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## Recommended tensions in dryer fabrics

### Scope

The purpose of the Technical Information Paper is to provide guidelines for selecting operating tension for dryer fabrics on paper machines.

### Safety precautions

The operating fabric tensions should not exceed those recommended by the fabric supplier or the fabric tension rating of the papermachine components. An active fabric tensioning system should be used. The movement of the tensioning roll should not be restricted or locked in position. Catastrophic machine component failures could result, as well as fabric seam line and permeability profile distortion.

### Utility

Dryer fabrics are used on paper machines to hold paper in close contact with dryers to increase the rate of heat transfer. Dryer fabrics are also used on many paper machines to provide paper web support and to transmit power to drive dryer sections. Dryer fabric tension also provides some resistance to shrinkage of the paper web.

Excessive tension in dryer fabrics, however, can cause damage to fabrics and paper machinery with no practical gain in drying capacity, driveability, or shrinkage restraint. Selection of appropriate fabric tension values is therefore of practical importance.

### Discussion

Several factors affect the fabric tension requirement. Among these are mechanical factors, quality factors, and drying factors. All three are related to the paper machine equipment and the grade and condition of paper being dried.

Mechanical requirements such as fabric guiding, fabric deflection, prevention of fabric wrinkles, and driving requirements prohibit use of exceptionally low fabric tensions. In most cases, fabric tensions below about 0.7 kN/m (4 pli) are too low. Dryer drivability continues to increase with fabric tension, but fabric tension quickly reaches a value that is adequate for the application. Fabric tensions, however, may have to be increased to 3.5 kN/m (20 pli) or more on high-speed machines in order to prevent the fabrics from deflecting into devices such as blow boxes and vacuum boxes that are used to control sheet runnability.

Sheet quality can also be affected by fabric tension. Quality effects include paper shrinkage, fabric marking, and sheet cockle. Paper tends to shrink in the cross-machine direction and cockle as it is dried. Increased fabric

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tension can reduce that portion of the shrinkage that occurs while the web is in contact with dryer surfaces. Reduced shrinkage has been found to improve sheet strength properties and reduce tendency for curl and cockles (5-6). Most of the shrinkage, however, occurs while the sheet is moving between dryer cylinders, so fabric tension alone cannot eliminate sheet shrinkage.

Increasing fabric tension can cause problems. The fabric can mark the sheet surface, especially at the fabric seam location. The marking is affected by fabric tension, fabric construction, paper grade, and sheet moisture content. Increased fabric tension typically makes a fabric mark more pronounced. When seam marking occurs, however, reducing fabric tension will generally not eliminate the mark.

Increased fabric tension can also contribute to stress and flexing of paper machine rolls. This may lead to severe fabric (trade line) distortion and localized variation in fabric permeability. These permeability variations may cause uneven drying and sheet marking.

Heat transfer (drying rate) increases with increasing fabric tension due to improved thermal contact between the paper and dryer surfaces. Heat transfer only improves, however, up to a certain point. Above that point, gains in heat transfer are minimal. This TIP focuses on this point.

Beyond certain values, gains in heat transfer, restraint, and drivability do not justify use of higher tensions. Higher tensions tend to shorten fabric life, cause fabric narrowing, seam bowing, and permeability variation, increase bearing and drive loads, and cause excessive deflection of fabric rolls. Some fabrics are heat-set by the supplier to run at a specified tension. Operation at other tension levels may cause problems with fabric runnability and tight or loose fabric edges.

Operating a dryer section with fabric tensions in excess of the machine design limit can cause serious damage to felt rolls, fabric tensioning equipment, and other equipment.

## Theory

A tensioned dryer fabric applies a pressure to the wet web as the fabric wraps the dryer surface. The pressure exerted by the fabric on the web is given by the following equation:

$$P = 2T/D \quad (1)$$

Where  $P$  is the contact pressure,  $T$  is the fabric tension, and  $D$  is the outside diameter of the dryer.

The contact pressure that the wet web exerts on the dryer surface is increased further by the tension in the wet web itself. The contact pressure may be reduced by the tendency for the web to “float” on the dryer surface. This tendency to float can be the result of entrained boundary layer air or the pressure developed by water vapor that is leaving the web surface as the web is dried.

The web tension is produced by machine draws and by the natural tendency for the web to shrink as it approaches the end of the dryer section. The web tension will be greatest near the dry end of the machine, so fabric tension will play a smaller role in heat transfer at the dry end, particularly for heavy weight grades.

With low fabric and low web tensions, the wet web may tend to float off the dryer cylinder due to the pressure that builds up from water evaporation, particularly with impermeable webs and high dryer surface temperatures.

Boundary layer air is pumped into the space between the paper web and dryers by these two surfaces as they approach each other. This effect is more pronounced at high speed. The air pressure in the space naturally increases as the surfaces move closer together. The air pressure tends to force the entrained air back out of the space and also tends to lift the paper web off of the dryer surface. This lifting tends to cause the web to lose contact with dryer surfaces, reducing both heat transfer and dryer drivability.

