Drive systems for off-machine coaters

Gerald I. Kheboian

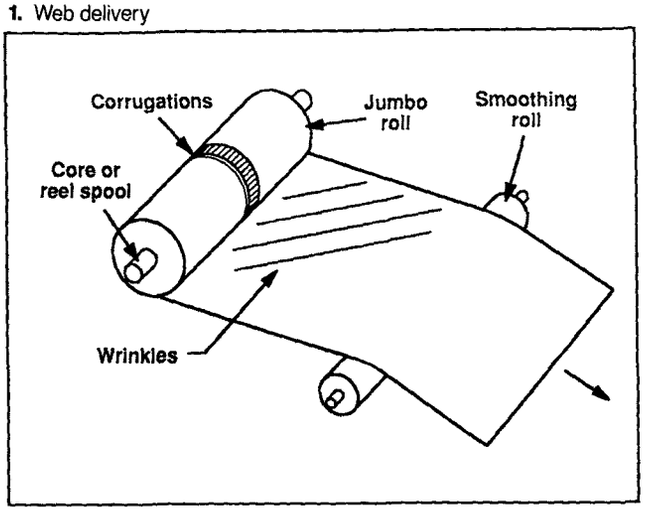
Successful application of a drive system to an off-machine coater requires thorough knowledge of the concepts of web transport and coater operation, as well as the sharing of information by the drive manufacturer, machine manufacturer, and user.

Important considerations for coater drive systems are frequently overlooked by equipment users and designers because they are not close enough to the manufacturing process to know which functions are needed for the different products being run on an off-machine coater. Engineers may fail to handle properly such things as selecting and maintaining an effective master or lead section, designing effective tension control systems, and selecting appropriate torque, speed, and horsepower for each drive.

Some of the points covered in this paper may seem trivial, but experience in the coating field has shown that they can be important.

Coating lines that produce merchant and publishing grades typically consist of an unwinder, draw rolls, two coaters in tandem (each followed by a dryer system), and a winder.

1. Web delivery



Wrinkles, web guides, and web spreaders

A web is any paper, film, foil, or fabric that is delivered in a continuous flexible strip to the process machine for coating, laminating, or other treatment (**Fig. 1**).

Wrinkles in the base web can be caused by nonuniform basis weight, uneven cross-machine web caliper profile, web camber, uneven moisture profile, and internal web stresses that occur during the web manufacturing process or subsequent processes. All these defects show up as unwanted wrinkles at a process point. Uneven profiles can often be felt in the jumbo roll as "corrugations." The defect will appear as wrinkles when the sheet is wet at the coater. If the wrinkles form before reaching a nip point, coating applicator, or metering device such as a blade, they will crease and may cause a web break.

Devices such as bowed rolls, smooth rolls, rolls with spiral-wound masking tape, rolls with a spiral-wound ground-in pattern, crowned rolls, and concave rolls have been used in the search for wrinkle elimination.

Web guides are devices that laterally position the web in the machine. They are total systems that consist of sensors, controllers, and positioning devices. Web spreaders are devices that remove wrinkles from the web at critical points in the process. On too many applications, web spreading and web guiding are treated as afterthoughts or left to be solved at machine startup.

The web frequently approaches the process laterally off-center for a number of reasons. Web guiding systems sense this lateral offset in position and make the necessary corrections to present the web in the proper lateral position. Rolls coming from the paper machine are sometimes wound offset on a reel spool and are then placed in a coater machine unwinder, where the rolls are presented to the process. The web from the offset-wound rolls must be positioned properly to get the best results from coating, laminating, or other processing.

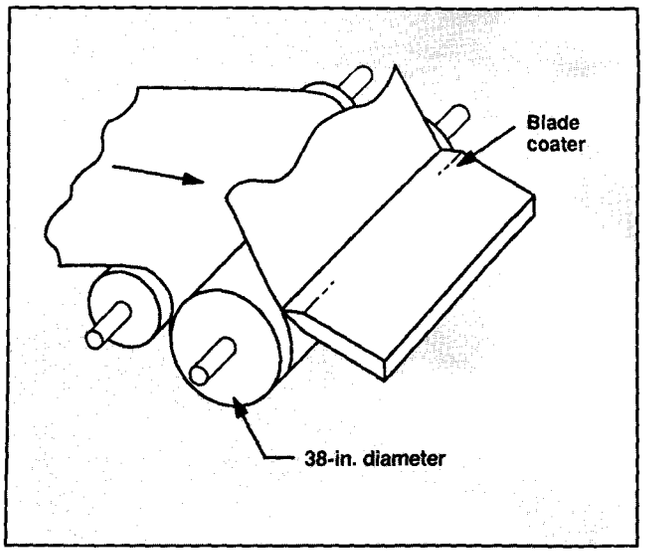
Some unwinders have hand-operated positioners that allow the operator to adjust the lateral position manually. Other unwinders have an automatic web position controller.

The following are some areas where web guiding systems are used:

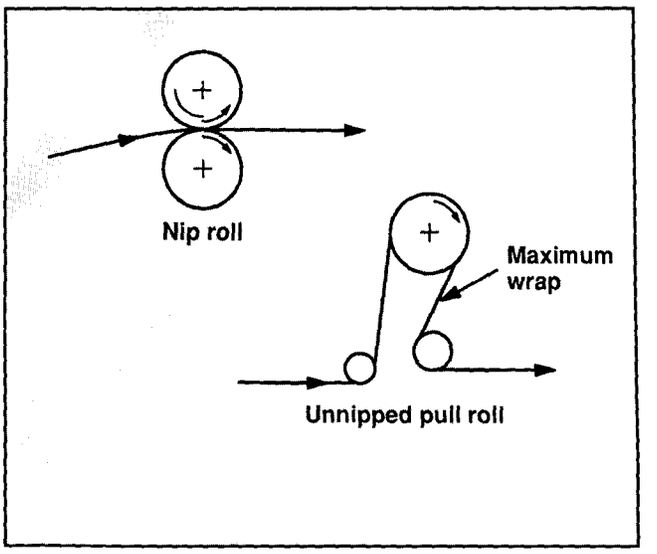
1. After an unwinder stand and just before the entry point of a coater
2. On the entry point of a laminator
3. On the entry point of a laminator that is laminating

Kheboian is a consultant, 24 Fiske St., Worcester, Mass. 01602.

