curvature. Though small, the subtle curvature is enough to violate the parallel entry rule.

As the baggy or curved web moves onto the roller, the contact point will shift toward the long lanes or outside curvature, moving the web's position on the roller laterally. For a baggy edge, this will shift the web toward the loose side. For a baggy center, this will shift both sides toward the roller's center, creating a wrinkle.

For all tracking wrinkle causes, shorter spans will prevent wrinkles. Since web bending mechanically is the same as beam bending, the force required to shift the web will go up with span length cubed. As spans get shorter, there may not be enough traction to drive the web to buckling and wrinkling.

Eliminate tracking wrinkles by understanding and stopping them at the source. If you can't stop the source, prevent the wrinkle by reducing traction or decreasing span length. If this is difficult, consider using a special anti-wrinkle or spreader roller.

Ten Tips on Anti-Wrinkle Rollers – Oct 2004

Spreader rollers are important tools for web handlers with two main applications. First, they can spread a web after slitting, creating a gap between slit strands. Second, they can ensure the web is laterally taut, removing or preventing wrinkles.

I've been laying the groundwork for this discussion on how spreader rollers spread. Over the past two months, I have covered the parallel entry principle (PEP) and the beam-like nature of web bending. Using these two concepts, let's dissect the commonly misunderstood mechanism and limitations behind two popular spreader rolls: the bowed roller and the expanding-surface roller.

Both rollers feature a surface of uniform cross-roller diameter that moves laterally, expanding and contracting, as the roller rotates. The spreading mechanism seems obvious: The web enters the roller at a given width, rides the roller's surface as it shifts laterally, and leaves the roller either taut (in the case of a single wide web) or spread with uniform gaps (in the case of multiple slit strands). Amazingly, on-roller spreading is a secondary effect. I would like to convince you that most of the spreading occurs before the web touches the spreader roller.

To learn more about how spreaders work, I recommend highly a milestone paper presented at the 1997 International Conference on Web Handling. Ron Swanson of 3M presented "Testing and Analysis of Web Spreading and Anti-Wrinkle Devices." In Ron's paper, he evaluated ten different rollers, empirically demonstrating their ability to prevent wrinkling and spread a slit web.

Ron's simple spreading test started with a 12-in.-wide web, under controlled tension and speed, tracking from an upstream idler, across a 24-in. web span, and over the target spreader roller. A razor blade slit the web down the middle, upstream of the spreader roller. A roller's spreading effect was quantified by measuring the slit gap that developed between the two web halves.

Two observations from this test firmly disproved on-roller expansion as the dominant spreading mechanism. First, for both the bowed roller and surface expanding roller, the web spreading was greater than the roller's surface expansion (about twice as much). Second, the slit gap opened up prior to contacting the roller.

How can a spreader roller move the web before it even makes contact? The answer lies in the parallel entry principle. The gap develops because the two halves are responding to the differing surface vectors of the left and right side of the spreader roller. The left side of a bowed roller angles to the left, the right side to the right.

The expanding-surface roller works on the same principle. The center of the roller surface vector is in the machine direction. The left edge of the roller surface vector is angled to the left, the right angles to the right. Again, each side of the web will be displaced by the parallel entry principle.

How much will these rollers spread the web? The lateral motion of a web created by the angled roller surface vector will be equal to approximately two-thirds of the angle (in radians) times the entry span length. Therefore, the web will spread more with more angle and longer entry spans. The strong effect of entry span on bowed and expanding-surface roller spreading commonly is overlooked.

Will the web spread and achieve parallel entry? Only if there are roller traction forces great enough to bend the web. Beam bending will determine if the traction forces are great enough to bend the web as far as the parallel entry. A common mistake for both these spreader rollers is to set them up with large surface vector angles, thinking more is better. Setting up a spreader beyond the traction limits will not spread more but will abrade and polish your spreader roller to an early retirement.

Next month: how a flexible-spiral spreader roller works, plus wrapping up our discussion on spreading mechanisms.

Where Does a Spreader Spread? – Oct 2003

Spreader rollers are important tools for web handlers with two main applications. First, they can spread a web after slitting, creating a gap between slit strands. Second, they can ensure the web is laterally taut, removing or preventing wrinkles.

I've been laying the groundwork for this discussion on how spreader rollers spread. Over the past two months, I have covered the parallel entry principle (PEP) and the beam-like nature of web bending. Using these two concepts, let's dissect the commonly misunderstood mechanism and limitations behind two popular spreader rolls: the bowed roller and the expanding-surface roller.

Both rollers feature a surface of uniform cross-roller diameter that moves laterally, expanding and contracting, as the roller rotates. The spreading mechanism seems obvious: The web enters the roller at a given width, rides the roller's surface as it shifts laterally, and leaves the roller either taut (in the case of a single wide web) or spread with uniform gaps (in the case of multiple slit strands). Amazingly, on-roller spreading is a secondary effect. I would like to convince you that most of the spreading occurs before the web touches the spreader roller.

To learn more about how spreaders work, I recommend highly a milestone paper presented at the 1997 International Conference on Web Handling. Ron Swanson of 3M presented "Testing and Analysis of Web Spreading and Anti-Wrinkle Devices." In Ron's paper, he evaluated ten different rollers, empirically demonstrating their ability to prevent wrinkling and spread a slit web.

Ron's simple spreading test started with a 12-in.-wide web, under controlled tension and speed, tracking from an upstream idler, across a 24-in. web span, and over the target spreader roller. A razor blade slit the web down the middle, upstream of the spreader roller. A roller's spreading effect was quantified by measuring the slit gap that developed between the two web halves.

Two observations from this test firmly disproved on-roller expansion as the dominant spreading mechanism. First, for both the bowed roller and surface expanding roller, the web spreading was greater than the roller's surface expansion (about twice as much). Second, the slit gap opened up prior to contacting the roller.

How can a spreader roller move the web before it even makes contact? The answer lies in the parallel entry principle. The gap develops because the two halves are responding to the differing surface vectors of the left and right side of the spreader roller. The left side of a bowed roller angles to the left, the right side to the right.

The expanding-surface roller works on the same principle. The center of the roller surface vector is in the machine direction. The left edge of the roller surface vector is angled to the left, the right angles to the right. Again, each side of the web will be displaced by the parallel entry principle.

How much will these rollers spread the web? The lateral motion of a web created by the angled roller surface vector will be equal to approximately two-thirds of the angle (in radians) times the entry span length. Therefore, the web will spread more with more angle and longer entry spans. The strong effect of entry span on bowed and expanding-surface roller spreading commonly is overlooked.

Will the web spread and achieve parallel entry? Only if there are roller traction forces great enough to bend the web. Beam bending will determine if the traction forces are great enough to bend the web as far as the parallel entry. A common mistake for both these spreader rollers is to set them up with large surface vector angles, thinking more is better. Setting up a spreader beyond the traction limits will not spread more but will abrade and polish your spreader roller to an early retirement.

Next month: how a flexible-spiral spreader roller works, plus wrapping up our discussion on spreading mechanisms.

Tale of the Tape – Mar 2001

The best wrinkle prevention costs pennies. Certainly you can spend more, but before you do, first try a simple approach.

Let's say you need a mousetrap. What do you envision? You are likely thinking about the old standard: a slat of wood, a coil spring, and some other simple components. Total costs? Pennies. There are more complicated designs, but this simple design is a great starting point.

In our industry, we don't fight mice we fight wrinkles. When I say "X removes wrinkles" what do you envision? A banana roller, a spiral roller, or something more complicated? I like to start simple. I first think about tape bands on a cylindrical roller. And the cost? As promised, pennies (assuming you have the roller already).

Tape vs. Wrinkle

A wrinkle, defined here, is a web that does not lay flat while in contact with a rotating roller. Quite commonly the wrinkles are rippling, forming at one end of a roller and walking across the roller some distance before disappearing, then another one forms, and on and on. We will save why the web wrinkles for another day.

With our tape bands, we will persuade each edge of the web to track away from the center. When a web wrinkles the edges are running too close together. We want to move them out laterally. This is done with an induced bending and the rule of normal entry.

Here is the mechanism. 1) The web tracking over the larger diameter taped bands will have increased strain and tension. 2) The laterally different tensions induce a moment (or torque) on the web. 3) The moment creates a slight inward bend in the web. 4) The web's bent shape conflicts with the rule of normal entry. The result: a slight lateral displacement; displacement enough to remove the wrinkle. Got it?

Some of you probably ran out to your machines after the third paragraph, but there are a few things to consider before applying wrinkle preventing tape bands to a roller. I'm sure many of you already know this trick, but let's see if I can even help even the experienced tape dispenser.

How much tape? Where? Consider three things: traction, web strain, and roller radius.

First, the tape must have good traction with the web. We are forcing the web (using friction) to do something it wasn't planning on doing. Good traction has two components, a reasonable friction coefficient (>0.25) and enough texture to prevent air lubrication.

The tape band at the edge creates a local tension increase. How much the tension increases is dependent on roller and web properties. The tape thickness divided by the roller radius will determine the strain change created by the tape band. How much tension increases is dependent on the web's spring constant (modulus times thickness). A typical starting point is to build up the roller similar to typical webs strains, around one tenth of one percent. For a three-inch radius roller we are starting with 0.003 inches of tape buildup. Not much. Add more as needed, cautiously.

The non-uniform tension at the roller's entrance causes the web to bend subtly inward. This angled web violates the rule of normal entry (A turning roller, with good traction, will displace a tensioned web to enter perpendicular to its rotational axis). The bent web is displaced toward the larger diameter tape band.

Let's jump to the conclusions: 1.Use good traction tape. 2. Use more tape for stretchier webs. 3. Use more tape on larger rollers. 4. Only apply tape to the non-rotating roller. 5. Spiral patterns are not better. (The web does not fall for optical illusions.)

Lastly, if you like the results you get with tape, but want a more permanent solution, a similar radial change can be machined into the roller's metal or elastomeric surface with the same benefits.

Is there room for a better mousetrap, a better wrinkle fighter? Yes. Tape bands are width specific, may fall off, and won't stop all wrinkle forms. There may be better, but not simpler.

Concave Rollers Pros & Cons – Jul 2005

I'm always amazed when a wrinkle problem can be solved with a few feet of masking tape. Got some nasty wrinkles on a roller? Some tape here, some tape there—wrinkles be gone. Adding tape collars or bands to a cylindrical roller just under each of the web's edges turns a cylindrical roller into a wrinkle-stopping concave roller.

Concave rollers go by several names but all feature a changing roller diameter, larger at the edges than the center. The opposite of a concave roller is a crowned roller; thus concave rollers also are known as reverse-crowned rollers. Depending on the exact diameter profile, concave rollers may have an hourglass, bowtie, dumbbell, or parabolic profile.

The mechanism: The web tracking over the larger diameters lanes will have increased strain and tension. The laterally different tensions induce a moment (or torque) on the web. The moment creates a slight inward bend in the web. The web's bent shape conflicts with the parallel entry rule (see "Going With the Parallel Flow," August 2003).

The result: a slight lateral displacement, enough to remove the wrinkle.

You can change a standard cylindrical roller into a concave roller quickly by adding tape collars to either side. Use a tape that has reasonably good friction relative to your product. Look for a tape that has some roughness if you would like this trick to work at high speeds and low tensions. Apply the tape to build up the roller diameter on a percent basis, targeting a buildup equal to 1–3x the stretch of your product.

If you need to build up the tape more than one–two layers, apply the tape in a tapering stepped profile. Too severe of a step from the tape collar to the untaped roller will create a high shear and a wrinkle-inducing roller profile.

If this trick is so great, why isn't everyone doing it? Good question. Let's review the pros and cons of concave rollers.

Pro #1: Concave rollers are inexpensive. Just pennies of masking tape can save thousands of dollars in waste. Even machining a concave profile into a metal roller is inexpensive compared to other anti-wrinkle roller options.

Pro #2: Concave rollers are low drag and can be low inertia. Other anti-wrinkle rollers have significant drag from rubber-stretching hysteresis and higher bearing drag. Concave rollers should have the same low mass shell and low-drag bearings as your other idlers.

Pro #3: Concave rollers can work at high speeds. It is easy to add air-lubrication-preventing texture to a concave roller. Concave rollers are not dependent on rubber deformation or rubber sleeve stiffness that may have changing or detrimental effects as line speed increases.

Pro #4: Concave rollers can have a hard-coated metal surface to resist wear or harsh chemicals.

Pro # 5: Concave rollers are a speedy solution. It can take as little as 2 min to have a taped concave roller up and running.

Con #1: Concave rollers are difficult to design to be effective with big width changes. The most effective concave roller profiles create a big torque on the web by shifting the web tension to the extreme edges. However, this effect may disappear or is greatly reduced when a narrow web runs on the same roller.

Con #2: Concave rollers will create wrinkles if they slip. Concave rollers need to have enough of a combination of tension, traction coefficient, and wrap angle to prevent slip and support diameter-induced tension differential from upstream to downstream sides.

Con #3: Concave rollers made from tape may cause contamination. If you look at tape collars that have been on too long, you'll see missing pieces that have picked off and gone downstream, possibly all the way to your customer.

Con #4: Concave rollers are less effective for low-modulus materials and pretty much ineffective for viscoelastic webs. The concave roller mechanism requires the web to act like a solid beam, creating a torque that induces a bending in the web. A viscoelastic web will flow instead of curving, defeating this mechanism. Low-modulus webs may need a more dramatic spreading mechanism to induce enough movement into the web to be effective.

When you look at the low cost, speed, and reduced application restrictions, I think the pros of concave rollers outweigh the cons.

Converting Rx: Using Bowed Rollers – Nov 2005

In pharmaceuticals, certain drugs are controlled substances: They are available to the public but require a doctor's prescription and strict instructions for proper use. In converting, there are some solutions that should be controlled, available to anyone but requiring detailed instructions for use. At the top of my list of converting controlled substances: bowed rollers.

For those not familiar with bowed rollers, they are a uniform-diameter but bow-shaped roller. The outside of a bowed roller is a rubber sleeve, internally supported by a series of narrow idler rollers mounted on a bent shaft.

For some thicker web applications, the rubber sleeve is left out, but only if the web is stiff enough not to fall into the gaps between segments. Many bowed rollers have a fixed bow (the depth of the chord), but some are adjustable, using a split shaft that can be dialed in from straight to slightly bowed to strongly bowed.

Why should bowed rollers require a prescription? Bowed rollers are strong medicine and thus should be prescribed for specific maladies and used only as directed. Also like strong medicine, it takes only a small amount to have a big effect. Thinking more is better will lead to the bowed roller equivalent of an overdose.

Let's read the "Directions for Use" fine print on the bowed roller bottle.

1. Bowed rollers have two active spreading mechanisms. The first and stronger one attempts to displace the web laterally, so all entering lanes follow the parallel entry principle (see "Going With the Parallel Flow," August 2003). The second, during the contact with the bowed roller, is from the expanding rubber surface attempting to pull the web out as it rotates on the expanding side of its rotation.

2. Bowed rollers require good web-to-roller traction to pull out or bend the web to a new lateral position. Webs with high lateral stiffness (length, width, thickness, modulus, tension) will need more traction forces to redirect the web. The total web expansion will fall short of theoretical spreading if the traction forces are too low. Air lubrication should be avoided (for cases with high speed, low tension, large radius, smooth roller, smooth web, nonporous web) by increasing roughness or grooving the bowed roller.

3. Bowed rollers can be used to spread a single web to tautness or create a gap between a set of slit strands. See special instruction for slit strand spreading (coming next month).

4. For most applications, bowed rollers should be wrapped between 30 and 60 deg, always wrapping the roller on the expanding side of its rotation. For a web path neutral setup, the wrap angle should be centered between the most contracted and most expanded positions on the bowed roller.

5. A bowed roller can tighten up symmetrical web bagginess, whether baggy edges or a baggy center. If the wrap is shifted toward the most contracted side (also considered a "nose" down wrap), the bowed roller will tighten the web edges. If the wrap is more toward the fully expanded side (considered a "nose" up wrap), the bowed roller will tighten a baggy center.

Like any prescription, the directions for use need to be followed by a list of known side effects:

1. Bowed rollers, like most spreading rollers, can increase lateral web shifting or destabilize the web, especially if the web is off-center.

2. Excessive bowing, which is smaller than you think, will lead to web-to-roller slip and bowed roller wear. Most bowed rollers wear more quickly than other rubber-covered rollers.

3. Bowed rollers have a local anti-wrinkle benefit but little or no downstream effects (except for not passing on a wrinkled web or creating a gap between slit strands).

4. Bowed rollers can exert large stresses on the web, enough to yield or break delicate webs.

5. Bowed rollers will create higher tension losses than most standard idler rollers due to the rubber hysteresis and internal bearing drag.

This concludes the side of the bottle instructions for the bowed roller "patient." Next month, we talk with bowed roller prescribing "doctors" to help them determine what dosage will be right for a particular application.

Converting Rx: Setting Bowed Roller– Dec 2005

Last month we picked up our prescription for a bowed roller and read the instructions and warning label. But what's in that bottle? How do we know we have the right dosage of bowed roller? Let's combine a little diagnosis and diagramming to see how to find the proper prescription.

The definition of a spreader roller is that the web enters at one width, WIN, and leaves at a greater width, WOUT. In this diagram, the bow is exaggerated, making the bowed roller radius look smaller than normal relative to span length. There are three similar triangles that determine the maximum spreading of a bowed roller setup. This looks complicated at first, but there are just five critical variables: bowed roller diameter, radius of curvature, the entry span length, wrap angle, and entry span angle relative to the bow plane (the last two are not shown here).

Step 1: Calculate the effective bowed roller radius of curvature. Hold a straight edge against the inside of the bowed roller and measure the gap at the center. The length of your straight edge is the face length, F. The gap at the center is the bow, B. The bowed roller's radius of curvature, RBOW, is equal to the face length squared divided by 8x the bow depth: RBOW=F2/8B. (This actually is a slightly simplified formula but good in typical cases where F > 10B.)

The effective radius of curvature is found by dividing RBOW by the cosine of the entry angle. For wrap angles under 20 deg, you can avoid this additional calculation. For wraps over 20 deg, this will begin to be significant.

Step 2: Calculate the chord length of the bowed roller wrap. The chord length, CBOW, is the bowed roller diameter times the tangent of the entry angle. This equation assumes the default bowed roller setup where the entry and exit angles are the same relative to the bow plane.

Step 3: Calculate pre-roller and on-roller spreading. This diagram has three similar triangles. The maximum pre-roller spreading is found by comparing the first two triangles. We've calculated the effective RBOW and know the entry span length, L. The maximum pre-roller spreading, DWPRE/WIN, will be the L/(RBOW-L). We can use our calculated wrap angle chord length, CBOW, to find on-roller spreading. The maximum on-roller spreading, DWON/WIN, will be the CBOW/(RBOW-L). Adding the two spreading mechanisms together, the maximum combined spreading will be (L+CBOW)/(RBOW-L). Multiply this number by 100 to get percent spreading or by WIN for width change in inches. Divide the predicted width change by the number of slits to calculate the anticipated gap for spreading multiple strands.

For full web spreading, you likely won't get to the maximum spreading for two reasons: 1) Wide webs are more beam-like and will not track in straight lines, instead shifting about two thirds of what is predicted; 2) the web will spread only as much as frictional force is available to pull the web, so spreading is often friction-limited.

How do you turn these calculations into a bowed roller prescription? For anti-wrinkle benefits and wide webs, I recommend 0.5%–1% spreading to prevent wrinkles. For strand spreading, use the calculations to get the desired gap. When you run the math, you'll be surprised to find how easy it is to overdose on bowed roller spreading.

So, just say "no" to too much bow.

Flexible Spreaders: Small Flexing, Big Benefits – Nov 2003

Spreading and antiwrinkle rollers are great tools for web handlers.

Like any good tool, having it in your toolbox is great, but what makes it valuable is understanding how it works and when to use it.

Over the past three columns, I have been laying out the knowledge a web handler needs to understand spreading rollers. Last month I described the primary mechanism of bowed and expanding-surface rollers. This month let's take on their similarly misunderstood cousin, the flexible spiral roller.

All spiral rollers, whether rigid or flexible, are con artists. Their turning roller's barber pole optical illusion tricks your eye. The rotating spirals, starting at the roller center, create a sense of outward motion. As the spiral turns relative to your fixed perspective, you almost can feel the plowing action. Don't be conned by this illusion.

A wedge spreads only if there is relative motion. A field plow spreads dirt as it's driven through the field. In web handling, the web and roller are not moving relative to each other — they turn together. Saying the wedge of a spiral roller spreads the web is like saying a plow sitting unattended in a cornfield moves dirt as the Earth rotates. If there is no relative motion, a plow's wedge does not spread.

