WINDER SYSTEMS

Systems

Concepts

Terminology

GE Industrial Control Systems
With a smooth metal surface material, a paper **liner** is sometimes wound with a coil. The paper is lightweight and runs with very little tension so it can be neglected by the winder. If the paper thickness approaches the gauge of the wound material, the diameter calculator must allow for the calculation of both thicknesses per wrap.

In the case of rubber sheeting, a liner of some non-negligible mass is wound with the sheeting. This liner’s tension can be greater than the sheeting’s tension. The winder tension setting must account for both the tension of the sheeting and the liner.
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A winder is “any of various machines for winding material.” To wind is “to encircle or to cover with something pliable.” Pliable is a relative term. Similarly, unwind means “to remove from tension, to uncoil, to wind off.”

**Winder Types**

**Centerwind**

A centerwind winds material around a core, or mandrel. It is called a centerwind because the center of the coil is driven by a motor. There are centerwinds that are current regulated and those that are speed regulated. Both of these can add dancers and load cells to provide very precise tension control.

**Surface Winder**

Surface winders drive the material roll from its surface to wind material. Surface winders run at a constant linespeed, and may use the roll diameter for compensations. Some surface winders have a companion roll that will load share (with adjustable balance) with it. Other configurations of surface winders may use a series of belts or rolls to hold the coil while it builds.
**Turret Winder**

Turret winders are actually 2 or more center-winds on a rotating axis that allows the next winder to be in position and ready to start a new roll on the fly. A flying knife will slice the process material and automatically hold the material in place while it starts to wrap on the new coil. The diameter calculation needs to hold while the turret moves in either direction in order for this operation to be successful.

As Centerwind #1 builds, the centerwind pivots to have centerwind #2 ready to start to wind on the fly.

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**Centerwind** - A machine that winds material onto a central core or shaft. The winding is done by directly controlling the speed of the center of the roll or coil. To keep the material speed constant on a winder, the RPM will slow down as the material builds. On an unwind, the RPM will increase as the material is unwound.

**Surface winder** - A machine that winds material onto a central core or shaft. The winding is done by controlling the surface speed of the roll.

**Turret winder** - Turret winders are actually 2 center-winds on a rotating axis that allow the next winder to be in position and ready to start a new roll on the fly.

**Mandrel** - Usually in metals, a winder uses a mandrel to wind on instead of a core or tube. The mandrel may be supplied with a mechanical gripper to grab the head end of the strip. The mandrel hydraulically collapses to remove a finished coil (winder) or mount a full coil (unwind).
Linespeed

Linespeed is the operational speed of a coordinated process, which refers to the speed of the material being processed expressed in meters per minute, feet per minute, yards per minute, bottles per second, etc.

Consider a motor running at a constant RPM winding material. As the material winds up, it builds diameter. If RPM is constant, as the diameter builds, the surface speed increases. Because most processes desire a relatively constant linespeed during steady state running, an increase in linespeed is undesirable and must be compensated for.

Tension

Tension is the longitudinal force being exerted on a process material, or simply put, how tight the material is pulled. Assume that the linespeed of a process is held constant with a pinch roll. The winder motor will be controlled by a motor controller, also called a drive, that will regulate a fixed motor current.

\[
\text{Tension or Force} = \frac{\text{torque}}{\text{radius}}
\]
Winding material using a motor controlled constant current/constant flux drive can be used with a speed regulated process. The actual tension of the material decreases with diameter. This is a very simple example and may be a desirable control if a speed regulated nip roll (or equivalent) is directly in line with the winder, and there are no other performance considerations.

Achieving constant tension despite transients has long been the goal of the drive controls. Processes do, however, require variable tension or tension based on the material being processed. **Stall tension** is a percentage of running tension that is required of a winder when a process is stopped. Stall tension keeps the material being wound prepared for a restart and keeps it from unwinding itself. **Taper tension** is a feature that reduces tension as the diameter builds, and is generally adjustable to its effect. Not all taper tensions are linear with diameter. The taper profiles are as variant as there is material to wrap. Tension can be expressed in units of lbs/ft, lbs/in, kg, kg/m, etc.

**TERMINOLOGY**

**Linespeed** - The operational speed of a coordinated process, which refers to the speed of the material being processed expressed in meters per minute, feet per minute, bottles per second, etc.

**Tension** - The longitudinal force being exerted on a process material. Simply, how tight the material is pulled.

**Pinch roll** - A roll that presses against another roll, belt, or conveyor to help transport material and keep the material in place. A pinch roll may be sized to be the main means of material transport or it may be a small size used only to help transport process material.