2. Master or lead section



3. Nip roll and unnipped pull roll



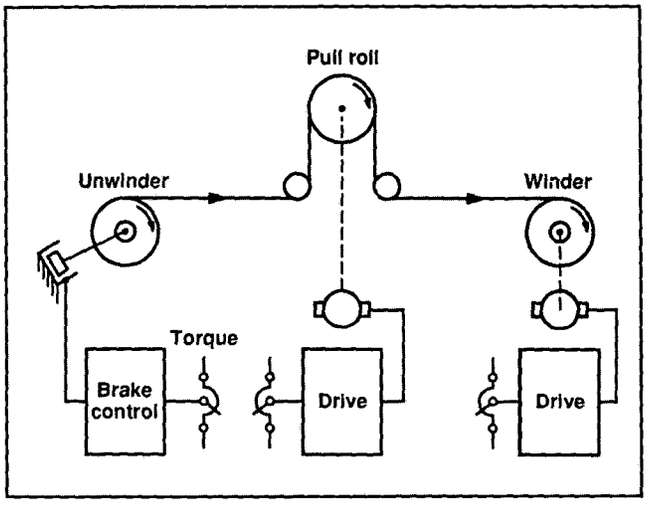
two webs by extrusion

4. On the entry point of the second coater in a tandem coating operation, following a dryer
5. After a web is turned over just before the next process point
6. At the entry point of the winder.

An oscillating edge guide on a winder distributes the coating bead edge stress or gauge bands from the various processes.

Web spreaders are required so that a flat and uniform web surface is presented to the process for the most uniform results in coating, drying, adhesive application, and laminating. Web spreaders are potential problem solvers after unwinding and before a nip roll, laminator, coater, or winder.

4. Constant torque unwind



Master or lead section

The master section is the lead section of the machine (**Fig. 2**). It establishes the speed of the web in the coater by "capturing" the web to control its velocity on its way through the machine. A good lead section maintains this control of the web at all speeds up to maximum design speed while enduring the transients that can occur at any speed. To control web speed, it must be capable of adding torque to the web ("motoring") or holding back torque ("regenerating").

Simply put, the lead roll in a machine must be able to transmit the torque from the motor, through the roll, to the web, without allowing the web to slip. That is an important attribute of a master section.

Problems with master section control

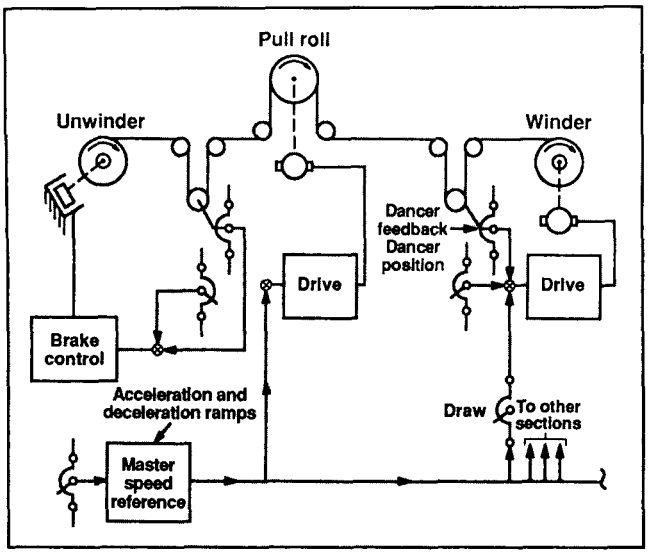
If a nip roll has been selected to be the lead section (**Fig. 3**), the operator may elect to run with the nip open. In this case, the section will slip at very low levels of differential tension. Nips on off-machine coaters can cause web breaks when web wrinkling occurs during a flying splice or because the web is nonuniform. Sometimes nip rolls are removed from the entry to each coating roll on a coating line because they cause web breaks. Only the nip roll before the winder is retained because it holds the web before the reel and can prevent an aborted transfer (web break) from causing a major web break within the machine.

Elastomer-covered drive rolls can become glazed, causing a reduction in the coefficent of friction. This condition allows the web to slip. Rubber covers must then be reground or roughened to maintain the effectiveness of the control.

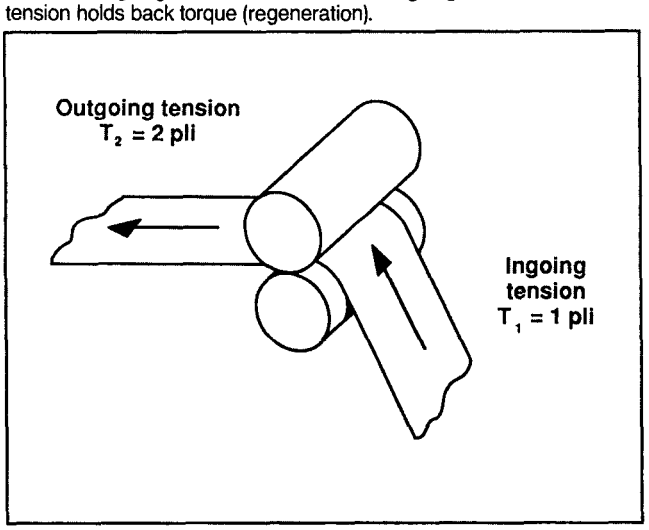
The coefficient of friction of some elastomer-covered drive rolls may be reduced by aging or temperature. The result is a great reduction in the differential tension that the section can control.

Some webs are precoated. Precoatings can be abrasive, which will reduce the coefficient of friction by polishing the elastomer covering. The coefficient of friction of some of the precoatings is so low that it may be difficult to prevent

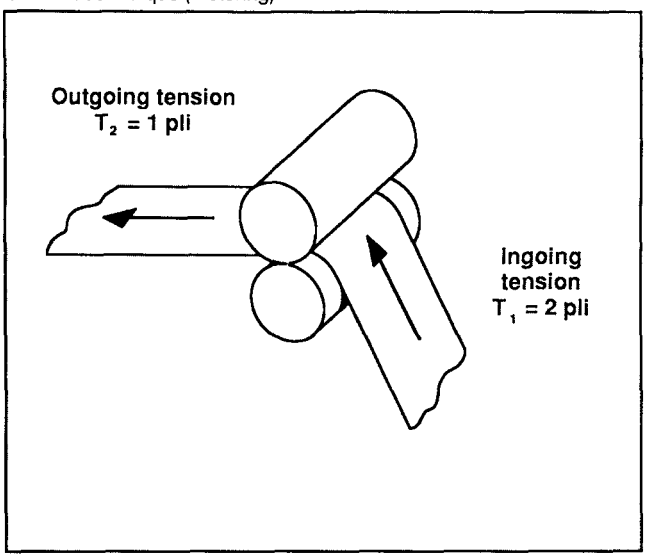
5. Constant tension unwind



6. When ingoing tension is less than outgoing tension, differential tension holds back torque (regeneration).



7. When ingoing tension is greater than outgoing tension, differential tension adds torque (motoring).



slippage unless a nip is used as the master. Some precoatings tend to leave dust on the surface of a drive roll, causing the drive roll to lose control of the web.