The key mechanism of the flexible spiral roller is not in the wedge-shaped groove but in the subtle deflections of the biased flutes. If you push on the flexible flutes with your thumb, you will notice they deflect laterally. The grooves are machined intentionally at an angle so the tensioned web will deflect the flutes away from the machine centerline.

The force you apply with your thumb is many times the force exerted by the web, so the web-induced deflection will be much smaller, in tenths of mils. How can so little motion have a significant effect?

Last month I described how the dominant spreading mechanism for bowed and expanding-surface rollers is the parallel entry principle. When the roller's surface motion is angled relative to the machine centerline, the roller rotation will displace the web laterally as it rotates. Greater surface vector angle or longer entry span will increase the spreading. For both roller types, the web spreading motion was greater than the roller's surface motion. The same angle surface motion is at the heart of how a flexible spiral roller works.

What determines a flexible spiral roller surface vector? The micro-deflection occurs quickly as the tensioned web contacts the roller. Dividing the lateral deflection by the similarly small length over which it occurs produces a significant angle surface motion, the heart of the spreading effect. This may sound shocking, but the flexible spiral works on the same mechanism as bowed and expander rollers.

Let's put some numbers on this effect. Again I will refer to Ron Swanson's landmark paper from the 1997 International Conference on Web Handling. For the given case, the flexible spiral roller's flutes deflected only 0.2 mils but were able to spread a short span of 10-30 mils, more than 50-150x the mechanical deflection. It wouldn't seem 10-30 mils of spreading would be significant, but compared to a standard idler, this roller was 5x less sensitive to wrinkling from misalignment.

Will the web re-gather on the downstream side of the flexible spiral roller when the tension and flute deflection is removed? No, remember the spreading is 50+ times the mechanical deflection. Without an entry span, the flute's elastic recovery is small compared to the overall spreading. Also, since the web is taut and cylindrical, it will gain shape stiffness to resist this small load on the downstream side.

How much wrap is needed? The surface vector angle is set within a degree or two of contact. Additional wrap is needed to have sufficient traction forces to bend the web. Thin, long-span webs will see benefits with 5-10 deg of wrap. Webs that are more difficult to bend will need more wrap.

A flexible spiral roller is a great web handling tool, especially if you understand the roles flute deflection, entry span, and traction play in its application.

Wrinkling of Foils – Aug 2011

In our everyday lives, our main experience with foil likely comes from wrapping a potato in kitchen-grade aluminum foil. Wrinkling thin aluminum foil is easy. If you are new to foil-based products, such as solar cells, batteries, packaging laminates, or flexible electronics, you may fear that handling foils in manufacturing will be a similar wrinkle-filled venture.

The most significant difference between foils and papers or films is the much greater modulus of elasticity. Foil may have machine direction Young's modulus 10-30 times higher than many papers and polyesters.

Does the high modulus of foils mean increased or decreased sensitivity to roller misalignment and diameter variations? On the anti-wrinkling side, higher modulus increases stiffness and resistance to buckling. On the wrinkling side, higher modulus increases stress variations created by the same roller misalignment or diameter variation.

Will copper and aluminum foil webs run wrinkle-free on equipment designed for paper and film handling? What is the recommended roller alignment and diameter tolerances for aluminum and copper foil web handling?

If you are a manufacturer of copper or aluminum foil, you would know some of the answers to these questions, having solved them by necessity. If you are new to handling copper, aluminum, or other foils, you easily could be quite fearful of the prospect, plus you may face an additional challenge that you foil suppliers do not — baggy foil. Even if you have manufactured foils for many years, you may find moving into thinner and wider foils can make you wrinkle-phobic.

Roller alignment and diameter tolerance specifications are one driver of equipment cost. If roller alignment and diameter tolerance specifications are loosened, then machining accuracies can be relaxed and machine alignment procedures will take less time. If roller alignment and diameter tolerances are tight, then equipment design, fabrication, assembly, and maintenance all will cost more.

Misaligned rollers and diameter variations can create lateral shifting in processes. However, most roller alignment specifications are and should be driven by wrinkling, specifically, shear wrinkles.

Based on some experimental work in which I was fortunate to participate, I have good news and bad news.

The Good News | Aluminum and copper foils are less sensitive to roller misalignment than theory would suggest. Two interesting things keep foil wrinkles at bay:

Foils are more difficult to buckle, so they need high web-roller friction (from friction, tension, and width) to apply the load needed to make a wrinkle.

The stiffness of foils means that misalignment effects quickly create large crossweb tension differential that cannot be contained in a single web span, spreading the forces out over a longer length of web and preventing wrinkles.

The Bad News | Foils are more sensitive to roller deflection and diameter variations. Where misalignment creates an asymmetric tension variation that can pivot and transfer into an upstream span, deflection creates symmetric tension variations that are contained within a span.

Conclusion | Don't overspend on ultra-precise roller alignment, but do invest in rollers with minimal deflection, accurate diameters, and web paths that avoid the effects of gravity (especially avoid long vertical spans).

“Wrinkling of Foils” was a paper and presentation I co-authored for the 2011 Intl. Conference on Web Handling held at Oklahoma State Univ. I would like to thank my co-authors, Dr. Kevin Cole of Optimation Technology Inc. and Jeffrey Quass and Stephen Zagar of Megtec Systems.

WINDING PROCESS

Pyramids and Wound Rolls: Long-Lasting Quality – Mar 2002

What comes to mind when you think about the pyramids? First, the pyramids have survived the test of time. Second, they have a distinct and impressive structure.

The pyramids' structure is responsible for their performance. If they had been built on swampland, they would have sunk long ago. If the Egyptians had built a less stable structure, the pyramids would be a large rock pile now.

Just like a pyramid's wide initial layers become a foundation for additional layers, a wound roll's initial wraps are the foundation for subsequent roll buildup.

In winding rolls we also create impressive performance through structure. Wound rolls are a package to store web materials and maintain quality between accumulating and dispensing. In wound rolls we hope for the same long-lasting performance found in the pyramids.

How can a cylindrical wound roll have anything in common with the structure of a pyramid? A stable structure for both pyramid and wound roll should consider three elements: foundation, buildup, and profile. The foundation of the wound roll is the core and core support. A pyramid's buildup and physical profile are analogous to the buildup and tension profile of a wound roll.

Important core properties include core diameter, core wall thickness, and core material. Many wound roll defects are avoided by using increasing core diameter, wall thickness, and material stiffness. You will not save money in the long run by building your wound roll on swampland.

But don't take this analogy too far. The rock-hard foundation ideal for office buildings is not ideal for wound rolls. Very hard cores can lead to high-stress defects such as blocking and deformation. The ideal core matches the web's stack behavior.

Build-up ratios can be high or low. A manufacturing plant usually has a low build-up ratio, one story high, and a large footprint. A skyscraper has a high build-up ratio. Both structures may have equal volume but significantly different stability. Which structure would you prefer to be in during an earthquake? The structural stability is independent of size. Whether building card houses or office buildings, small rolls or jumbos, the structure will determine stability.

In wound rolls, the critical buildup is the ratio of the final diameter to the core diameter. The skyscraper of wound rolls is a small core wrapped with product until the final roll is many times the core diameter.

Though small-diameter cores save space and expense, it is the wrong direction when our goal is long-lasting roll quality. Large-diameter cores with a reduced number of wraps have higher stability. Build-up ratios above three become increasing difficult. As roll size grows, consider increasing core size to maintain a reasonable build-up ratio.

Profile also is important to a pyramid's stability. If a pyramid were built upside down, it would topple easily. In wound rolls we cannot taper the roll geometry; instead, wound rolls are profiled with tapering tension. Tension taper involves reducing the winding tension as the roll grows.

Just like a pyramid's wide initial layers become a foundation for additional layers, a wound roll's initial wraps are the foundation for subsequent roll buildup. Using high relative tension at the beginning of a roll creates a sturdy support for external layers. In both buildings and rolls, tapering is more important for larger build-up ratios.

Think of wound rolls as little pyramids. Start with a good foundation. Choose a geometry that balances economics with stability. Use a tapered profile to improve the stability as buildup increases. Your rolls may not last for 4,000 years, but they will last long enough to impress your customers.

The Pressure of Winding Rolls – May 2006

We are halfway through our roll-to-roll relay race of the unwinding process (click here for Part I). Our rolls are loaded, spliced, and ready to run. To complete the unwinding relay, we need to finish strong with our plan for web alignment and tension control.

Unwinds must be able to align the web, compensating for web position errors from unwind installation, web-to-core, core-to-chuck, and layer-to-layer within roll. The three most common methods to align unwinding rolls laterally are manual alignment, automatic sidelay guiding, and automatic displacement guiding.

In manual alignment, you put the roll on and align it by eye to the threaded web or to a physical reference mark. For short, compact processes, the small amount of web wander through the system combined with good input roll straightness will meet the downstream process requirements.

Our other two choices, sidelay and displacement guiding, both are automatic guiding systems with web position sensors, controllers, and actuators.

Sidelay guiding is the most immediate and gentlest option since it can start as early as the second roller from the unwinding roll and doesn't require web twisting. The nimble displacement guide beats out sidelay when the inertia from high roll mass and fast correction rates overly degrades the guide's system responsiveness.

Displacement guides, with their smaller actuators, usually will have a lower capital cost, but for sensitive webs, the long-term benefits make sidelay guiding a good return on investment.

The anchor runner in our unwinding relay is the tension and speed control plan. These decisions will make or break your productivity. How much torque is needed? How should I create torque? Where should I apply torque? How should I compensate for the changing roll diameter? Should I close the tension loop? If I close the loop, what feedback system is best? Whew! I'm tired even before I begin the final lap.

The following points address the most common questions in unwind tension control plans:

Unwind torque is the sum of tensioning, inertial, and lost torque determined by roll radius, tension, inertia, acceleration, mechanical losses, and adhesive peel forces. As you make a wish list of tension, width, and diameter ranges, it's easy to define an unrealistic unwind torque specification. Brakes and motors usually are limited to a 30:1 range. Beyond this, you are in fantasy land (except for some wide torque range frictional devices).

If your minimum and maximum torque desires exceed the 30:1 range, you'll have to curb your torque appetite. I recommend focusing on your low-end torque needs and accepting the limits at the high end. I've seen too many unwinds where oversized brakes are turned off or the motors can't control at low tension or small diameters.

Center torque unwinds are everywhere, beating surface unwinding in any democratic election. Surface unwinds eliminate the need for radial torque adjustments, but they are relatively rare due to their increased complexity and nip- related web defects.

When inertial torque is more than 10%–20% of tensioning torque, make sure your control system has inertia compensation (a.k.a. a WK&8473;2 function). When the inertial torque is more than 30%–50% of the tensioning torque, I think motor-driven unwinds are a better choice than brakes and clutches.

At-speed splicers always will be driven to speed match the new roll in a smooth transition of control from spindle to spindle.

Dancer rollers are helpful in reducing tension shocks from splicing, inertia, and out-of-round rolls; however, all feedback systems have degrading benefits at high frequencies. Tension shocks over 10 Hz will have little dampening in any system. Any downstream tension or speed-sensitive process will benefit from an unwind pull roller station isolating it from the inevitable unwind upsets.

This completes all four legs of planning our unwind relay race. Loaded, spliced, aligned, and tensioned—we're ready to run.

Is Wound Roll Pressure Greater Than Tire Pressure? – July 2011

I'll bet you that your wound roll has more internal pressure than a car tire. To win this bet, I have to prove that internal roll pressure is above 30 psi (just over 2 bar or 200 kPa).

Measuring car tire pressure is easy. Measuring pressure inside a wound roll is certainly not so easy. How would you measure it, and what is the least expensive way?

A tire pressure gauge measures the difference between the atmospheric pressure outside the car tire and the internal tire pressure. If you are on earth, which most of us are, you are under pressure all the time.

If your tire pressure is 29 psi (or 2 bar or 200 kPa), the actually pressure in the tire is 43.5 psi (or 3 bar or 300 kPa) since atmospheric pressure adds 14.5 psi (or about 1 bar) to every reading. This differential reading is called the gauge pressure.

Pressure in wound rolls comes from web tension. When you stretch a rubber band around something, it creates tension proportional to how much the band is elongated beyond its untensioned length (a.k.a. strain). The pressure under a rubber band on a cylinder or a tensioned web wrapped around a core is the tension in force per width divided by the cylinder radius.

If the tension is 1 lb/in. of width (175 N/m) over a 2-in. radius (0.050 m), the pressure under the single wrap will be 1 PLI/2 in. or 0.5 psi (175 N/m/0.05 m = 3.5 kPa.

This single wrap is much lower (60x) than car tire pressure. However, if we add nine more layers, the combined pressure could increase to 5 psi (35 kPa), and 99 more layers could get us to 50 psi (350 kPa). At this point, it seems that our wound roll, with only 100 layers, could be above car tire pressure.

This is as small as 0.1 in. (2.5 mm) of buildup if the 100 layers are a 0.001-in. (0.025-mm) thick product. Imagine how much higher the pressure could get with 1 in. (25 mm) or 10 in. (0.25 m) of buildup on a core. Yes, 1,000 psi (7 MPa) or 35x atmospheric pressure is not out of the question.

These additive calculations assume that each layer maintains its pressure-created tension and strain. In many materials, this isn't true. Radial compression lowers tension in the roll, and pressures do not build up to ocean depth levels.

Stretchy films, like polyethylene (PE) or polypropylene (PP) can get up to 1,000 psi in a roll. Stiffer films, like polyethylene terephthalate (PET), can be all over the map, depending on their thickness, surface roughness, and winding tensions/methods, but 50-500 psi might be expected at the loose and tight extremes of winding.

Uncoated papers and foils tend to wind with low internal roll pressure, less than 100 psi. Pressure under a thick gauge band can have pressure 5-50x average internal roll pressures.

A frictional sandwich is an easy and inexpensive way to measure roll pressure. Make a frictional sandwich by inserting an unlubricated strip of steel feeler gauge (0.002 in.) in a folded piece of brass shim stock (0.001 in.), like a hot dog in a bun. Wind this brass-steel-brass sandwich into a roll with part of the sandwich sticking out the side of the roll (or both sides for narrow rolls).

After winding, pull on the steel feeler gauge and measure the force to get it to break away from the brass and slide just a bit. This force is the frictional force created by the pressure in the roll over the area of contact on the steel. With a little math, you can convert this frictional force into local internal roll pressure.

Friction Force (F) = COF (brass to steel, about 0.25) × Internal Roll Pressure (P) × Area of Contact (A). The area of contact is the steel strip width times the length of steel in the roll times 2 (since friction develops on both sides of the steel). Therefore: P = F/(COF × A).

Example | Steel strip is 0.5 in. wide and 4 in. are in the roll, A = 2 in.2. If measured force is 20 lb, P = (20 lb)/(0.25 × 2) = 40 psi.

In this case, 40 psi is greater than 30 psi, and I win my bet. Send your money to me at [address withheld by PFFC lawyers].

Winding Doesn't Add Up – Jul 2009

When things in life are linear, they make sense. Driving two hours usually gets you twice as far as driving one hour. Adding two doughnuts a day to your diet likely will lead to gaining twice as much weight as one doughnut a day. These are linear relationships — they "add up."

In converting, some things are linear. If you pull on 1-mil polyester with 1 PLI, it will stretch 0.2%. If you double the tension, it will stretch twice as much (this should be far from the yield point).

If you double the air pressure on a nipped roller, you will double the air cylinder's contribution to the nip load (don't forget gravity and tension).

In winding, few things are linear. You may see pressure and friction within your winding roll go up 10x or even 50x if you do the following:

Double the winding tension.
Double the winding nip load.
Double your product thickness variations.
Halve your product thickness.
Halve your product roughness.
Halve your winding speed.
Double the length or diameter of the roll.

Why are all these winding effects non-linear? There are two different strong effects in winding that can change faster than linear. Both involve the softness or compressibility of a roll in the radial direction — what you could consider (thanks to Mr. Whipple of Charmin fame) a roll's squeeze-able softness (or lack thereof).

Technically, this is referred to as the radial modulus of elasticity or stack modulus when the property is measured in a stack of sheets representing the layer in a wound roll. If you measure the compressibility — what percent the layers will compress for a given increase in pressure — you will find a strongly non-linear relationship, nearly exponential.

Radial modulus is one of the strongest variables in how tight a roll will be for a given winder setting and roll size. This makes winding non-linear because as you shift toward the stiff end of the continuum from spongy to fully compressed layers, a roll gets little or no relief of adding tensioned layers from compression and circumferential relaxation.

More tension, more nipping, less roughness, and higher speed all can increase radial modulus, leading to a dramatic increase in roll tightness. Increasing thickness variations has the same effect because the thick, larger diameter lanes will see above-average tension and nip load, creating an increased tightness in those winding bands.

The thick gauge bands will gain much more in tightness than the non-thick bands lose, creating an overall tighter roll. If you ever wondered why some rolls telescope and others don't, it may be the non-telescoping rolls have worse gauge variations locking them up with high pressure and friction.

The other big non-linear effect in winding is air entrainment. You folks with a porous web, such as tissue and nonwoven, won't see this, but everyone else will. Large diameter, higher speed, lower tensions, and lower nip loads all will allow more air into a roll.

This will loosen a roll in two ways. Air will fluff up a roll, making its radial modulus lower, and it may bleed out over time, allowing the pressure and friction creating tensions to relax away.

Besides porosity, higher surface roughness provides a space for entrained air to stay with the roll, reducing air effects. More roughness or texture to a product likely will lower a product's natural stack modulus also, so it may have two effects leading looser rolls.

These non-linear effects make winding difficult to predict. If you change too many of these factors, be prepared to be surprised when you wind a roll. The roll might just explode or form a black hole. Proceed with caution.

Reflections on Deflection – Dec 2010

After reading last month's column, you should have resolved all of your deflecting roller problems. However, the alert web handler is not done with deflection diagnosis yet.

A winding roll is much like a roller: cylindrical and rotating. It's amazing that 3-in. dia rollers are rare in processes wider than 60 in., but the 3-in. (75-mm) core remains quite popular by customers and hence must be accommodated by winders. These winding shafts with a length-to-diameter ratio above 20:1 are deflecting, whipping noodles ready to destroy your profits.

Any spinning shaft has a critical velocity. Most converters won't run into these conditions, but combining deflection with high rpms will wobble a core or shaft into its own destruction.

Not all 3-in. shafts are prone to the same problem. The core, the journal supports, the winding layers of the roll, and well-placed nip rollers or support arms can alleviate the woes of deflection.

A shaft will have less deflection when winding a full width product. In these cases, the shaft often will be reinforced by the pressure and structure of the winding layers. Slit rolls will not create this same benefit since their independent stucture will have a negligible reinforcing effect.

How a shaft is captured or mounted into the winder will affect deflection. If the shaft is simply supported (held loosely from each end), the mounting will not help to reduce deflection. If the shaft is rigidly mounted (holding the ends level), deflection will be cut in half. Shafts that extend beyond the supporting mounts have surprising benefits from the extra length, even more so if the extended lengths have dual support points at each end.

Differential winding shafts have the most deflection per load and will see the most problems when winding narrow and large diameter rolls. As narrow slit rolls grow, the combination of roll weight, tension, and nip loads will tilt the out cuts inward, leading to weave or full roll collapse.

A solid steel shaft will have the lowest deflection, but it also will weigh you down (2 lb/in.). Many shafts are hollow, using air pressure and moving elements to grab the core. Obviously, reducing the cross sectional area will lead to more deflection.

Core-independent differential winding shafts will be worse yet, having a series slipping core-grabbing element mounted on something less than a 3-in. dia (often 2.5 in.). Advanced shaft designs replace missing steel or aluminum structures with tensioned carbon fibers, making a fine (but more expensive) substitute for steel.

In slitting, shear knife systems are the most sensitive to deflection. Shear slitting is best with minimal overlap between top and bottom knives; however, the force of slitting fracture will deflect an undersized knife shaft, leaving the poor options of jumping knives or excessive overlap.

Both differential and shear knife shaft deflection problems often are resolved easily with a single central support arm that can reduce deflection by eight times. In winding, a strategically placed winding nip roller will serve the same anti-deflection function.

Nipping from above or horizontally will only aggravate or rotate deflections; however, nipping from below with a large diameter roller is a great preventer of winding deflections. The paper industry has done this for years.

Anti-deflection nips are much less common in film winding, relying on their higher internal wound roll pressure to stiffen the winding roll, but I think even film roll quality improves with anti-deflection nips.

As with rollers, once deflection is diagnosed, either structural or strategic solutions will do the trick. If you haven't tired of deflection problems at this point, look next to the rigidity of how your equipment is connected to the Earth.