**Nip roll** - A roll that presses against another roll, belt, or conveyor to help transport material and keep it in place. A nip roll is used with a belt, conveyor, wire or work roll, and typically doesn’t have the motor power size to convey the material itself, only to help.

**Stall Tension** - A percentage of running tension that is required of a winder when a process is stopped. Stall tension keeps the material being wound prepared for a restart, and keeps it from unwinding itself.

**Taper Tension** - A feature that reduces tension as the material diameter builds, or as motor speed increases.
**Tension Example:**

A material is wound on an empty core of 2 feet diameter. The material is wound until the diameter is 4 feet. If a 100 ft-lb constant torque is supplied to the center of the roll, the empty roll tension is 100 lbs.

\[ \text{tension} = \frac{\text{torque}}{\text{radius}}, \quad \text{radius} = \frac{\text{diameter}}{2}, \quad \text{resulting in tension} = \frac{100 \text{ ft-lb}}{1 \text{ ft}} \]

The tension at the roll surface will lessen as the diameter builds at constant torque. The material tension when the diameter is 4 feet equals 50 lbs.

\[ \text{tension} = \frac{\text{torque}}{\text{radius}} \quad \text{radius} = \frac{\text{diameter}}{2} \quad \text{tension} = \frac{100 \text{ ft-lb}}{2 \text{ ft}} \]

If the roll needs to be wound at a constant tension, then the applied torque must be applied linearly with diameter. The torque would start at 100 ft-lb and finish with 200 ft-lb output torque.

**Inertia**

Inertia is the physical property for a body in motion to stay in motion and resist a rotational speed change.

For a brick with a known mass to move, it must be pushed with some force. It would go forever, except that friction slows the brick down and eventually stops it. Inertia is this same principle for rotating objects. Torque must be applied to cause a change in the angular speed.
For a symmetrical cylinder (coil), this classic formula can be used for calculating material inertia:

\[ J = \frac{\text{coil width} \times \text{density} \times (R^2 - r^2) \pi}{2 \times g} \]

\( J \) = inertia, also called WK squared
\( \text{coil width} = \text{ft} \)
\( \text{density} = \text{lb/ft}^3 \)
\( R = \text{outside roll radius in ft} \)
\( r = \text{inside roll diameter in ft} \)
\( g = \text{gravity} = 32.2 \text{ ft/sec}^2 \)
\( \pi = \pi = 3.14 \)

The effective inertia, as seen from the motor =

\[ \frac{\text{material inertia}}{\text{gear box ratio squared}} \]

**Why do processes care about inertia?**

While accelerating or decelerating a motor and its load, the motor, gearbox, and process equipment mechanically resist the speed change. If extra power is not given during acceleration or deceleration, the inertia can cause undesirable process transients in tension, strip breakage, or web sagging.
Automatically applying (or subtracting) extra power is called compensating. Compensations automatically adjust for extra motor power required for increasing inertia with buildup diameters, speed changes, and other operating condition changes. A basic compensation is motor and gearbox inertia compensation. Acceleration torque is given by the equation:

$$t = \frac{\text{inertia (ft lb}^2\r) \times \Delta \text{speed (RPM)}}{308 \times \Delta \text{time (sec)}} = \text{lbs}$$

The material inertia built up on the winder is another variable that is commonly compensated for in a winder control. The wound material may change from product to product on the same machine. More complex compensation schemes would also account for a change in material weight or density, and also changes in material width.

Additional compensations can be made for friction losses, motor windage losses, material bending losses, losses for air resistance, rate of change in diameter, etc. Because actual losses may be non-linear, compensations can be in the form of a look up table or curve based on speed and/or load.

**Constant HP** is a technique to achieve constant tension, usually with DC drives. While running a motor with constant current and constant field (flux), the force (tension) applied to the material is diameter dependent. If the field current or flux is adjusted by diameter, then the resulting tension is constant. When modifying DC field current or AC flux current to achieve constant tension
or HP by diameter scaling, the actual tension is not linear to flux current. A better tension control is realized when the linear diameter used to scale field current or flux is modeled by an appropriate curve. The high performance drives will actually measure and save these curves during tune-up.

