Driveability of a dryer section using dryer felt drives

Francis X. Swietlik III

As paper machines become wider and faster, the practice of driving a dryer section through the dryer felt becomes more complex. The driveability of the dryer-to-dryer felt interface becomes critical, as does the dryer felt tension throughout the felt loop.

In the conventional papermaking process, the wet paper web is dried by alternately passing it over and under cast iron, steam-heated cylinders. The web is pressed against the cylinders by tensioned dryer "felts" or fabrics (the terms are used interchangeably), and the entire section of cylinders is driven by a series of interconnecting gears.

As the operating speed of a paper machine is increased, a number of problems begin to develop with the dryer gears. This is particularly true of older machines when the speed is increased above the original design speed.

In response to these developing problems, an alternate method of driving the dryer section was developed in 1984 (*1, 2*). The interconnecting dryer gears were eliminated and the dryer felt was used to drive the dryers as well as apply pressure to the paper web.

The first complete commercial installation of this drive design was started up in late 1984 (*3, 4*). In this installation, the felts were driven by intermediate felt rolls. All of the dryers were driven by the dryer felt.

The top felt was used to drive the top tier of dryers, the bottom felt was used to drive the bottom tier of dryers, and the two tiers were synchronized by a digital electronic reference.

With the elimination of dryer gears, there was a marked reduction in gear noise (*5*), and the concept was dubbed the "Silent Dryer"® drive.

Although the application of the Silent Dryer drive is quite simple in concept, there are a number of pitfalls which must be avoided. The driveability of the dryers is a complicated function of machine speed, paper properties, felt construction design and transient loading, and number and location of drive points.

This paper presents a brief overview of the advantages of the Silent Dryer drive concept and highlights some of the important mechanical variables with simplified drive belt equations.

Swietlik III is product line engineer, electric drive, at Beloit Corp., 1 St. Lawrence Ave., Beloit, Wis. 53511.

Dryer section driveability

Silent Dryer drives power the dryer section through the fabric. The conventional main section drive and dryer gear train are replaced with several smaller drives. These driven rolls transmit power through the fabric to the undriven rolls, as illustrated in **Fig. 1.**

One of the keys to a successful Silent Dryer drive installation is to provide the minimum number of drives to satisfy the power requirements of the system without exceeding the driveability of any driven roll-to-fabric interface.

Another key consideration is the maximum tension level in the fabric loop. The maximum tension levels in the loop affect not only driveability but also the bending stress levels produced in the dryer felt rolls.

The maximum power that can be transmitted by a dryer section roll to a dryer felt without slipping is dependent on:

1. The angle of wrap by the fabric on the driven roll
2. Material factors (e.g., coefficient of static friction)
3. The tension of the fabric at the outgoing side of the driven roll (slack side tension).

The angle of wrap between the fabric and roll is a constant, determined by the paper machinery builder. The following relationships, as shown in **Fig. 2**, can be used to determine the maximum tension differential in a fabric across a roll at the point of slipping. These relationships can be used to determine the maximum allowable horsepower input to a given roll.

$$T_2 = T_1 e^{\mu\alpha} \tag{1}$$

where

T_2 = Tight fabric tension (pli)

T_1 = Slack fabric tension (pli)

μ = Coefficient of static friction (dimensionless)

α = Angle of fabric wrap (in radians).

The fabric tension differential can be expressed by:

$$\delta T = T_2 - T_1 = T_1(e^{\mu\alpha} - 1) \tag{2}$$

where

T = Tension differential (pli or lb/in. fabric width).

The horsepower input at a given tension differential can be expressed by:

$$hp = \delta T WS/ 33000 \quad \text{(Horsepower)} \quad (3)$$

where

W = Fabric width (in.)

S = Machine speed (ft/min).

An important point to note is that the driveability equations are independent of roll diameter. This fact opens the possibility of driving the dryer felt rolls and eliminating all gearing in the Silent Dryer drive scheme.