When to Upgrade to a Driven Unwinding Process – Aug 2009

How do you know when its time to upgrade from a brake-controlled to a driven unwinding process? When an unwinding roll is small and speeds are slow, you may not notice the tension upsets that occur during acceleration and deceleration, but when was the last time your customer asked for smaller rolls and your boss told you to run your process slower? Never? Yeah, that's what I thought.

As you start pressing your old braked unwind into more challenging service, the most obvious sign that you might benefit from a driven unwind is whether your web loses most or all of its tension during deceleration — something that commonly occurs on braked unwinds of a slitter/rewinder.

Stopping a large diameter unwinding roll involves two opposing torques. The unwind brake torque pulls backwards to create the desired tension at the roll's outer radius. The spinning roll's mass creates an inertial torque that pushes the roll forward. If you try to decelerate the roll too quickly, the inertial torque will overwhelm the braking torque. When this happens, the unwinding roll will not stop as rapidly as the rest of the machine, and the excess web will pay out into looseness or onto the floor.

A slack web at slitting is rarely a good thing. The loose web may fall out of a web guide sensor, wrap a roller, slip on rollers and get scratched, and shift laterally, losing your edge trim. Even short of slackness, the inertial torque can create a big tension upset that may lead to poor slit quality, wrapping rollers, and web breaks.

To determine when your product needs a driven unwind to avoid inertia-related tension losses and associated problems, you have to calculate these two opposing torques. The tensioning torque is easy to calculate; just multiply the total tension force by the roll radius. This will increase linearly with tension and radius. It also will increase with web thickness, as many products run at a tension proportional to thickness (keeping tensile stress and strain constant).

Calculating inertia torques is a little more complicated. The inertial torque is related to mass and radial deceleration. The radial deceleration is proportional to line speed, roll diameter, and deceleration time. The inertia will be proportional to your material density and roll geometry, especially diameter. Inertial torque will go up directly with density but go up much faster with diameter. A large roll turns at slower rpms than a small roll, so this helps reduce the deceleration rate, but increasing diameter adds mass more quickly, making inertial torque increase with the square of diameter.

Example | How big does a roll of polyester film need to get for a driven unwind to make sense? On the tensioning side, let's assume a lower-end tension of 0.5 PLI/mil of thickness (500 psi stress). On the inertia side, let's assume a fairly aggressive deceleration of 100 fpm in 1 sec.

At what diameter does the torque from inertia overcome the tensioning torque? For a 2-mil polyester film running at 1 PLI, the roll's inertia will drive the web into slackness during the 100 fpm/s deceleration if the roll diameter is 39 in. (and cut the tension in half at 31-in. dia). The problematic diameters are smaller for a lower-tensioned web, dropping to 24 in. for slackness and 20 in. to cut tension in half with 0.5-mil web running at 0.25 PLI.

You can get by with a braked unwind if you stay under these diameters, run higher tensions, reduce your deceleration rates, or run material less dense than polyester film. Driving your unwinding roll doesn't guarantee you won't have tension upsets, but at least a properly sized motor has the capability, when combined with a good inertia compensation control software, to smoothly accelerate and decelerate your big rolls.

Winding: What We Know & What We Don't Know – Aug 2008

Winding is an amazingly complex process. Our understanding of winding can be broken into three areas: the winding process, winder design, and wound roll quality. For each of these three areas, there are some things that are well or generally understood. There are also some mysteries for which we still need enlightenment.

One measure of understanding is whether something can be modeled (and verified) from engineering principles. Winding process models are aimed at predicting the layer-by-layer pressures and residual tensions (or lack thereof) within a wound roll and, from the stresses and strain, predict defects.

The simplest models find roll stresses from web and core properties, tensioning profile, and roll geometry. Though a winding roll is a continuous spiral, almost all models treat a wound roll as a series of pre-tensioned elastic rings or hoops.

The greatest hurdle to useful winding models is measuring the mechanical properties of a stack of material such as we would find in a wound web. Low stack modulus — what Mr. Wiffle would have called squeezably soft — relieves in-roll tensions and keeps roll pressures low.

The high load, precision strain stack test rarely is done, and without it, you are left either modeling with great assumptions or resorting to understanding by experiment only. We would go a long way toward understanding the differences in winding our various products if we would stack test everything.

With stack modulus knowledge, we can know the pressures and tensions within our rolls and can modify the models with the real world variables: air, dimensional changes, and profile. The effects of air are fairly well known, including the air entrained with and without a nip, side leakage during winding, and the loss of roll tightness as air escapes over time.

The effects of dimensional changes due to viscoelasticity, temperature, and moisture are well understood, However, similar to stack modulus, the coefficients of these effects are largely unmeasured.

The third dimension — crossweb thickness variations — greatly challenges our ability to model real world winding. Work is underway in this area, but predicting when crossweb defects, such as bagginess or regional buckling, will or will not form is not here…yet.

In winder design, we have a good handle on winding single rolls; understanding the differences in driving from the center, surface, or both; nipping or not nipping; and tapering tension or nip load versus roll radius. The effect of nip position — above, below, after initial contact — is a little muddier, including the many perturbations of two-drum surface winding.

For post-slitting winding, we have a good handle on locked versus differential center winding. The use of individual or common nip rolls is understood.

Regarding roll quality, most sources of laterally shifted layers are well-understood, including from upstream web handling or telescoping from air lubrication, cinching, and roll handling. Less understood are shifted layers from dishing, creep of adhesives, and sawtooth-shaped edge patterns.

Most buckling defects are at least partially understood, including starring, spoking, sagging, and tin canning. All buckling defects in adhesive products (gapping, delaminating) — since they are dependent on viscoelastic creep as a function of temperature and humidity — are difficult to fully grasp, but the general direction away from the defects is known.

Other roll defects moving from more to less understood include: slitter rings, blocking, dimples/pimples, slip knots/wrinkles, and crepe wrinkles.

Now you know what we do and don't know. Take time to learn and use what is known. If you've figured out the unknown, use it as a competitive advantage until the rest of us get to know it, too.

The Coefficient of Winding Trouble – May 2009

In winding, the important coefficient of friction (COF) is always about the two surfaces that will come in contact as the entering layer hits the winding roller. The COF values that are troublesome to winding fall into three categories: low, high, and pressure-dependent.

Friction is the force that opposes the sliding of two solid surfaces relative to each other. The COF describes the ratio of the force of friction and the force pressing two solid surfaces together. Friction is never a property of one material or surface but a property that describes the interaction of two surfaces.

If the COF is too low, it will be difficult to transmit torque through a roll. Low COF products are prone to cinching and cinching-related telescoping. (For more on cinching, see “Belt Tightening Gone Bad: Part 1” and “Belt Tightening Gone Bad: Part 2”)

Winding a product with a COF of 0.1 relative to 0.3 will require three times the nip load to create the same roll tightness. But since low COF rolls need more, they usually need to be wound at higher tension and more than three times higher winding nip load.

If COF is high (defined as greater than 0.7), increased wrinkling is the first problem. All winding rolls have diameter variations and poor alignment — both are known wrinkling causes. Combined with high friction and long entry spans, winding high COF webs quickly becomes a trip to Wrinkle City.

High COF products often use controlled gap winding to avoid problems associated with long entry spans and winding. However, this solution is limited to low speeds since nip-less winding will let too much air in at high speed-to-tension ratios and large diameters.

The most problematic COF — what I call the coefficient of winding trouble — is when COF is a function of pressure. In high school physics, we learn that COF is independent of surface area of contact or pressure. It doesn't matter if you slide a brick across a table laying down or standing on end, even though the pressure under the brick will be higher if the brick is horizontal. Too bad this isn't true for all materials.

Many polymeric films, especially optically clear films, have the annoying property in which the side A-to-B COF is a function of pressure (a.k.a. non-Coulomb friction). A simple hand test can detect this in your product.

Take two sheets and slide them between your finger and thumb. They initially will appear to have a reasonable COF. For the annoying problematic films, if you push harder still, you will find they want to stick together and will not slide cooperatively.

Why is this a problem? If the pressure across a winding roll is uniform, it isn't, but in the case of a crossweb pressure difference, trouble is on the horizon.

The outer layers of a winding roll require a small amount of skidding or sliding as the layer first touches the winding roll and the air bleeds out or is rejected upstream. If the full width of the web skids as one, then there's no problem. But if one lane or spot in the outer layer sticks (due to a large debris particle or gauge band) while the rest slides, a local shear stress will develop near the sticking point.

This local shear may form a small buckle or soft wrinkle in the top layer. In non-Coulomb friction products, the next layer will not smoothly wind over a bump or ripple but instead will conform over the bump and form a slightly larger bump or ripple.

As additional layers are added, like a rolling snow ball, the defect often will get bigger with each turn. These defects sometimes are called slip knots or convolution wrinkles.

Smart products are designed with this in mind by using internal or external slip additives, engineered surface roughness, or winding interleave webs to avoid problems. High yield winding is dependent on avoiding the coefficients of winding trouble.

Difficult Winding: Part 1 – Jul 2006

What is it that allows one product to run all year with 2% waste and another can't get on the core without problems? Consider this a lesson in product design for manufacturing or design for winding — or in some cases, design for difficult winding.

In winding challenges, there are many things to consider, but I look at the terrible trifecta of winding: roll modulus ratio, roll buildup ratio, and product front-to-back COF.

This month, let's take on the number one difficulty factor — roll modulus ratio.

I first learned this concept in the early 1980s from Dr. Lien Struik of TNO, the famous Netherlands research institute. Dr. Struik described the two extremes of winding as “spongy” and “fully compressed” rolls, where the difference between the two was the roll modulus ratio. This ratio is found by comparing the stiffness or modulus of a material in the machine direction (Et, also called the Young's modulus or tensile modulus) and the stiffness or modulus of a stack of material (a.k.a. Er or radial modulus).

If Et/Er is near one, a wound roll is “fully compressed.” Rolls approaching the fully compressed state are trouble. However, if Et/Er is much greater than one, what Dr. Struik called a “spongy” roll, you have a good chance for trouble-free winding.

The Young's modulus of a material is a straightforward concept. The modulus of aluminum is approximately 10 million psi; polyester films or many papers are about 500,000 psi; an elastic rubber band will be much lower, say 5,000 psi. Many QC labs have this value readily available or easily found from tension-elongation testing.

The stack or radial modulus is tougher to characterize. It's a difficult measurement to take. Loads are quite high, and strains are quite small. In measuring stack modulus, the real kicker is that there is no one value. Stack or radial modulus is a nonlinear variable and can be described only with an exponential or polynomial function. Fun, eh?

In the May column, I described what determines how internal roll pressure builds up (or doesn't). The key to whether roll pressure continues to grow with increasing roll size, what I call the tourniquet effect, is dependent on how much the core and inner layers compress and how much that drops the circumferential tension in outer layers.

The Et/Er ratio is the key to this. When these material properties are similar, roll compression has little effect on roll pressure buildup. Thus, similar to wrapping additional layers of a tourniquet, larger rolls mean more pressure, more stress, and more diameter differential from crossweb thickness variations.

On the good side, when Et/Er is high, roll compression reduces diameter variations and relieves pressure buildup. You can build your rolls as high as the ceiling.

What are examples of the modulus ratio working for or against you? Paper products are relatively easy to wind; paper usually is high modulus in the sheet direction but fluffy in a stack, at least at typical wound roll pressures. Paper commonly winds on a 3-in. core and ends at people-sized rolls. Don't try that with most films.

Uncoated films and foils usually are high on the difficulty scale. A film or foil will have similar modulus properties in sheet or stack. If you have crossweb thickness variations in your film or foil, look out! Even minor thickness variations quickly will create roll diameter variations, pulling in the web nonuniformly and creating wrinkles, hardbands, and baggy webs.

How do you make film or foil winding easier? Anything that lowers the stack modulus will help. Lower the tension and pressure in the roll, wind on a compliant core, increase the surface roughness, add a soft coated layer, or wind with a soft interleave material.

Difficult Winding: Part 1 – Sep 2006

Last month I introduced you to roll modulus ratio, the first of the terrible trifecta of difficult winding. This month let's move on to the next two of winding's troublesome trio: roll buildup ratio and coefficient of friction (COF).

A roll's buildup ratio is simply its final diameter divided by the core's outer diameter; the trouble starts when buildup ratios go beyond three or four. Customers and accountants love larger buildup ratios, since larger buildups mean longer time between splices, lower core costs, and denser packaging. Be cautious of these apparent savings opportunities. If larger buildup ratios create more winding waste, the potential savings quickly goes in the dumpster.

Why are large roll buildup ratios difficult? Larger buildup in center winding or unwinding means more torque transmission from the core to the outside layers, leading to more cinching and telescoping. More buildup ratio tends to create more pressure within a roll and more of the associated high stress defects of starring, blocking, and core crushing.

The third factor in winding difficulty is a product's front- to back-side COF. The standard and ideal product COF is between 0.2 to 0.5. Troublesome COFs fall into three categories: slippery, tacky, and pressure dependent. I consider a product slippery if the COF is lower than 0.1 and tacky if the COF is close to or above 1. If you measure a COF over 1, you've gone beyond friction into adhesion.

The most troublesome tribological condition is when the COF is a function of pressure. Why? When the web hits the top of the winding roll, there a small slip zone as the web lands and adjust to the roll's diameter variations. If this slip isn't uniform, the web will shear and buckle, creating a defect called slip knots commonly seen in uncoated, smooth films.

My advice on these three winding challenges (isotropic modulus, large buildups, and unusual frictions) is to take on one, maybe two, but if you're faced with all three, run.

I can figure a way to wind isotropic materials if either the buildup is reasonable or the friction is normal. I can wind large buildup ratios if the product is relatively soft in the radial direction or the friction is optimized. And I'm willing to try some challenging frictional materials if the roll buildup is small or relatively soft radially. Just don't be cruel and make me (or yourself) face all three.

With this knowledge of what makes winding difficult, what do you do? First, you can look at a product design and decide whether you should take it on or delegate it. Second, armed with this knowledge, you can start further back in the product design cycle and make material or process decisions with windability in mind.

What makes a product easier to wind? Many films and coated products are modified intentionally to create cooperative frictional properties. PET films have internal slip particles to avoid tackiness. Videotape has a special back-side coating largely to improve winding friction. Some expensive and difficult-to-wind products will use a sacrificial interleave layer in winding to change the radial modulus of the roll and improve windability.

Changing either friction or radial modulus requires major product or process changes, which often are unacceptable or overly expensive avenues to windability.

What does this leave? Roll buildup ratio. Almost all winding processes will be more forgiving by reducing buildup ratio. If you can't sacrifice roll length, this means increasing core or hub size.

It may be difficult to convince your customers to accept a larger core and the associated expenses, but there are many cases where the roll you wind is being shipped inside your company. Winding on larger cores always will improve quality as jumbo rolls are shipped to the next converting process.

WINDING EQUIPMENT AND OPERATIONS

How to Drive a Winding Roll – Dec 2006

What is the best way to drive a winding roll? You have three choices: from the surface, from the center, or both.

The default answer in the converting industry seems to be center winding. Grab the core, connect to a motor or clutch, and start cranking. Center winding can be improved by using a close-proximity gap roller or a nip roller controlling the web's entry into winding.

In pure surface winding, the core is idling. All the work to drive the roll is applied to the roll's surface via a driven roller (or belt). Surface winding dominates the paper industry but is less common in the rest of the converting industry.

How do you choose between center and surface winding? Here's a short survey to lead you to the right answer for your product.

How big is your final roll diameter relative to your core diameter (a.k.a. the roll build-up ratio)? Center winders definitely have more trouble with larger build-up ratios. A center winder's torque and motor size will be a direct function of final tension and radius. Also, center winding transmits the core-applied torque to all the winding roll's layers. If you have marginal friction or pressure within your roll, the increasing torque of large build-up ratio often will cause slippage, cinching, and telescoping.

Surface winders don't care about roll size and don't have the same internal roll friction needs. A surface winder's torque is transmitted at the surface via a constant diameter roller, so larger rolls don't need more torque or larger motors. Do you need automatic at-speed roll transfers? At higher process speeds, you can't design an accumulator big enough for a zero-speed transfer system, so you need an at-speed transfer system.

At-speed, auto-transfer center winders are common in the converting industry. Auto-center winders use two spindles: one for winding and transfer, the other for roll unloading, core loading, and auto-splice preparation. Since each winding spindle is driven, it's easy to drive the empty core to web speed before transfer. Many equipment suppliers have inventive (and patented) ways to sever the web from the finished roll and attach it to the new core. Automatic transfers on surface winder, though not impossible, are more complicated and are made by dramatically fewer equipment suppliers.

Do you need tighter or looser rolls? Both winder styles can produce a wide range of roll tightness with adjustments to winding tension, torque, and nip force, but center winding always will tend to make tighter rolls and surface winding looser rolls. Surface winders have an especially hard time tightening up a roll with a loose core start.

Is your product nip-sensitive? Most surface winders use a nip, but some special designs drive the roll with a surface belt. Center winding is the more common nip-free winding option.

Is your product porous? In surface winding, the air that slips through the winding nip can get caught ahead of the nip point in the roll's topmost layer. As the trapped air bubble grows, it will create wrinkling in thinner products. Porous products don't face this potential surface winding liability, since the air just leaks out through the web. Why center winding doesn't have this trapped bubble problem is unclear, but likely it is related to the tightening direction of the nip-induced tension and slippage.

Why would you ever do both? Center-surface winding seems like a "belt and suspenders" approach. Most center-surface winders are really just modified surface winders with a center-assist option. Having a torque-driven core on a surface winder can help tighten up loose starts, speed match a new core for the auto-transfer process, and control the deceleration of the finished roll. Center, surface, belt, suspenders, or all of the above—choose the option that keeps your rolls fit and your pants up.

Winding Better Rolls – Jun 2003

It's not obvious how winding adds value to your product (it does), but it is obvious when it's done poorly.

Winding — the final step in many web converting processes — is like bagging groceries. You go through the store. Pick out bread, eggs, and milk. At the checkout line, the checkout assistant opens a bag, drops in your bread, then your eggs, then the gallon of milk — splat. Winding is like that. It seems easy enough, but done poorly, winding can turn 100% good product into waste very quickly.

One key to quality wound rolls is the winding nip. The winding nip is a roller, driven or idling, that remains in contact with the winding roll throughout its buildup. The winding nip has many aliases, including lay-on roller, pack roller, surface roller, and contact roller. Some of the same roll quality benefits also are found using a close cousin of the winding nip — the gap roller.

Q: Are winding nip rollers used in both surface and center winding?

A: Yes, winding nip rollers are used in both. You can't have a surface winding without a winding nip roller (a.k.a. surface roller). Pope reel winders have one large central drum that contacts the winding roll. A two-drum winder has two winding nips that cradle the winding roll (and often a third winding nip on top of the roll). Adding a winding nip to a center winder improves roll quality.

Q: Which is most common — surface or center winding?

A: If you survey winding equipment shown at the CMM show, center winding dominates the converting industry. This dominance is not because it is the best winding method, but because it is simpler to build and easier to automate roll transfers.

In the paper industry, you will see more surface winding for two reasons. First, paper roll properties allow winding to extremely large-diameter build-up ratios, where the final roll's diameter may be 20x the core diameter. If tensioning torque is generated from the roll's center — the definition of center winding — the torque required (tension × radius) will have a torque range impossible for most motors. Surface winding takes roll diameter out of the torque range requirements. Second, many paper winders use a simple "rip and tuck" roll transfer. If there is a core start wrinkle, the soft paper layers quickly mask them. You could never do a "rip and tuck" with films or foils without a lot of waste from wrinkles and impressions, so center winding and automated (or stopped) transfers are preferred.

Q: Which is better — surface or center winding?

A: It's not about which is better. They both have important niches. As mentioned above, surface winding is good for rolls with large build-up ratios. Surface winding often can wind at lower tensions than center winding and exerts less torque on the building roll (avoiding torque-related cinching). Center winders have more automatic cut and transfer options. For many products, center winding is better for winding multiple rolls on a common shaft, especially with differential winding bars.

Q: Why does a winding nip improve roll quality?

A: Winding nips do a better job of managing the web's last span and initial contact onto the winding roll. Mismanagement of the web's final span before winding is like the poor grocery bagger. A "well-bagged" roll will have less defects such as weave, dishing, telescoping, roll shape errors (non-cylindricity), wrinkling, excessive air entrainment, and loose winds. Understanding the importance of winding entry span length and the use of nip and gap rollers at winding will lower your waste and produce a better "package" for your next operation or customer.

Q: What are the benefits of a winding nip?

A: The winding nip has four main functions. First, it reduces the span length into the winding roll, reducing tracking errors and wrinkling. Second, it acts as a squeegee, reducing the air entrained into the winding roll. Third, it tends to form more cylindrical rolls. Finally, it tightens the winding roll.