**Compensation** · **Compensations automatically adjust for extra motor power required to overcome motor and load inertia due to speed changes, friction losses, and a variety of process inefficiencies that cause speed or tension variations.**

**Constant Tension** · **Refers to keeping the actual material tension of material being wound at a constant value throughout speed and diameter changes.**

**Constant HP** · **A technique to achieve constant tension, usually with DC drives. While running a motor with constant current and constant field (flux), the force (tension) applied to the material is diameter dependent. If the field current or flux is adjusted by diameter, then the resulting tension is constant.**
Knowing the material build up/build down diameter allows for diameter dependent compensations like material inertia compensation. Diameter can be used for scaling drive regulator gains, field current/flux adjustment for constant HP operation, rescale compensations, and for scaling speed referencing. The diameter can also be used in a display for an operator or for automatic machine sequencing.

Diameter can be measured using a sonic sensor or a rider roll with analog feedback. The diameter can be calculated (particularly with current regulated centerwinds) from a signal representing the linespeed divided by RPM.

Another, simpler, diameter calculation can be an accumulation of RPM changes while winding. This accumulation or linespeed signal can be tracked by a tachometer riding on the material, by an analog output, by the speed feedback from a drive controlling linespeed, or not as accurately, by the linespeed reference.

Diameter can also be calculated by multiplying the material thickness, also called gauge, by the number of wraps or motor revolutions that have occurred since the start of the wind. Some winder algorithms actually have a gauge regulator.
Winders that have a diameter calculator usually require a means to reset it when the finished coil is removed.

When a winder is calculating diameter and there is some process transient that is known to cause severe tension disturbance and cause an error in the diameter calculation, a more sophisticated control can tell the diameter calculation to hold until the disturbance is over.

Low speeds can cause inaccurate diameter calculations due to a lack of resolution in line-speed or RPM. Many diameter calculators have a lower speed limit that disables the diameter calculator. This is an acceptable compromise as long as low speed operation is of a short duration with small resultant diameter buildup.
A common and simple winder arrangement used to maintain a constant line-speed is called a winder with a dancer. The dancer is a mechanical roll or wheel that rides on the material. The dancer position moves up and down while the roll builds. The dancer position (feedback) is fed into a regulator that automatically adjusts the winder speed reference. Weighting or loading the dancer provides a rudimentary tension setting. Note that in this example the winder is running as a speed regulator. Therefore, adding dancer weight increases tension and will show up as increased motor load and be diameter dependent.

This is a very common winder configuration especially where:

- Linespeed is relatively slow, approximately 200-300 feet per minute, 100 yards per minute, 100 meters per minute.
- The high gear ratio minimizes the effect of the wound material inertia.
- Acceleration and deceleration is relatively slow, 30 seconds to 1 minute or more to accelerate up to top speed.
- The dancer regulator has the time to adjust itself to transients caused by overcoming machine friction and inertias.
- The dancer has sufficient up and down movement (storage or accumulation) to buffer the transients caused by acceleration/deceleration, mechanical problems, inertia changes, etc.
Another way to get constant tension regulation is by way of a **load cell** that converts tension to an electrical signal for use as feedback to a tension regulator. The regulator adjusts speed control or motor current control to keep tension constant. A load cell trim in a current regulated winder control is more common with a more sophisticated control utilizing inertia compensations.

An **accumulator**, also known as loop control, uses a configuration just like a dancer and can ride on the material itself, or the feedback can be detected by a photosensor, sonic sensor, or other devices.
More sophisticated winder controls may have extras built in for measuring accumulated material length, automatic stopping on an accumulated length, automatic tail out or head in, gripper position stop, etc.

A mandrel is what some winders use to wind on, instead of a core or tube. Grippers and belt wrappers may be used to get a metal coil started on a mandrel. A gripper is a small mechanical flap across a rewind’s mandrel. The gripper flap opens when starting a new coil and the headend of material (usually a metal sheet) is slipped under the gripper’s flap. The gripper then closes, pinching the material and forcing it to wrap around the mandrel when the rewinder starts to rotate and wind a new coil.

Typically with stiffer materials, the process material is fed into the winder while the winder is running in overspeed, that is, the winder surface speed is running a little faster than the material linespeed. With the help of a belt wrapper, the material will wrap tight around a mandrel, and the belt wrapper will move out of the way once a sufficient wrap is established.
While using overspeed in a belt wrapper serves a distinct purpose, with a current regulated centerwind overspeed can have a negative impact. For example, if the material breaks while running in a current regulated mode with material under tension, the motor current used to deliver material tension accelerates the motor until an overspeed trip occurs, or the motor flies apart. Neither of these conditions is desirable.

More advanced winder controls will sense the undesired sudden acceleration or the speed difference between the desired motor speed and the real motor speed as a material break. This breakage, or slippage signal is used to regain speed control before a system trip or runaway motor fails.