Controlling web tension with load cells: Part 1 of 3

Many engineers and technicians are unfamiliar with the use of load cells for web tension control. But well-selected load cells improve web applications.

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During manufacturing or converting processes, material is generally pulled off a roll, processed, and rewound — in sections called unwind, intermediate, and rewind zones, respectively. Knowing the unique tension values for each zone is important to making proper process adjustments.

There are several ways to measure and control tension in these zones; some are more sophisticated than others. As we'll see, load cells are the only accurate way to measure web tension. They're important because without accurate tension values, adjustments are inconsistent and may actually reduce throughput or quality.

Basic method: An operator taps on the web and by "feel" tries to determine the amount of tension. With this basic method, tension is adjusted by manually changing brake torques, dancer loads, gear ratios, or motor speeds. The operator continues tapping the web and making adjustments until a satisfactory result is achieved. Because this is a manual process, adjustments take time, and as a result, much wasted product is produced.

Too, there is no consistent way of measuring or altering the tension. Attempts may be made to record settings, but as brake pads and other machine parts wear, the settings produce different tension levels. Temperature changes and inconsistencies in the material also affect tension. Furthermore, different operators have differing opinions on which tension feels right. Product quality is suspect and inconsistent, and this method can even be unsafe. Since tension is unknown, so are the limits to which line speed may be increased. Trying to run at high line speeds may produce stretch or even break the web. Running at low line speeds may be required to produce acceptable product; this greatly limits throughput.

Better method: Load cells are used to measure tension and the value is displayed on an indicator. An operator still manually adjusts the tension. Load cells are added to the rollers (or sheaves and pulleys) in the tension zones to measure the tension and the values are displayed on tension indicators — meters or screen displays. The operator takes the appropriate corrective action to adjust the tension by manually changing brake torque, dancer loads, gear ratios, or motor speeds.

Here, the measure and display of tension is consistent but the control of it is not. Product quality is greatly improved but is somewhat inconsistent. Since the tension is known, so too are the limits to which the line speed may be increased before the material stretches or web breaks. The line speed may be increased but only to the amount that it can be controlled. Manual intervention by the operator still limits the response time and how tightly the tension values can be controlled. As a result, much wasted product is still produced.

Best method: Load cells are used along with controllers and actuators to automatically meas-

Definitions

The terms *load cells* and *tension transducers* are used interchangeably to describe a sensor that measures tension in a moving web. The term *load cell* commonly describes weigh-scale sensors that measure the force or load due to the weight of an object. The term has carried over to the web-processing industry, since similar sensors measure the force produced by web tension. *Transducers* transform one type of energy into another. Therefore, a tension transducer is a sensor that measures the force resulting from tension in a web, and transforms it into electrical energy.

ure and adjust web tension.** In this setup, load cells are added to the rollers (or sheaves and pulleys) in the tension zones. The load cells are connected to a device that displays the tension value and automatically controls the brakes, dancers, gear ratios, or motors. An operator enters the desired tension setting and the appropriate corrective action is performed automatically. The controller may be any closed-loop standalone device, PLC, or programmable drive. They continually compare the tension set point to the actual tension being measured by the load cells and automatically take corrective action to ensure that these values agree. This method provides a consistent means of measuring and controlling tension. Tension control is done automatically and requires minimum operator intervention. Product quality is at its best and consistent. Corrective action takes place immediately. As a result, little wasted product is produced.

Because the tension is known, so too are the limits to which the line speed is increased before the material stretches or web breaks. Also, highly responsive automatic closed-loop tension devices tightly control tension values — so the only limiting factors are control loop response time and actual process limitations.

How they work

Load cells employ strain gages, LVDTs (linear variable differential transformers) or other electromechanical sensing devices.

Consider a strain-gage cartridge-style transducer. The transducer is fastened to the machine frame at one end, and to a roller on the other. Then, the web is wrapped over the roller. Inside each transducer, strain gages are attached to a pair of beams made of spring steel. Referred to as dual beams, they are fixed at one end with the free end connecting to the roller. As tension is applied to the web, the force is transferred from the roller directly to the transducer.

