Roll Diameter Requirements in Converting Processes

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Roll Diameter in Converting Processes

Roll diameter accuracy is critical in many converting processes

Roll diameter accuracy = Increased machine performance
Roll Diameter in Converting Processes

Center Driven Tension Control

Starting Diameter

Running Diameter
Roll Diameter in Converting Processes

Center Driven Tension Control (Torque)

- Tension set point
- Taper tension
- Diameter
- Web velocity
- Override
- Web velocity
- Web velocity
- Speed setpoint
- Diameter
- Diameter
- Diameter
- Diameter
- Winder rotational speed
- Drive
- Gain
- Inertia Calc
- Acceleration precontrol
- Acceleration torque
- Acceleration
- Diameter
- Diameter
- Diameter
- Tension setpoint
- Diameter Calc
- Inertia Calc
- Taper Tension

J total
Roll Diameter in Converting Processes

Center Driven Tension Control (Speed)
Unwind flying splice requires actual roll diameter for firing the bump roll and knife at their correct positions and speed matching of new roll.
Roll Diameter in Converting Processes

Turret Indexing

- Stopping positions of the rolls.
- Modification of the spindle velocity setpoint during indexing.
Zero speed splicing is diameter dependent for auto splicing at the required minimum diameter.
Roll Diameter in Converting Processes

Gap and Lay-on Rolls

Lay on rolls applied in gap winding must precisely follow the roll diameter accurately throughout the winding process.
Roll Diameter in Converting Processes

Surface Wind Rider Rolls

Rider rolls on surface winders require roll diameter to apply the correct specified pressure throughout the roll build.
Common Diameter Determination Methods

How to get it?

Measurement - Sensor

Calculation
Common Diameter Determination Methods

- Lay-on Roll Measuring Arm
- Diameter Sensor
Common Diameter Determination Methods

Lay-on Roll Measuring Arm

Advantages

- Simple and robust.
- Relatively low maintenance.
- Diameter value does not require spindle or web motion.
Common Diameter Determination Methods

Lay-on Roll Measuring Arm

- Must contact the roll
- Out-of-round rolls
- The output signal may require filtering
- Angle must be transformed to a linear distance.
- Must be loaded against the roll
- Roll changing / mechanics

Disadvantages
Common Diameter Determination Methods

Diameter Sensor

- Linear output proportional to roll diameter.
- No material contact with the roll.
- The diameter value does not require motion.

Advantages
Common Diameter Determination Methods

Diameter Sensor

Disadvantages

- Measurement can be affected by moving air and temperature drift (ultrasonic).
- Periodic maintenance and calibration.
- Susceptible to dirt and dust.
- Low density materials absorb the signal.
- Damage from roll changes.
- Does not work well with out of round rolls.
- Signal typically requires filtration.
Acceptable for starting diameter but neither are practical for providing a process running diameter
Common Diameter Determination Methods

How to Calculate?

Calculation

- Web Velocity / Winder Shaft RPM (V/n)
- Roll Turns & Web Thickness
Common Diameter Determination Methods

**Web Velocity / Winder Shaft RPM ($V/n$)**

Web Velocity / Winder Shaft Rpm ($V/n$) is the most common method of determining *Running* roll diameter for center driven spindles.

Diameter ($D$) is determined by using the relationship between surface web velocity ($v$) and the angular velocity of the spindle ($\omega$) with the calculation $v/n$.

\[
v = \omega \cdot r = 2\pi n \cdot r = \pi n \cdot D
\]

\[
\Rightarrow D = \frac{v}{\pi n} \Rightarrow D \sim \frac{v}{n}
\]
Common Diameter Determination Methods

Web Velocity / Winder Shaft RPM (V/n)

Web Transport

Drive System

Unwind

Tension Controller

(V/n) = Diameter
Common Diameter Determination Methods

Web Velocity / Winder Shaft RPM (V/n)

Legend:
V: Line speed
n: Rotational speed
D: Diameter
Common Diameter Determination Methods

Web Velocity / Winder Shaft RPM (V/n)

Advantages

✓ Requires no additional machine hardware.
✓ Simple calculation, directly proportional.
✓ Provides acceptable steady state diameter status.