Vacuum rolls are frequently designed with too little wrap angle. A vacuum roll with a shallow wrap is incapable of handling large values of differential tension and frequently creates web tracking problems, tension interaction problems, and web scratches. Drive rolls should be designed with maximum wrap, and vacuum should be added to enhance the ability of the drive to handle differential tension.

Vacuum tables may be too short to handle the differential tension requirements during transients (splices, acceleration, and deceleration).

Influence of unwinder and winder

Make no mistake, the real "bosses" on a coating machine are the unwinder and winder. Transients from the unwinder and winder can be felt throughout the machine. If the unwinder tension is lowered for poor rolls and the winder tension is increased in an effort to wind a "bulls-eye" roll, the web can break away from the lead section and accelerate to a speed higher than that of the lead section. This condition is difficult to detect unless all sections are being monitored or unless a coating defect monitor or scratches on the web attract the operator's attention.

If a constant-torque center unwinder (**Fig. 4**) is used, then the tension will increase as the roll diameter decreases. The tension can increase to the point where the sheet breaks away from the lead section and runs slower than the lead section unless the operator intervenes and reduces unwinder tension as the roll diameter decreases. If the operator becomes distracted by other tasks, slip can be a continuing problem on constant-torque machines. On coaters using a constant-tension unwinder (**Fig. 5**), slip is a problem only when the unwinder is set to run higher tensions than the rest of the machine.

Most off-machine coaters tend to run best when all the tensions throughout the machine are set at the same level (called "flat tension profile"). Using the same tension throughout the machine reduces the differential tensions that a section must handle during steady state and will increase the chances of handling tension transients during splicing and acceleration. If a machine is handling a large differential tension during steady-state conditions, a splicing transient can cause the differential tension to increase beyond capability of the section, and the web will slip.

Tension in a coating machine

Tension through a coater is the force that is applied to the web between adjacent machine sections. This force tends to stretch or to elongate the web and is expressed as some unit of web width, e.g., ounces per linear inch, pounds per linear inch, grams per centimeter, or kilograms per meter.

Tension on a coating machine is also expressed as total tension, which is the product of unit tension times the web width. It is expressed as total pounds or kilograms and

is used in calculating tension horsepower.

Differential tension

Differential tension, as referred to here, is the difference in web tension between the ingoing side of a section and the outgoing side of that section (**Figs. 6 and 7**). Every section has a limit on the differential tension that it can control. When that differential tension limit is exceeded, the web will "break away," and the roll will slip and no longer control the web.

Draw rolls are added to a machine to allow differential tension to be run in the process or to drive the web when there are long expanses of web between driven sections. Draw rolls can be nipped, single elastomer rolls, vacuum rolls, or vacuum tables. All must be designed to handle the differential tension that the process requires.

Tension zones

Depending on the process requirements or web characteristics, different zones of tension may be appropriate through the process. To establish a tension difference, the controlled roll must be nipped or have a large angle of wrap plus a covering with a coefficient of friction capable of adding or holding back torque to the web. The following are examples of different tension zones:

1. Unwinder tension as opposed to winder tension
2. A loosely wound roll on the unwinder that runs at a lower tension than the entry side of the first coater
3. The input or entry side of the coater versus the outgoing side, where the wet paper web is apt to stretch
4. The entry side of a laminator versus the exit side of the laminator.

If two webs of different characteristics are being laminated, one web may require a significantly lower tension than the other. The resulting laminate may or may not require a higher tension on the laminator exit, depending on both the laminating process and the tension required to successfully track the heavy laminated structure. Many laminating processes require a zero differential tension to assure the best laminating results.

Determining web tension to be run

Sheet tension in an off-machine coater should be just high enough to allow good tracking of the web. **Table I** gives some typical values. Lower tensions tend to reduce sheet breaks due to sheet defects (holes, wrinkles, and edge cracks). Excessively low tension will allow the web to wander in the machine and will contribute to the telescoping that occurs in loosely wound rolls.

Stall tension

Stall tension is used on an off-machine coater to establish an acceptable level of web tension while the machine is standing still before acceleration to process speeds. With the machine at rest, the unwinder and winder drives are energized so that they can pull the web taut throughout the machine. This is called stall tension. It is usually a fixed percent of running tension.

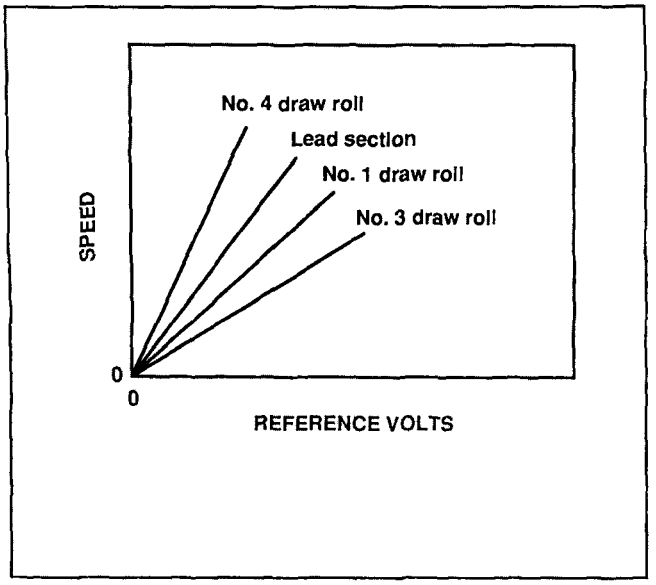
For the benefit of operators, some engineers have converted stall tension systems from integrating controllers to proportional controllers. Proportional control is a gentler control and does not suffer from reset windup, which is apt to break the web if the operator leaves too much slack in the machine when stall tension is initially applied. After the proportionally controlled stall tension applies the desired tension, the system is converted into an integrating control as a function of the operator's run command.

Sometimes stall tension of the unwinder and winder cannot sufficiently influence tension on the interior of long coating lines. Some companies have found it helpful to place the entire coating line into stall tension in order to establish desired tension conditions with the machine at rest. Stall tension is a proportional control when the entire drive system is used to establish the proper tension levels.