The component of force applied perpendicular to the beam deflects or bends them. This bending (typically 0.002 to 0.004 in.) creates a strain or elongation of the molecules in the beams. The strain gages measure this elongation and generate an electrical signal proportional to the amount of force applied — the web tension value.

To accommodate larger force, beam cross-sectional area can be increased by making it either wider or thicker. The greater the transducer load rating (maximum working force or *MWF*) the larger the beam. So, a transducer with an MWF rating of 150 lb has a beam both wider and thicker than one rated for 25 lb. Overload stops are provided on many cartridge-style transducers, allowing them to accommodate overloads of 150 to 300% of their rating.

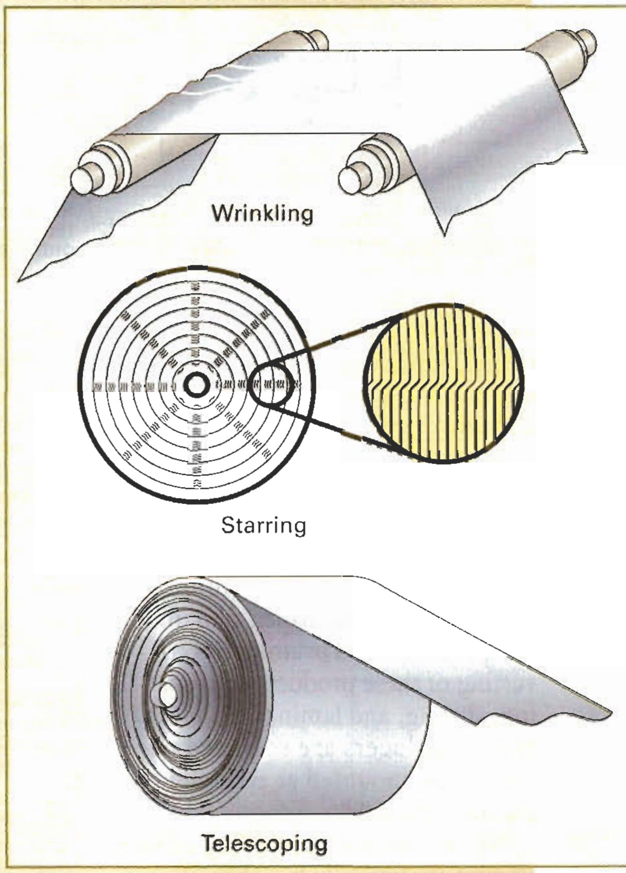
Which style?

Selecting a load cell first requires that the proper style be chosen. Different load-cell units are designed

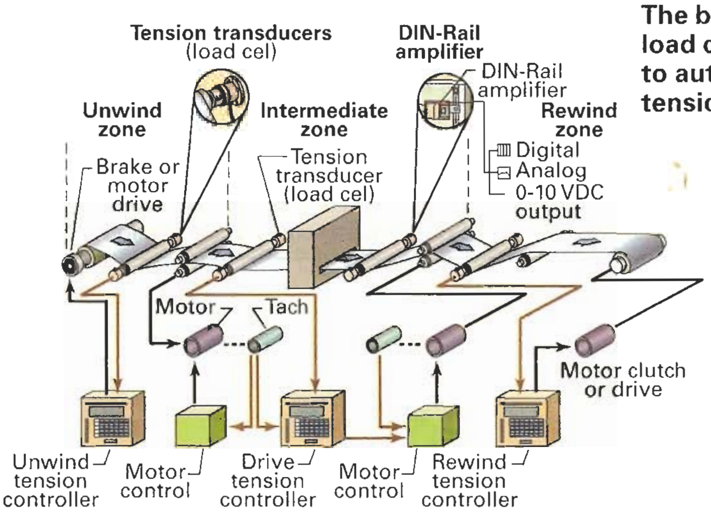
What is web tension control?