Q: How does winding entry span length promote tracking and wrinkling defects?

A: The three sources of web tracking error are misalignment, diameter variations, and web bagginess. Winding rolls can have one or all of these errors, especially diameter variations. Because the web's flexibility goes up with span length cubed, the magnitude of tracking error from these sources will increase with longer entry spans.

Q: What is an example of span length increasing tracking error?

A: Many turret winders have wrinkles and tracking error during the index cycle. Entry-level turret winders have a winding nip in the primary winding position, but the nip doesn't contact the roll once the index cycle begins. As the roll indexes away from the winding nip, the winding entry span length increases. In many cases, the non-cylindrical winding roll and the long span formed during indexing will cause wrinkling or tracking error. For faster processes and thicker products, this will cause a high percentage of wasted product.

Q: How are indexing wrinkles eliminated?

A: In some designs, rollers on the turret that limit the span length during indexing are enough. More advanced winders keep winding nip contact throughout the index cycle.

Q: Where do roll diameter variations come from?

A: The cross-web caliper variations and slit edge quality create roll diameter variations. Winding conditions and material properties (such as the radial modulus) will determine whether winding magnifies or masks web thickness variations.

Q: How does a winding nip help?

A: A winding nip, like most rollers, presents a uniform cylinder at the end of the span, therefore not inducing lateral tracking error. The winding nip then holds the web in place as it presses it onto the winding roll, ensuring a laterally aligned roll edge. The traction of the web to the winding nip holds the web in position, preventing web reaction to the airflow at the web-roll convergence.

Q: Do winding nips need to be cylindrical?

A: Yes, winding nips should be true cylinders.

Q: Should a winding nip be hard metal or compliant?

A: A compliant winding nip is best, since the compliant covering will reduce the cross-web nip pressure variations from roll diameter variations. An overly hard winding nip roller may ride only on the high diameter lanes, creating stress concentrations in the web.

Q: Can a spreader roller be used as a winding nip?

A: Since most spreader rollers are not cylindrical, they are not a good choice for a winding nip. If you need to ensure lateral tautness at winding, use a spreader roller just upstream of the winding nip. If the web is flat on the winding nip, it will be flat entering the roll.

Q: Will a winding nip promote a cylindrical roll shape?

A: Yes. For many products, the winding nip pressure will compress the high diameter areas. With higher-speed winding, winding nips will allow more air to wind into the low diameter areas. Both effects tend to improve roll cylindricity.

Q: Should a winding nip be held parallel or allowed to float to the roll's profile?

A: Floating winding nips can promote tracking errors. Most winding nips are designed to maintain their tram and level (parallelism).

Q: How does a winding nip reduce air wound into a roll?

A: Air is entrained with the moving web's surface on both the entering web and the outside of the winding roll. The boundary layer of air travels at nearly the web's speed. Without a winding nip, the high- velocity air creates high pressure at the web-roll convergence. An unnipped web, which creates only low pressure (less than 1 psi), can be lifted by the air velocity pressure. A winding nip can create more than 100 psi, opposing and compressing the entrained air's pressure.

Q: Is entrained air bad for roll quality?

A: Not always. Air can be a great masker of caliper and diameter variations. However, if the air bleeds out over time, the roll layers will settle to a small diameter and loosen the roll. More air inside a roll will increase pump downtime for vacuum processes, such as metallizing. Winding in a vacuum process quickly reveals the benefits of entrained air. Without entrained air, caliper variations translate strongly into diameter variations, and often wrinkling.

Q: How does a winding nip increase roll tightness?

A: More winding nip force creates a tighter roll, similar to winding with higher tension. Dr. Keith Good at the Oklahoma State University Web Handling Research Center did some excellent work over the last decade to understand and predict how a winding nip increases tension.

To understand the “nip induced tension” effect, think about rolling a cart over a rug. The nip force of the cart's weight on the wheels has a rolling pin action, elongating the rug. As the cart rolls in one direction, the rolling wheels elongate and pin down the stretched rug. The elongated material is pushed ahead of the cart, forming a bulge in the carpet.

If you held the rug at both ends while you rolled the cart, you would find the rug behind the cart got tighter and the rug section ahead of the cart got looser. This same elongating and pinning happens with a winding nip, only in the reverse direction. The web moving under the nip is elongated and pinned onto the winding roll. Therefore, the web tension increases as the web passes under the winding nip.

Q: What determines how much added tension is created by a winding nip?

A: In both the rug and winding nip case, the top layer (or rug) must slide relative to the surface below it to elongate. If the layer (or rug) can't slide, it can't elongate. The interesting finding from Dr. Good's work is the winding nip tightening must exceed the break-away friction, but it also is limited by it. The winding nip cannot induce more tension than the frictional force at the sliding point. Therefore, front-to-back web coefficient of friction (or rug to floor friction) determines how much elongation or tensioning occurs for a given winding nip load.

Q: Is wound-in tension from a winding nip a benefit?

A: It may be a benefit, but mostly it is important to understand when it increases roller tightness and when it doesn't. The benefit of nip-induced tension is that it can reduce the tension that must be transmitted through a center winding roll. Too much center torque can lead to cinching and telescoping. Winding nip tension can create a tighter roll without these defects.

Q: What is the best geometry for the winding nip?

A: There should be some wrap on the winding nip, so the web is placed onto the roll by the nip. If the web touches the roll then later is nipped, some of the anti-wrinkle and improved tracking benefits are lost. A winding nip after the web tangent point still will have some air squeegee and induced-tension benefits.

The best winding nip geometry is a 180-deg wrap. This does two things. First, it orients web tension perpendicular to winding nip force, making the winding nip load independent of tension. Second, if the winding nip roller deflects or skews, a 180-deg nip wrap ensures it will be perpendicular to the entry span, reducing the likelihood of tracking or wrinkling.

Q: What is a gap winding?

A: A gap winding is similar to a nip winding, but it does not contact or load against the winding roll. Instead, as the name implies, the gap winding positions the final roller at a small gap from the winding roll's outer surface, creating an extremely short entry span.

Q: What are the benefits of a gap roller relative to a winding nip?

A: A gap roller has the same anti-wrinkle and improved tracking benefits of a pack roller. However, since it doesn't create pressure or force on the outer layer, there is no air squeegee or nip-induced tension benefits.

Q: When is a gap roller used instead of a winding nip?

A: If you want the tracking and wrinkling benefits, but have a pressure- or tension-sensitive product, then gap winding is a better option. If your product has high friction or adhesive coating, the outer layer will not slip relative to the winding roll, so you can't benefit from nip-induced tension. If you find entrained air improves your winding quality, gap winding is better for your product.

The function of the last roller before entering the winding roll is critical to optimized roll quality. Nip and gap winding both will reduce lateral errors and wrinkling associated with long entry spans and roll variations. Winding nips will reduce entrapped air, and the associated loose wind or vacuum process pump downtimes. Winding nips are an alternate variable to increase roll tightness and may promote roll cylindricity.

Just like a good grocery assistant will put your milk and eggs in a bag safely, nip and gap winding will secure your web safely onto the winding roll.

Cores: The Foundation of Winding – Nov 2009

Where would you prefer to build your next house — on swamp land or solid bedrock? This should be an easy question since it's clear a house starts with the earth upon which it is built. If the earth moves, not much good happens. Doors don't line up anymore; walls separate from the ceiling; concrete cracks; and basements leak. It becomes quite clear the importance of a good foundation and that a home is more than just bricks and lumber.

A core is the foundation of winding. Instead of building upon the core with bricks and lumber, we build atop a core by wrapping hundreds or thousands of tensioned layers. Like a stack of bricks, each layer may add to the pressure exerted on a core.

Core pressures are commonly 10?100 psi but easily can reach 1,000 psi in winding stretch films. The core will respond to pressure by compressing and, in cases of extreme pressure, by collapsing.

Core compression is impossible to avoid but can be minimized. All materials respond to stress (pressure) by straining (dimensional change). A core will respond to the pressure of the winding roll by losing both outer and inner diameter. Excessive inner diameter loss can make a roll impossible to remove from a shaft.

Core compression is especially troublesome for stiff materials (foils, polyester, many papers) in which even a subtle outer diameter loss will loosen the layers near the core, possibly leading to a telescoped roll (see "Cinching: Belt Tightening Gone Bad, Part 1" and "Cinching: Belt Tightening Gone Bad, Part 2"). However, some core compression isn't necessarily a bad thing.

If the core doesn't give a little, core pressures will be many times the pressure elsewhere in the roll. In many film and foil products, high core pressure will create more waste near the core. Any imperfection of the roll start, even a single piece of tape used to attach the web to the core, will imprint and damage hundreds of layers of product. The nightmare defect of high core pressure is blocking, in which the layers of the roll fuse together and tear out rather than unwind.

Since a core is not a solid cylinder, how it responds to pressure is a combination of the geometry (inner diameter and wall thickness) and material (the modulus of elasticity in the hoop and radial directions). The effective modulus of a core always will be much lower than the material of which it is made, as low as 5% for thin-walled cores or as high as 30%?40% for thick-walled cores.

For a given wall thickness, smaller diameter cores will be stiffer than their larger brothers since core stiffness is proportional to the ratio of wall thickness to diameter. To have the same stiffness, a 6-in. core must have twice the wall thickness of a 3-in. core.

Calculating core stiffness for uniform materials, such as aluminum or plastic, is straightforward. The core stiffness of complex core structures, such as dual material cores or non-uniform materials, like traditional paper cores, may be found only from core compression testing.

To avoid defects associated with too hard or too soft cores, the core compressibility should be tuned to your product's radial modulus of elasticity (which is a function of material properties and how tight you wind the roll). Matching core to product will create the smoothest transition of stresses from the body of the roll to the layer near the core and the least high or low pressure defects near the core.

Core matching may include changing paper core geometry or hard coating but also can include switching materials. If paper cores prove too soft and metal cores too hard, consider intermediate modulus materials such as plastics or phenolics.

Core compressibility is only one of many considerations in choosing the best core for your product, but it may be the most important one. No matter how beautiful a home is, it will lose its luster if it slides off the cliff during the rainy season.

Are You Getting the Shaft? – Jul 2010

Getting the shaft may sound bad in street lingo, but in winding there are good and bad aspects of whether you want to get the shaft (wind with a shaft inside your core) or not (wind with a core supported by end chucks or other no-shaft options). To clarify:

Shafted Winding | Converting equipment used to accumulate the web, starting with a core supported by a full-width shaft inside the core, to form a wound roll.

Shaftless Winding | Converting equipment used to accumulate the web from an upstream process but without a continuous full-width shaft inserted through the core. There are two common designs for shaftless rewinds or winders: two drum surface winding and end-chucked center winding. Shaftless rewinds eliminate the need to handle the shaft between the finished and new core, improving productivity, safety, and ergonomics.

WHY YOU WANT TO GET THE SHAFT

These are the advantages of shafted winding and the disadvantages of shaftless winding.

Due to the structural support of the shaft, shafted rewinds can use thinner, less expensive cores and will have less deflection than a shaftless rewind. Due to the lack of structural support of the shaft, shaftless rewinds need to use cores with a stronger structure, unless the winding roll is supported from below by a non-deflecting support roller or rollers, such as two-drum surface winders.

Since the shaft can support rolls of various widths, the rewind arms do not need to be laterally adjustable, simplifying the rewind design and lowering equipment costs. If the shaftless rewind uses two chucks to support the roll, the arms must have a mechanism to engage and retract laterally, requiring a more complicated machine design.

Shafted rewinds have more contact area with the core, transmitting more torque without slippage. Shaftless rewinds have less contact area with the core than shafted rewinds, so they have less capacity to transmit torque to a winding roll without slippage (though a keyway on a core can greatly improve chuck torque transmission capacity).

Since the shafted rewind has a temporary shaft extending out both sides of the wound roll, the roll can be removed from the machine without contacting the roll of material or using a core wider than the web.

WHY YOU DON'T WANT TO GET THE SHAFT

These are the advantages of shaftless winding and the disadvantages of shafted winding.

Manual shaft handling is an ergonomic challenge and safety hazard. Automatic or semi-automatic shaft handling may eliminate the ergonomic and safety problems but requires added equipment costs, maintenance, and space.

Shaft handling greatly increases the time required between finishing a roll and starting a new one. The added mass of a full-width shaft adds to the weight needed to be lifted to remove a roll and increases the inertial torque needed to accelerate or decelerate the winding roll, increasing motor and energy costs.

Shafted rewinding usually requires an operator to manually inflate a pneumatic bladder and, if forgotten, leads to waste from slippage-related contamination and lateral shifting. Since shaftless chucks are fixed to the winding equipment, any pneumatic inflation of bladders can be automatically engaged and detected to prevent slippage-related contamination and lateral shifting.

Of all these issues, ergonomics and productivity are the top reasons many folks try to avoid the shaft. Lightweight shafts can greatly reduce ergonomic concerns and help with productivity.

In most winding, getting the shaft is the preferred option to create the best roll quality. If core deflection, handling damage, and torque transmission problems kill your yields, you can win by improved ergonomics and productivity.

A Torque Devil is in the Details – Oct 2009

In center winders, like the classic Rolling Stones song, you can't always get what you want.

Imagine you need to buy a new center-driven winder or unwinder. To determine the size of the brake, clutch, or motor you will need, you need to know the torque and horsepower requirements.

You probably don't know the torque in ft-lb or N-m required for your winding or unwinding process, but it's not hard to figure out. Here's an example of what you might come up with in calculating high and low torque requirements.

Let me know if you see anything wrong with this specification:

Wanted | Center winder and unwinder

Tension range | 0.5-3.0 lb/in. (6:1 range)

Width range | 30-60 in. (2:1 range)

Cores | 3- and 6-in. inner diameter (0.5-in. wall thickness)

Roll Size | 40-in. maximum diameter (10:1 range)

Let's calculate the low- and high-end torque requirements. The low-end torque requirement is the lowest tension × the narrowest width × the smallest radius (0.5 lb/in. tension)(30-in. width)(2-in. radius) = 30 in.-lb of torque.

The high-end torque need is the highest tension × the widest width × the largest radius, (3 lb/in. tension)(60-in. width)(20-in. diameter) = 3,600 in.-lb of torque.

We're done. We need a low-end torque of 30 in.-lb and a high-end torque of 3,600 in.-lb. Great. Okay? Hmmm. Gulp.

What's wrong? There is nothing wrong with either of these torque requirements, except that you were hoping to get them on the same winder.

The torque range — the ratio of the high-end torque to the low-end torque — is 120:1 (3,600 in.-lb/30 in.-lb). This range is outside the capability of any one normal brake, clutch, or motor.

Most brakes are pneumatically regulated with a maximum 80 psi and controllable minimum of 2 psi for a range of 40:1. Some disc brakes allow you to use multiple discs to double and triple their torque range, but that involves turning discs on and off.

Motors are sized by horsepower or kilowatts, which is a function of torque and speed. For a given mechanical drive train, a motor will have a 30:1 torque capability, but if you modify the leverage of the drive train, such as with a two-speed gearbox, you could sacrifice speed to get more torque.

Clutches are sized by torque, but as they run at faster speeds, they are limited by heat dissipation and sized by slip-watts, a strange unit that is a function of torque and speed, effectively similar to horsepower.

If you send the above 120:1 torque requirement to an equipment supplier for a quote, there are three possible responses, two of which are bad.

First, they may calculate the high-end torque, combine that with high-end speed, add a safety factor, and provide you with a big motor (and find later they can't get within 4x of your low-end needs).

The second option, which almost never happens, is they calculate the low-end torque and design a system to meet that need, but fall shy of the high end by 3x or 4x.

The third option — and the one I'm hoping for — is the supplier calls and tells you there is a problem with your specification.

What can you do if you have an excessive torque need? You'll have to make some concessions by reducing any of the tension, width, or diameter ranges.

Eliminate the 3-in. cores and narrowest width for the low-tension products. Reduce the maximum roll size for the high-tension products.

The other big torque range trimmer is taper tension — the process of decreasing tension as roll size grows. You can cut the high-end torque need in half by using 50% taper whenever you run the high-tension, wide, large-diameter products.

You may not be able to get what you want, but with the proper specification of torque range, you may get what you need: a winder that works.

The Case for Automatic Splicing – Oct 2005

The relay race of roll-to-roll converting gets exciting when the roll changes start happening more than 2/hr. Manually loading and splicing a roll easily can take 10 min, so at 2 changes/hr, this downtime could cost you a third of your productivity.

Dual or turret winders, with their ability to load a new roll while another is running, help reduce downtime. Dual winders still leave you with the choice of stopping to splice or risking operator life and limb by performing at-speed manual splicing. The risks of manual at-speed splicing should not be played down. Every time you ask an operator to crawl into or lean over a turret winder to make a slice and tuck transfer, you are playing Russian roulette with a possible broken arm, cracked ribs, or most unforgivable, loss of life. Many operators are overly conscientious and place the process before their own safety.

It's sad when an automatic transfer upgrade is justified only after someone is hurt but not before. Manual at-speed transfer should be allowed only when the applied torque is so low that an operator can stall the winder spindle with one hand. Don't put your operators in the position to choose between safety and productivity. To reduce the risk to your operators and avoid waste in your speed-sensitive process, you have two roll transfer choices: zero-speed splicing or at-speed splicing.

Zero-speed splicers use a web accumulator to handle the web length supply and demands. The length of web you need to accumulate is the total time required to decelerate and splice times your line speed.

For example, if your line runs 100 fpm (20 in./sec), you decelerate in 2 sec, and the splice time is 10 sec, you need to accumulate 20 x (2+10) = 240 in. or 20 ft. Accumulator rollers will take up web length 2x the distance they travel, so 20 ft of web is collected by moving two rollers with 5 ft. This is a reasonably sized accumulator.

As line speed and splice time increase, the size of your accumulator grows. If we speed up our process to 1,000 fpm and decel time increases to 5 sec, our accumulation length grows to 200 in./sec x (5 +10 sec) = 3,000 in. or 250 ft. Yikes, this is getting to be a big accumulator with 20 rolls moving over 12 ft each.

At-speed splicing becomes the more reasonable option when speed and time make accumulator size unreasonable. The move away from zero-speed splicing can make many operators, engineers, and managers quite nervous. If you had trouble with splicing in 3–10 sec, how can you succeed with only a fraction of a second?

There are four steps to any at-speed splicer. First, the new input roll or core must accelerate and match speed to the running web. Second, a pasting function must attach the new web or core to the running web. Third, the expiring unwind roll or finished roll must be severed from the newly spliced web and stopped. Fourth, but not necessarily last, the new roll must move into the running position.

Over the past 20 years, many equipment suppliers have produced unwinds and winders that perform these functions very reliably. For an at-speed splicer to be successful, a tape or adhesive must develop a bond in a fraction of a second, pasting with solid and uniform crossweb contact. The pasting event must be timed smartly to avoid contact ahead of or partially on the tape.

I've worked more on the auto-transfer of winders than unwinds. The keys to at-speed transfer on winders include finding the best cutting geometry, ensuring the finished roll and web-to-core bond can oppose the force required to cut the web, and maintaining the precision positioning and alignment of moving components.

Beyond 100% reliability, don't forget about quality. Productivity gains from a new auto-winder can vanish quickly with excessive at-core or indexing wrinkle waste.

Zero-speed splicers are a good choice for difficult-to-cut material, precision splicing, scratch-insensitive webs, and when the combination of line speed and splicing times leads to a reasonable size accumulator. At-speed splicers are the best choice when accumulation lengths become unreasonable. Even for short accumulation cases, at-speed splicers may be a better choice for easy-to-cut or scratch- or wrinkle-sensitive webs. Either auto-splicing option is the right choice to save your valuable process and people.

WOUND ROLL DEFECTS

Cinching Belt Tightening Gone Bad: Part 1 – Feb 2003

In today's economic climate, belt tightening sounds like a fiscally wise move. Belt tightening, also known as cinching, is good for budgets, trash bags, and keeping your pants up; cinching during roll winding, however, may have less desired results, such as filling trash bags and losing your shirt.

What is cinching? “Cinch” comes from the Latin word for belt. Cinching is used to describe the relative motion of two layers around a curved surface like the motion used to tighten a belt before buckling it. In winding, cinching is any tightening or loosening motion of outer roll layers relative to inner roll layers. This action is sometimes called “clockspringing,” referring to how the roll's layers will tighten like a clock's spiral spring.

When does cinching occur? Cinching occurs when any point in a roll is pushed beyond its torque capacity. Each layer of a roll has a torque capacity defined as the product of the radius, the layer-to-layer traction coefficient, the inter-layer pressure, and the area of contact. Calculating torque capacity is difficult, because inter-layer roll pressures aren't easy to measure or model.