Felt roll driven dryer example

The determination of whether to drive the felt rolls or to adapt a dryer mounted gear case to several dryer cans is based on the driveability of the driven rolls and the tension levels that occur throughout the fabric loop. **Figure 3** illustrates a possible arrangement for a felt roll driven dryer section.

Taking as an example a 300-in. wide machine geared in at 4000-ft/min machine speed with 72-in. diameter dryers, the normal running load (NRL) and recommended drive capacity (RDC) for the dryer section per TAPPI recommendations on a "per dryer" basis would be:

NRL = 0.0012 hp/in./100 ft/min × 4000 ft/min/100 × 300 in.
NRL = 14.4 hp
RDC = 0.0035 hp/in./100 × 4000 ft/min/100 × 300 in.
RDC = 42 hp/dryer

Typically, there are two to three felt rolls per dryer in a section, depending on the number of dryers in that section. The TAPPI normal running load and recommended drive capacity for each dryer includes a factor for these felt rolls.

An approximate value for the NRL of each felt roll is 0.0002 hp/in. width/100 ft/min, and the RDC for each felt roll can be approximated at 0.0004 hp/in. width/100 ft/min.

NRL = 0.0002 hp/in./100 ft/min × 4000 ft/min/100 × 300 in.
NRL = 2.4 hp
RDC = 0.0004 hp/in./100 ft/min × 4000 ft/min/100 × 300 in.
RDC = 4.8 hp

The above information can be used to calculate the normal running load and recommended drive capacity for each component in the dryer section. Subtracting the felt roll hp from the section hp per dryer gives the hp for a single 72-in. dryer.

Normal running load = 14.4 hp - (2 × 2.4)hp = 9.6 hp
Recommended drive capacity = 42 hp - (2 × 4.8)hp = 32.4 hp

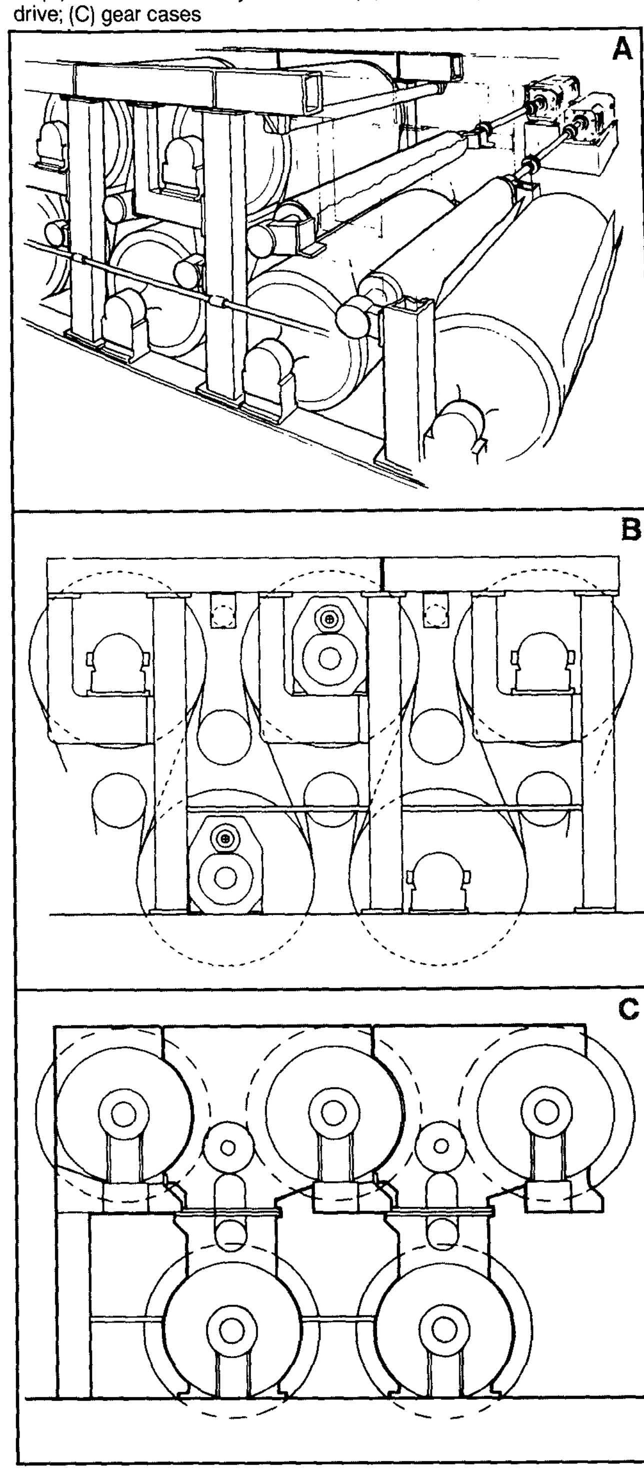
These values can be used to calculate the total section motor horsepower. Using a section as shown in Fig. 3, together with the example machine, the RDC is calculated as follows:

