

Flexo Presswise – Tension Control

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Web Tension Basics

Tension is the “pull” in the web, or the force that is pulling the web through the machine. Tension can be measured by a variety of methods, and it can be stated in Pounds (of Force, Tension).

It is important to “quantify” tension by measuring it, so that it can be understood, controlled, and repeated from one job to the next.

Different units can be used to measure tension (grams, Kilograms, pounds etc) but for the purposes of this discussion we will refer to pounds. Despite the metric system making great advances in our industry, pounds and inches are still used for the most part in our day-to-day experience.

Just as you could weigh groceries or a fish with an old-fashioned spring scale, you can measure tension in the same way. If you hook up a spring scale to a web that is threaded through a machine, and you pull on the web by pulling on the scale, you can read the pounds of tension in the web by reading the scale. Of course, you can't do this while the machine is running, but fortunately we have other devices that measure the tension while the web is running through the machine.

Once we understand what tension is, and how to measure it, the next step is to figure out what it should be.

What should the web tension be?

Charts, graphs and tables of tension values are available from a variety of sources. The most common specifications for tension are stated in PLI – that is, Pounds per Linear Inch. This method of stating tension allows you to determine tension for a given material, regardless of how wide the material is. Therefore, if you run a web 20 inches wide or 80 inches wide, the tension per inch across the width should be the same. This is the “Linear inch” part of PLI. So if the specified tension is 2.5 PLI, then the web width (Say 20 linear inches) is:

$$2.5 \text{ PLI} \times 20 \text{ inches wide} = 50 \text{ pounds (total web tension)}$$

The chart accompanying this discussion has the various tension specifications broken down by type of substrate. For film such as Polyethylene, Mylar etc, the

PLI value is provided per .001” of thickness. In order to calculate total tension, an extra step is required:

- Example: 5 mil polyethylene, which is .005 inches thick
- Look up in chart: .25 PLI per mil of thickness
- In this example, 5 mil x .25 PLI per mil = 1.25 PLI
- Now multiply by the web width, say 40 inches wide
- 1.25 PLI x 40 inches wide = 50 pounds (total web tension)

For Paper tensions, check the “Basis Weight” which is stated in Pounds per Ream or Grams per square metre (GSM), then look up the correct PLI value.

For Paperboard tensions, check the caliper or thickness, then look up the correct PLI value.

What causes Tension to Change?

Tension will be effected by anything that is driven (Nip Roller, Motorized Roller, Belt Driven Roller etc) or any device like a brake on an unwind. Other things that effect tension are: Drying Tunnels (web heats up and stretches), Chill Rolls (web cools down and contracts), coating processes (lacquers, roll coaters) and rollers that are not “free running” (seized bearings, fixed turnbars etc)

Understanding Tension Zones

Web presses should be studied as a series of Tension Zones. A Tension Zone is a length of web between two places that can effect tension. For Example:

Unwind Zone to Infeed Roller

Infeed Roller to Printing Section

Printing Section to Outfeed Roller

Outfeed Roller to Rewind

It is important to understand what is the “Master Section” of the printing press. The Master section is the one that determines how fast the press will run. In most presses, it is the drive that runs the printing section. (for example, the CI drum and Bull Gear on a CI Press, or the Line Shaft and Impression Rollers on an inline Label Press). As you speed up or slow down the machine, the master is the one that is acted on first by the main drive, which is speeding up or slowing down.

Once you understand what the master is, then work towards each end of the press to understand the tension zones.

For example, if the master is the CI Drum, then follow the web path back to the unwind. If there is no other driven roller between the master and the unwind brake then this is the Unwind Tension Zone.

Simple Control Systems (Part 1 – Unwind Tension Zones)

Consider an unwinding roll as it feeds into the press. The goal is to supply the printing section with material at a constant tension. If an unwind brake is used to create tension, this brake must be set with the correct torque to give the desired tension. But as the Unwind Diameter gets smaller, the brake torque must be reduced to keep the tension constant.

No Control System – Operator Controls Brake Manually

In this example, the operator checks the web tension, then sets the brake pressure. As diameter gets smaller, operator continually checks tension and reduces brake pressure. Each time the operator checks the tension, he is getting Feedback about what the tension is, then he makes a decision about the next adjustment required on the brake.

Closed Loop Control System with Tension Load Cells

Instead of the operator adjusting the brake, the Load Cells measure the tension, and compare the actual tension to the desired tension. If the actual tension is lower than the desired tension, the brake pressure will be automatically increased. If the Actual tension is higher than the desired tension, the brake pressure will be automatically decreased. Each time the brake is adjusted by the controller, the load cells will tell the controller if the desired tension was reached. This is the feedback.

In the following drawing, the Closed Loop is made by the following sequence:
Brake puts tension on web → Load Cells measures Tension → Controller compares actual tension to desired tension → controller increases or decreases brake pressure by i/p converter → brake adjusts tension on web, and so on.

Closed Loop Control System with Dancer Roll

The Dancer Control does the same job as the above example, but with a different feedback. In this case, the feedback to the controller comes from the position of the dancer. If the dancer in the picture is too high, then tension is too high, and the controller knows that it must reduce the brake pressure. Likewise, if the dancer is too low, then tension is too low, and the brake pressure will be automatically increased. Each time the brake is adjusted by the controller, the dancer position will tell the controller if the desired tension was reached. This is the feedback.

In the following drawing, the Closed Loop is made by the following sequence: Brake puts tension on web → Web Tension pulls up against the counter-pressure air cylinder → Controller checks voltage on potentiometer to see if dancer arm is in middle of travel → controller increases or decreases brake pressure by i/p converter to get arm to middle → brake adjusts tension on web, which will correct the balance between counter-pressure air cylinder and web tension.