Disadvantages

✓ Must be above minimum line speed for calculation (diameter hold).
✓ Filters required for output smoothness.
✓ Filter changes may be required for changes in material thickness.
✓ Poor accuracy during acceleration and deceleration.
Common Diameter Determination Methods

Roll Turns & Web Thickness

Drive System

Diameter (New = Diameter Old + (Thickness * 2))
Common Diameter Determination Methods

Roll Turns & Web Thickness

**Advantages**

- Theoretically the most accurate diameter calculator.
- Not susceptible to acceleration / deceleration / speed disturbances.
- Does not require filtration.
- Does not require a diameter hold

**Disadvantages**

- Open Loop System.
- Web thickness variable must be accurate.
- Requires an accurate starting diameter
Two improved methods can be utilized and offer several benefits over the common diameter determination methods.

1. Integration of Web Velocity / Spindle RPM
2. Web Position / Spindle Angle
Improved Methods of Diameter Calculation

Integration of Web Velocity / Spindle RPM

In this method of diameter calculation, velocity is integrated over time to determine a linear position change of the web and a angular displacement of the spindle.

\[ r = \frac{S}{\theta}, \quad D = 2 * r \]

The diameter is calculated based on calculated web length \( S \) and calculated angular displacement of the spindle \( \theta \).
Improved Methods of Diameter Calculation

Integration of Web Velocity / Spindle RPM

Calculating with a web length and a spindle angle provides an increased stability of the measurement and does not require the filtering that is used in v/n. The added stability of this method is especially seen during acceleration and deceleration.
Improved Methods of Diameter Calculation

Integration of Web Velocity / Spindle RPM

**Advantages**

- More accurate than \((v/n)\) during acceleration / deceleration / speed disturbances.
- Does not require filtration.
- Can be used to also determine starting diameter (Actual position mode).
- Diameter hold not required.

**Disadvantages**

- Integral update time must be fast.
Improved Methods of Diameter Calculation

Actual Web Position / Actual Spindle Angle Calculation

Motion controllers and some drive control systems can provide the actual positions of drives controlling the web and spindle.
Improved Methods of Diameter Calculation

Starting Diameter

- Direct operator input (*subject to errors*)
- Sensor Measurement

- High degree of accuracy!
- Only possible with a position based control

\[ r \approx \frac{2x}{\theta} \]
Next Step, Evaluation of the actual results. The following analysis will look at the three calculation modes under different conditions.

- Constant speed operation
- Speed changes & update frequency of the diameter calculator logic
Performance Review - Diameter Calculation Methods

Constant web speed: 100 m/min

RED - V/n diameter
GREEN - INTEGRAL diameter
BLUE - POSITION diameter
Performance Review - Diameter Calculation Methods

Update (sampling) time: 6 ms

Acceleration profile: 50 m/min > 300 m/min > 10 m/min

Update (sampling) time: 6 ms

- **RED** - V/n diameter
- **GREEN** - INTEGRAL diameter
- **BLUE** - POSITION diameter
- **BLACK** - Web Velocity
Update (sampling) time: 1 ms

Acceleration profile: 50 m/min > 300 m/min > 10 m/min

RED - V/n diameter
GREEN - INTEGRAL diameter
BLUE - POSITION diameter
BLACK - Web Velocity
Performance Review - Diameter Calculation Methods

Web Velocity over Winder Shaft Velocity ($V/n$)

- **Web Velocity**
  - Sample
  - Actual

- **Winder Shaft Velocity**
  - Sample
  - Actual

Sample Periods: $v_1$, $v_2$, $v_3$
Integration of Web Velocity & Position Based Calculation

Interpolation error does not exist in a position based controller

ACCELERATION

CONSTANT SPEED

Increased Sampling rate
Conclusions

Roll diameter is critical in many converting processes.

By utilizing new techniques and new technologies we can more accurately determine diameter and help converting machines and converting processes to reach higher performance levels.
Thank You

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