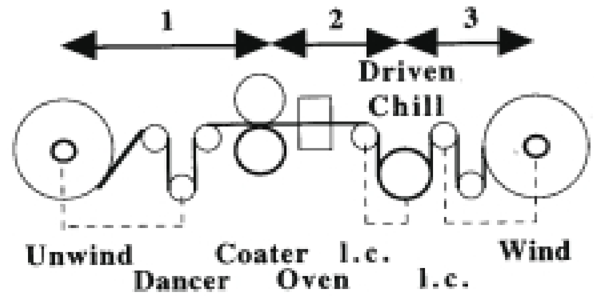
BETTER WEB PROCESS CONTROL THROUGH TENSION SENSING

Accurate tension measurement and control can go a long way toward reducing the negative effects of process deviations on printed and converted materials in a continuous web process, particularly in cases where flexible, extensible substrates are being run. Physical inconsistencies of difficult substrates can also often be compensated for. Even a press with sophisticated register controls can benefit from the refinement in output quality brought by an accurate transducer-based tension system.

By reducing web scrap and allowing a web press to run at higher speeds with defect-minimized output, a reliable web tension control system will not only improve a press' bottom line performance but can often pay for itself in as little as a few weeks.

Tension Related Web Problems

Loss of color-to-color registration while running at speed, splicing or changing speed; inconsistent repeat length; and slack web which can cause web breaks and wrap-ups around driven rolls are perhaps the most obvious consequences of inadequate tension control on a web press. Others include deformation of web due to stretching or wrinkling; variation of coating thickness; unwind or rewind core crushing; reduction of machine speed to accommodate web handling problems or any of the problems above; hard rolls; soft rolls; telescoping rolls; excessive waste of web material; and the inability to run a wide range of web thickness', widths and materials.



Drive sections in roll-to-roll converting on a coating line--a common application requiring closed-loop tension control

Many of these problems are simply accepted as normal and are not attributed to inadequate control of web tension. However, printers and converters experiencing such trouble and recognizing the relationship can improve efficiency and profits by employing better tension control methods.

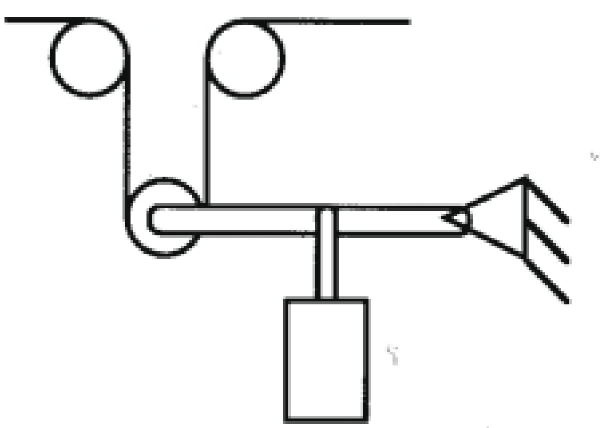
Selecting a Web Tension Control System

The determining factors for the level of sophistication necessary for a tension control system on a particular press include: 1) the material nature of the substrate; 2) the level of print quality required of the jobs being run on the press; 3) the magnitude of tension transients introduced into the system by the combination of all process variables; and 4) the speed at which the press should be run.

Open loop tension control systems such as roll followers and draw controls work well in printing and converting applications with forgiving substrates, but they cannot measure the actual tension on a moving web and compensate directly for any deviation from a preset value. Nor can they compensate for speed for speed changes, brake fade, temperature and humidity variations, non-uniformities in the web and other factors that affect web tension. The only way to achieve accurate web tension measurement and control is to use tension transducers combined with automatic tension control electronics in a closed loop system.

The dancer system, one of the more common closed-loop web control technologies, warrants comparison to tension transducer systems. A dancer system uses a position controller rather than a tension controller, and a special idler roll designed into the frame of the web press. The dancer roll is free to move in a line or an arc under the influence of web tension. A counter-force created by a weight or air cylinder opposes the tension force. A sensor connected to the dancer detects its position. The position signal is fed to an electronic regulator where it is compared to a desired position set point, usually representing the mid-point of the dancer travel, set by the machine operator. The dancer will maintain its position in the middle of its travel as long as this condition exists.

The dancer control system is similar to the transducer system in that changes in tension ultimately result in a corrective reaction. In a dancer system, however, the controller signals the dancer roll to move in response to a significant change in *position*. Although the initial position change is the result of a change in web tension, the controller does not measure tension or react to *force* changes as directly as a transducer-based system does.