$$RDC = (6 \text{ dryers})(32.4 \text{ hp/dryer}) + (17 \text{ felt rolls})(4.8 \text{ hp/felt roll})$$
$$RDC = 194.4 \text{ hp} + 81.6 \text{ hp} = 276 \text{ hp total} \quad (4)$$

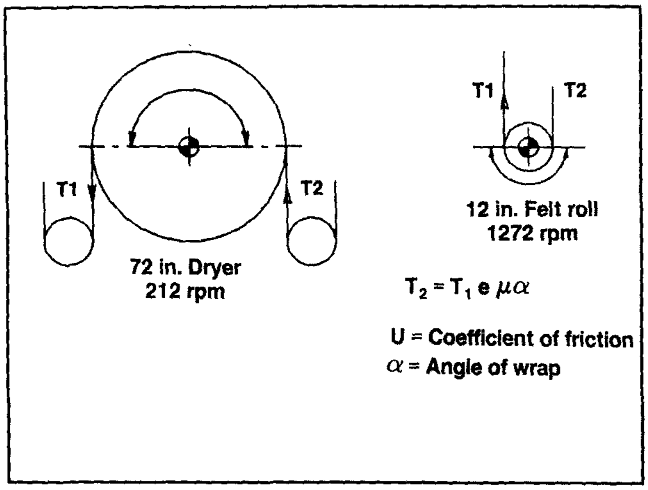
To determine the minimum number of drive points, the driveability of the driven roll must be determined and compared to the motor horsepower that would be chosen.

Either a felt roll or a dryer with a large angle of wrap should be chosen as the roll (or rolls) to be driven. For

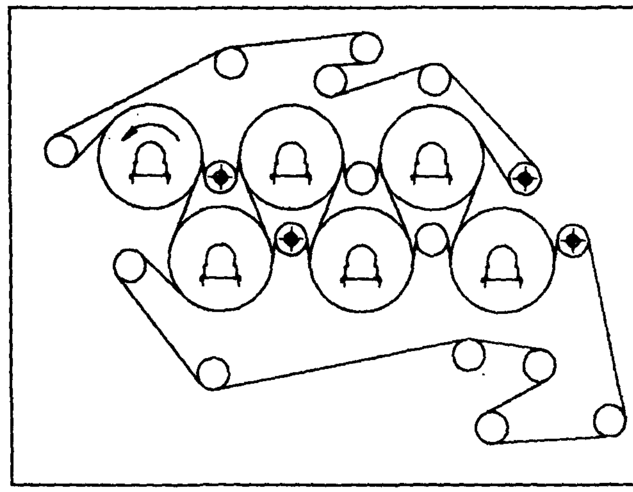
1. (A) Felt roll driven dryer section; (B) driven dryers—Silent Dryer drive; (C) gear cases



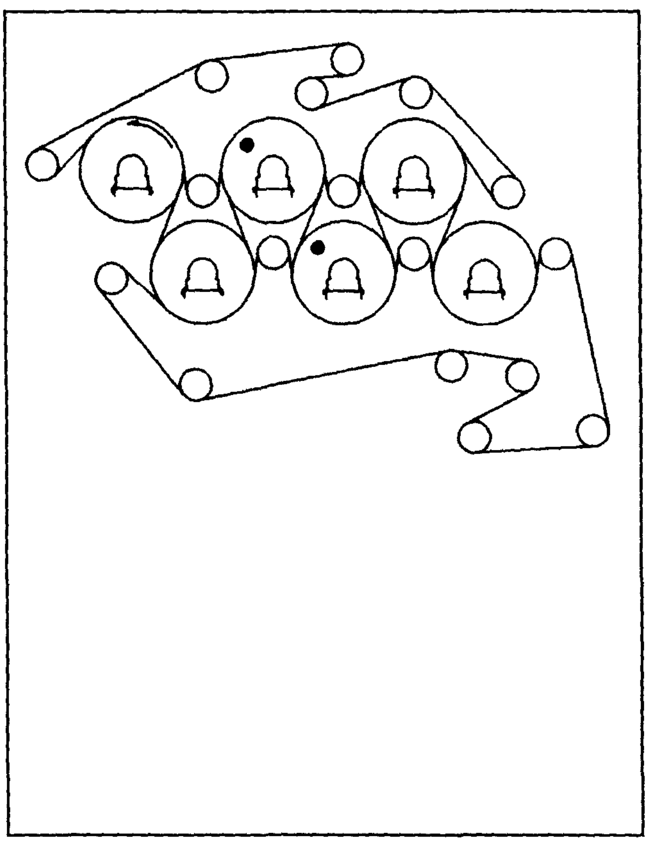
2. Roll speed and driveability, 4000 ft/min



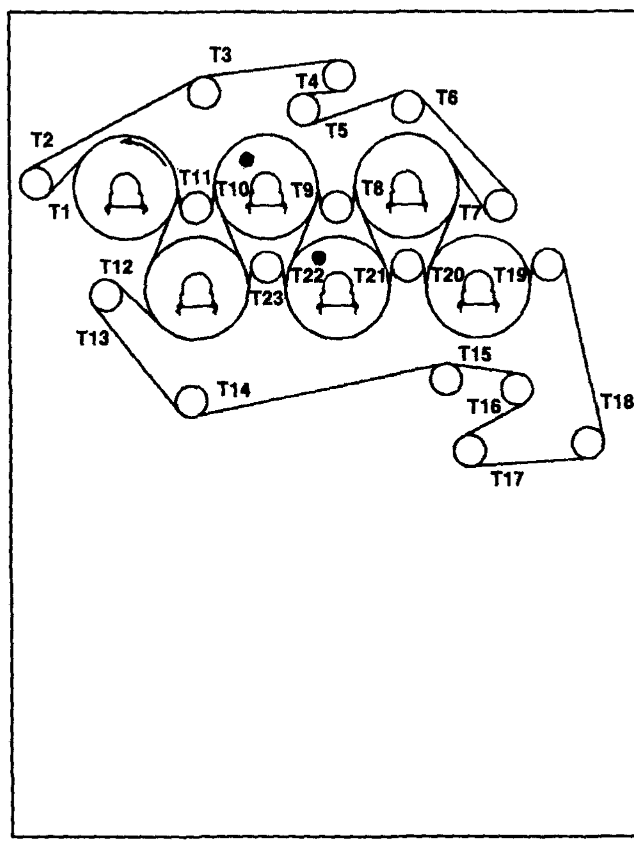
3. Felt roll driven Silent Dryer drive



4. Dryer driven Silent Dryer drive



5. Fabric tension levels



the initial calculations, a value of 180° angle of wrap will be used. The exact wrap and driveability must be checked as part of sizing the drive.

The minimum number of drives that can be used in the example would be two drives, one per felt. By choosing a motor hp of 150 hp for a two-drive system, one can compare the driveability to the motor capability.

$$hp_d = \delta T \; WS/33000 = T_1(e^{\mu\alpha} - 1) \; WS/33000 \qquad (5)$$

where

T_1 = 8 pli (assumed minimum)

μ = 0.18 (typical)

α = 180° (radians)

$$hp_d = 8 \, (e^{\pi}(.18) - 1) \, 4000(300)/33000 \quad hp_d = 221 \text{ hp}$$

at the point of slippage

The RDC values used are based on using a drive with an overload capability of 200% full load for 60 s.

For the purpose of this paper, the TAPPI NRL and RDC values have been used. At machine speeds above 2500 ft/min, it is recommended that the acceleration hp of the section be calculated using the inertia values of the components in the section. This acceleration horsepower, when added to the NRL for the section, is compared to the motor manufacturer's recommended allowable overload capacity for the motor. The relationship between the overload level and the acceleration duration is nonlinear and based on SCR bridge design, and is beyond the scope of this paper.

In the above example, the motor overload capability (300 hp) is beyond the driveability (221 hp) of the felt rolls. The following choices are available to match these two values more closely:

1. Increase the static fabric tension
2. Increase the number of drives
3. Drive the dryer cans in the fabric loop as opposed to the felt rolls, thereby reducing the amount of hp transmitted by the fabrics by an amount equal to the acceleration load of one dryer
4. Reduce the overload capability of the motor by reducing the drive current limit to a value less than 200%, thereby reducing the acceleration rate of the section and increasing the time required to accelerate the dryer section.

Dryer roll driven dryer example

At this point, we explore the results of driving only one of the dryers per fabric loop, as illustrated in **Fig. 4.** With a drive system configured as shown here, the fabric tension throughout the loop can be calculated. These tension levels can be compared to the mechanical constraints of the system (e.g., stress levels in the rolls, stretcher limitations, etc.). The acceleration hp values for each component in the section can be used in conjunction with Eq. 3 to calculate the tension levels in **Fig. 5** and **Table I.**

The tension levels listed in Table I must be used in the mechanical analysis of the components throughout the section. In the event that the mechanical criteria are exceeded, either the component must be replaced or the number of driven dryer cans must be increased to reduce the tension levels in that area of the fabric loop.

Summary

Choosing the optimum silent dryer drive requires investigation in the following areas:

1. The ability to transmit the required power from the driven roll to the fabric
2. Tension levels in the fabric loop and the effect of these levels on mechanical components within the loop, as well as the fabric
3. Cost analysis comparing multiple drives directly connected to the felt rolls vs. multiple drives connected through dryer mounted gear cases.□

I. Felt tensions of example shown in Fig. 4

Top felt		*Bottom felt*	
Location	*Tension, pli*	*Location*	*Tension, pli*
T1	7.44	T12	7.50
T2	7.60	T13	7.64
T3	7.76	T14	7.78
T4	7.92	T15	7.93
T5	8.08	T16	8.07
T6	8.24	T17	8.21
T7	8.40	T18	8.36
T8	10.09	T19	8.50
T9	10.25	T20	10.18
T10	5.60	T21	10.33
T11	5.75	T22	5.67
		T23	5.81

Literature cited

1. Justus, E. J., Beloit Corp., U. S. pat. 4.495,711 (Jan. 29, 1985).
2. Justus, E. J., Beloit Corp., U. S. pat. 4,495,712 (Jan. 29, 1985).
3. Evans, J. C., Pulp & Paper 58(8): 74 (1984).
4. Murray, J. B., and Davies, I. S., 1985 CPPA Annual Meeting Proceedings, B409.
5. Crouse, J. W., Tappi J. 72(7): 73 (1989).

Received for review Dec. 10, 1989.

Accepted Jan. 5, 1990.

Presented at the TAPPI 1989 Engineering Conference.