Cinching is more common on center winders than surface winders. Whether rewinding or unwinding, center winders apply torque at the core, transmitting it through the body of a roll to create tension at the roll's outer surface.

Cinching can be a localized event, happening at a distinct radial position in a roll, or it can be a pervasive, full-roll event.

Cinching from unwinding or rewinding tension will always shift layers in a tightening direction. Tightening-direction cinching usually is self-limiting, since the tightening action increases internal roll pressures and torque capacity.

Cinching from inertial torque may shift layers in either a tightening or loosening direction. If a winding roll is decelerated too quickly, its outer layers develop an inertial torque that resists stopping. This loosening cinching action, if great enough, can drive the web tangentially into compressive buckling, forming a crossweb or crepe wrinkle inside the roll. Cinching in the loosening direction is self-promoting, because the loosening action decreases internal roll pressures and torque capacity.

Is cinching a defect? Your product may cinch every roll and show no ill effects, but watch out for these undesirable cinching by-products:

Scratching, abrasion, and debris generation: When you press two surfaces together and slide them relative to each other, you will have some wear.

Lateral shifting of roll layers: This is a curious side effect, since cinching is a machine-direction event. When cinching occurs, the applied torsional load has consumed the roll's traction; therefore, there is no traction left over to oppose any internal lateral forces from crossweb nonuniformities such as caliper variations or skew.

Crepe wrinkles: Inertial cinching that drives internal layers into compressive buckling may create permanent creases or crepe wrinkles in the web.

Can you live with cinching? I have seen a number of operations that simply live with cinching. Cinching is tolerated if your product is insensitive to scratching. Loose-direction cinching is avoided by minimizing acceleration and deceleration rates. Lateral shifting from cinching may be small enough that subsequent web guiding can handle it easily. If the lateral shifting gets severe, using winding flanges or spool walls can contain the shifting layers.

If you are not so lucky and cinching by-product defects fill your cinch sacks and cause you to lose your shirt, join us next month to understand how to eliminate the belt-tightening pain of cinching.

Cinching Belt Tightening Gone Bad: Part 2 – Mar 2003

The expression “it's a cinch” usually means something is easy, as easy as tightening a belt. However, as we learned last month, cinching is not something we want to hear about in the winding business.

How do you know if your product is cinching?

At unwinding, draw a spoke line from the core to the outside of the roll. Apply the tension and start unwinding. If the line remains in the spoke direction, the layers are not slipping relative to each other. If the spoke line turns into a spiral or forms a step, your roll is cinching.

At winding, this is a little trickier. If the speed isn't too high, try snapping a chalk line in the spoke direction. A more advanced, safe — but expensive — way to detect winder cinching is to coordinate an ink jet printer to mark the outermost layer of the winding roll once/revolution. If the series of ink jet dots form a spoke line, there is no cinching.

How is cinching eliminated? Cinching occurs when torque capacity is less than applied torque. Stop it by changing either side of this equation.

Reduce the applied torque

Center-winding torque is the double-edged sword of cinching. If we turn it up to create a tighter roll, we increase the torque transmission demand on the roll. Luckily, there are other ways to make a roll tighter.

Surface winding — in which a driven roller or belt at the roll's surface creates tension — eliminates the need to transmit torque through the roll's layers.

A pack roller nipping the outside of a roll during winding adds to the tension of the incoming web, forming a tighter roll with minimal increase in applied torque.

You can reduce applied torque in other ways. Big changes in roll diameter usually mean increasing tension and torque; therefore, reducing roll build-up ratio with larger cores or shorter roll length may help. Always unwind a roll at a tension lower than it was wound. Don't expect an unwinding roll to have more torque capacity than when it was wound. Prevent inertial torque loads with moderate acceleration and deceleration rates.

Increase the roll's torque capacity

Torque capacity increases with higher traction coefficient or more internal roll pressure. The obvious approach here is to wind tighter. It is counter-intuitive that higher tension could prevent cinching. It seems that more tension would increase torque capacity and applied torque equally. However, the nonlinear nature of roll buildup and the tourniquet effect means doubling tension can more than double internal roll pressure.

If your product doesn't have an inherently high friction coefficient, think of ways to increase layer-to-layer traction. Moisture, magnetism, and electrostatic pinning are some options to change the bond between roll layers.

Sometimes the wrong things save you. Hardbands, baggy web, and poor slit edges can prevent cinching. Intuitively, it doesn't seem these defects, which change cross-web tension distribution, should increase torque capacity. Therefore, the tension concentration from these nonuniform characteristics easily can stop cinching. If you have a product that occasionally cinches, look to see if that roll is too uniform.

Some products are designed with a knurl or other locking mechanism at the product edges that is trimmed off before the final product.

Watch out for cinching caused by compression or shrinkage of the core or internal roll layers. Paper cores can fall away from the product if they start too moist and dry out. Product layers can fall radially due to air bleeding out a roll or shrinkage of a film or coating over time.

Don't lose your shirt while tightening your belt; cinching can be eliminated in most products. Fight the battle on both fronts, and you may find it's a cinch to stop cinching.

Bagginess: How Bagginess Causes Waste, Part 1 – Apr 2007

This is the first of four columns on baggy webs, starting with understanding the problems they create.

To most converters, the ideal web is one that is uniform in all aspects, especially geometry. It is uniform in thickness, width, and length. If you cut an ideal web, it will form into rolls, slit strands, or sheets that are identical and will delight customers. Ideal webs often are seen in elevation drawings of web lines, represented as perfectly straight lines that travel from one roller tangent point to another. When you see an ideal web running, you may confuse it for a pane of glass. That's the ideal (i.e., dream) world.

The nightmare that spoils the ideal dream for many converters is a baggy web, one with non-uniform geometry in the plane of the web, usually crossweb variations in length.

Web bagginess is one of the main quality complaints about webs bought in roll form. Instead of forming glass-like straight and flat web paths through the machine, baggy webs droop and flutter like sheets on a clothes line. When you see this web running, you'll think about things such as broken wings, rippled chips, and hammocks. The nightmares of baggy webs keep many a converter awake at night.

What problems do baggy webs cause?

ESTHETICS

Baggy webs look bad, at least when they are under no or low tension. It will not matter that some amount of bagginess is inherent in all webs or that a slight bagginess can be pulled out with tension and cause no measureable performance problems. For some people, looks are everything.

TENSION VARIATIONS

Most baggy webs, due to their crossweb length variations, will have crossweb tension and strain variations, leading to myriad potential problems.

COATING VARIATIONS

In some precision coating methods, such as kiss gravure or fluid bearing dies, web tension directly affects coating thickness, so a baggy web leads to crossweb coating variations.

SLITTING VARIATIONS

Low-tension lanes of a baggy web may see poor slit edge quality or failure to cut. Strands cut from low-tension lanes may go loose after slitting, leading to weave in wound roll or wrapped rollers and web breaks.

ROLL VARIATIONS

Wound roll tightness is highly sensitive to web tension. A baggy web will have crossweb tension variations that will lead to crossweb variations in roll tightness. Crossweb roll variations may be minor in winding a single wide roll but cause high waste in lock-bar winding after slitting (creating sales for differential winding shaft suppliers).

REGISTRATION ERRORS

Registration to pre-printed web may be impossible when yielding within the wound roll produces baggy web and out-of-spec pattern dimensions.

CORONA TREATMENT ERRORS

Lanes of baggy web that carry no or low tension will air-lubricate on rollers, which leads to unwanted backside treatment.

LATERAL MOTION

Webs with asymmetrical bagginess will have a weak but real tendency to shift toward their low tension sides, especially with long spans, low tension, and in air flotation ovens.

WRINKLES!

The last and biggest problem with baggy webs is that they lead to increased wrinkle waste. Baggy webs with loose lanes or centers will wrinkle in long spans, especially if combined with subtle roller misalignment. Unless sufficiently tensioned to avoid loose lanes, all baggy webs will have trouble running through nips without wrinkles.

I hate to leave you with these nightmares, but you must face your demons before you can exorcise them. Over the next three columns, I will try to make your baggy web nightmares go away by reviewing options to measure the problem, helping you understand root causes, and advising you on how to de-sensitize your process to baggy webs.

Bagginess: How to Measure It and Why, Part 2 – May 2007

I'm not usually a big fan of management adages, but this is one I often can support: “You can't manage what you don't measure.” How do you expect a defect to go away if you don't measure it?

The minimum measurement is binary (“got it vs. don't got it”). True measurement begins with quantifying something (the defect was this big, or there are this number of defects per a population). The next step in measurement is to add trending to it, either by location or by time.

Regarding baggy webs, what should you measure? Bagginess by itself isn't usually a problem until 1) you try to run the baggy web through a nip, or 2) it is so bad the web wrinkles or your laminates are curly on one side and flat on the other.

The goal of measuring baggy webs is not to get a number but to correlate bagginess to real, permanent defects and to work to reduce the source of your bagginess. The trouble with unmeasured baggy webs is you can't decide if a particular roll of material will cause problems or not. Also, if you aren't measuring it, it is difficult to convince a supplier that the web they are sending you is too baggy or baggier that it was before.

Here's a fairly exhaustive list of options to measure your baggy web. Tests 1 through 6 measure bagginess off-line with a sample in lab. Tests 7 through 12 are on-line measurements to check a moving web.

Sweep out a length of web and measure skew from a straight line.

Lightly tension a web sample in a horizontal span between two aligned rollers and measure crossweb droop variations.

Inspect a web sample from the top of a wound roll and qualitatively judge the force to pull the web taut (0 is a perfect web, 1-5 requires finger, wrist, elbow, shoulder, or full-body strength to pull out the bagginess.

Combine 2 and 3 above, measuring tension to pull horizontal span up to a target sag dimension, for example less than 0.5 in.

Mark parallel crossweb lines on the flat tensioned web, then cut it into machine- direction strips and measure the length differential of the untensioned strips.

Place a sheet sample on a flat plate and measure ripple or curl deviations from planar.

Perform Test 2 online with a scanning distance measuring device, such as a laser triangulation micrometer or an ultrasonic sensor.

Perform Test 2 online and compare the lines displayed on a web from perpendicular and low-angle light sources. The low-angle light will appear wavy when compared to the perpendicular line if there are any crossweb sag variations. Combine this with a camera and vision system to quantify bagginess.

Measure crossweb tension variations with a segmented tension roller.

Measure crossweb tension variations with a segmented tension beam. This is similar to Test 9 but uses narrower, non-roller elements (a service provided by PAPRICAN, Canada's paper research institute in Montreal).

Measure crossweb tension variations while the web is pneumatically conveyed over an air turn bar.

Measure crossweb tension variations in the speed of sound through the web (a device developed in the lab of Dr. Richard Lowery at the Oklahoma State Univ. Web Handling Research Center).

I don't want to leave the topic of measurement without the necessary warning: Before you go crazy measuring web bagginess, invest some time in finding out whether your measurements actually correlate to defects.

Bagginess: What Causes Bagginess, Part 3 – Jul 2007

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Bagginess: Minimizing Bagginess and Related Problems – Aug 2007

What does minimizing a baggy web mean? Two things. First, we would like to minimize the level of bagginess in our webs. Second, we would like to minimize the waste associated with running the inevitable baggy web in our processes.

To minimize the creation of baggy webs, we must take on their causes. In last month's column I said, "The biggest cause of bagginess is the web's response over storage time to cross-roll stress variations created by magnifying the effect of crossweb thickness variations." This statement is basically a flow diagram of what creates most bagginess.

How to make a baggy web:

Make a web with crossweb thickness variations and stiff properties in the thickness direction.

Magnify the thickness variations by winding with no lateral oscillation and ensure the final roll is many times the diameter of the core.

Wind the roll with high tension, no taper, and at low speed to avoid entrained air softening the roll tightness.

Ensure the product will be easy to yield or flow visco-elastically by promoting high moisture in papers and elevated temperatures in films.

Store the roll for a long time. With film, make sure to store it in a hot environment like a summer warehouse or semi-trailer.

Unwind the roll to enjoy the bagginess. Make sure you don't measure it.

This is the recipe to maximize bagginess. But how do you minimize it? Just reverse all of the above steps.

None of these steps alone is responsible for creating a baggy web. So reversing one step will not fix the problem. Reducing bagginess is often a long, tough project, but taking a multi-pronged attack on this baggy creation process will reap benefits.

What can you do as a converter to desensitize your machines to baggy webs?

Increase Tension—Pull out length variations. Bagginess that is pulled out with tension usually is not a problem.

Eliminate Nips—If tension doesn't pull out your bagginess, you will almost assuredly see wrinkling at all your nipped processes. Nips are needed for many processes, such as coating, laminating, and calendering, but avoid nipped rollers for web handling only.

Apply Spreader Rollers—Use spreaders judiciously, such as just upstream of nipped processes, slitting, and winding. The best spreaders for baggy webs are bowed rollers, expanding surface rollers, edge nips, and D-bars.

Consider an Adjustable Roller—In the case of left-right bagginess, a manually skewed roller can change the side-to-side web path length and eliminate slack web and related wrinkles. I haven't seen an automatic system do this successfully, but a well-trained operator can save the day. If you choose to use an adjustable roller, place it as close to the nip as possible, wrap it 90 deg, skew it in the plane of the web entering the nip, and have an indicator to return it to the parallel position.

Add a Bagginess: Removing Process—This is a little dangerous, so I don't want to advocate this too much, but some film bagginess can be greatly reduced with a heat, stretch, cool process. Why is this dangerous? You may change the characteristics of your film, such as heat stability or stiffness.

I would have loved to title this column "Eliminating Baggy Webs" or "Eliminating Bagginess-Related Waste," but I don't want to get your hopes up too high. I think minimizing is the best many of us can hope for.

SLITTER REWINDER PROCESSES

Stripe Slitting: The Challenge of Staying within the Lines – Jun 2002

Lines make life more difficult. Remember coloring as a child. At first it was just you, your crayons, white paper, and free expression. Life was easy. Later, you graduated to coloring books. Now you were constrained; you were supposed to stay inside the lines. Life became more difficult. How about learning to drive a car as a teenager? It was easy practicing in the parking lot, but hitting the highway and staying in your lane was another story.

The same line constraint applies to slitting web products. Slitting a homogenous wide material into narrower rolls is relatively easy. However, slitting material with lines or stripes, where the stripe-to-slit edge dimensions are critical, will make you feel the same constraints as the child with a coloring book and the teen driver on the highway.

You may have experience with precision slitting, holding width tolerances to ±0.003 in. Be warned: The same specification for slit-to-stripe width position registration is at least ten times more difficult. Where precision width slitting is a college course, precision stripe slitting is graduate-level material!

What makes stripe slitting so difficult? Tolerance stacking. Precision slitting itself is not easy. Three tolerance factors stack up against you — tensioning, flatness, and knife setup. For precision stripe slitting, you add four more tolerance factors. Let's review all seven factors important to precision stripe slitting. Each factor has variability, and controlling variability is harder for some than others.

Consistent Tensioning

Constant tension is needed to create constant necking into the knives and consistent width recovery when tension is removed. Tension also will affect tracking and guiding.

Web Flatness

The web should be visibly flat entering the shear knives. Many slitters include a web-spreading device immediately upstream of the slitter knives to ensure the web is taut laterally.

Knife Setup and Performance

Knife setup spacing will dominate the resulting slit width. Knife position doesn't stop at setup. Runout, wobble, deflection, and other factors may cause the slit point to differ from the accurate setup.

Input Material

The input stripes must have consistent width and spacing. The material also should have consistent thickness, modulus, and splices. The input roll should not exceed the web guide's range or rate. Any web bagginess should be pulled out easily with normal tensions. Input material variability may be the most difficult of these factors, since the input quality is usually out of your control.

Pattern Sensing

The sensor must consistently detect the target stripe edge. Any sensor detection error or dead band will affect stripe-slitting error directly.

Guiding

The guide's mechanics and controls should be responsive and rigid. The guide should have a range and actuation rate to match input roll quality and web speeds.

Guide-to-Knives Tracking

Don't assume an accurately positioned stripe at the web guide will lead to consistent stripe-to-knife alignment automatically. Just as last month's column addressed slit-to-wind tracking, many of the same factors can create guide-to-knife tracking errors. A short web path, good tension, cylindrical rollers, good traction, and good roller alignment all lead to low transport tracking error.

It is a lot of work to stay between the lines. Doing doughnuts in parking lots and doodling may be fun, but the professional artist, the NASCAR driver, and the experienced converter all understand that staying between the lines can be a profitable approach to life and slitting.

How Web Tensioning Improves Slitting: Stress and Strain, Part 1 – May 2009

A properly tensioned web always will lead to better slitting. Good tensioning is important up to, through, and out of the slitting blades. A poorly tensioned web may try to bypass razor-in-air slitting; or deflect and deform more in razor-in-groove slitting; gather and buckle ahead of the nip point of a crush knife; and flutter out of plane, contacting shear knives ahead of the overlap point. In all these scenarios, a perfect knife setup can be ruined by poor tensioning.

THE BENEFITS OF GOOD SLITTING TENSION

A tensioned web will play a better role by keeping a stable cut point. A tensioned web has the force to drive into a razor blade, creating the stress required to fracture the web. A tensioned web will have minimal flutter, contacting the shear knives at, not ahead, of the overlap point.

Tensioning a perfect web is relatively easy; it's tensioning baggy webs in and out of slitting where knowledge eliminates waste. Tension is the first line of defense against bagginess.

A baggy web under no or low tension will show its crossweb length variations in loose lanes or edges. Any looseness into slitting is an edge quality killer. For moderate bagginess, medium to high tension will pull out the short lanes equal to the long lanes and greatly aid slitting quality.

Bagginess that can't be pulled out with even high tension is grounds for complaining to your supplier (even if you are your own supplier). Web spreaders commonly are used immediately upstream of slitting where the lateral tensioning will prevent wrinkles and looseness at slitting. Through the Poisson's effect*, the lateral pull of a spreader will provide some help to pull out bagginess.

For solid materials, tensile and compressive stresses do not significantly change density. Increases in length (MD strain) is offset by decreases in the width and thickness.

Besides affecting slit edge quality, a tensioned web is important to accuracy of slit width. Any lateral buckles in the web between slitting positions will create web width variations. Tensioned webs are more likely to be flat, wrinkle-free, and the correct width.

Slit width accuracy also is dependent on good tensioning to maintain a consistent relationship between knife spacing and final web width. What is the correct knife spacing to create a 50-in. wide web? For stiff materials, the answer is usually 50 in., but not so for other webs. Stretchy webs like many fabrics and nonwovens will elongate the web in the machine direction by 2% or even 10% under tension. The tension also will reduce the web width (through the Poisson's effect, also known as necking) by 1%-5% or more. For stretchy materials, tension will reduce a 50-in. web down to 49 in. or less, so knife spacing must account for necking.

Slit width accuracy not only is dependent on setting the right knife spacing for a given tension and necking but also relies on the minimum tension variations. Many slitting processes rightfully try to reduce waste with small trim widths, but uneven tensioning will cause the web to neck in away from the trim knives. No web at the knives means no trim, improper web width, waste, and downtime.

Tension in slitting can help reduce abrasion of the slit edge in stretchy materials. A stretchy material elongates more under tension and will also neck in more. Inserting a blade into a stretchy tensioned web can be like cutting a ripe watermelon. The web will open a gap at the slit point as the necking width loss is divided between slit strands. This slit gap can pull the web away from the knife edges, reducing abrasion-related deformation and debris generation.

HOW IS SLITTING TENSION CONTROLLED?

If your slitting zone has closed-loop tension control, in which tension is constantly corrected in response to load cell roller or dancer roller feedback, then it's easy to understand how your average slitting tension is controlled. However, though closed-loop control is common on coaters, laminators, and other multi-drive converting lines, it is fairly rare to see it in the slitting section of a slitter/rewinder.

The logic behind how tension is controlled in slitter/rewinders may be the result of “how we've always done it” more than engineering or economic analysis. However, the simple designs that are repeated in most slitter/rewinders are logical when you dig into them.

There is an economic argument to keep the cost down for the tension control system in a slitter/rewinder. A high-speed coater or laminator line may need two or more slitter/rewinders to keep pace with the output, so any equipment design cost is doubled or tripled.

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The biggest difference between slitter/rewinders and most other converting equipment is the constant speed changes. Most slit rolls are one-third or even one-thousandth the length of the input roll. But due to the nature of finishing and unloading a slit roll and loading and starting a new core — possibly tens of new cores — the slitting process has many stops and starts. This can lead to a good amount of process time spent in accelerating and decelerating.

During rapid acceleration designed to increase slitter productivity, roller inertia can create large torques and steal or add tension to the web. Inertia-induced tension variations would lead to all the problems of poor tension control at slitting. The solution is to drive many of the rollers in a slitter/rewinder slitting zone.