Vertical Dancer

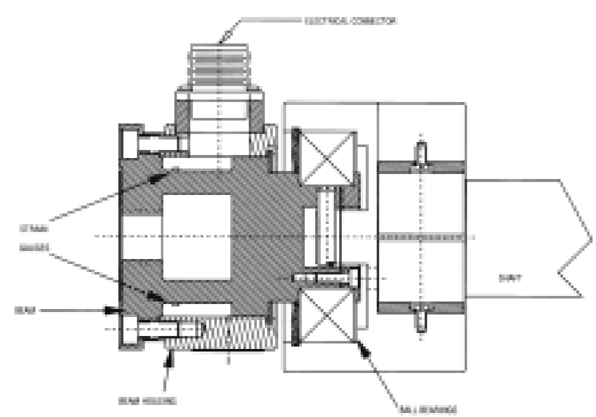
If tension increases, the dancer changes position, moving the sensor, which is usually a potentiometer, and signaling the controller to reduce or increase torque and allow the dancer to return to its original position. If tension decreases, the opposite sequence occurs.

Dancers are actually position controllers, not tension controllers. The system's principal advantage is its web accumulation ability, which tension transducer schemes lack. A dancer is also more forgiving of speed variations as created by out-of-round rolls or frequent starts and stops.

But dancers have certain drawbacks. Compared to tension transducer systems they are expensive to design, build and install. They are difficult to properly engineer. They are prone to errors caused by mass, damping and friction. And they cannot read out tension or compensate for small but significant tension transients in the process.

In a tension transducer system (see figure 1), specially designed force transducers measure actual web tension in the converting process. The transducers, or tension sensors, are typically used in pairs with one installed on each end of an ordinary idler roll shaft.

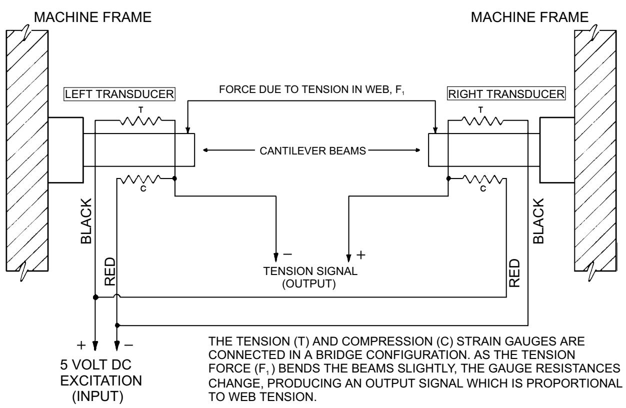
They can be configured in various ways to support the idler roll; the most typical arrangement being a rotary coupling design, rotatable for live-shaft idler rolls and stationary for dead-shaft rolls. Acting as small electronic scales, the transducers weigh the forces due to tension and the weight of the roll. The resultant total force is dependent on the web's wrap angle over the transducer roll and the roll weight.



Tension Transducer For Rotating Shaft

Figure 1. This cross section shows one end of an idler roll shaft being supported by the coupling of a typical dead-shaft transducer. Supporting plates (beams) in the base of the transducer deflect slightly under the combined load of the idler roll and a moving web. The deflection causes deformation of the strain gauges which create a change in voltage output.

Tension transducers incorporate some type of spring support for the roll, generally a stiff aluminum beam inside the transducer housing. In most cases tension transducers use either strain gauges or variable inductors attached to the beam as a sensor mechanism. The strain gauges detect beam deflection (of even a few hundred microns) under load and convert the mechanical deflection into a voltage (see Figure 2) that is proportional to web tension and highly accurate (~ 1%).



Electrical Connections for Transducer Pair

Figure 2. The tension (T) and compression (C) strain gauges are connected in a bridge configuration. As the tension force (Ft) bends the beams slightly, the gauge resistances change, producing an output signal that is proportional to web tension.

Comparison of Strain Gage and LVDT Transducers

There are alternatives to silicon or foil strain gages as the sensing mechanisms in tension transducers. One of the more popular technologies is LVDT which stands for Linear Voltage Differential Transformer. Strain gages are more prevalent by far, due to their simplicity, small packaging requirements, and other advantages.

Strain gages are made of piezoelectric materials. When a mechanical force is applied to them their electrical resistance changes. The change of resistance is converted to a voltage or current which represents web tension. The load rating of the transducer is determined by the strength of the cantilever beam.