Web tension control refers to methods used to measure and adjust tension in a moving web. In this context, a web is any material continuously pulled from a roll through some manufacturing process. Tension is the measurable force that stretches or elongates the web. Web tension control methods range from feeling and controlling tension by hand to advanced systems that automatically measure and make adjustments to the process.

Most processes involved in the production or converting of paper, film, plastic, foil, textile, wire, and cable require some form of tension control. It is also necessary on products that require winding onto rolls, printing, coating, laminating, slitting, and extruding. Here we discuss only continuous roll fed (and not sheet-fed) material.



If tension is not properly controlled, wrinkles in the material may result in defective or wasted product, or the outer layers may crush the inner layers, leading to starring, or the inner layers may telescope out resulting in ruined product. When printing on a roll of material, improper tension control results in smeared ink and fuzzy images from poor registration. Applying too much tension may stretch some materials beyond their elastic limit rendering them unusable. In contrast, properly controlling web tension results in higher quality product and produces greater throughput by allowing processes to run at high speeds without sacrificing product quality.



Complete converting system

The best method for web tension is to use load cells along with controllers and actuators to automatically measure and adjust web tension.

for different applications and tension ranges. Several application-specific questions must be answered before choosing.

❶ Determine if you have a wide or narrow web. Typically a wide web is over 20 in. wide and utilizes a roller assembly supported on both ends. Some production processes utilizing a wide web include paper, film, foil, and plastics — and printing and converting of these products with coating, slitting, and laminating. Here, two transducers are required per roller: one mounted at each end of the roller assembly.

Narrow spools for winding cable or wire are typically less than 20 in. wide, and utilize a cantilevered roller or pulley supported at one end by a load cell. Commonly, the outer sleeve rotates on bearings around a center shaft that runs the length of roller assembly. The shaft is held in place on one end and hangs free on the other. The amount of deflection of the shaft due to the overhung tension load limits the practical length of the cantilevered roller to about 20 in. These also accommodate fiber-optic strands, filaments, some hygienic products, and other narrow products that run over a pulley or guide roller.

Standard load cells can often accommodate customer-mounted pulleys to eliminate the expense of integrated rollers. Other styles are designed for specific applications. Only one transducer is required per roller since it supports a cantilevered roller or pulley.

❷ Determine if you have a stationary or rotating shaft roller. Stationary shaft rollers have a shaft that run all the way through the assembly. The outer shell or sleeve is a cylinder that rotates around the shaft on bearings. The shaft does not rotate but

Tension data

Material	Tension, lb/in./mil (1 mil = 0.001 in.)	Paper and laminations	Tension: lb/ lineal in. (PLI)
Aluminum foils	0.5 to 1.5 (1.0 average)	20# /R - 32.54 gm/m^2	0.5 to 1.0
Cellophanes	0.5 to 1.0		
Acetate	0.5	40# /R - 65.08 gm/m^2	1.0 to 2.0
Mylar (Polyester)	0.5 to 1.0 (0.75 average)		
Polyethylene	0.25 to 0.30	60# /R - 97.62 gm/m^2	1.5 to 3.0
Polystyrene	1.0		
Saran	0.05 to 0.20 (0.10 average)	80# /R - 130.1 gm/m^2	2.0 to 4.0
Vinyl	0.05 to 0.20 (0.10 average)		

Substrate	Approximate tension, lb/in.
Mylar, oriented propylene, and polyester	
0.0005in.	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 (3,000 sq. ft.)	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
120 lb/ream	3.5
160 lb/ream	4.5
200 lb/ream	5.5
240 lb/ream	6.5
280 lb/ream	7.5

