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Web Processing & Finishing Technologies

Slitting: From knives to winding to finished-roll discharge

2014 Quarter 2

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Controlling web tension with differential shafts

By Sean L. Craig, global product manager, Maxcess Intl.

Introduction

Your web is schizophrenic. Whether it is film, foil, non-woven or any other variety of substrate, your web has multiple personalities, characteristics and properties, each of which affects the quality and structure of your finished roll. Properties of your web include porosity, strength, flexibility, extensibility and compressibility.

You account for these characteristics by applying the TNTs of winding – tension, nip and torque – to ensure your finished product meets the rigorous expectations of your customers (see Figure 1). You apply taper tension so that each roll has a hard start or foundation, a smooth transition and then a soft finish. You may apply a nip or lay-on roll to remove entrained air and pack your rolls adequately. Yet, in spite of all your efforts, the finished package for your customer – your wound roll – is unacceptable. The symptoms include: loose edges, baggy lanes, telescoping or dishing rolls, starring, loose or excessively tight rolls.

A cause of wound-roll defects

The reason your efforts are for naught is that the cause of these defects lies not in your upstream process and controls, but in each individual roll as it is building. Caliper or gauge variation in your web combined with the properties of the material you are running allow the effect of this variation to rear its ugly head in wound-roll defects.

Consider what happens to a web in any given process. You start with a parent roll of material that you hope meets the quality standards you expect of your supplier. But even so, that roll is quite diverse in its makeup. Depending on the material, there will be variation in thickness and quality across the web. Then you run it through your process

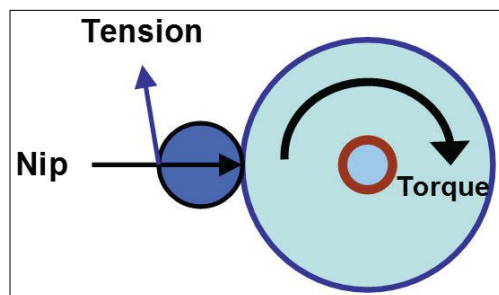


FIGURE 1. TNTs of winding

Web Length	Thickness 0.0019		Thickness 0.0020	
	Actual Ø - Roll 2	RPM	Actual Ø - Roll 1	RPM
0	4.0	955	4.0	955
689	6.0	637	6.1	628
2894	10.0	382	10.2	374
6201	14.0	273	14.3	266
8267	16.0	239	16.4	233
13228	20.0	191	20.5	186
20978	25.0	153	25.6	149
30451	30.0	127	30.8	124

TABLE 1. Effect of material thickness on winding RPM

where you may coat it, laminate it, print on it, emboss it or do any number of other processes. After this, you then slit it into multiple webs and wind it up into a package – a wound roll. At this point, you have taken that web in all of its diversity, personality and character, and have split it up into individual rolls. Your expectation is that each roll will behave the same; however, subtle differences in the portion of the web running into each roll begin to affect how the roll is building, which leads to differences in wound-in tension for each roll.

Compensating for these differences requires more than simply adjusting tension. You need to understand what effect your diverse web is having on how the roll builds and what factors need to be controlled to compensate for this effect.

Controlling web tension begins with a taut web created by tension zones throughout the process line. These zones are designed to ensure consistent tension across the entire web. But the single web passes through the slitters and becomes multiple webs feeding into individual rolls, which you are trying to control with the same system used for the web prior to the slitters – only now the various characteristics across your web are being isolated into each respective lane. One of the most common characteristics in the web is caliper variation, and it is this variation that causes many of the wound roll defects in finished rolls.

Table 1 illustrates what's going on. When you slit a web with caliper variation, each roll now begins to build at a different rate, which in turn affects both the speed of the roll and the tension in

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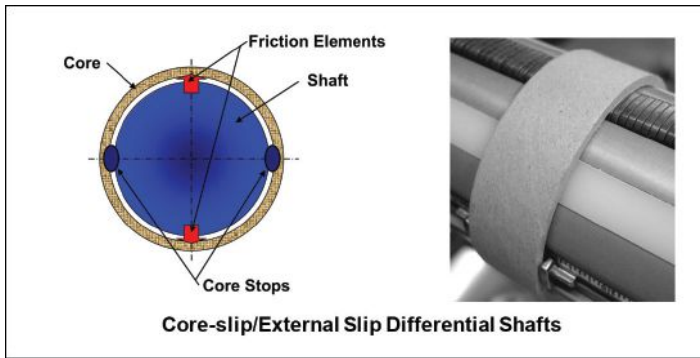