The LVDT transducer is completely different. It usually consists of a plate hinged at one end, operating a metal plunger at the free end. See Figure 3.

The load is applied at the middle of the top plate which moves down, driving down the plunger and a connected magnetically conductive core. The ferrous core acts as an inductance coupler. It is positioned in the center of three electrical coil windings: a primary and two secondaries on either side of it. These components together make up the LVDT portion of the transducer. The secondary windings are wired together to form a series-opposing circuit. AC excitation is applied to the primary creating an inductance. A position change of the core causes a differential in inductance between the two secondaries and thus a change in voltage output. The magnitude of output change is related linearly to the magnitude of the core's off-center travel. The load rating is determined by the strength of the hinge.

The basic electronic components of a strain gage transducer consist of a regulated DC power supply and a DC amplifier, while the LVDT transducer

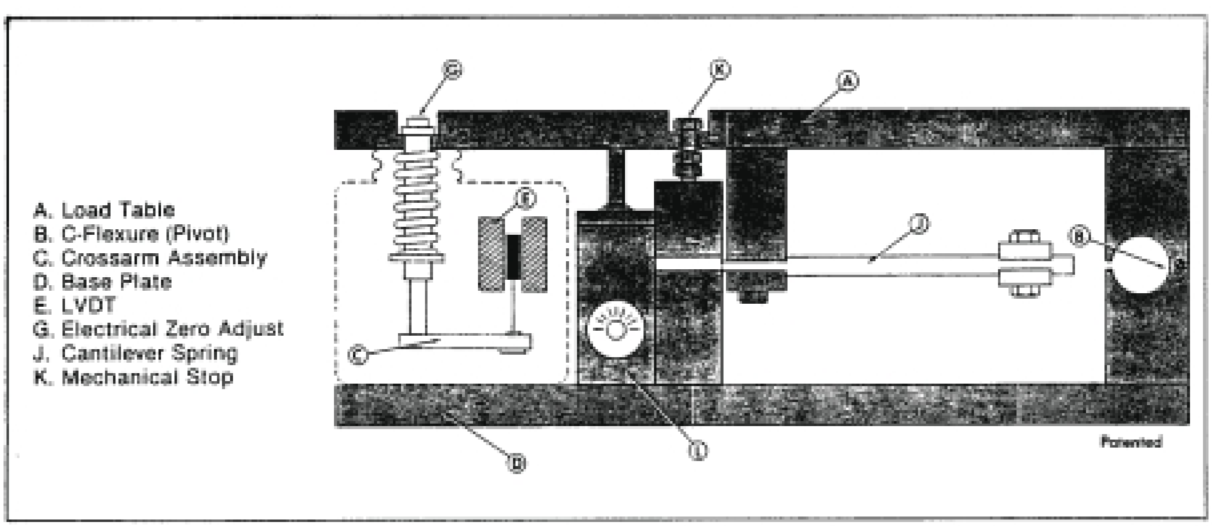


Figure 3 **- LVDT Transducer**

requires more complex and expensive electronics, consisting of a variable frequency oscillator, a frequency-to-voltage converter, and a DC amplifier.

The strain gage transducer requires very little movement to produce a signal, normally in the range of 1/2 to 5 thousandths of an inch. The LVDT transducer typically requires as much as 30 thousandths of an inch. The web potentially can be disturbed by higher movements of the LVDT transducer.

Some LVDT transducers are designed to have adjustable load ranges. However, the typical useable load range is narrow, 4:1 or 5:1. Strain gage transducers are routinely operated at ranges of 20:1.

Tare and calibration are performed electronically with strain gage transducers. LVDT transducers can have either mechanical or electronic adjustments, but these usually require accessing the transducer itself to make the adjustments.

Strain gage transducers, especially the cartridge type, narrow web and tension roll types are more accurate than LVDT transducers. The hinged plate design of the LVDT units is susceptible to bearing drag which causes a false output, sometimes equal to actual web tension, depending on the drag torque of the bearing and its seals. The design of strain gage transducers is such that bearing torque is ignored. Strain gage transducers are typically well sealed and therefore quite resistant to contamination by dirt, grease, water, ink, etc. LVDT units, which have a less perfect seal, can be affected by contamination.

LVDT transducers usually contain a viscous damper of some kind. Strain gage transducers do not. A damper would serve no purpose in strain gage units because of their very small movement and the ability to electronically damp any unwanted tension fluctuations.