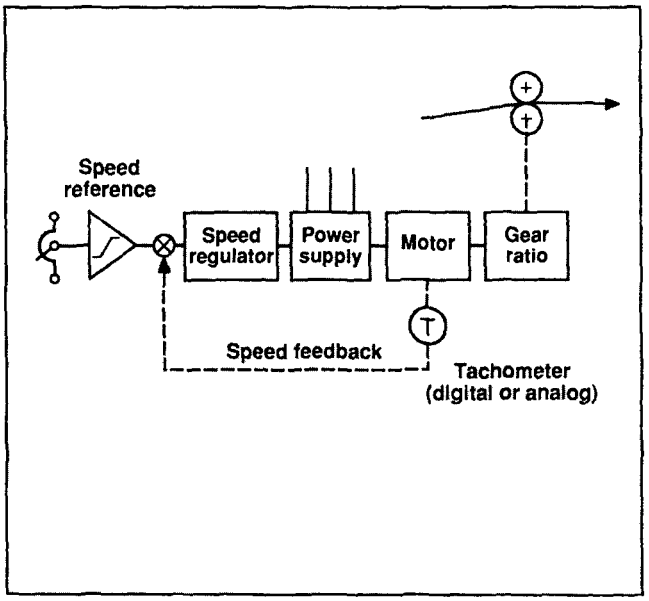
I. Tension data for typical converting materials

Material	*Tension, lb/in.·mil*	*Approximate tension, pli*
Aluminum foil	0.5-1.5 (1.0 avg.)	
Cellophane	0.5-1.0	
Acetate	0.5	
Polyester	0.5-1.0 (0.75 avg.)	
Polyethylene	0.25-0.30	
Polypropylene	0.25-0.30	
Polystyrene	1.0	
Saran	0.05-0.20 (0.10 avg.)	
Vinyl	0.05-0.20 (0.10 avg.)	
Paper and laminations		
20 lb/ream (32.54 g/m²)		0.50-1.0
40 lb/ream (65.08 g/m²)		1.0-2.0
60 lb/ream (97.62 g/m²)		1.5-3.0
80 lb/ream (130.1 g/m²)		2.0-4.0
Substrate		
Polyester		
0.0005 in.		0.25
0.001 in.		0.5
0.002 in.		1.0
Cellophane		
0.00075 in.		0.5
0.001 in.		0.75
0.002 in.		1.0
Nylon and cast propylene (non-oriented)		
0.00075 in.		0.15
0.001 in.		0.25
0.002 in.		0.5
Paper		
15 lb/ream (3000 ft²)		0.5
20 lb/ream		0.75
30 lb/ream		1.0
40 lb/ream		1.5
60 lb/ream		2.0
80 lb/ream		2.5
Paperboard		
8 pt.		3
12 pt.		4
15 pt.		5
20 pt.		7
25 pt.		9
30 pt.		11

8. Tracking curve for individual sections. Section No. 5 was not plotted.



9. Basic speed regulator



Selecting tension indicating systems

All tension measuring systems measure the total tension. The operator and engineer can use the indicators for balancing machine tensions or for troubleshooting. They can see at a glance how much tension is being run on the machine. Many machines run multiple web widths and require a tension indicating system that is accurate for all widths.

If web width is entered as a control system variable, modern computer-controlled drives can accommodate varying web widths in their menus and display the exact tension in whatever units the operating personnel prefer.

Why tension control is needed

Tension control is a valuable tool for production personnel, the machinery builder, and the drive vendor. It allows the operator to thread the machine and get into production faster than a pure speed controller would allow. Drive vendors can use it to compensate for factors that are within their control but that may go undetected except through changes in web tension.

Tension control corrects for the tension transient that occurs when a machine goes on or off coat.

Tension control allows a machine to handle webs of varying width, weight, and caliper. This feature increases the flexibility of the coating line since it allows webs of different characteristics to be spliced and transferred. Quick, knowledgeable, and repeatable adjustments can be made to tensions when grades are changed during the coating process.

During the coating operation, tension control corrects for the normal manufacturing variations that occur in most webs. During processing, some webs shrink and some stretch. Paper web tends to stretch when wetted during the coating process, while plastic webs can shrink or stretch, depending on the process temperature. Older analog speed-regulated drives drifted so much that web tensions changed radically during the coating process, resulting in web breaks unless some form of tension control was added.

Signal distortion can cause poor drive performance when individual sections drift and make step changes in speed whenever a motor is started or stopped. Separate conduit should be used. Combining signal and power wiring produces a machine tracking characteristic that shows each section tracking a machine acceleration ramp at a different rate and to a different end point (**Fig. 8**). When a drive does not track properly, the drive designer needs tension control of some type to compensate for the fact that the speed of a section may not be exactly proportional to the machine line reference signal. Old machines will not accept more exacting processes unless a properly installed tension control system is added to the machine drive system.

Tension control compensates for the tension transients that occur during acceleration and deceleration. Each machine has a wide range of inertias that must be accelerated from zero speed to process speed and then decelerated to zero speed at the end of a run. The high-inertia sections may not follow the acceleration ramp as closely as the sections adjacent to them.

For example, an unwinding jumbo roll or a section of steam dryers represents a high-inertia load. They may not track the line reference as closely as a low-inertia draw roll or a coating roll. The ratios of horsepower to inertia for all sections are not equal, and the section with the lowest horsepower/inertia ratio will determine how fast the whole machine can be accelerated. Clearly, tension control of some type is required to ensure that all sections accelerate together and that tension transients are small during acceleration and deceleration.

Use of pure speed control

Pure speed control, instead of tension control, can be used when web stretch or shrinkage is intolerable during processing (**Fig. 9**). The cause is typically a product or process requirement, rather than machine and drive control considerations. Speed control may be necessary

when a process requires the web to be stretched to a specific ratio between adjacent sections. Tension controllers maintain tension by modifying section speed and torque. If the web tends to shrink, then too low a tension may allow it to shrink.

When process conditions create a pliable web, and stretch or shrink is undesirable, the attributes of tension control may produce web deformation even to the point of web break.

When the web is so weak that it can barely support its own weight, a tension regulator often causes web breaks.

Applying constant tension to the lead section of the machine can produce varying results whenever a process creates or treats a pliable web with characteristics that change from roll to roll. In such cases, a speed regulator may be the only tool available for producing good results. In any case, a tension measuring device helps to monitor the machine process.

If the machine has multiproduct requirements, a drive system should be capable of running either in the tension mode or in the speed mode, depending on web and final product requirements.