FIGURE 2. Core-slip differential shafts

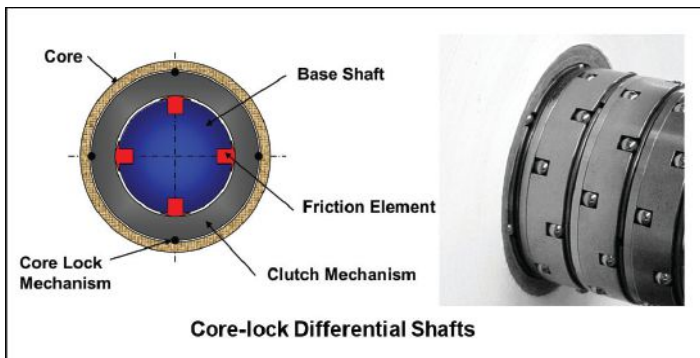


FIGURE 3. Core-lock differential shafts

the roll. To wind an equal amount of 0.0019-in.-thick material on Roll 2 and 0.0020-in.-thick material on Roll 1, Roll 1 will eventually be at a greater diameter than Roll 2. The result is that the revolutions required to build each roll uniformly begin to differ. If you maintain the RPM needed to wind Roll 2, Roll 1 will become increasingly tight. If you maintain the RPM to wind up Roll 1, Roll 2 will become increasingly loose.

Now, introduce the variable of controlling tension. Tension is equal to the torque required to rotate the roll divided by the radius of the roll. If Roll 1 is building at a different rate than Roll 2 and has a different radius, it will be impossible for the tension between the two rolls to be equal. Therefore, to accurately overcome the effects of caliper variation in the web, you must not only control the speed of each roll relative to its position in the wind cycle, but you also must control the tension in each entering web lane to ensure the desired wound-roll tension required for the material. And because these effects differ from roll to roll, you must control these two variables at each roll.

Differential winding is a tool that helps you achieve that level of control. It is the process of winding each independent roll at the speed and tension appropriate for each diameter roll and entering web length. It achieves this by varying the torque applied to the core on which the product is wound and by allowing the roll to slip through reduced torque when tension in the roll increases above the set point.

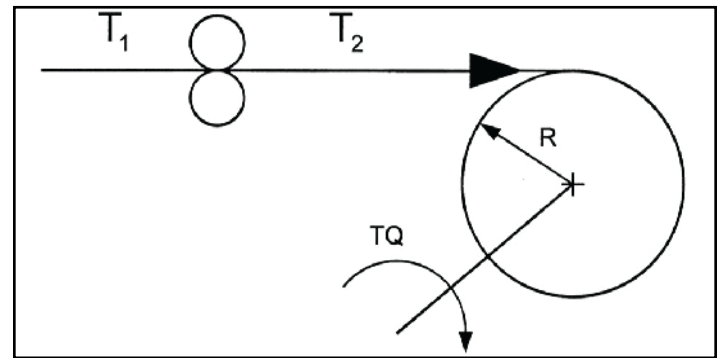


FIGURE 4. Differential shaft as a tension-control device

Differential shaft technology

Pneumatically-controlled differential shafts – also called friction shafts – allow each roll to slip on the shaft as the roll is building. Unlike a lock-bar shaft that transmits enough torque through an expanding element to keep the rolls from slipping, a differential shaft applies only enough torque through the expanding element to maintain the tension required at a given roll diameter.

There are two types of pneumatic differential shafts: core-slip and core-lock – also called external slip and internal slip shafts. Core-slip shafts rely on the core to slip about the diameter of the shaft (see Figure 2). Because the core is allowed to slip radially, these shafts also employ some form of core stop to prevent the core from slipping laterally. The primary advantage of the core-slip design is greater load-carrying capacity. They are more readily available for odd-size and larger-diameter cores. The tradeoff with this design is that, depending on the quality of the core, some dust can be generated from the slip action. In addition, tension control is heavily dependent on core quality.

Core-lock shafts have some mechanism or cartridge that locks onto the core (see Figure 3). The core and the cartridge rotate about some base shaft that transmits a radial force to control tension. Because the cartridge locks to the core, these designs do not require a secondary stop to prevent the core from moving laterally. The primary advantage to this design is that no dust is generated by the core. These designs typically provide the best quality roll builds. Tradeoffs of this design include: they have limited load-carrying capacity due to the inner-shaft diameter, and they are typically available only for more common core sizes.

Both designs use the same principles for controlling tension in the wound roll. They use “torque control,” where the required torque (tension) is achieved by adjusting the tangential force between the core/cartridge and the tension elements. This tangential force depends on the contact pressure (created by air pressure) and the dynamic coefficient of friction, which means the roll and shaft must be slipping relative to each other.