Because of cost constraints, the driven roller must be controlled in open draw mode (also known as speed ratio control). Open draw is a common tension control strategy, especially when space and budget limitations make it the only alternative. But draw control is the least understood of the tensioning options.

Understanding draw control of slitting tension requires an understanding of how the stretch (a.k.a strain) of the web creates tension. Elastic webs are like springs. To elongate them requires force proportional to how much you stretch them and their spring constant. A web's spring constant is the product of Young's modulus of elasticity†, web thickness, and width. In a draw zone, there are two dominant variables that control tension. The obvious one is the draw ratio. If you drive the web with a succeeding roller with either a speed increase or decrease, you will change the stretch of the web. The less obvious factor is the input tension. A draw zone only modifies the web's existing stretch or tension.

In a traditional slitter/rewinder, the slitting tension is nominally the unwind tension plus or minus the change induced by the draw ratio of the driven rollers. If the driven rollers create a speed increase, the slitting tension will be higher than the unwind tension.

TENSION EXITING SLITTING

This is where many slitting processes get into trouble. The mostly likely problem is the tension of the two trimmed edges. Pneumatic take-away systems are a great way to manage the difficult-to-wind narrow trim but usually are lousy at creating a consistent slitting exit tension. Pneumatic trim systems often compound the tension problem by pulling the trimmed strand laterally out of the knives.

The best practice to reduce trim tensioning problems is to have the trimmed strand follow the other slit strands for at least one roller after slitting. This one post-slit roller rule will buffer the pneumatic tension variations and lateral bending from the knives that degrade slit quality.

Another problem with post-slit tensioning is caused by slitting a baggy web without sufficient post-slit tension or differential length compensation to keep the strands from baggy lanes or edges tight. Differential shaft winding would compensate for slit strand length variations if the path from slitting to winding was short and nearly roller-free. However, too many rollers between slitting and differential winding will create a buffer between the differential shaft and slitting. The shaft still will help with slit roll uniformity but lose the ability to create uniform slitting exit tension.

Many of the features of good slitter tensioning are not things you can change after you purchase a slitter. Thankfully, many slitter/rewinder manufacturers have learned through experience what works and include these features in their standard machine designs. Understanding how tensioning and slitting work together puts you in the best position to choose the best slitter design or maintain your slitter's high quality, productive life.

*Poisson effect: When material is stretched in one direction, it tends to contract in the other two directions perpendicular to the direction of stretch. This phenomenon is called the Poisson effect, named after French mathematician Simeon Poisson.

†Young's modulus of elasticity: Young's modulus, named after British scientist Thomas Young, is the ratio of tension stress to the resulting strain.

Slitting Debris: Cracking the Case – Nov 2004

Dust and debris are a common but unwanted side product of slitting. Slitting debris comprises the small particles that break off a product's edge during the slitting process. It is created through fracture and abrasion. Uncontrolled slitting debris will lead to defects in your customer's product and equipment downtime.

When you slit your product, you use knives to concentrate stress mechanically, breaking the web along a narrow line. The product splits when a crack forms. When the stress is high enough, the web will snap apart like breaking glass. Though the stress-induced crack usually is contained within a high-stress zone, the cracks will bifurcate (split or fork). Like ice cracking along a river's edge, if two cracks rejoin, they may create an unattached chip.

Even if the fracture process doesn't create debris, it may leave a ragged or slivered edge that will chip away easily if touched. All three conventional slitting methods (razor, crush, and shear) require the freshly fractured edge to drag along the blade's flank as it passes downweb. The side load and relative motion during contact cause abrasive wear of both web and blade, creating a dull blade and slitting debris.

Which materials create the most debris? Slitting brittle materials generates the most debris. Think about the difference between cutting soft bread and brittle toast. Since brittle materials reach their fracture stress quickly, the cracks in the slitting or abrasion zone will bifurcate more, forming more unconnected material.

Which slitting method creates the least debris? It is rare to try all three methods on one material, so my empirical comparison is biased by real-world applications. Material plays a dominant role in which method makes the best edge or is easiest to apply. Also, consider how stress is concentrated to create fracture stress and how much inherent web-knife abrasion there is. Given those caveats, I rank the slitting methods — from least to most debris generation — as shear, razor, crush, and shear.

Shear is listed twice as it is both the best and worst debris generator. Done poorly, with nicked, dull knives and arbitrary geometry, shear slitting can be a debris factory. Worse yet, shear slitting can create angle hair (long strings of skived material) and double cuts. Shear also can be the cleanest, most precise slitting method. Shear slitting's tip-to-tip stress concentration can be more focused than razor or crush slitting. The rotating knives reduce web-knife relative motion and abrasion debris. Precision shear slitting, with tight control of runout, engagement, and sharpness, is the cleanest (and most expensive) slitting method for many products.

Razor slitting creates a small fracture zone when sharp, but this will diminish continuously by dulling abrasion over time. Oscillating or hard coating a razor blade will reduce dulling rates, but due to their low cost, most people opt to just change razor blades frequently. If your slitting is relatively inaccessible, prohibiting frequent blade changes, razor may be a poor choice.

Crush slitting blades work with the dullest blade edge (a.k.a. tip radius), but when used on brittle materials, the slit edge will be surprisingly crisp. Like shear slitting, the rotating knives have little relative motion with the web's edge, so abrasion wear is minimal.

Where does slitting debris go? It is most obvious at the point of slitting. Dust and debris will build up on knives and pile up below knives. Slitting dust can get into bearings and cause early failure. Slitting debris also will go downstream, clinging onto the top, bottom, and side surfaces of slit edges. Rubber rollers downstream of slitting will develop dust rings aligned to the slit edge contact. Without a mechanism to transport the debris laterally, slitting debris will stay near the web's edge.

How can you minimize slitting debris? Minimize the two sources of debris: uncontrolled fracture and avoidable abrasion. Sharp knives with proper geometry and loads are a good start. Take care to avoid abuse in handling, installing, and running your knives. Higher slitting zone tensions will provide a starting point to reach fracture stress and encourage the web to neck away from the knives after fracture, reducing abrasive wear and debris.

If you have a slitting debris problem, look into improving your existing process before pursuing alternatives. For new materials, consult with material or slitting equipment suppliers on their recommendations.

Differential Rewinding: Part 1 – Nov 2002

Don't try to do ten things at once. While this is good advice, sometimes ten things come flying at you at once. If you focus on one item, you risk dropping the other nine.

If you operate a slitter/rewinder, you know what I'm talking about. It would be nice to wind one roll at a time, taking care to start each roll smoothly and give it dedicated tension control. On a slitter/rewinder, however, it's common to rewind ten slit rolls (or more) at once. Losing nine of the rolls is not an option.

The simplest approach is to wind ten rolls abutted side by side on a single shaft. Winding rolls on a common shaft without roll-to-roll separation usually leads to shuffling, where adjacent winding rolls interleave with each other. Shuffling is prevented by using a spreader device to create a gap between neighboring strands or splitting the strands between two rewind bars (duplex rewinding). Spreading can degrade the natural accuracy of the post-slit edge, but duplex winding preserves tracking accuracy of slitting.

What is lock-bar winding?

Lock-bar winding couples multiple rolls directly to a common shaft. Each roll turns once per shaft revolution. This approach often is plagued with web slackness and roll structure variability. Slackness in lock-bar winding comes from either web bagginess (from cross-web length variations) or roll-to-roll diameter variations (from cross-web thickness variations). Even before the onset of slackness, these variations are causing roll tightness variations. Longer strands or small-diameter rolls need to rotate faster than average to prevent slackness or soft roll defects. Shorter strands or larger-diameter rolls must rotate slower than average to prevent hard roll defects. Roll tightness uniformity from lock-bar winding is dependent on product length and diameter variability.

WHAT IS DIFFERENTIAL WINDING?

Ideally, each winding roll would take up its strand with the proper winding tension independent of length or diameter variations. With differential winding, each winding roll turns at the rpm appropriate for roll diameter and entering web length. Differential winding bars have a variety of designs, but all feature a clutching mechanism for each roll. In general, differential bars have an internal shaft driven faster than the winding rolls. A clutching mechanism limits the torque transmitted from the shaft to each roll. Roll tightness uniformity (and yield) from differential winding is independent of product variations, now a function of roll-to-roll clutching variations.

When is differential winding needed?

Since all products have some degree of dimensional variations, it would seem differential winding is always needed, but in fact, this is not the case.

Differential winding is needed if baggy web length variations are significantly large relative to web strain. Higher-modulus baggy products, where it is difficult to simply pull out the bagginess, are more likely to need differential winding for baggy webs.

Differential winding also is needed when caliper variations create significant diameter variations. Surprisingly, thicker-than-average slit strands do not always make larger rolls. The relationship of caliper to common shaft winding roll diameter is dependent on, to paraphrase a famous toilet paper commercial, how “squeeze-ably soft” the roll is. More squeeze-able rolls, like many paper or thick adhesive-coated products, may compensate for caliper variations through changing roll density. Less squeeze-able rolls, like most film and foil products, cannot compress radially, so caliper directly creates roll diameter. Roll squeeze-ability (a.k.a. radial or stack modulus) is dependent on thickness direction modulus, roughness, coatings, air entrainment, and winding tension.

Do you need differential winding?

Try lock-bar winding with your worst input material. If you have slack web or significant roll hardness variations, you need differential winding.

Armed with differential winding, you are well prepared to handle ten things at once — at least ten rolls.

Differential Rewinding: Part 2 – Dec 2002

Last month we made the case for using differential rewinding shafts. This month, let's talk about what differentiates one differential shaft from another.

Differential shafts can be divided into two categories, axially or radially loaded, depending on the direction of the clutching action.

Axially loaded shafts, the granddaddy of differential winding, load a stack of cores and spacers laterally against a fixed collar, creating friction at every core-spacer interface. The cores are free to rotate, but the spacers are keyed to turn with the shaft. As the shaft turns, the spacers are driven at an rpm greater than the web-restrained cores.

The friction created at the core-spacer interface, two sides per core, limits the torque that creates winding tension for each roll. As with all differential shafts, each core rotates independently to compensate for strand-to-strand variations. The torque transferred is roughly proportional to the axial load, usually set by air pressure to a pneumatic cylinder.

Axially loaded shafts are an inexpensive, mechanically simple design used by most differential slitter/rewinders. They can differentially wind slit strands less than ¼ in. wide successfully.

Where axially loaded shafts have an advantage in handling narrow widths, inherently they are weak at handling differing widths on a common shaft. Since torque is created at the core-spacer interfaces, the torque and winding tension are equal for wide and narrow rolls within a loaded set. This disadvantage doesn't discourage many converters, since many slitting processes run uniform slit width. Some axially loaded systems have two zones per shaft by using a central locked collar and loading from both sides.

Other potential concerns of axially loaded shafts include core dust, heat dissipation, and frictional torque variations. At high torques and speeds, both dust and heat are generated and can damage the core or product. Due to the frictional variations of paper cores and plastic spacers, torque variations as high as 2:1 are common. Radially loaded differential shafts attempt to address these concerns, plus provide torque proportional to core width.

Radially loaded shafts inherently create torque proportional to core width. An internal bladder pushes multiple elements out radially against the core's inner surface, creating friction. Wider cores engage more frictional elements and receive more torque than narrow cores. Radially loaded shafts still may use the core as a frictional element but use the core's inner surface rather than its sides. This greater frictional surface area reduces dust, heat, and torque variations.

More advanced differential shafts take the core out of the clutching mechanism by using a core-gripping ring. In these designs, a core gripper locks onto the core, moving the clutch slip point to the core gripper-shaft interface. The core-independent clutch design uses engineering materials and lubricants, resulting in a dust-free, heat-tolerant, and consistent torque generator. The frictional core gripper shafts cost 3x-5x more than core-dependent alternatives.

Core-based shafts' frictional torque is created by axial or radial load and roll weight. Differential shafts with core grippers have an internal bearing to reduce influence of roll weight on torque generation. The ultimate differential shafts use magnetic hysteresis in place of frictional clutching. This improves rewind torque accuracy and repeatability greatly. You pay for this performance, with custom magnetic hysteresis shafts over 10x more expensive than entry-level alternatives.

Both of these core-independent shaft designs have a minimum element width (usually around ½ in.). Therefore, these advanced shafts cannot handle extremely narrow widths or tight roll-to-roll spacing.

Understanding the advantages of climbing the differential shaft evolutionary designs will help you find the right design for your product.

Differential Rewinding: Part 3 – Jan 2003

This month we continue our diagnosis of differential rewinding. The last two columns reviewed the whys and hows of differential rewinding, but before filling your prescription for two new differential shafts, let's review potential detrimental side effects.

Unknown Tension

Differential rewinding is a torque-based system, changing current, overspeed, or air pressure to vary the torque and — through the roll's radius — winding tension. One repeated theme in this column is measure your tension. A tension-sensing roller, whether used for control or measurement only, will ensure you get the right tension or know when you don't. If you can't afford to measure tension, at least know the tension you can get by calibrating your system with a spring scale.

Roll-to-Roll Torque Variations

Differential shafts eliminate tension variations from differing diameters or incoming web length, but they introduce a new source of tension variability: clutch performance. Differential shaft clutching mechanisms, especially systems dependent on consistent core-to-spacer friction, commonly have 2:1 cross-shaft torque variation. More advanced designs still will have torque variations caused by nonuniform machining, assembly, lubrication, or wear. I strongly recommend measuring your differential shaft's variability using a spring scale. Differential shaft suppliers should be able to answer questions about torque variation.

Too Mmuch or Too Little Torque

All torque-based systems, whether pneumatic, electronic, or magnetic, will be hard-pressed to operate over more than a 40:1 ratio. If you design for high torque requirement, you give up the low end, and vice versa. Absolute high-end torque, like any clutching system, is limited by heat dissipation. A differential shaft's clutch is trapped inside the core, making heat dissipation difficult. Controlling at extreme low torques is limited by rolling resistance and breakaway friction.

Core Gripper Torque Limit

Differential shafts with core grippers are less prone to core slip and associated heat or debris generation, but they are not immune. Many core grippers are designed to sink their teeth into paper cores but may fail if asked to grip plastic or metal cores, or even paper cores, under high-torque winding.

Pack-Differential Incompatibility

Differential shafts and pack rollers don't go together well. The combination of close proximity, differing diameters, and quick width changes makes pack-winding many rolls on a differential shaft a daunting task. Using a short-entry web span ahead of differential rewinding will reduce wrinkling and tracking problems but won't squeegee out entrained air. Lack of a pack roller limits differential wind quality, especially with increasing speeds, widths, diameters, and decreasing tensions.

Slipping in the Wrong Place

The simplest slitter/rewinders drive their transport rollers and, via a clutch, the rewind shafts from a single motor. The rewind clutch controls torque when full width or lock bar rewinding. If a differential shaft is used with this type of slitter, it puts two clutches in series. With two clutches in series, only one will slip. If a differential shaft breakaway torque is higher than the drive train clutch torque, the differential bar will fail to slip, creating the world's most expensive lock bar. To ensure the correct clutch slips, turn up the torque of the drive train clutch when differential rewinding.

Difficult Integration

Differential shafts are most prevalent on slitter/rewinders and rarely are seen at the end of extruding or coating lines. Why? Coaters and extruders must run continuously for product uniformity. Maintaining quality of edge trim and single-roll transfers with minimum downtime is hard enough. Differentially rewinding, with multiple knives and core starts, increases the downtime risk exponentially, a risk too great to put in-line with highly valued continuous processes.

That completes our differential rewinding diagnosis. Take two differential shafts and we'll see you in another month for your next appointment.

Differential Winding Limits: Part 1 – Nov 2007

The purpose of differential winding is to apply a desired torque to two or more rolls winding on a single shaft. Differential winding allows multiple rolls to turn at differing speeds, with each roll free to slip at the speed required to compensate for roll-to-roll diameter variations and strand-to-strand length variations.

For more on why differential winding is needed, how it compares to locked-shaft winding, and some of their limitations, check out my three columns starting in November 2002 at pffc-online.com/web_lines.

Differential shafts in all their varied designs are a great invention. They are the “sliced bread” of slitter/rewinding operations. However, what I’d like to cover in this and next month’s columns is the idea that even a great invention has its correct application and limitations. Let’s start with what is at the heart of differential shafts—torque. How do they create torque and are you getting what you need?

Most webs run at 0.3-3.0 lbf/in. of width (a.k.a. PLI). On a typical 3-in. inner diameter core, this is nominally a starting torque of 0.6-6.0 in.-lbs of torque. Many small rolls will wind great at constant torque, allowing the web tension to drop off inversely with the roll diameter. With large roll buildups (final diameter/core diameter > 4), the tension of constant torque winding may drop too much, making the roll’s outer layers too loose to hold the roll together.

The primary differential winding torque is created by the shaft’s frictional slip clutching mechanism. A clutch is any device that engages or disengages a rotating shaft and a driving mechanism. A slip clutch is a clutch in that when you engage it, instead of locking gears together like a car’s clutch, loads two non-locking surfaces together. By controlling the load between the two slipping surfaces, you control the friction-limited force that develops when the clutch slips. Most differential shafts have their torque regulated by air pressure, either the air pressure that pushes laterally on a stack of slipping cores and locked spacers or that pushes radially from an internal bladder out against slipping elements or the core’s inner diameter.

As you apply more pressure, the clutching mechanism will slip at a higher frictional force and a winding roll will receive more torque. The torque applied at the core then is transmitted out through the radius of the winding roll to create tension at the roll’s outer diameter.

Unfortunately, this is not the only torque-creating mechanism of a differential shaft. Gravity creates a force on the differential shaft from the roll’s weight, creating an increased torque component as the roll grows. For larger rolls, this may be all the torque you need, and the applied load from air pressure should be turned off.

An advanced differential slitter has a roll weight compensation control, but if you don’t tell your machine the roll diameter, material density, and roll width, you probably don’t have this important capability.

Two last factors that add to torque are nips and inertias. If you use a winding nip roller to prevent air lubrication at high-speed winding, the nip load also loads the core against the differential shaft, creating an additional torque. Inertia isn’t much at roll starts, but as a large winding roll decelerates, it doesn’t want to slow down (it’s a flywheel) and creates an additional torque proportional to your deceleration rate.

Differential torque is the sum of torques created by:

applied load and slip clutch friction

roll weight

nip load

roll inertia.

It’s great, just like sliced bread, but it’s quite confusing to figure out how wide our slices are going to be.

Differential Winding Limits: Part 2 – Dec 2007

Differential shafts are great tools, but like any tool, they have their limitations. Last month I covered the complexity of a differential shaft's actual applied torque. This month we cover more differential shaft limitations. My goal isn't to put down differential shafts but to avoid the frustration that occurs when delivered results don't meet expectations.

AXIAL-LOADING SYSTEMS

Axial-loading differential shafts stack alternating cores (or cores with special inserts) and keyed spacers on slotted shafts. The well-known limitation of axial-loading is that each core receives nominally the same torque, which isn't good when winding different widths on the same shaft. The second, less obvious limitation of core-spacer stacks is their sensitivity to core width variations, especially at narrow slit widths. If core width is slightly off, the stacking error creates a slit-to-core misalignment that's nearly impossible to compensate for.

On the plus side, the side contact between the cores (or core inserts) and spacers reduces lateral wander and core twisting. Since the shaft is both solid and the maximum possible diameter to fit within the core's inner diameter, these systems will have the least shaft deflection, especially important for heavier rolls or high winding nip loads.

RADIALLY LOADING SYSTEMS

In radially loaded shafts, the torque applied to a core is proportional (or nearly so) to the number of elements that grab the core, and each core receives torque as a function of width. Most radially loading differential shafts are slip-core or core-locking.

Both designs adjust air pressure within the shaft to radially pushing out on slipping elements to transmit torque to the winding core. The slip-core designs have small, nonrotating elements, often less than 18 in. wide, that push against the core. The core-locking system uses a series of disks 0.5-1.0 in. wide mounted on a smaller internal shaft. Each individual disk or “doughnut” has a mechanism, usually cam-lock buttons or bearings, to grab the core. A radially loading system should be used on slit rolls so narrow that two rolls would be locked on one element.

All radially loading shafts will have easy core positioning and adjustment, but how the core stays in its position varies by design or supplier. The slip-core systems may contain a core lateral motion with the torque elements outside the core's width; they may have adjustable pins or bearings; or some operations may default back to using a spacer or core between winding rolls, such as axial loaded systems. The cam-lock systems don't have a problem with lateral position, since the locking mechanism restrains the core laterally.