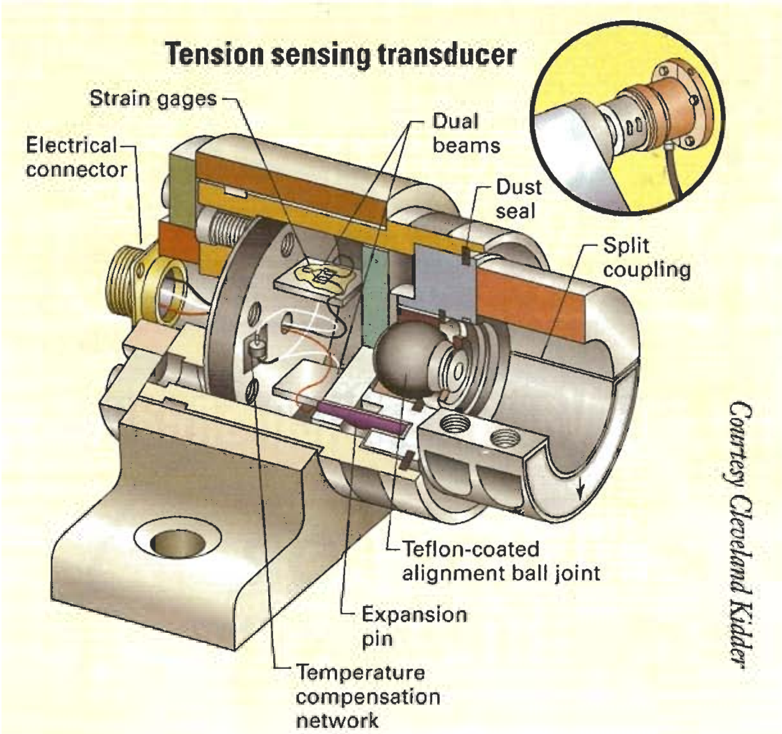
Substrate (1 pt. = 0.001 in.)	Approximate tension, lb/in.
Paperboard	
8 pt.	3.0
12 pt.	4.0
15 pt.	5.0
20 pt.	7.0
25 pt.	9.0
30 pt.	11.0
35 pt.	13.0
45 pt.	15.0
65 pt.	19.0
Laminations	
25-lb. paper/0.0005-in. PE/.00035-in. foil/.001-in. PE	3.0
0.001-in. cello/.0005-in. PE/.001-in. cello	1.5

Note: When these substrates are coated with polyethylene, nylon, polypropylene, EVA, EAA and EEA, add the following tension values to the values listed above for the substrate only.

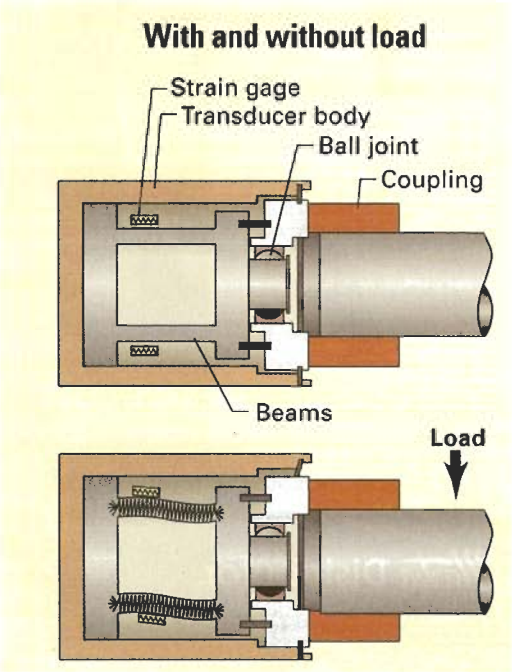
Coating thickness	Approximate tension, lb/in.
0.0005 in. to 0.001	0.12
0.0011 in. to 0.002	0.25

Copper wire

AWG	Tension	AWG	Tension
8	30.0 lb	20	5.0 lb
10	20.0 lb	24	4.5 lb
12	12.0 lb	30	1.25 lb
14	9.0 lb	36	0.25 lb
16	6.0 lb	40	0.1 lb



The transducer is first fastened to the machine frame at one end and to a roller on the other end. Then, the web is wrapped over the roller. Inside each transducer, strain gages have been attached to a pair of beams made of spring steel.