Basic differential shaft operation

Core-slip differential shafts: These designs have two or three air

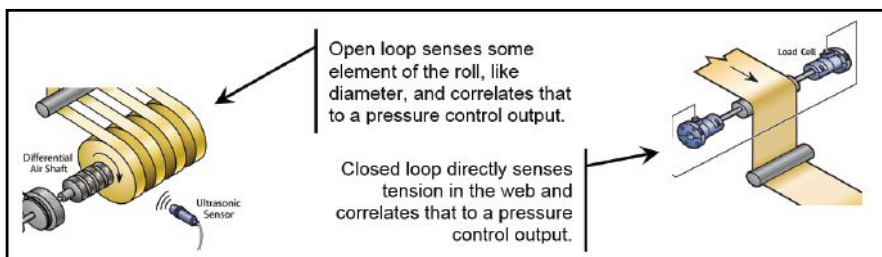


FIGURE 5. Open- and closed-loop tension control

circuits. One air circuit controls the tension segments, one air circuit raises the core-stop tray and one controls the individual core stops in the core-stop tray. This final function can be done mechanically.

Core-lock differential shafts: These designs typically require only one air circuit to control tension via air pressure underneath the cartridges.

Controlling tension and speed in a differential shaft

Over-speed and differential winding: Differential shafts use the principle of slipping the roll relative to the shaft combined with air pressure to help control tension. This slippage is equally important for controlling roll speed relative to the shaft. As we

consider tension, air pressure and over-speed, what you will see is that none of them operate in isolation to solve the challenges presented by your web. These controls must be considered in relation to one another.

Rolls building at different diameters rotate at different speeds. By allowing one roll to slip relative to the next, you can build rolls at their correct rotational speed. Furthermore, by creating a system in which every roll is dynamic and

slipping relative to the base shaft, you have optimal and equalized tension control. With differential shafts, this is done by over-speeding the shaft relative to the building rolls. By applying only enough air pressure to maintain the torque necessary for the desired tension and by driving the shaft a small percentage faster than the fastest rotating roll, the core will slip on the shaft. This creates dynamic friction in which all the rolls are slipping continuously throughout the roll build.

Air pressure and tension control: Because a differential shaft is a tension-control device, the principles of controlling the tension in the web through a differential shaft are the same as those used to control tension in the web under any other process (see Figure 4). To maintain constant tension (T) in a given application,

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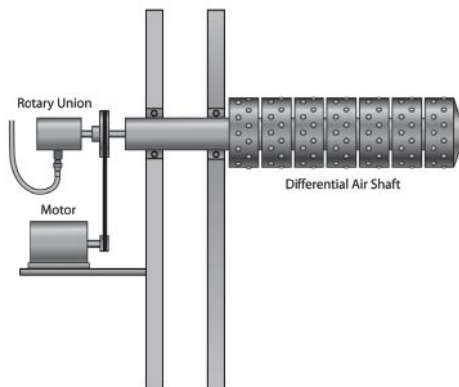


FIGURE 6. Air pressure to differential shaft

we must increase torque (TQ) as the roll diameter (R) builds. For a differential shaft, this increase in torque is controlled by air pressure to the shaft. To control tension, there must be some form of feedback to the shaft that results in a change in air pressure corresponding to the desired tension. Two types of tension-control systems help you achieve this: Open-loop or closed-loop.

Open-loop tension control: In an open-loop system, there must be some form of measurement that controls air pressure into the shaft (see Figure 5). The most common is an ultrasonic sensor that measures the diameter of the roll and gives feedback to a controller that provides an output, which is converted to air pressure via a current-to-pressure transducer.