Control methods for drive systems

Three methods of tension control are applied to drive control systems:

1. Motor current regulation
2. Swing roll or dancer roll control
3. Force transducer or load cell control.

These systems have been used successfully over the years. The best results are obtained when the designer knows the advantages, disadvantages, and some of the pitfalls to avoid with each system.

Motor current regulation

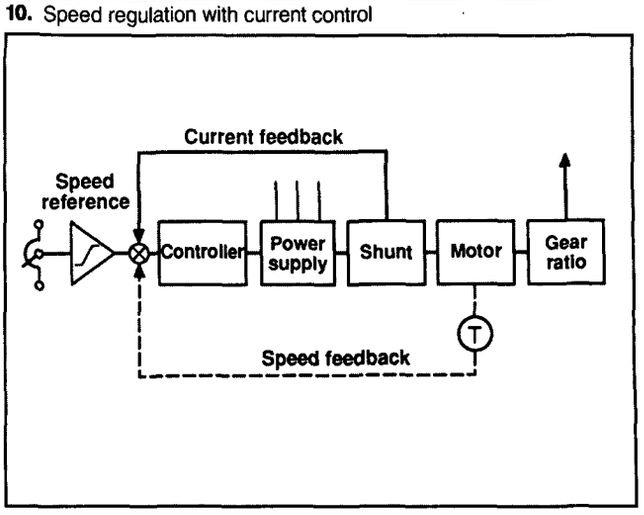
Motor current regulation is the simplest concept and also is the simplest to implement. It may be the only way to control web tension if process conditions do not allow a tension sensor to touch the web. Speed regulation with current control is sometimes called current compounding or speed droop.

A current regulator controls the current to a fixed value set by the operator. It also uses total motor current to sense the tension in the web. However, total motor current is only approximately equal to actual tension. Total motor current is equal to tension load and the losses in the system, and a current regulator cannot differentiate between tension and the load losses. If the load losses in the system are a small part of motor current, a current regulator will be an effective way of controlling web tension on a coating line. If load losses are a big part of total motor current, a current regulator is a poor selection for tension control.

The increased current needed for acceleration of a section to operating speed will cause a decrease in tension unless circuitry to compensate for inertia is part of the section control strategy. Inertia compensation is especially important on unwinders and winders, where roll inertia is constantly changing as roll diameter changes.

Opening and closing a nip or changing the nip pressure on a nip section can cause tension changes at that section.

10. Speed regulation with current control



An increase in nip pressure increases the load-loss component of total motor current and reduces the tension component. The result is a reduction in web tension. The converse is true.

A skewed oscillating doctor on any section represents a varying load that will cause constant fluctuations in web tension. Tension changes when dryer doctors are loaded or unloaded, or when doctor loading is increased to clean dryer surfaces.

An unbalanced roll represents a varying load as the roll rotates, resulting in changing web tensions. Among other mechanical load disturbances that influence web tension are misaligned couplings, sloppy belts, sloppy chains, and gear backlash.

Applying, removing, or adjusting blade pressure on a blade coater affects web tension. Acceleration and tension will be compromised, depending on whether the blades are loaded or unloaded.

Closing a pinch roll on a dryer to aid in threading can affect web tension.

Bad bearings on an undriven paper roll (idler roll) that leads into a section can raise havoc with the web tension between sections.

Cold oil in gear reducers and cold grease in bearings are two of the load factors that change as the machine warms up.

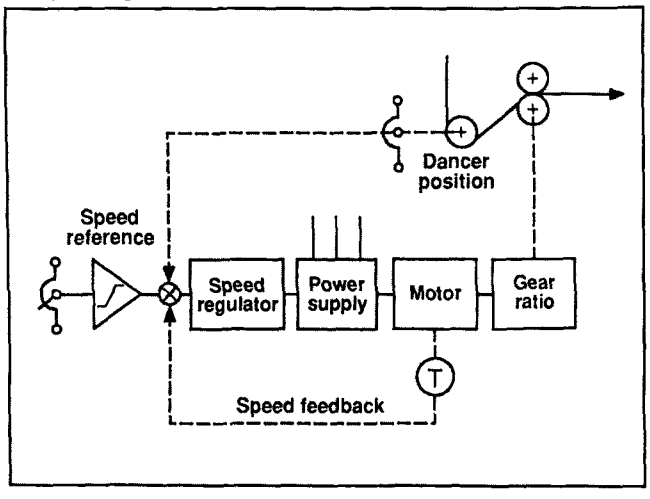
The changing friction characteristics of steam joints and water joints represent changing load losses on surface windups, steam dryer drums, and chill rolls. Such friction characteristics result in web tension changes when current regulators are used.

The condensate level of the steam dryers may vary. Higher condensate levels represent a higher water load, and therefore more load losses. This varying load will certainly result in tension changes. Water removal from chill rolls or surface windups produce similar changes in tension. In the case of the surface winders, changes in water load will also affect the quality of the wound roll.

Use of a current regulator to control winder tension

A simple current regulator can be used if a center wind has simple specifications, i.e., taper that varies with diameter, tension that is not critical, and no more than

11. Speed regulation with dancer trim



a 2:1 buildup. Any center wind with a range of about 0.5–3 pli and a buildup more than 5:1 with constant tension needs a more sophisticated control system (a constant horsepower system). A more sophisticated system senses motor current to infer motor torque and includes a tachometer on the windup motor to determine windup speed. A calculation is made of these values to help control the input power to the motor. In such a system, as the windup roll diameter increases, the speed of the windup decreases and the motor current increases in proportion to the diameter increase. Motor torque increases to keep constant tension as diameter increases.

Losses in the system are functions of friction, windage, and magnetic losses of the motor, as well as the losses of the windup. All these losses are a function of speed, so the speed of the system is at its highest when an empty core is on the rewinder. These losses can be equal to or exceed the magnitude of the tension power requirements. Therefore, it is important to keep external losses to a minimum if constant tension is to be maintained. Loss-compensation circuitry is important for this kind of system.

Motor torque is a function of motor field strength and motor current. As a result, starting with a cold field means that motor torque can vary significantly as the motor field heats up and the motor field excitation decreases. The operator must adjust the tension pot as the motor warms to keep tension at the proper value.

Use of a current controller on constant-diameter sections

The current controller (**Fig. 10**) is frequently used as a tension controller on constant-diameter sections when it is impossible to design a dancer roll or tension sensing roll into the web path. This may occur simply because space is not available or because the coating is still wet at the point where the sensing roll is required.