The component of force applied perpendicular to the beam deflects or bends them. This bending creates a strain or elongation of the molecules in the beams.

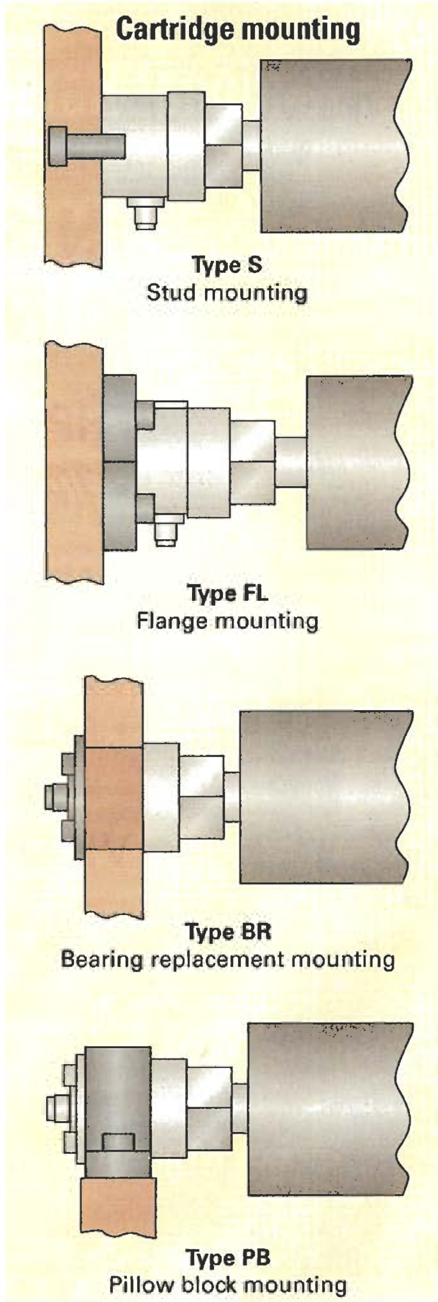
remains stationary. Stationary shaft rollers are also referred to as fixed or dead shaft rollers. They're used in many applications because they are relatively easy to manufacture and are readily available.

Narrow-web cantilevered rollers and pulleys generally use stationary shafts. Here, the most suitable transducers are designed so the web can be positioned anywhere along the length of roller face without affecting the tension measurement.

Cartridge-style and slim cell transducers are most suitable for wide web rollers with stationary shafts. The former comes with flange and pillow mounting kits. Low-profile designs, on the other hand, can be mounted inside or outside machine frames. Under pillow block loads, load cells with bearings are most suitable.

Rotating shaft rollers are designed so that the shaft is part of the rotating assembly. The outer shell or sleeve is integral to the shaft; there are no bearings in the assembly, and the shaft rotates.

Rotating shaft rollers are generally utilized for very high speed requirements, since they exhibit higher resonant frequencies than stationary shaft rollers. Large diameter roller construction (with typically large loads) favors rotating shaft rollers



Cartridge-style load cells can be mounted in a number of ways, making them convenient for a myriad of applications.

with pillow block bearings.

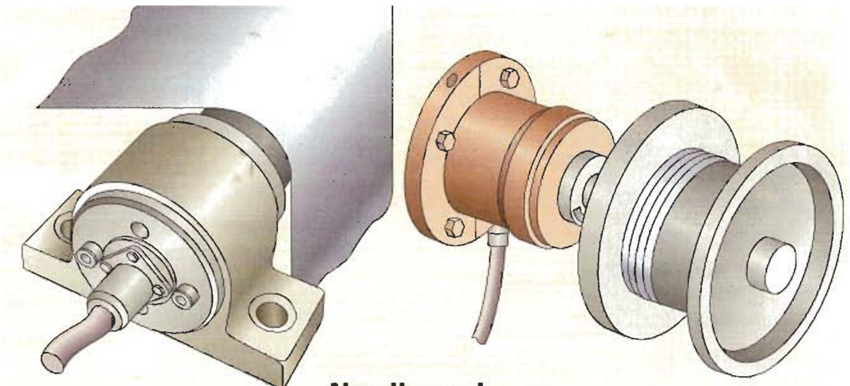
❸ Determine the proper tension. Many times, process or production engineers have a good idea of what running tensions should be. If these are not known, approximate the tension based on the thickness and type of material. Charts (as the one on page 16) can be used to approximate tensions. Tension is measured in lb per lineal inch, *PLI*. To determine the tension in the material, multiply the PLI by the width of the web. For example, nylon or cast propylene four mils thick requires approximately 1 PLI of tension: 0.25 lb/in./mil x 4 mil = 1 lb/in. To run a 60-in. wide web of propylene, a typical tension of 60 lb. is required: 1 lb/in. x 60 in. = 60 lb. To estimate load requirements for wide web transducers, use the running tension value. Ensure that the transducer you are considering is designed for this load.

❹ Determine space and mounting requirements. Slim transducers are better for tight spaces. Again, cartridge-style transducers offer a variety of mounting options — stud mount, bearing replacement, flange mount, and PB mount. Also check the roller shaft diameters that the load cell can accommodate. A split bushing may be required to accommodate smaller shaft diameters. You may need to turn down the ends of the roller shaft if it is larger than the load cell can accept.

❺ Determine environmental restrictions. Wet environments may require a corrosive and water resisting design. Chemical environments may require stainless steel or special coatings. Ensure that the transducer you are considering meets these requirements. In what temperature ranges will the load cell operate? Many load cells are temperature compensated so that the output does not change by more than 0.02% per °F from 0° to 200°F. Does the application require operation in a special atmosphere or vacuum? Special transducers are available for use in very high temperatures, special atmospheres, and vacuums.

❻ Select the proper load cell style. Review the load cell's data sheet and selection guide, and any other available information, and consult with your supplier for recommendations and tips on mounting and orientation for optimum performance. This is useful in determining the parameters required for sizing load cells to the proper load rating, which is the next step.

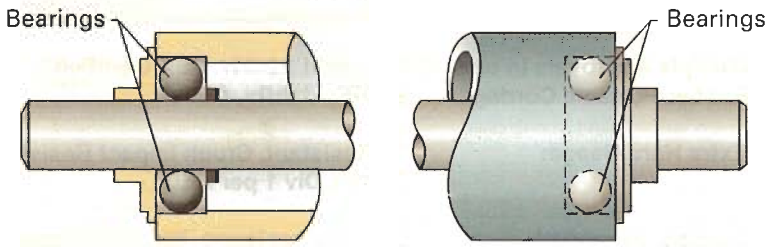
Stay tuned for the next installment of this series. For more information, visit cmccontrols.com.



Needing only one

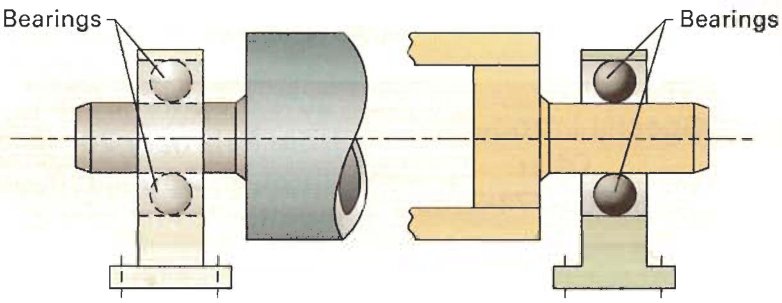
Left: On narrow webs, rollers are typically cantilevered — and the setup requires only one load cell. Right: Lines that spool wire or cable often run over pulleys. Again, only one cell (at the support) is needed.

Dead roller



On stationary rollers, the shaft stays put while an outer sleeve rotates around the shaft on bearings.

Live roller



Rotating shaft rollers are designed so that the entire shaft is part of the spinning assembly.