Regarding deflection, since a core-lock cross-shaft may be as much as 78 in. smaller than the core's inner diameter, they will see more deflection-related defects such as dishing, collapsed rolls, or shifted layers with heavy rolls or high nip loads.

OTHER LIMITATIONS

Dust can be a problem for any differential shaft; some will create core dust, and others will fail if core or product dust gets inside them. Differential shafts should have good overspeed control to reduce heat and wear. All differential shafts work better when cores are neither too large nor too small. Core-lock shafts may fail to lock onto hard plastic or metal cores.

Differential winding after a well-wrapped surface drum or several idler rollers will have limited ability to pull out anything, but they have the most extreme bagginess at slitting. If differential shafts are turned up to a torque beyond the capacity of the driving motor or clutch, they won't slip differentially and you'll be winding on the world's most expensive lock shaft.

I'd like to thank three differential winding experts for valuable discussions that helped in preparing this two-part column: John Pretto (Goldenrod), Sean Craig (Tidland), and Dan Cain (Tekkote).

Why Isn't Your Slitter Running? – Jan 2006

Walk by any slitter and more likely than not, it won't be running. Why? Besides having no input material or no demand for slitting, your slitter likely is not running because the slitter operator is busy doing all the work needed to support the slitter. Your slitter may not be running, but I bet your slitter operator is!

From an equipment uptime analysis, most slitter/rewinder operations inherently are inefficient. Few slitting processes can justify the capital expense of automatic unwind splicing or rewind roll starts. This makes for busy slitter operators. When the slitter stops, the operators go to work, cutting off and unloading the finished rolls, loading and starting the new cores. But the operators' work doesn't stop there; knife setups, unwind splicing, roll packaging, paperwork, etc., also take time.

Operating a slitter can be divided into several categories: actions completed every input jumbo; actions completed every knife change; actions completed every cut; and actions completed every order.

For a single short order of ten rolls, converting one jumbo in one cut, the following might be typical times for these slitter tasks: For each input jumbo of material: inventory and load/unload = 20 min. Each knife change (including core cutting) = 12 min. For each cut: unload rolls, load, and attach new cores, packaging of finished rolls = 22 min. After each order is complete: paper work and pallet handling = 10 min. Oh, I almost forgot, for each cut: run time = 6 min (cut length divided by speed, ignoring accel/decel time).

If all these tasks are completed by a single operator, it would take about an hour to finish this simple one-cut order. In that hour, the slitter was running only for 6 min—less than 10% uptime.

There are several ways to improve slitter uptime. Take more time to slit each cut. Either run slower (which doesn't make much sense) or run longer cuts. Most customers like longer rolls—the challenge is making larger rolls and avoiding increases in waste. Write a note to yourself: Not all slit rolls cost the same. Short and narrow mean more slitting overhead per square yard.

No product gets out the door without running through the slitter. To improve slitter productivity, uncork the bottleneck. Dedicate your resources to getting the bottleneck—the slitter—back up and running.

Looking at all the actions of a slitter operator, often only two-thirds of the tasks are on the critical path. One-third of the operator's time is spent on non-critical tasks. A second operator dedicated to completing the non-critical tasks reduces your time between cuts by a third. But a second slitter operator can do more; he or she can assist the first operator with the critical tasks. The second operator can load and splice a new input roll while the first operator changes the rewind cuts. For products with lots of narrow cuts, the two operators can combine their effort and speed up the roll unloading and loading cycle time. For short or narrow cuts, the two-operator team nearly can double the output of your slitter.

Lastly, you could eliminate your slitter by sending material to a contract converter. But be careful—outsourcing the slitting process has expenses of its own that may wipe out any savings.

"Why isn't your slitter running?" may be the wrong question. Instead, ask yourself, "What does my slitting operation cost?"

The Converting Relay Race: Part 1 – Aug 2005

Converting productivity is a race to see how much material we can get through our process. Instead of a marathon, with one runner going the distance, converting processes are more like relay races, with a series of runners. Like a relay, we need to pass the baton from roll to roll so each roll can run its leg of the race.

The converting relay begins with a well-designed unwind station. Whether you plan to use a broomstick or a million-dollar, auto-splicing, double-turret unwinder for a paper coater, you should think about four unwinds: roll loading and support, web threading and splicing, web/roll alignment, and web speed and tension control.

Roll loading and support should be an integrated system and should start with ergonomic thoughts. How heavy is the heaviest load you need to move, including roll and shaft weight? How many operators are available, and what are their lifting limits? How many times per shift will new rolls need to be loaded? How awkward is the roll and shaft handling?

The options for loading rolls and shafts include lifting manually, using an overhead hoist, or using a floor-mounted lift (such as a roll cart, lift truck, or a lifting mechanism built into the unwind station). I think floor-mounted systems are the best. Manual lifting and overhead hoists are back strains and toe crushers waiting to happen.

How best to support your roll, whether to use a full-width expanding shaft, shaftless chucks, or some combination of chucks and shafts, depends on your core and torque transmission needs. Bigger rolls need more support. The more support provided by your core (such as a large metal drum or thick-walled paper core), the less support is needed from the shaft or chucks. When the torque applied via the shaft is high, the shaft or chuck needs to have a friction or keyed coupling that can transmit that torque. (We'll go into what torque is needed next month.)

Shaft handling is easier with lightweight shafts, but when possible, it's better to eliminate shaft handling. For narrower processes, use a cantilevered shaft to ease roll loading. Usually I think of cantilevered shafts when the product is less than 12 in. wide, but the real limit is deflection. You can cantilever in wider processes by adding an outboard shaft support that swings into place for the running process.

Once the roll is loaded, we need to either thread up the machine or splice it to the existing threadup. Manual threading is inherently a stop-start operation. Stops and starts combined with large-diameter roll inertia lead to breaks from tension spikes and wrinkles from excessive payout. Threading up with a small input roll saves some of these inertia headaches, or a driven unwind with a jog mode provides welcome assistance in the threading process.

Splicing can be manual or automatic, with auto-splicers designed to work on either a stopped or running web. Manual splicing, by far the most common method, can be done at the nearest flat spot or roller, on top of the new input roll, or at a fixed splicing table.

Zero-speed splicers are used for continuously running processes such as a coater. The zero-speed splicer works with a web accumulator to feed the downstream process while the stopped-web auto splice is made. Zero-speed splicers are good when a product is difficult to either cut or to splice, but due to accumulation limits, they're rarely used in high-speed operations.

At-speed splicing requires special preparation of the new roll with double-stick and tabbing tapes. Just before the active roll is exhausted, a synchronized ballet begins. The new roll is brought up to line speed in close proximity to the exhausting web. Then "Bang, Slash," the new roll's leading edge is adhered to the running web, and the exhausted roll is severed.

Failure to connect the new web smoothly is a catastrophic event for a high-speed process. If the missed splice goes too far, a coating or printing process stops painting the web and starts painting the back-up roller and equipment. No at-speed splicer is perfect, but the right combination of equipment design, tapes, and control can make failure a rarity.

After roll loading and splicing, we complete two of the unwind's four functions. Next month, we get the second leg of the unwinding relay race: covering alignment and tension control.

The Converting Relay Race: Part 2 – Sep 2005

We are halfway through our roll-to-roll relay race of the unwinding process (click here for Part I). Our rolls are loaded, spliced, and ready to run. To complete the unwinding relay, we need to finish strong with our plan for web alignment and tension control.

Unwinds must be able to align the web, compensating for web position errors from unwind installation, web-to-core, core-to-chuck, and layer-to-layer within roll. The three most common methods to align unwinding rolls laterally are manual alignment, automatic sidelay guiding, and automatic displacement guiding.

In manual alignment, you put the roll on and align it by eye to the threaded web or to a physical reference mark. For short, compact processes, the small amount of web wander through the system combined with good input roll straightness will meet the downstream process requirements.

Our other two choices, sidelay and displacement guiding, both are automatic guiding systems with web position sensors, controllers, and actuators.

Sidelay guiding is the most immediate and gentlest option since it can start as early as the second roller from the unwinding roll and doesn't require web twisting. The nimble displacement guide beats out sidelay when the inertia from high roll mass and fast correction rates overly degrades the guide's system responsiveness.

Displacement guides, with their smaller actuators, usually will have a lower capital cost, but for sensitive webs, the long-term benefits make sidelay guiding a good return on investment.

The anchor runner in our unwinding relay is the tension and speed control plan. These decisions will make or break your productivity. How much torque is needed? How should I create torque? Where should I apply torque? How should I compensate for the changing roll diameter? Should I close the tension loop? If I close the loop, what feedback system is best? Whew! I'm tired even before I begin the final lap.

The following points address the most common questions in unwind tension control plans:

Unwind torque is the sum of tensioning, inertial, and lost torque determined by roll radius, tension, inertia, acceleration, mechanical losses, and adhesive peel forces. As you make a wish list of tension, width, and diameter ranges, it's easy to define an unrealistic unwind torque specification. Brakes and motors usually are limited to a 30:1 range. Beyond this, you are in fantasy land (except for some wide torque range frictional devices).

If your minimum and maximum torque desires exceed the 30:1 range, you'll have to curb your torque appetite. I recommend focusing on your low-end torque needs and accepting the limits at the high end. I've seen too many unwinds where oversized brakes are turned off or the motors can't control at low tension or small diameters.

Center torque unwinds are everywhere, beating surface unwinding in any democratic election. Surface unwinds eliminate the need for radial torque adjustments, but they are relatively rare due to their increased complexity and nip- related web defects.

When inertial torque is more than 10%–20% of tensioning torque, make sure your control system has inertia compensation (a.k.a. a WK&8473;2 function). When the inertial torque is more than 30%–50% of the tensioning torque, I think motor-driven unwinds are a better choice than brakes and clutches.

At-speed splicers always will be driven to speed match the new roll in a smooth transition of control from spindle to spindle.

Dancer rollers are helpful in reducing tension shocks from splicing, inertia, and out-of-round rolls; however, all feedback systems have degrading benefits at high frequencies. Tension shocks over 10 Hz will have little dampening in any system. Any downstream tension or speed-sensitive process will benefit from an unwind pull roller station isolating it from the inevitable unwind upsets.

This completes all four legs of planning our unwind relay race. Loaded, spliced, aligned, and tensioned—we're ready to run.

CLEANLINESS AND OPERATIONS

Clean Up Your Act (PDF) – Mar 2001

The age old adage say cleanliness is next to godliness. I would like to add “clean means green”; green meaning profits. Many markets served by flexible packaging (food, medical, electronics) require a extra effort in cleanliness. A product or process designed to be clean is a competitive advantage.

Clean packaging may be required for functional or cosmetic reasons. Functionally, foreign particles can prevent sealing, short circuits, and contaminate lab samples. Cosmetic defects make any product unattractive. A black speck in a clear package defeats the intended effect.

Clean manufacturing has two major components, internal and external cleanliness. Internal cleanliness is the result of clean coating, resins, and filtration. I have more experience in the latter, improving external cleanliness of products.

Clean manufacturing is mostly about keeping out contamination. There are two approaches to clean manufacturing: 1) Make it clean; 2) Make it, then clean it. I strongly recommend putting 95 percent of your effort into “make it clean”. Don’t make the assumption that a process is inherently dirty without a thorough evaluation. Preventing contamination will always be more effective and less expensive that a post-process cleaning step.

To achieve clean profits we have to sell clean for more than the cost of clean. To many “clean” means expensive clean rooms. Clean rooms are designed to create barriers between contamination sources and the product. People are packaged, shedding materials are removed, and airflow is laminar and filtered. Clean rooms are designed to keep contamination out, but do nothing to improve the debris-generating process it surrounds. A clean product needs to start with a reasonable clean environment, but more important will be a focus on clean processes through engineering and detective work.

The Clean Detective

Despite best efforts new contaminates will occur. When they do put on your detective’s cap and start a clean investigation. Sherlock Holmes would pull out his magnifying glass. The modern clean detective uses a microscope. (I recommend a dual eyepiece stereoscope with a camera, monitor, and photo printer as a great package to see and share contamination samples.)

Follow the trail of the clean crime. The successful cleanup plan will include five steps, starting with the customer requirements and working your way back.

1) Define the contamination problem. What is the problem and what will be considered successful resolution?

2) Gather the clues. What does the contamination look like? Where and when does it occur? Get samples and look at them under the microscope. Follow the contamination trail. Where does is the source? Where does it first occur? Start at the end of your process and move upstream. Map out contamination crossweb and timing.

3) Round up the suspects. Where does the contamination come from? Contamination sources include: materials, equipment, process, people, and environment. Get samples of suspects from any of the five contamination sources. Match up the clue samples to the suspects in a line-up.

4) Determine the modus operandi. How does it happen? A key to understanding contamination is to define the transport mechanism. For example, a film handling operation may be contaminated with fine film dust across the web. Debris from both slitting and scratching are suspects. The contamination position should help resolve the modus operandi. Slitting debris often lacks a mechanism for moving crossweb. Therefore, scratching is a more likely candidate.

5) Clean up you act. Once the source is clearly identified, focus on mitigating or eliminating the problem. This may be as easy as replacing a roller bearing or bigger task about rethinking a process or equipment design.

A Clean Advantage

Your detective work will payoff with better understanding about how to give you product a competitive advantage. Make the clean choice. Make clean manufacturing part of your competitive strategy

Clean Thinking – Apr 2005

W hat is your definition of clean? What people think of as "clean enough" in their homes is staggeringly different. Hopefully, your definition for your converting operation is the same as that of your customers.

Cleanliness could be defined by particle size and frequency per area, but more often it is defined by product performance. A debris particle leaves an unsatisfied customer when it becomes a visible dimple, a coating streak, or a laminate bubble.

Some converting processes inherently are dirty. Products with mineral components, such as abrasives or roofing shingles, are difficult to contain. Paper processes are next up where fibers from breaks, sheeting, abrasion, and slitting tend to float around and are difficult to keep ahead of. The more brittle your web is, like dry paper and minerals, the more likely it will fracture into difficult-to-contain fine particles.

The cleanest converting processes are food, pharmaceutical, medical, and electronic applications. Good manufacturing practices and FDA requirements force them into a cleaner plant environment. Most of these products help their odds by using films, foils, and coated papers.

How clean is your plant? Find out by using a witness plate. Set out a microscope slide near your converting processes. After a day or a week, put a cover slide on it and go to a microscope. What do you find? A skilled microscopist can help identify what's falling on or near your web.

For a more dramatic test, hang a sheet of clear film over your converting process. As the days go by, watch to see if it remains clean or slowly grays and blocks out the light. All the stuff that collected on your film canopy would have otherwise fallen on your web and been shipped to your customer.

Thankfully, the witness plates are a magnifier of what your customer sees. Running at 100 fpm 24/7 for a week is 1 million lineal ft; therefore, if your product is exposed to the environment for 10 ft, it would be 100,000x cleaner than the witness plate. This may give you some comfort, but it won't satisfy the customer that gets even a single dead fly.

For a more official environmental measurement, use an automated particle-in-air counter. These electronic sniffers vacuum up air samples in a tube, pass the sample across a laser detector, and count the number of particles larger than 0.5 micron in a cubic foot of air. Clean rooms are classified from these measurements, ranging from semiconductor-manufacturing clean at class 10–100 to computer-room clean at class 100,000.

Where does all the airborne debris come from? Everything is falling apart, it's entropy. Paint flakes off, metals oxidize, clothing loses lint and fibers, shoes and wheels track dirt in, insects bug up things, nature blows in through open doors, and we humans like to shed, too. We shed like snakes but in much smaller pieces. There a giant clean room industry based on fighting off entropy. Converters rarely need to go as far as IC chip manufacturers, but there are helpful things to learn. Does clean air guarantee a clean web? No. Converting processes in clean rooms can be a good idea, but they also commit the worst clean room sin: creating debris in the clean room. Air filtering will do little to prevent slitting and scratching debris on your product.

For a more complete cleanliness picture, run a thin, clear film through your process and look for dimples in the wound roll. Inspect the wound roll. Does it have pimples? In thin films, a single particle can create dimple and pimple impressions through tens of layers. It doesn't take a high level of particle per square yard to make a roll look ugly.

Start collection debris samples. Cut out a sample several layers deep around the big pimples. Peel away the layers until you find the pimple-causing "tent-pole" particle and identify what it is. Compare your dimple causes to your witness plate collection. You'll see some overlap and some new creatures. The difference will be either non-airborne particles or bonus particles sent from your roll supplier (be sure to thank them).

Cleaning up your act starts by identifying particle sources. You can't stop it until you know what it is. Practice thinking clean thoughts, and you'll be ready to move forward and start thinking about clean actions.

Can't Touch This (Web): Part 1 – Apr 2003

More than a decade ago, rapper MC Hammer made famous forever the line “U Can't Touch This.” I've worked with converters who use this phrase to describe their product. When facing “no touch” challenges, start by understanding the most common reasons “U can't touch this.”

“Wet Paint” — Topping the charts of “no-contact” webs is the freshly coated web still wet on one side. Just like we should do if we see a park bench with a “wet paint” sign, we need to wait before any roller “sits” on the fresh paint. The touch-free zone starts at the coating head and extends into the drying or curing oven. Here “no contact” is qualified as one-sided and temporary.

“How long?” is a question of time and length. The chemistry will dictate the untouchable time. Multiply this time by the line speed to get the “no-touch” length. A 30-sec drying time doesn't seem long until you want to run 600 fpm and have to install an oven the length of a football field. Converters' need for 300 ft (and more) of touch-free web handling has funded today's advanced understanding of air flotation web handling. Where once a 300-ft air flotation oven was feared for the technical challenge, now only the price causes fret.

The “wet paint” scenario requires us to address another touch-free challenge: tension control. Coating and drying differ in their tension needs, especially with films. When coating, high tension is good to deliver a taut web. In drying, high tension and high temperature will turn coated films into taffy, or worse yet, into rope.

How will we isolate the high-low tension change with single-sided contact web? Wrap angle limits prevent significant unnipped tension change. Nipping the wet web is a no-go. The preferred choice employs vacuum-assisted, driven rollers or roller sets.

“Precious” — A touch-free policy also may be insurance against undue damage. To prevent scratching, gouging, or contamination, the safety motto “the person who isn't there can't be hurt” is translated into “the web that isn't touched, can't be damaged.”

“Beware of Web” — With precious webs we are concerned about damaging the web. The reverse can be true. We may worry about the damage the web can do by shedding and cross-contaminating subsequent products or personnel. (I once toured an estrogen patch coater and felt touching the web wasn't a good idea.)

“Bumpy and Jagged” — Some webs are more “difficult to touch” than “can't be touched.” These include profiled, bumpy, sharp, abrasive, or hot webs where contact leads to wrinkles, abrasion, deformation, or breakage.

“Exposed” — Like an orchid needs sunlight, air, and attention, some web processes require exposure. Contact by rollers, belts, or carrier webs will block the web from exposure to radiation or special atmosphere. Obstructing the line of sight to a web may prevent optical inspections.

“Don't Tread on Me” — Crushable webs are vulnerable to the pressure created by a tensioned web wrapping a roller. Web compression or density increase may change the pressure drop of a filter product, the diffusion properties of a medical test strip, or the absorbency of a paper towel.

You can probably imagine other scenarios of “don't touch” webs (for example, I don't advocate licking a frozen web).

With our untouchable challenges now defined, it is time to review the equipment options, but I can't touch that without more space. Join us next month to review the no-touch qualifiers (time, sides, edges, and pressure) and review the equipment solutions to the touchy subject of no-contact web handling.

Can't Touch This (Web): Part 2 – May 2003

Last month we covered the web and process motives for touch-free web handling. This month we ll begin to review web line options for “Can t Touch This” webs.

Often, a touch-free requirement applies only to one side of the web or may not include the uncoated web edges. These no-touch qualifiers will make a dramatic difference in how to approach the “can t touch this” challenge. Let s start with the toughest case: true touch-free handling, where the web cannot be touched whatsoever.

Touch-free handling over a short range occurs on every web line. Once the web leaves a roller, it qualifies as “untouched” until it reaches the next roller. But how long can we keep this up? The answer can t be calculated from a simple equation, but all long spans — whether vertical or horizontal — have practical limits.

Long spans are subject to gravity. In long horizontal spans, gravity creates catenary sag, deflecting the web from the roller-to-roller tangent line similar to a suspended clothesline or chain (catena is Latin for chain). Catenary sag is a direct function of tension, web weight, and length. With a moving web, the sag will oscillate due to web density or tension variations.

Long vertical spans are real estate savers and avoid catenary sag, but they still are subject to gravity. The top portion of a long vertical span carries the rest of the span s weight (and tension). With wimpy webs, an overly long span may yield or break the web. When web weight is small relative to web tension, vertical spans are preferred over horizontal spans. Alas, the bigger headache in long vertical spans is not web handling but the operations hassles of working on a multi-level web line.