Constant-diameter sections usually use speed regulators as the primary control. Current control is used as a vernier or trim adjustment of the speed controller. The combination of speed control with current trim is a very stable method of controlling constant-diameter speed. This type of tension control works very well on heavyweight products that are run over a limited speed range.

With speed control as the primary control for constant-diameter sections, dancer roll control or tension roll control can be used as a vernier or trim adjustment for effective and stable tension control.

At one time dancer control and tension control were used to control a section from zero to full speed. This technique was inexpensive but very unstable because small transients that occur during acceleration, deceleration, and splicing created large changes in section speed. The changes in section speed caused interaction between sections, which eventually resulted in severe machine tracking instability. Web breaks were not uncommon.

Dancer roll control

The dancer roll (**Fig. 11**) is a force balance system where the force of the web pulling in one direction is balanced by the loading of the dancer pushing in the other direction. The dancer position is precisely monitored and controlled to ensure that the full storage capability of the dancer is available. This is the reason that the dancer (or swing roll) is called a position regulator.

With increased machine speeds, drive vendors and machinery builders want to ensure that the dancer has adequate storage to respond to transients such as flying splices, transfers, acceleration, and deceleration. The dancer measures web tension directly and therefore is not as affected by system losses as the current regulator. The dancer control system compensates for step changes in load losses due to doctor loading, changes in nip loading, changes in the coater, and higher than normal condensate loads in dryer drums. The system senses a change in tension and adjusts the section speed to reestablish tension to the preset value.

The loading of the dancer creates some unique problems for the mechanical designers. First, the sheer mass of the dancer can create sheet tension excursions when transients cause the dancer to move in one direction or the other. Similarly, the force from the weight of the dancer and the dancer arms can exceed the force required to control the minimum tension value that has been specified. The friction force in the dancer mechanism also can exceed the force required to control the minimum tension value.

Friction-free cylinders often are used in modern dancer loading systems. The pneumatic system for these cylinders must be designed so that the cylinders are always pressurized. The diaphragm will jam between the cylinder body and the piston if a cylinder is operated without air pressure.

Pneumatics can add to system problems. If the air pressure system has a low capacity, air pressure changes as the dancer moves. (Line pressure increases as the air is compressed and decreases as the air is allowed to expand.) An increase or decrease in the line air pressure changes the force on the dancer, and this change in force changes the web tension.

This capacity problem has been dealt with by placing a surge tank in the pneumatic line between the pressure regulator and the dancer piston. The problem of excess friction in an air cylinder can be handled by removing the rod and scraper, removing the excess chevron packings, chrome plating the piston barrel, and using only Teflon®-coated packings where packings are necessary.

A pneumatic system for loading the dancer at the winder provides a taper tension system that reduces windup ten-

sion as the roll builds from core to the maximum specified diameter. Taper tension is used to prevent blocking and the damaging buildup of forces within the roll.

Dancer rolls are most commonly used for control of unwinders and winders because these sections can produce transients during splicing and transfer cycles. Speed mismatches of the incoming roll during splice and transfer can produce slack unless a dancer is used. Dancer storage capacity can overcome many process conditions that are out of control but that may not be apparent until startup.

Tension regulation with force transducers

In comparison with a dancer roll, a force transducer system (**Fig. 12**) is more expensive electrically, but not as costly mechanically. Two force transducers are mounted on a roll that is in the web path. Transducer rolls often can be fitted into an existing web path and under an existing roll without difficulty. Their signals are summed and sent to the tension regulator, which adjusts motor power output to satisfy setpoint tension.

Additional rolls may be used to fix the wrap angle of the web over the roll and thereby to ensure that the force being measured is always directly proportional to web tension. It is important to maximize the measured force vector from web tension and to be sure that the tare-to-signal ratio is compatible with specifications of the transducer manufacturer.

It is also important to keep the wrap angle constant on tension sensing rolls that are located on a multiproduct machine where multiple threading paths exist. Since the force transducer directly measures web tension, it ignores many of the load losses that affect the current regulating system. However, rolls mounted on transducers must be balanced very precisely. Dynamic roll balance is especially important on rolls that are used as tension feedback devices for tension control systems.

Force transducers are now applied to all sections of the machine, from the unwinder to the winder. The fast response capability of modern drive systems makes force transducers effective in applications that formerly required the storage capability of dancer rolls.

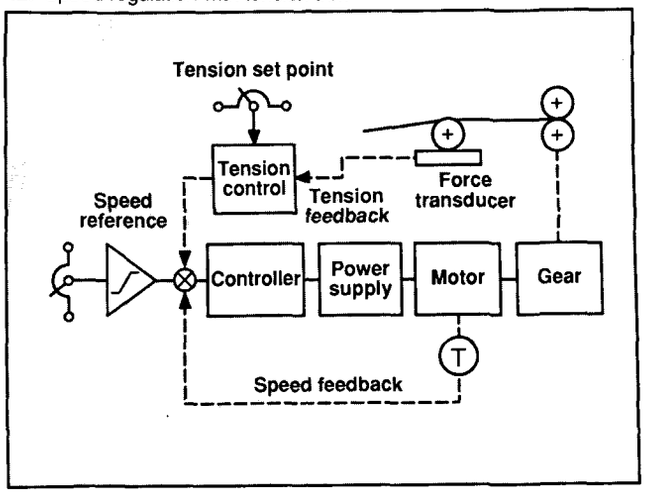
Other tension control considerations

Any section that is used to control tension has the same characteristics as a good lead section. It can handle large values of differential tension at all machine speeds and can handle the transients that are generated by acceleration, deceleration, splicing, and transferring. As is true for the lead section, a tension-controlled section in a machine must be able to transmit the torque from the motor, through the roll, to the web, without allowing the web to slip.

Tension isolation

Some sections can use the ability to handle large tension differentials to break the machine into tension zones, thus allowing different processes to be accommodated. For example, draw rolls separate a tandem coating operation into discrete process zones. This zoning capability is called isolation. Isolation is valuable only when the need for different tensions actually exists in different parts of the process. Many off-machine coaters for the paper industry and many plastic web converting lines run no differential tension from the unwinder to the winder. Because draw rolls that precede the coaters can cause web breaks, they have been eliminated. These machines seem to run better without the extra complexity of isolating sections. Isolation may be grossly overrated on coating machines that simply coat web in a tandem mode and do not have to deal with any other process.