Closed Loop Tension Transducer Systems

The simplest type of complete closed-loop transducer system consists of a pair of transducers, an enclosure with a display meter, a circuit card that provides excitation voltage to the transducers and amplifies their output, and a pair of interconnecting cables. The circuit card will typically have voltage and current outputs proportional to tension that can be fed to variable speed drives, recorders, or PLC's or computers.

In addition to being displayed on the meter, the tension signal can also be fed to a regulator circuit where it is compared to a desired tension signal set by the machine operator. The regulator sends an output voltage or current to a servo valve, motor, brake or clutch to automatically control tension in a closed-loop control scheme. This accomplishes closed-loop control. Such a system can be used in

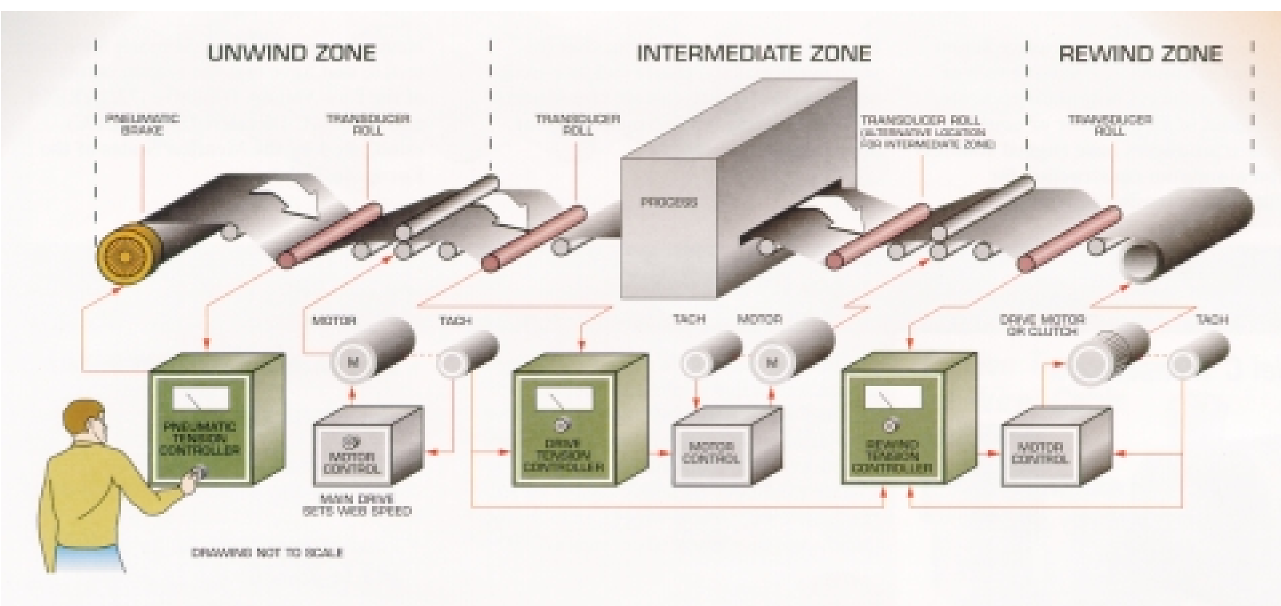


Figure 4. From zone to zone the output signal from the control electronics used in a closed-loop tension control system varies. The signal required from the controller is determined by the type of mechanism creating tension in a particular zone. Three standard output versions are pneumatic, 0-10 VDC for variable speed drives, and 0-90 VDC for electric brakes or clutches.

any of the three classifications of tension zone (see Figure 4) in a web process: unwind, intermediate or rewind, to provide the degree of tension control necessary for a particular press application.