Tracking and sailing problems are more likely to limit span length than is gravity. Increased web flexibility in long spans magnifies tracking errors, leading to misalignment and wrinkling defects. A long web span is an effective sail, fluttering in any ambient airflow. Due to tracking, wrinkling, and airflow sensitivity, I usually recommend keeping unsupported span lengths to less than three web widths.

With unsupported vertical or horizontal long spans, we must pull on the web from afar like we would on a marionette. Air flotation systems provide mid-span forces needed to maintain control of a web without roller contact. Using directed, pressurized air streams, air flotation systems shape the moving web into planar, sinusoidal, cylindrical, or helical forms.

Air foils, the gentlest air floating system, blow air parallel to the web, using the Coanda effect to control web position and planar shape. Air impingement, the more aggressive method, blows perpendicular to the web from both sides. Alternating top and bottom air nozzles force the web into a sinusoidal shape, creating a down-web curvature to oppose cross-web buckling. Air foil and impingement nozzles are effective answers for controlled, touch-free handling over long distances; however, they can t replace the roller function of turning or reversing a web.

Cylindrical air turns (a.k.a. reversers) are roller substitutes. To be touch-free guaranteed, an air turn must be more than a simple air-lubricated cylinder. True touch-free air turns maintain a calculated float height with sufficient air volume and internal cushion pressure to fend off tension spikes. As an added benefit, air turns also can support a web in a helical shape for 90-deg turns or as part of a web flip. Air turns are an effective and overly feared web handling tool.

All air flotation systems will always have less stability than rollers. They will have more problems with tracking, web flutter, noise, and maintenance, but they are the first choice for long touch-free handling of low-porosity webs.

Next month, we will address the qualified “can t touch this” that applies to one-sided or edge-only contact.

Can't Touch This (Web): Part 3 – Jun 2003

Over the last two months, I have reviewed why some webs demand “U Can't Touch This” and web line options for true touch-free web handling. This month, let's cover qualified touch-free cases, where limited contact is allowed, including one-sided and edge-only contact.

One-sided web handling is like holding buttered toast or a DVD — touching one side is no problem, but touching the other side may cause a big mess or damage. A videotape cassette is an example of a backside-only web handling system where the magnetic coated face is the “untouchable” side. A videocassette unwinds, transports, guides, tensions, and rewinds the tape without faceside contact (not counting the contact within the winding roll). A videocassette is an example of a lazy C web line layout where the entire line from reel to reel will avoid face-side contact.

One-sided contact, whether for a short distance or an entire web line, is a game of wrap angle allocation. On many coaters or printers, the game begins once the web exits the coating station. The web exits the print station heading up and returns from the dryer heading down, leaving 180 deg of wrap for all one-sided web handling functions in between.

If the dryer has ten idler rollers, we have 18 deg for each. However, if we also need a single roller web guide (90 deg), a pull roller (90 deg), and a tension-measuring roller (30 deg), we won't have enough web wrap to go around.

Fortunately, we can change the rules of the game. We can increase the total wrap allotment by changing the start and end orientations. In the lazy C web line, we can increase the total one-sided wrap by changing how we enter or exit the winders. For more wrap angle, you can imagine a web path that resembles a loose scroll, spiraling in and out of the winders for increasing total wrap angle and true one-sided handling.

There are other ways to change the wrap game rules. We can reduce the wrap for various functions by using a vacuum pull roller, a more sensitive tension roller, or tendency drive idler rollers. We also could eliminate some functions by simplifying tension control or using chase guiding to eliminate actuating the web.

Air turns or suction boxes restart the wrap allocation game. Face-side air turns, discussed last month, reverse the web's direction, creating more wrap angle. If you fear face-side turns, a backside air bar can redirect the 90 deg. Suction boxes combined with a set of driven rollers can pull the web in an otherwise zero-wrap web path. A vacuum dancer system combines a suction box between two rollers with a position sensor to provide tension feedback in a zero-wrap position while also resetting the wrap allocation game.

The buttered toast and DVD analogies offer a third alternative to touch-free handling — edge-only contact. Undercut rollers, sprocket gears, and tenters take advantage of touchable edges that are uncoated or to-be-trimmed.

Undercut and sprocket rollers exert force on the web's edges, so they require a relatively stiff web to avoid buckling in the unsupported center. Movie film projectors use undercut rollers and sprockets to prevent scratching and maintain registration. Web stiffness required for undercut rollers comes from a combination of modulus, thickness, tension, radius of curvature, and width.

A tenter grips the web on either edge using a series of clips attached to a belt, chain, or screw drive. A tenter is an expensive, complex device, used primarily for polymer film orientation, rarely used for simple handling.

Whether your touch-sensitive web requires true touch-free, one-sided, or edge-only contact, there is a web handling technique for your application. If you have more questions about touch-free web handling, feel free to contact me directly.

OTHER TOPICS

Web Line Knowledge Offers a Competitive Advantage – Feb 2002

Web lines are the backbone of the converting industry — the equipment used in converting paper, film, foil, and other webs into valued product. In this monthly column, I will try to help converters understand how web lines work, how they can be improved, and mainly, how this knowledge can increase profits.

The primary motive for increased web line knowledge is defect prevention. The four main defect areas are abrasion, wrinkling, deformation, and breakage. Each can take a bite out of yields; in combination, they can be catastrophic.

To prevent these defects, we must understand how webs and web line equipment work, and how the two interact. Web line knowledge starts with web handling: how to unwind, transport, and rewind web materials. We must be able to handle the web before we can process it. Topics include:

Web Properties: Tailor web processes to web material. We must consider the web's mechanical behavior and limits, surface characteristics, and interaction with the environment.

Roller Design: The primary “hand” on the web is the simple rotating cylinder. Rollers should be designed based on web surface, tension, and speed.

Nips: This includes the advantages, applications, and pitfalls associated with creating high pressure on a web sandwiched between two rollers.

Traction: The “grip” of web handling cannot be assumed. An unintentional sliding web can be as catastrophic as a sliding automobile.

Tension Control: The tension control system determines length, registration, width, and speed. More importantly, web tension magnitude and variation are at the root of all four major web defect areas.

Lateral Position Control: Web tracking relative to machine centerline may involve the “normal entry rule,” variable diameter rollers, or sophisticated closed loop control.

Winding and Unwinding: Many operator hours are spent tending winders. Winders must be designed based on material properties, roll geometry, cores, roll splicing, and operator interaction.

Floatation: Though not required by all web lines, it is used to turn a web without touching one or both sides. While infrequently applied due to cost, noise, and instability, floatation should be included in your web line design bag of tricks.

Web line knowledge is of most value when you apply it to more complex web-dependent systems:

Controls: Web spring constants and wound-roll inertial variations make web control unique. Lateral control is limited by the web's mechanical limitations.

Safety: Process engineers provide input into personnel safety. Government agencies and industry associations provide guidelines, but line experience will make safety measures effective and convenient.

Auxiliary Equipment: Systems intimately integrated into the web line commonly are the domain of the web line engineer. These systems include web cleanliness, slitting, sheeting, stacking, and folding.

Process Interaction: This is what it's all about. Web lines are built to process the web. Coating is not just fluid handling, drying is not just air handling, and laminating is not simply normal pressure. All web value-adding processes rely on a well-behaved web.

Process Integration: This is one of the advantages of web lines and continuous processing. Winding and unwinding always involve some waste. Integrating process steps into a single web line reduces costs, increases yield, and improves productivity.

That last part sounds like improved profits. And you thought this was just about the technical stuff!

This month's column provides a framework for future web line discussions. I would appreciate your input on where you would like this column to go and how it can be valuable to you. Please write or call me with your ideas for topics to discuss or debate.

The Harms of Harmony – Dec 2004

On Bravo network's "Inside the Actor's Studio," James Lipton asks each guest, "What sound or noise do you love?" followed by "What sound or noise do you hate?" The "loved" answers include harmonious sounds such as a child's voice, falling rain, or the ocean waves. The hated sounds are less harmonious, such as a baby crying, traffic noise, or car alarms. The ear and brain enjoy harmony, so it may surprise you when harmony is a bad thing. In many web processes, however, harmony creates waste.

A harmonic is a wavelength or vibration. Web processes are filled with rotating elements. If any rotating element is out of balance or eccentric, it will create a one-per-revolution upset into the web motion or harmonic.

From a simple handling viewpoint, these harmonic motion hiccups may be no problem, but combined with coating, extrusion, slitting, or winding operations, they may lead to waste.

Harmonics in web speed or tension are one source of chatter (crossweb stripes in coating or extrusion thickness). Speed variations are usually a bigger problem than tension variations. For roll coating methods, a roller's speed is a key variable to control coating thickness. For extrusion coating, precision in coating flow and web speed combine to create thickness uniformity.

For many coating methods, tension variations won't cause a significant problem until the web slips on drive rollers and fails to hold the line speed setpoint. Some thin film coating methods called free span coating use the web's tension to create back pressure that controls coating thickness. With free span coating, tension variations directly create coating thickness variations.

If you suspect a web harmonic is responsible for your chatter, what are the top suspects? The harmonic could come from mechanical or electronic components. The problem could be poor tuning of the motor's speed control loop or motor cogging, but the mechanical suspects usually are to blame.

Assuming we have perfect rotation from motor output, what harmonic trouble can happen on the way to the web? Every mechanical component is suspect, including couplings, drive shafts, pulleys, timing belts, bearings, gearboxes, roller shafts, and roller shells. If any component is misaligned, bent, or eccentric, harmonics are produced.

Reducing speed variations is straightforward—improve or simplify your drive train. Based on harmonic frequency, you can divide the harmonics between the low- and high-speed side of the gearbox. Reduce speed harmonics of poor shaft alignment, shaft deflection, and coupling backlash by minimizing your drive train. Change from a line shaft to individual servo motors. Change from a chain or timing belt to a flat belt. Eliminate your gearbox by changing to an AC motor that can create full torque at low speed.

Reducing tension variations is a little trickier. Now drive and idler rollers both are suspects. Initially, look at the local tension zone, but also look at the immediate upstream tension zones. Don't be fooled into thinking a high-friction drive roller completely isolates tension upsets from passing from zone to zone. Every tension zone works off the baseline of the incoming web strain. As tension and web strain change upstream, downstream tension zones will respond. Web strain travels with the moving web, independent of how much frictional "isolation" you have.

To diagnose a tension harmonic, do a Fourier analysis on the raw, unfiltered signal from a tension roller. Divide the harmonic wavelengths by line speed to get the effective circumference and diameter of the source. Look for unbalanced rollers, eccentricity, bent shafts, and rollers moving from stick to slip conditions. For high-speed processing, watch for rollers or shafts reaching their critical speed, the rotation rate at which the roller's mass and deflection hit its natural frequency.

While taming the harmonics of web speed and tension, don't forget to look at the fluid delivery side of things. Coating or extrusion chatter also can come from uneven flow control and elastic vibrations in fluids. Beyond speed and tension variations, look out for harmonic problems in slitting and web guiding.

What sound or noise do you hate? How about the sound of the plant manager crying over the product waste created by web speed and tension harmonics?

Outsourcing Is Trendy, But Is It Right for Process Expertise? – Jul 2002

On Bravo network's "Inside the Actor's Studio," James Lipton asks each guest, "What sound or noise do you love?" followed by "What sound or noise do you hate?" The "loved" answers include harmonious sounds such as a child's voice, falling rain, or the ocean waves. The hated sounds are less harmonious, such as a baby crying, traffic noise, or car alarms. The ear and brain enjoy harmony, so it may surprise you when harmony is a bad thing. In many web processes, however, harmony creates waste.

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Fun with Force Gauges – Mar 2004

In today's world of high-tech electronic gadgets, a force gauge may seem unglamorous, but I hope to convince you a force gauge is something you should have and use.

A force gauge essentially is a handheld bathroom scale. The scale doesn't know how much you weigh; it simply shows a number proportional to how much your weight compresses the springs. A handheld spring scale is the same, with the ability to measure force of compression or elongation in pushing or pulling directions.

For a handheld force gauge, I think 0-50 lbf is a good size; it is an amount I can pull by hand comfortably and has good resolution to 0.5 lbf. Most force gauges are pre-calibrated and have a zero-offset adjustment to compensate for the angle of measurement. It will have a threaded rod for attaching a hook or clamp.

I prefer a purely mechanical spring-based force gauge, but for techie bragging rights, an electronic force gauge will have better resolution, plus data storage and output. You also will need a few accessories, which I include in the description of each test method.

Measure dancer roller or nip loads

Wrap a strap around your nip or dancer roller and measure the force to move it. Make a calibration chart of nip or dancer force versus air pressure from zero to as much as you can pull. For higher force measurements, strap the force gauge to a fixed point. Even if you can't measure all the way up to your normal running pressure setting, you should be able to extrapolate from the data you have.

For dancers, measure this force in both the accumulating and dispensing directions, then divide the difference of these two readings to see the tension variations caused by hysteresis and friction.

Measure torque of bearings, brakes, and clutches

Attach the strap to the surface of a braked or clutched roller or core. Pull with the force gauge to measure the breakaway force and the force to keep it turning at a slow steady rate. Again, take multiple force readings with the air or amps off and at increasing increments. Multiply the force values by the radius of the roller or core to convert force to torque.

For slitters with differential rewinding, I highly recommend doing this to compare cross-shaft and shaft A-B variation. This shows how consistent your process is (or isn't).

Measure web-to-roller friction or traction

Wrap a strip of your web around a roller with the free weight on one side and the force gauge on the other. Holding the roller stopped, measure the force to slide the web around the roller, keeping the wrap angle constant. Measure this in both the weight lifting and falling direction. Use the capstan equation to calculate the friction coefficient from the two forces and the wrap angle in radians.

To quantify air lubrication, measure the force to keep a roller from turning at increasing speed or decreasing tension. As this force decreases, you are measuring web-roller air lubrication (though this test excludes the half of entrained air created by the spinning roller).

Measure web modulus

If you need a quick estimate for the modulus of a material, a force gauge and tape measure can be used as the poor person's tensile-elongation tester. Cut a long strip of web, fixing it at one end and pulling on the other end with the force gauge. Modulus is the change in stress (force/thickness/width) over the change in strain (percent change in length). This test isn't accurate enough for foils or thicker products, but it can estimate modulus within 20% for many webs.

Measure internal wound roll pressure

Make a sandwich of the steel feeler gauge in a sleeve of brass shim stock. The brass sleeve should be longer than your roll is wide and the

steel longer yet. Insert the brass-steel-brass sandwich crosswise into a winding roll so it sticks out both sides. When the roll is finished, use the clamping pliers to grab the steel and measure the force required to slide the steel relative to the brass.

With a little frictional algebra, you can translate this force into the local layer-to-layer pressure in the wound roll. There are roll width limits to this test, but it provides valuable and inexpensive insight into the pressures within a wound roll.

While you are all busy perfecting these new force gauge tricks, I'm taking mine out to the lake to weigh my latest catch.

Thinking About New Equipment? – Feb 2008

A new year often brings new budgets and thoughts about new equipment. If you are lucky enough to be handed a project to buy new converting equipment, take some time not only to think about the "value adding" process involved (coating, printing, etc.) but also about the backbone of any converting line: the web handling process.

If you haven't figured out by now from reading my columns, I'm a process guy. More specifically, my career at 3M was mostly in the role of process development. So though I never had the lead role as new equipment project manager or equipment designer, I often was involved in providing the process specification for new equipment.

Also, in my role over the years as a process problem solver, I've seen many equipment designs that I don't like because they make a process more sensitive to web handling and winding defects. Here are some tips on what to consider when ordering new converting equipment for any web handling process.

STEP 1 | PROCESS FLOW DIAGRAM

What are the key process steps and their web handling needs? I think about web handling in the same order I cover the web handling process fundamentals in classes: web properties, tension control, rollers and traction, guiding, wrinkling/anti-wrinkling, winding and unwinding.

STEP 2 | TENSIONING

What are the mechanical properties of your webs? Think about the extreme cases of high tension (wide, thick, stiff) and low tension (narrow, thin, stretchy). A good starting point is to set tension at 10%-20% of the web yield or break point, whether in pounds per width or percent elongation.

STEP 3 | PROCESS TENSIONS

What special tension considerations are needed in your different process steps? Consider noisy tension at unwinding, smooth speed and high tension at coating, low tension in heating films, and taper tension for winding. Break down a tension control plan from the process needs, including number of zones, preferred tension feedback by zone, and drive roller traction preferences. (I like to avoid nipped drive rollers). Include the proposed tension control plan in the specification to allow an apples-to-apples comparison of supplier quotes.

STEP 4 | SPEEDS

Include maximum speed and desired accel/decel rates as well as the need for emergency stopping. This will allow the control engineers to size the motors.

STEP 5 | ROLLERS

Specify roller surface to meet your traction needs, especially at high-speed, large-diameter, low-tension conditions. Specify bearings, support, and alignment design. Specify roller straightness, deflection under load, diameter tolerance, and alignment needs.

STEP 6 | GUIDING

Specify a web guiding plan: Where do you need it; what accuracy; what type of guide is preferred; and what type of detector is preferred? Specify brands of web guides if you have one or two preferred suppliers and want to avoid having to learn four different systems and spares. Get rollers on the web guides that match the rest of your process.

STEP 7 | WRINKLING

Specify any special locations that may need anti-wrinkle or spreading rollers and what kind are preferred.

STEP 8 | UNWIND/WIND

Specify core material and geometry; preferred core support (shafted vs. shaftless, core grabbing mechanism); splicing type and roll transfer needs; and preferred roll loading and handling plan. Include a performance spec on auto roll transfers and some winding quality features (such as edge alignment).

This isn't everything, but it's a start. Add to this list cleanliness, footprint, cost considerations, check-out plans, and start-up support, and you've got a good start. Feel free to send me your tips.

Buyers and Suppliers: Can We Dance? – Mar 2008

Buying equipment is a partnership between the equipment buyers and equipment suppliers. The dance begins when a buyer has a need (and hopefully the money) for new equipment. Eventually a dance partner is found, and the two must find a way to work together. Will things turn out to each party's satisfaction?

The equipment supplier, who knows “the nuts and bolts,” provides the knowledge to build the equipment. The best equipment suppliers go a little further. After years of working with smart converters, a smart supplier's equipment will change and reflect what works and what doesn't.

The buyer-converter defines the process and equipment specifications. The converter knows his materials and, hopefully, his process — how the material interacts with the equipment. Though the supplier may have some general process knowledge, he will never know as much as the experienced converter (much like knowing how to build a race car doesn't make you a great race car driver).

Beyond process knowledge, the converter has the additional responsibilities to hire and train a staff of management, engineering, operators, and maintenance. The converter is responsible for providing and preparing the facilities to support the equipment and the production quality plan.

How should a buyer-converter work with an equipment supplier? Depending on how much the converter knows or wants to share with the equipment supplier, there are at least three options:

A. THE CONVERTER ORDERS STANDARD EQUIPMENT FROM A CATALOG.

Option A is more common when your competitive advantage is in your chemistry or business savvy rather than your process. Many converters are making a one-of-a-kind product requiring one-of-a-kind equipment. Some equipment suppliers, especially in narrow web printing, laminating, and die-cutting processes, have moved toward modular equipment that can be mixed and matched to create unique processes from catalog components.

B. THE CONVERTER SHARES PRODUCT RECIPES WITH THE EQUIPMENT SUPPLIER.

Option B, sharing product recipes, is the most trusting relationship but should pay off in less surprises (i.e., lower risk). By providing a clear recipe, the converter may request production performance guarantees.

The equipment supplier, seeing the recipes and intentions of the buyer-converter, must decide what performance levels he is willing to guarantee. In a recipe-sharing approach, the converter is likely to share a more generic recipe, knowing that if the equipment can make one product, it will be more likely to make the secret recipe products successfully.

C. THE CONVERTER TRANSLATES RECIPES INTO EQUIPMENT SPECIFICATIONS.

Option C is common when the converter will be the integrator, such as when purchasing coating, drying, and web handling equipment from different suppliers. The converter assumes more responsibility in exchange for holding on to proprietary knowledge.

Maybe it's the type of projects I've worked on, but I've found most converters opt for plan C and keep their product recipes secret. This puts more responsibility on the converter, requiring that their recipes be translated into process specifications, such as driven roller speeds, roller widths, coating viscosity and thickness, oven heating transfer coefficient, and oven lengths.

The experienced converter knows if the equipment has the desired performance capabilities, he will be able to manufacture the intended product at the intended speed.

Once the equipment is installed and the supplier is paid, the dance is over. Was it a success? If you choose the same partner for the next dance, probably so. Otherwise, you will be looking around for someone new with whom to face the music.

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- Tim

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