12. Speed regulation with tension trim



Isolation can also insulate the coating section from the effects of poorly wound rolls on the unwinder. But poorly wound rolls produce a web with edge cracks and with wrinkles. Many times the wrinkles are turned into creases at the isolating draw roll and then broken at the coater. The adage "garbage in, garbage out" assumes new meaning when an attempt is made to unwind poorly wound rolls on any off-machine coater.

When isolation is needed

Isolation may be necessary if other processes are included in the coating machine. Examples include (a) laminating thinner webs to thicker webs, (b) laminating webs of different characteristics to the basic substrate, (c) wetting the web to the point where it becomes weak, and (d) heating a plastic web to the point where it becomes pliable.

Isolation may take the form of speed control or tension control. Careful consideration of process needs will indicate the form of tension control that will give the best results.

Control capabilities of different sections

Sections that can control tension include:

1. The unwinder or winder
2. A nip roll when it is nipped
3. A calender stack
4. Some types of coaters (no slippery nips)
5. Saturators.

Some sections can provide limited or no tension control. Due to the lubricating effect of the boundary layer of air that is carried with the web, the following sections become less effective as web speed increases:

1. Unnipped nip rolls

2. Vacuum sections with small wraps or low vacuum
3. Coaters with slippery nips
4. Coaters that apply coatings with the characteristics of a lubricant
5. An unfelted drum dryer section. The web will slip at speeds over 500 ft/min. Tension control is needed during acceleration and deceleration.
6. A dryer section with half of the dryers felted (the side where the felt contacts only the uncoated side of the web)
7. Single drum dryers that support high velocity impingement dryers. These drying drums slip at speeds around 500 ft/min. Tension control is necessary during acceleration and deceleration.

Methods with limited tension range

Selection of a practical tension range for the machine is the first consideration. If all webs are run at 1 pli, a range of 0.5-2 pli may be more practical than 0.5-3 pli.

Too large a tension range will eliminate the use of current regulators and force transducers. Transducer selection may be difficult if it must satisfy the highest and lowest tension and still provide adequate tension overload capacity.

Too large a tension range may compromise the ability of the dancer roll to handle the high or low end. Dual dancer loading systems have been used to provide high and low ranges of tension. Generally, tension control specifications call for a tension control system to provide 0-10% tension trim, separately adjustable for each section.

Speed trim values for constant-diameter sections

Typical speed trim values for constant diameter sections include:

1. Draw rolls, usually 3-5%
2. Coaters, 3-5%
3. Single dryer drums that back up high velocity dryers, 0.5-1%
4. Unfelted dryer groups, 1-3%
5. Felted dryer groups, 1-3%
6. Calender, 1-5%.

These values of tension trim must exceed any drift that exists in analog systems. If the drift of the drive system exceeds the tension trim, tension control will be unpredictable. Dryers of any type can create problems during acceleration and deceleration. Typically, too much tension trim is incorporated into the dryer tension regulator, which causes web control problems during acceleration and deceleration.

Dryer tension is controlled to speeds of about 500 ft/min. At that point the coating blades are loaded, and the machine is accelerated to process speed. Problems with the dryer occur when the web breaks away from the dryers during acceleration and continues slipping during steady-state operation. The tension controller will integrate the prevailing error that exists between setpoint and actual tension until the tension controller will stay in saturation. The dryer will slip until the stop button is depressed and the dryer decelerates to about 500 ft/min.

If the tension trim is set above 1%, the dryer speed will be badly out of speed match with the web. At about 500 ft/min, the dryer will stop slipping and a transient will occur. With a large speed mismatch, it is doubtful that the dryer drive can correct the resulting transient before the web breaks.

Integral versus proportional control

There are times when simply reducing the range of tension trim is not enough to allow a section with marginal tension-control capabilities to regain control of the web.

All modern controllers use operational amplifiers as the heart of the control system. These amplifiers are more precise than the old proportional amplifiers, but the integrating attribute of the amplifiers may never allow marginal sections to perform properly. There has been some success in converting tension controllers from integral to proportional control.

The softer characteristic of the proportional controller, together with the tension trim limit, has allowed sections with marginal tension-control capabilities to control tension acceptably. For high speed coating lines, the combination of proportional control and tension trim limit may be particularly effective for dryer drums. Where unnipped rolls such as coaters and pull rolls tend to break away easily, the combination of proportional control and tension trim limit may provide stable performance to a machine that otherwise cannot support the demands that an integrating controller places on it.

Adding and holding back torque

The ability of a drive system to add torque to the web (motoring) or to provide a braking effort to the web (regeneration) can be important in control. Both motors and motor-generator sets can perform these functions, but modern silicone controlled rectifier (SCR) power supplies will be equipped for regeneration only if the need is specified.

The user should examine the present operating technique of the machine to establish a desired tension profile, whether a drive rebuild or a new drive is being considered. This information will be used by the drive vendor to select the horsepower and type of power supply that each section needs for proper operation.

A number of applications require the addition of torque for proper operation.

Unwinders need to motor and brake when controlling tension. Some unwinders that use armature control provide a motoring effort when the unwinding roll is reduced to its smallest diameter at low tension values. At that point, the losses of the electromechanical system are at their greatest and may exceed the value of braking effort required to maintain tension. The drive motor will supply a motoring effort to maintain tension control at the proper level. Motoring effort is also needed whenever the jumbo roll is accelerated to line speed prior to a splice attempt.

Center winders need to supply motoring effort when they are winding web, and they may need to regenerate when the roll is braked to a rapid stop. The rate of deceleration of large rolls of paper on winders and unwinders may be limited to a rate that prevents the roll from cinching or telescoping.

All high-inertia sections, such as Yankee dryers, steam dryers, and calender stacks, may need regeneration for deceleration. If tension on the exit side of these sections is higher than the entry tensions, regeneration will be needed for effective tension control.

The master section needs regenerative capability for effective web velocity control.

Any coater, draw roll, or laminator may need regenerative capability, especially if the exit tension is higher than the entry tension or if the primary purpose of the section is to provide tension isolation.

Characteristics of power units

Motor-generator sets are the oldest form of power supply for multisection drive systems. They have the ability to provide positive or negative current to the motor to allow the drive system to add or hold back torque.

SCR power units can be ordered with unidirectional or with added regenerative capability. Regenerative capability must be specified, which may be overlooked in replacing a motor-generator set. Errors have been made during drive rebuilds when the user and drive vendor neglected to establish the tension profile for a machine and supplied unidirectional SCR power units in place of motor-generator sets for all sections on the machine, including the master.

Servo power units (pulse width modulated) are supplied with regenerative capability in sizes that are common to the converting industry.