One objective of fabric tension is to squeeze air and water vapor from the space between the paper web and dryers. A tensioned fabric exerts pressure on the paper and on the space between paper and dryer. Higher fabric tensions and smaller dryer diameters decrease the tendency of the paper web to lose contact with dryer surfaces.

The paper permeability also affects the level of fabric tension required for optimum drying. If a major part of the air and water vapor trapped under the paper web can bleed through the web and fabric with little resistance, higher levels of tension will be of little value in reducing the separation of the paper web and the dryer surface. On the other hand, if the paper has a very low permeability, the amount of separation will tend to increase and higher fabric tensions may be of some value.

Boundary film conditions in the ingoing wedge-shaped space between a smooth roll and a smooth impermeable web under tension have been described by Riddiford (1,2). The residual thickness of air film between roll and web beyond the wedge area is given by the following equation:

$$H = 0.75D \left[ \left( \frac{\mu S}{T} \right) \left( \frac{3\pi\sqrt{2}}{4} \right) \right]^{2/3} \quad (2)$$

in which  $D$  is again the roll diameter,  $\mu$  is air viscosity,  $S$  is machine speed, and  $T$  is the combined fabric and web tension (using appropriate dimensional units, per Ref. 1-2). An interesting aspect of this theoretical study is air between an impermeable web and roll surface cannot be totally eliminated, since infinite tension is required to reduce  $H$  to zero.

The theoretical tension required to reduce the air film to a given value can be obtained by rearranging Equation 2 as follows:

$$T = 2.2 \mu S \left( \frac{D}{H} \right)^{1.5} \quad (3)$$

This relationship shows that the tension needed to produce a fixed air film is directly proportional to machine speed and varies with roll diameter to the 1.5 power. Thus, a 1.52-m (60 in.) roll should need about 40% more tension than a 1.22-m (48 in.) roll, and a 1.83-m (72 in.) roll needs about 31% more tension than a 1.52-m (60 in.) roll.

## Experimental results

The effects of fabric tension on 1.52-m (60 in.) dryers on newsprint machines were measured by Belanger and Anderson (3). They found that condensing rate, a direct measure of heat transfer, increased with fabric tension to a certain level beyond which no further gains could be measured.

Anderson's data for a dryer (No. 20) on a machine running at 747 m/min (2450 ft/min) indicated that no significant increase in heat transfer could be obtained with fabric tensions exceeding about 1.3 kN/m (7.5 pli). Belanger's data for a dryer (No. 10) on a machine running at 683 m/min (2240 ft/min) showed no significant increase after fabric tension reached 1.1 kN/m (6.0 pli).

For reference, theoretical air film thickness in the case of Anderson at a tension of 1.3 kN/m (7.5 pli) is 0.08 mm (0.0032-in.) for an impermeable web. In the case of Belanger at a tension of 1.1 kN/m (6.0 pli), it is 0.09 mm (0.0036-in.).

Roughness of the paper surface may also affect the level of tension required for optimum drying. Recent data (7-8) indicates that heat transfer can be increased for rough paper with fabric tensions above normal values. This is a result of void areas being reduced by fabric pressure.

Increasing fabric tension, however, does not continuously increase the overall heat transfer. One reason is that paper is not impermeable. The air film bleeds out through the paper web under the pressure exerted by the tensioned fabric.

As the air film thickness decreases, other thermal resistances (condensate, scale, dryer shell, etc.) become controlling resistances. Paper with low permeability (coated paper or highly refined grades) requires higher fabric tension levels than paper with high permeability to produce minimum air films.

More recent studies (7-12) have indicated that the effect of fabric tension can still be significant at higher levels than previously reported, but with the effect of the tension levels decreasing above some plateau. Comparison of these results can be difficult due to differences in roll diameter, paper grade, testing procedures, and moisture content.

Tests on the effect of fabric tensions on newsprint, fine paper, and linerboard were reported by Lang (13-14). The drying rate was found to increase by approximately 15% when the fabric tension was increased from 1.8 to 2.8 kN/m (10 to 16 pli) on a newsprint machine with 1.8 m diameter dryers running 1250 m/min. Laboratory simulations indicated a 5% increase over the same change in fabric pressure. The maximum drying rate was achieved at a fabric pressure around 3 kPa. This corresponds to a fabric tension of 2.25 kN/m (12.8 pli) for a 1.5 m (60-in.) diameter dryer and to a fabric tension of 2.7 kN/m (15.4 pli) for a 1.8 m (72-in.) diameter dryer.

The drying rate was also found to increase by approximately 15% on a fine paper machine when the fabric tension was increased from 2.1 to 3.7 kN/m (12 to 21 pli) with 1.8 m diameter dryers running 1255 m/min. The