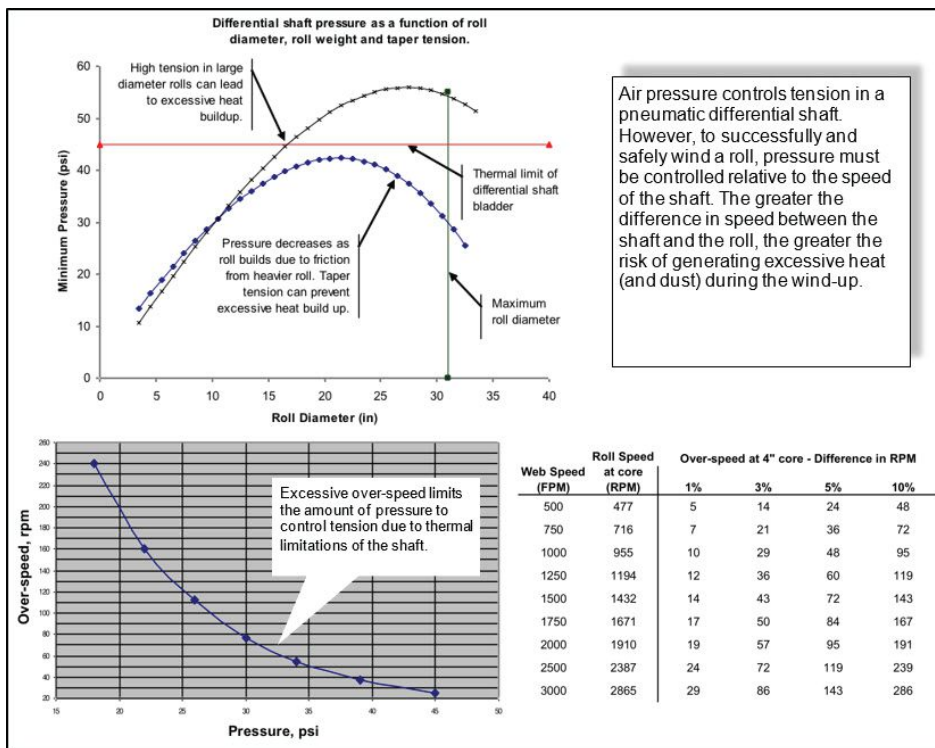


FIGURE 7. Differential shaft pressure as a function of roll diameter, roll weight and taper tension

Closed-loop tension control: In a closed-loop system, there must be some means of measuring tension directly and converting that feedback into air pressure to the shaft (see Figure 5). The most common way to do this is to use a load cell to measure tension in the web with the feedback to a corresponding controller that provides an output, which is converted to air pressure via a current-to-pressure transducer.

Air pressure to the differential shaft: To maintain constant tension in the building-roll differential shafts requires continuous air, which is typically delivered through a single- or dual-port rotary union (see Figure 6). Air pressure to the differential shaft can be

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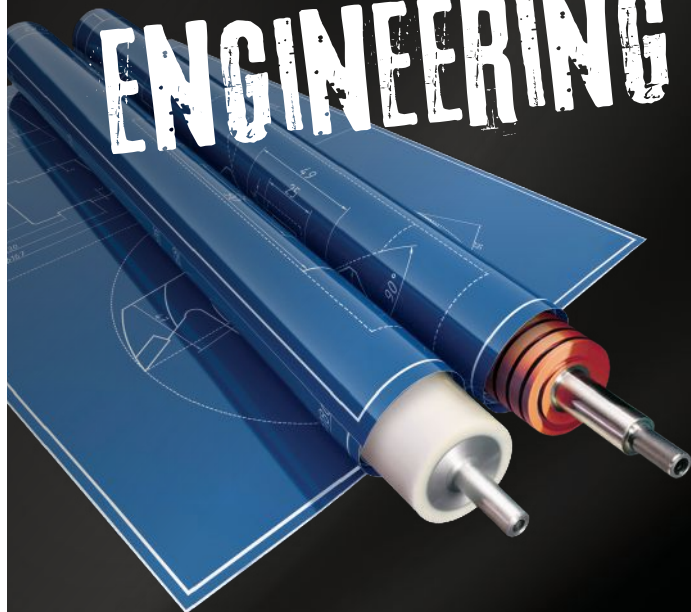
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controlled manually through the machine interface or through the tension-control system.

Because the differential shaft is now controlling the tension in the web, as the roll diameter builds the pressure to the shaft will change. However, this is not a linear relationship. As the roll builds, the weight of the roll also contributes to the friction between the tensioning elements and the inside of the core or cartridge. As a result, the amount of pressure required to achieve the desired tension will plateau and eventually will decrease depending on the density of the material. This effect is usually greater on core-slip differential shafts because the core is the primary contact point for the tensioning elements, and the resultant coefficient of friction is greater. Data in Figure 7 illustrates this principle.

An important consideration related to controlling air pressure to the differential shaft is the effect of speed and pressure on heat and dust generation from the shaft. Differential shafts act very much like a clutch, whether they are a core-lock or core-slip design. Core-slip designs rely on friction between the core and the tensioning element, and excessive pressure and speed difference between the core and the shaft can lead to dust and heat buildup. While less dust is generated with the core-lock design, heat buildup is still a concern. Therefore, it is important to manage the speed of the shaft relative to the speed of the roll. Typical over-speed should be between 1-3 percent.

Conclusion

Differential winding is one more tool to carry in your web-handling toolbox. By properly managing air pressure and roll speed, you can offset the effects of caliper variation and other web properties to ensure you build good-quality rolls every time. ■

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