The big differences with dancer systems are as follows:

- There is no meter or gauge to tell you what the tension is.
- Dancer must be set up with correct counter-pressure for desired tension.

These two facts can make dancer systems difficult to understand and set up unless the relationship between counter pressure and desired tension is understood.

The printing press supplier or designer should provide a chart which relates the counter-pressure air cylinder to the web tension. If this is not provided, the press operator should document the air pressure that works for various materials, to build an understanding of the required pressure for desired tension.

Open Loop Control Systems

A simpler kind of tension controller does not have feedback to know if the desired tension was reached. These systems generally reduce the air pressure as the roll diameter gets smaller. They simply measure the roll diameter with an Ultrasonic Sensor or with a following arm that rides on the roll. The operator sets the starting pressure and then the controller reduces the pressure in the brake to account for the smaller roll diameter.

Simple Control Systems (Part 2 – Intermediate Tension Zones)

The above examples of Closed Loop and Open Loop Control Systems were referring to the simple example of an unwind where the roll gets smaller and the goal is to supply the web to the process at a constant tension.

Now let's consider a chill roller that is pulling the web through a drying tunnel after the printing section.

The chill roll can be driven by several methods. Printing Presses with line shafts will drive this chill roller via a special gearbox or differential, commonly called a PIV. The PIV can be adjusted to make the chill roller run a small percentage faster or slower than the master printing section. If the PIV is adjusted to give the same output speed as input speed, then the chill roll will run the same speed as the printing section. However, if the web is relaxing in the heat of the drying tunnel, you may need the chill roller to run faster than the printing section, to keep a suitable tension.

The control of the PIV to get the desired tension, can be carried out by a closed loop control system.

On newer printing presses, the PIV has been replaced by a DC or AC variable speed motor and drive.

In either case, the control can be the same. The chill roll drive follows the speed of the master printing section (by line shaft or encoder speed matching) and the speed is then "trimmed" by a tension controller, which measures tension in the zone (feedback) and corrects the speed of the chill roll until the desired tension is achieved.

Simple Control Systems (Part 3 – Rewind Tension Zones)

The rewind is usually controlled by a DC or AC variable speed motor and drive. Once again, this motor and drive is following the speed of the master printing section. However, due to all the other things effecting web tension, such as heating, cooling, friction etc, the rewind needs to be controlled with respect to tension, not just the speed of the machine. The tension control on a rewind works on the same principle as the unwind. A closed loop controller will check the tension in the rewind zone, and adjust the motor to pull with more or less torque, depending on the desired tension. The major difference between unwinds and rewinds is the concept of Taper Tension.

Taper Tension

Recall that on the unwind, we supply the master printing section with material at constant tension. However, if we wind up material with constant tension, we can

have problems with our roll quality. The problem is that the outer layers of the roll will wind up tighter than the inner layers. This causes a pressure imbalance in the roll, and the roll may telescope or crush the inner layers.

To solve this problem, an extra control parameter is added to the system that controls the tension. The taper tension is expressed as a percentage of the total tension. If the desired tension is 100 lbs and a taper of 10% is input, then the roll will start out winding at 100 lbs, but by the time the full diameter is reached, the tension will have been reduced by 10% to 90 lbs.

Dancer vs Load Cell

Rewind tension control can have feedback from a dancer or a load cell. The same advantages and disadvantages can be found here, as on the unwind. Once again, they can be tabulated as follows:

Control Type	Advantage	Disadvantage
Load Cell	Clear readout of actual tension	No shock absorbing effect of dancer
Dancer	No actual measurement of tension	Moving arm allows forgiveness for imprecise drive mechanics. Inertia or poor adjustment is difficult to correct/troubleshoot.

Troubleshooting

The topic of troubleshooting can be complicated, and it touches on all of the above concepts and many more. For purposes of this short presentation, the simplest form of troubleshooting is to take a controller out of its “Automatic Mode” and revert to our example above, where the operator is the control system. If the operator can control the process manually, but the automatic mode causes instability and problems, then the problem is likely in the tuning of the controller or the feedback device. If the process cannot be controlled in manual, then there is likely a mechanical problem or breakdown of one of the other systems on the machine. This basic troubleshooting exercise can pinpoint many problems in the systems that relate to tension.

Understanding Relationship between Tension Control and Quality

As printers strive for repeatable, documented procedures to achieve the best quality, tension control should be understood as it relates to the overall job. The operator should be able to quantify what the tension should be in each zone, and then have a method to set this tension every time the job is run. Similar jobs will benefit from past experience of what works for various substrates. This requires documenting what the tension was to get best results on a given job, and how the machine was set up to achieve these tensions.

Without clearly marked controls, calibrated meters and documented tension values, the job will be very difficult to produce with consistent, high quality.

Background Information – How do tension load cells work?

Tension load cells use sensitive measuring devices called strain gauges, to measure force. The strain gauge has an electrical resistance that will change as force changes. This changing resistance will cause a voltage change which can be related to tension. Therefore, the load cell must be calibrated so that a control system can relate voltage to desired tension.

For example, if the maximum tension for a machine is expected to be 100 lbs, the load cells will be calibrated so that 10 Volts output is equal to 100 lbs. The relationship will hold for all tensions then, so that 5 Volts is equal to 50 lbs, and so on.

The calibration procedure usually requires that a rope is threaded over the tension sensing roller in the same path as the we would follow, so that the geometry of the web path is accounted for in the calibration. Then, a known weight is hung on the rope and the desired voltage is set y the technician.

The following sketch is a representation of how the load cells operate: