TENSION CONTROL AND WINDER

Dynamatic® Eddy-Current equipment, because of its simple, flexible speed adjustment and control characteristics, provides an inexpensive and accurate means of solving tension control problems. You will find tension control and winder applications in all industries.

Constant tension winders are typically divided into two main categories: centerwinds and surface winds. The determining characteristic is the point of power input. On centerwinds, the power is introduced at the core shaft or center of the roll. On surface winders, the power is applied to the surface of the winding roll.

Surface winders normally make use of one or two drums against which or upon which the roll is wound. Torque applied to the drum shaft always reacts with the fixed radius of the drum to provide tension. This radius is constant regardless of wound roll diameter. Therefore, constant torque at the drum will result in constant tension on the web. Surface winders are, then, constant torque drive applications. Relatively straightforward speed controls involved.

Centerwinds are significantly more complex. As the web is wound, the diameter (or radius) increases. The circumference also increases. With a constant FPM (foot per minute), the winding roll will be forced to decrease in speed as the roll builds up. Thus, the winder drive is faced with an every increasing torque arm and a continually decreasing RPM requirement. In order to maintain constant tension on a centerwind, a drive must deliver the proper value of torque at the proper RPM at any instant in the roll buildup.

Three mechanical relationships exist on centerwinds under constant tension conditions:

1. Torque versus diameter in a linear function.
2. Torque versus RPM is a hyperbolic function.
3. Diameter versus RPM is a hyperbolic function.
AUTOMATIC LAMINATOR MODEL

AUXILIARY UNITS

Upper and Lower Pinch Rolls Are Mechanically Coupled or Driven (Individually)
Centerwinds are, therefore, constant horsepower applications. In theory, any electrical, hydraulic or mechanical drive that can deliver constant horsepower could function as a centerwind drive. Other variables on the average machine rule out many of these drives. Some of these variables are:

1. Variable FPM
2. Wide Tension Range
3. Wide Speed Range
4. Tapered Tension
5. Speed Transients
6. High Maintenance
7. Tension Accuracy Requirements

Other important information includes:

8. Variable Inertias
9. Large Buildup Rations
10. Economics

In order to properly apply drives to centerwinders, certain basic information is required, such as:

1. V – Maximum and minimum machine FPM
2. F. – Maximum and minimum tension in Lbs. per inch.
3. W – Maximum and minimum width of web
4. D₀ – Maximum full roll diameter
5. D₀ – Minimum core stock OD
6. Pₛ – Power (strip)
7. Pₘ – Power (motor)
Other important information includes:

1. Density of material
2. Maximum and minimum thickness
3. Acceleration and deceleration rates of material
4. Main drive breakaway characteristics
5. Thread and/or job speed
6. Operating sequence

To size and Eddy-Current drive for a centerwind, the following formula may be used:

\[ P_s = \frac{VFW}{33,000} \]

\[ P_m = \frac{P_s \times D_c}{D_o} = \text{Motor HP} \]

Consideration should be given for friction losses and acceleration of maximum winder inertia.

If tension is to be tapered, the above motor horsepower can be divided by the taper ratio to arrive at drive size.

Full thermal capabilities are normally required of the drive, inasmuch as the winder may be stalled (zero FPM) and yet provide full tension at approximately full roll diameter. The drive must then provide maximum rated torque at zero RPM. On larger winders, this may require liquid-cooled, Eddy-Current units.

Once the drive unit has been determined, the proper reduction ratio must be calculated. The maximum ratios will equal:

\[ \frac{N_d \times D_c}{V \times 3.82} = ?:1 \]

Where Nd is the maximum rated drive output speed and 3.82 is \( \frac{12}{\pi} \).

At this time, it should be determined whether or not braking is desired or required. If so, either an Eddy-Current brake or a friction brake must be added to the mechanical unit.

The next and often difficult part of centerwind applications is determining the type of controller to use. Several type are available, and which one is chosen depends on the variables listed above, the material being wound, and the process involved.

Three basic factors must be kept in mind:

1. In a system, something must regulate FMP and something must regulate tension. A given controller and drive, at a given moment, can regulate either speed or tension (torque) – never both.

2. The FPM of the system must be positively controlled at all times – from stalled conditions through breakaway and acceleration, at steady-state speeds and through deceleration back to stalled conditions. A tension controlled winder must have something to pull against. The line speed setter must be able to hold FPM regardless of design tensions at the winder.

3. A winder drive must always supply enough torque to overcome losses with a surplus for tension. Unless the centerwinder is a constant FPM centerwind (described below), it can do nothing relative to setting RPM. The winder RPM is dictated by the FPM and the roll diameter at any instant. It is, therefore, often more desirable to think in terms of winder torque and diameter than in terms of RPM.
In the case of simple slitters, embossers, coasters, inspection winders, etc., it is often possible to use a constant FPM centerwind. The centerwind actually sets line speed. The controller would be the common main drive type, incorporating such features as jogging, threading, controlled acceleration and braking. Instead of using tachometer feedback from the winder drive itself (which represents winder RPM), a strip generator would be used (which represents FPM). The FPM would then be held constant, regardless of the changing roll diameter. Tension must be set elsewhere in such a system.

Those applications which require a minimum of accuracy and a minimum cost can often be accommodated by use of a simple “clutch motor”. Under these circumstances, a fixed value of excitation is set for a clutch coil. As the roll diameter increases, the torque actually being delivered would be that which the inherent torque/speed curve of the particular drive would provide. Such a winder setup would normally provide a sizeable degree of tension tapering as the roll diameter increases. For all practical purposes, on the average installation, winding would be accomplished at constant torque rather than constant horsepower. The taper ratio would approximate the buildup ratio.

Another quite economical method of approaching constant horsepower would be the use of what is commonly called straight-line tension. Such a controller is essentially a speed control with extremely poor regulation. Thus, as the winding roll diameter increases, the clutch would be forced to decrease in RPM. This increase in slip would provide an increased torque due to controller speed regulation, even though the regulation is poor. By proper adjustment, the drive can slip back sufficiently to wind a full roll without the torque becoming exorbitant. With this type of winder control, the tension would tend to be light at the beginning of the roll, heavy in mid-roll, and, again, light at the full diameter. With a buildup ratio of 2 ½ to 1, the maximum tension error would be approximately 7%. If greater builds are used, this error grows accordingly. Tapering the tension, however, tends to reduce the errors. Taper adjustment is normally inherent to the controller.

All constant tension or tapered tension centerwinds have one thing in common, and that is the requirement of measuring or simulating the diameter continuously. In as much as the essential item being controlled is motor torque, the radius of the roll must be known at all times. Then the proper torque can be determined by the logic circuitry so as to produce the desired tension. As stated above, the torque must increase directly with diameter increase. This can be accomplished by using a rider roll or lay-on roll operated potentiometer to adjust the torque of the drive. This potentiometer would swing the torque from a preset core value to a preset full roll value. The major disadvantage of this system is the nuisance value of the rider roll.

Tapering the tension of a rider roll or lay-on roll potentiometer type of rewind is accomplished simply by setting the proper full roll diameter torque in the controller.

When relatively narrow webs are involved and contact with the surface of the material is allowed, it is often highly desirable to use a dancer position control on a centerwind. This method of control is probably the most accurate of all forms of tension control. If the sides of the dancer loop are approximately parallel, the mass of the dancer assembly is made as low as possible, and there is a
minimum of friction or resistance to
the dancer travel, then changes in
dancer position would have minimal
effect on the webs tension. With
such a controller, it is necessary to
mount a feedback potentiometer on
the dancer assembly such that its
resistance is proportional to the
dancer position. This feedback
information (which is position
information) is compared to a
regulated reference voltage in such
a manner as to supply sufficient
torque to hold the dancer in the
preset position. Inasmuch as the
controller is a proportional band
controller, any change in dancer
position due to roll buildup would be
extremely small. The amount of
change required to compensate for
buildup torque chances would
depend upon the gain of the
controller. In addition to the above
described reference circuit and
dancer feedback circuit, rate circuits
are required for stability.

Dancer position controlled
centerwinds may be used when a
very high torque ratio or high
speed ratio is required. Other forms
of tension control incur significant
ersors at very low speeds and
torques. Inasmuch as the actual
web tension is determined by the
effective “weight” on the dancer
assembly, the winder does not
actually regulate tension. Its
fundamental function is to wind
material at the same feet per
minute as it is being delivered by
the process machine. It is usually
desirable to load the dancer with
adjustable, regulated air pressure,
inasmuch as this method
contributes a minimum of mass to
the dancer assembly. The air
pressure regulator is then used as
the tension-setting device. It is
necessary, however, to use an air
pressure regulator system capable
of relatively high air flow rates to be
sure there will be no restriction or
“dash-pot” effect. Such practices as
using counterweights and/or shock
absorbers are detrimental to
maintaining the most desirable
tension accuracy under transient
conditions.

A dancer position control, as so far
described, will provide constant
tension only. In order to taper the
tension on a dancer-controlled
centerwind, it is necessary to
change the effective “weight” of the
dancer as a function of roll
diameter.

This is accomplished by tapering
the air pressure as a function of roll
diameter. This utilizes a radius
generator circuit (described below)
to determine diameter and a
voltage to air pressure converter to
load the dancer.

The most recent tension controller
for centerwinds (and unwinds)
makes use of a radius generator
circuit. It utilizes FPM information
from the line speed setter (or strip
generator) and core shaft RPM
from the winder tach generator to
calculate roll radius continually. The
result of the calculation is DC
voltage that varies linearly from 1
volt to 10 volts as the roll grows
from core diameter to ten times
core diameter. These 1 to 10 volts
are then used as a reference
voltage for a constant current
controller (clutch motor or torque
regulator). Any buildup ratios less
than 10:1 are automatically
accommodated. Greater build up
ratios can be accommodated by
proper setup.

The overall speed range is 1600/40
RPM. At winder drive RPMs below
40 RPM, the controller automatically
goes into a stall tension mode. Field
adjustments are as follows:

1. Stall tension (a function of
set tension).
2. FPM
3. Inertia compensation
4. Friction compensation
5. Breakaway pulse
6. Taper
The taper is infinitely adjustable from constant tension to constant torque. Constant tension is constant horsepower; constant torque results in taper ratio equal to the buildup ration.

The taper and/or the stall potentiometers can be mounted either in the control enclosure or at the operator’s station.

The radius generator circuit is on a separate printed circuit board and can be used with a Model 4050 or Mark III Eddy-Current controller.

Although the above covers the main points relative to Eddy-Current centerwinds, it does not cover all possibilities. There are other variations which DSI/Dynamatic® application engineers have addressed. Some of these are:

1. Slipping core differential winders
2. Dual duplex differential winders
3. Ajusto-Spede®/Variator rewinds
4. Turret rewinds
5. Unwind stands

Please contact DSI/Dynamatic® to discuss your tension/winding application.