Tension Control In Multiple Zones

A tension control system that supplies control output to a pneumatic brake in the unwind zone (see Figure 5) is perhaps the most commonly found tension-sensor based control loop in flexo printing. Rewind tension control is unnecessary in printing operations that are strictly web-to-sheet

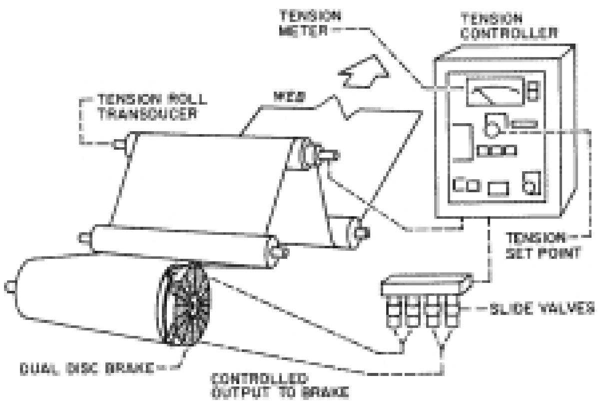


Figure 5 - Closed loop tension Indicators control on a web unwind

Tension Control Retrofit Options for a Wide Web Press

Let's consider a wide web flexo press for a complete tension control retrofit, starting at the unwind. The unwind section of the press could have dancer or sonic sensor control or even manual control with a tension indicator; but to attain the highest level of control an automatic tension controller with tension transducers (and any one of an array of unwind tensioning mechanisms) is recommended. If the press runs a variety of substrates such as film, foil, or paper, then a microprocessor-based controller would be preferable to an analog version.

The tension range required is what governs the load ratings for the transducers to be used. If the type of jobs run varied so significantly that a wide tension measurement range were required, for example, ten pounds to 200 pounds total tension, then we would need to find either a single transducer with an extremely wide measurement range, or more likely, we could look at the low range with a tension roll style transducer mounted in a higher range pair of standard tension transducers. In this case we would need the dual transducer input option with our tension controller and the dual PID control feature would be used. If a microprocessor controller were used in place of the analog controller we could have many different calibration and PID controls with each assigned its own recipe name or number. Each controller would operate with either a pneumatic brake, electric brake, or drive.

Some presses have an infeed nip to control the tension into the first color. This serves to isolate tension surges or spikes from the unwind zone. The control required in this section depends on whether the press is a stack press or a Central Impression (CI) press. If the infeed nip speed is controllable then a tension roll should be positioned between the first print station and the infeed nip. An automatic tension controller, taking a signal from the tension roll, should be used with the line speed follower and tension trim features to control the speed of the infeed nip.

The next section of a standard wide web press is usually the main drive section, where the line speed of the press is set. After passing through 4, 6, 8, or 10 color print stations, the web may go into a drying tunnel. When the web exits the dryer it usually goes around a single (or double) chill roll to cool the substrate before the next operation. One of these drums has a rubber nip roll and is driven by either a line shaft through an adjustable gear box, i.e. PIV, or a separate drive motor. A separate drive motor is preferable to using a PIV and line shaft because of its lower maintenance requirements. The drive motor would be line follower and tension trim controlled with an automatic tension controller receiving a tension signal from tension transducers on a roll placed between the dryer and the cooling drums. This closed loop system controls the tension from the last print station through the dryer. The drive, whether it be DC or vector, must be regenerative to hold back from the rewind torque. This zone would isolate the print and dryer tension from the rewind tension.

If the printed web is being rewound (rather than going to a sheeter or slitter first) proper rewind tension is straightforward, with tension control being applied typically to a drive or eddy current clutch on the winder.

If the rewind is a single shaft, then a standard analog or microprocessor tension controller with a taper tension feature is used. Taper tension is usually required for uniform roll buildup of large rolls. The tension signal would be provided to the controller from transducers on an idler roll before the winder.

If the rewind happens to be a dual spindle turret winder, an automatic tension controller with integrated splice control should be considered. The application requires a line speed signal and an RPM signal by DC or AC tachometer from the rewind shaft motors, and input to the controller. Comparing the line speed and rewind shaft speed the controller can calculate the rewind roll diameter. With this information, we can modify the torque and therefore produce a taper tension which is adjustable by the operator.

A rewind splice controller is a great productivity enhancer. It allows the operator to activate the entire splice sequence by pushing one button. In this sequence, the empty core comes up to line speed match, the turret indexes to a limit switch, the lay-on roll brings the web to the empty core to touch the splice tape, and the knife fires to cut the web for a successful splice. Then the full roll motor stops and tension control is switched to the new core to start a new roll at the desired tension with the correct taper tension.

Many companies are pushing out the rewind section and adding a downstream printing or coating section to their existing presses for special over-coat or backside printing and many times this section is a solvent ink or coating. This section must be tension controlled with respect to the main press. If the coating is solvent-based, an intrinsically-safe transducer interface should be used to send a 0-10 volt signal to a controller for drive control. There would also be another set of chill rolls after this section with the same controls as were required in the main press cooling drum section.