Specifications for a drive system should list which sections require regeneration and which do not. It should not be assumed that regeneration is inherent. Frequently, vendors redesign drive systems to be cost-effective and competitive, which may change a drive normally supplied with regeneration into a unidirectional drive.

Effect of gear reducers on power supply selection

Some gearing types have high losses and will provide a braking effort to a drive section. This is especially true for worm reducers or for gear reducers that have very high reductions. The losses in such gear reducers may be high enough to provide the braking effort that normally would be provided by the section power supply. This braking effort must be replaced when new gear reducers are supplied during a rebuild and machine speedup. If, as part of the speedup, regenerative power supplies are replaced with unidirectional power supplies, the master section may not be able to maintain control of web velocity, and tension control will be unpredictable.

If an existing drive system has unidirectional power supplies and high-loss gear reducers, the reducers may provide the necessary braking to prevent a section from being overhauled and machine performance may be acceptable. After a drive speedup, the new reducers may not supply the necessary braking to prevent overhauling, and regenerative power units will be required.

Care must be taken to establish the tension profile of the machine for each process and operating speed. The profile permits the drive designer to evaluate the need of the individual power units.

Do not assume that a positive motor current during process conditions means that the section is not being overhauled. Instead, compare motor current without web to motor current under various process conditions. If motor current under process conditions is less than no-web motor current, the section is in a braking or regenerative mode. A regenerative power supply will be the power supply of choice.

Sizing of power supplies for off-machine coater drives

Power supplies should be sized to motor capabilities and the needs of the load. Since all machine sections have low friction and high inertia, it is necessary to provide regenerative power supplies to ensure rapid emergency stops and controlled normal stops. Most dc drive motors can sustain a 150% overload for 1 min. Power supplies for low-inertia sections should have the same overload capacity. High-inertia sections, such as unwinders, winders, calenders, and dryers, may need drive systems (motor and power supply) that can accelerate and decelerate the section quickly. The manufacturing department wants the machine up to speed as quickly as possible. Regulatory agencies and corporate safety requirements may dictate how fast these sections may be decelerated to a stop.

Drive system capability for high-inertia sections should be based on the need to accelerate and decelerate the inertia load in a reasonable time. For machine speeds above 2500 ft/min, the inertia may require additional drive capacity for acceleration at a suggested rate of 40 ft/min·s. Since a 150% rating for 1 min is not enough for the acceleration or deceleration of high-inertia loads, a 200% continuous overload capability for motors and power supply may be more appropriate for these sections.

Overload capability of power units

Many engineers have used the gross overload capability of motor-generator sets to solve a startup problem or to reduce the downtime and capital cost of a major rebuild. An example is a 200-in., 4000-ft/min coater that was equipped with two Yankee dryers, driven by 75-hp motors. The motors, which were powered from motor-generator sets, went into current limit during acceleration due to dryer inertia and high condensate levels in the dryer. The problem of acceleration was solved by increasing current limit to 400%. The drive successfully accelerated the drum to 4000 ft/min in 100 s. At the end of the acceleration period, the normal running load of the drive motor dropped to 30% of the full load rating of the motor. With today's constraints on power units, the same problem could not be solved so easily. A 75-hp motor may still be used, but the power unit must be rated to handle an overlaod of this magnitude.

As a second example, the speed of a coater was increased by 50% after the normal running loads of individual sections were documented and evaluated, permitting a determination that all existing motors and power units could be used. We also changed the gear ratios of the existing gear reducers and the belt ratios to the unwinder and winder. We noted that the unwinder and winder drives would be overloaded to 200% of full motor nameplate rating when they were called upon to accelerate large jumbo rolls. The existing motor-generator sets accepted the work without incident. Retaining the existing power units saved considerable cost for new equipment and also saved considerable downtime and construction costs.

Getting the most out of power supplies

Modern power units are most likely to be SCR with an isolation transformer. Drive vendors design the power units to handle a range of horsepower loads, rather than a single motor size. The power unit will have extra capacity if the design section horsepower is less than the maximum rating of the power unit.

A user may wish to apply some of the extra capacity when a helper drive is added to a section or when machine speed is increased. However, a vendor may limit the user's access to this extra capacity if armature components and isolation transformers are based on the section design horsepower instead of the maximum rating of the power unit. Unless the user specifies that these components should match the maximum rating of the power unit, the competitive nature of the drive business almost assures that the ratings will be less. Then future machine changes may require complex drive changes, allocation of funds, machine downtime, and construction time.

The user also should establish the maximum kilowatt rating of each power unit and determine the cost of increasing the size of all transformers and armature loop components in each power unit to ensure that the maximum power capacity is available whenever it is needed.

Continuous and intermittent processes

Most off-machine coaters in the paper and converting industries are continuous process machines. The web is delivered to the process in a continuous stream to ensure the most efficient operation. The continuous process avoids some losses that are inherent in an intermittent process.

Coating and web may be wasted when the machine is stopped at the end of each roll, and further coating may be wasted while the process is being reestablished at the start of each new roll. The web that is in the machine during acceleration and deceleration will be out of specification.

The web that is left in the machine after each stop is most likely to be scrapped because it will not meet specifications for coating, drying, and coating defects.

Dryer temperature is reduced at the end of a roll to minimize damage to the web left in the machine. After a new roll is hand spliced to the tail of the existing web, the coating process is begun again. The energy costs for bringing the dryers back up to temperature after each roll change add to product costs.

The web that is left in the machine may become overdried and brittle and may break when the machine is restarted after a roll change. Each web break requires time for cleanup and rethreading. Productivity decreases, while coating waste, base stock losses, and energy costs increase.

In some cases, it is acceptable to shut down the process at the end of each roll. One example is a pilot operation, where new coating formulations, new coating and drying systems, and new equipment are tested prior to the commitment of funds to a major production facility.

Summary

This paper discusses the fundamentals of web transport drive control, together with some mill operating conditions. The full text and a list of references is available for those who want more details.*

Web transport engineers must thoroughly understand the needs of each mill site so that they can supply drives that will deliver maximum flexibility at the least installed cost.

Understanding begins by observing actual operating conditions and techniques in the mill and then applying established guidelines to select the proper web transport systems.

Before specifying the parameters of a new system, engineers should use the operator's log and instruments such as ammeters, voltmeters, speed indicators, and recording oscillographs to characterize existing machine performance.

Characterization of an existing machine for the purpose of determining actual process needs is one way of avoiding the mistakes that come when systems are specified from guidelines only.□

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*Kheboian, G. I., 1989 Coating Conference Proceedings, TAPPI PRESS, Atlanta, p. 65.