Trends in Tension Control Product Development

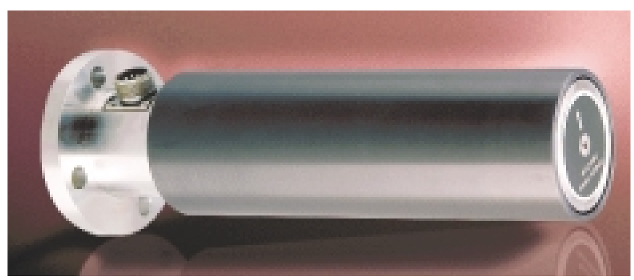
With the exception of flexography and converters who serve the flexible packaging industry--two industry segments that are still growing at a healthy pace--the user markets for web tension control products in North America are fairly mature. Product development from tension measurement and control equipment manufacturers has been incremental and evolutionary over the past ten years, changing with corresponding technological changes in the markets served: primarily the converting, printing, flexible packaging, paper and paperboard, and textile industries.

There are a few significant trends in the flexo printing and flexible packaging industries today that are shaping product developments coming from the tension controls manufacturers. Two of the trends are derived from the non-stop growth of competition in many consumer packaged goods categories. Manifesting itself in the proliferation of brands and customized regional promotions for popular product categories on our local grocery store shelves, today's marketing differentiation fever has forced demand to increase for shorter print runs and more new and exciting packaging options. Environmental regulation has also been instrumental in the shift to new substrates.

Printers and converters have had to respond with faster turnarounds, greater process versatility, increasing sub-process capabilities, the ability to print on a wider variety of substrates, and economical methods to complete short print runs.

Tension control equipment manufacturers have responded to the fast turnaround and substrate variety issue by developing and offering microprocessor-based PID tension controllers that store job setup parameters

The program storage and recall features of digital controls are obviously desirable for flexo printers who run a wide variety of substrates or even the same substrate at various thickness. The challenge for tension controls manufacturers is to develop intuitive and simple enough user interfaces on the microprocessor controls to rival the North American popularity of analog controls. Europe and Asia have been much faster to adopt the use of digital menu-driven controllers, versus the longstanding analog controllers, than their American counterparts.



The growth of narrow web has created a need for cantilevered tension transducers.

Another change in tension control has been the result of changes in web press technology. The wider-style narrow web printing presses, which are enjoying steady growth as an economic alternative to wide web for shorter print runs, has spurred

WebHandler ™ 3 Microprocessor Tension Controller. Tension control has made good use of computer technology. Microprocessor-based controllers can store and recall job set-up parameters to assure repeatable results from one to the next

demand for a new type of tension transducer. Tension equipment manufacturers have been called on to produce cantilevered tension transducers of various lengths for the single-sided frames of narrow web presses. Transducer design in general will always have to adjust to accommodate the presses and machines they will run on.

Other trends in tension control are the result of long term macroeconomic forces that effect every free market industry. With respect to the natural course of web printing growth over the last twenty years, a proliferation of related accessories manufacturers has also developed. Tension control equipment, being one of those accessory categories, is now more competitive than ever. Even so, the technologies used for controlling web tension have seen no revolutionary change in the last decade. Dancer systems and strain gage transducers with dedicated PID controllers are still the standards in web tension control due to price and performance versus the alternatives.

Real growth in 'tension measurement and control' is now occurring in only a few ways:

1. Individual manufacturers are working to drive down component and system costs in order to stay competitive. They must. Because with the field so saturated, tension measurement and control devices are being perceived by customers as commodities. As a result of lower component prices, the potential user market for tension equipment is expanding. The smaller printers and manufacturers, in the U.S. and internationally, who could not previously afford sophisticated tension control are beginning to be able to.

2. Tension controls manufacturers are battling for market share by differentiating the user interfaces and mounting styles of the measurement and control electronics. Standardized digital communications features are being added to control electronics so that customers can integrate the sensor outputs from their various process parameters into a supervisory control center. This should allow for more efficient monitoring and control of individual press components.

3. Competition to dedicated tension controllers is creeping in from the D.C. drives manufacturers who have integrated a PID control function for tension control right into some of their drive packages. This solution may be more cost effective than to purchase a dedicated tension controller and a separate drive, but the downside is the difficulty in determining which part of the system needs to be tuned if the process becomes unstable. A dedicated tension control system with one supplier having technical support responsibility throughout may be preferable for customers with limited technical staff or experience.

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