Web Tension Control Fundamentals

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Improving Tension Control Performance

Performance

THE BASICS
Most converting machines have more than one tension zone. Each zone requires a control system and isolation from the neighboring zone(s).
Unwinds

Center Driven

Surface Driven

Center / Turret
The Unwind

Tension is provided through a mechanical brake or a regenerative drive system.

The driven unwind is capable of a higher level of tension control performance.
The Unwind Section

A brake controlled unwind can only apply torque in the opposite direction of shaft rotation.
The Unwind Section

A driven unwind can operate in each of the four quadrants of rotational speed and torque.
Advantages - Driven Unwind

**Acceleration**
- Applying torque in the direction of rotation

**Tension Disturbances**
- Response time & torque in the direction of rotation

**Performance**
- Wider torque range, better torque regulation and faster torque response.

**Results:** Wider tension ranges, larger build ratios and greater tension control accuracy.
Advantages - Driven Unwind

The combination of improved operation, reduced maintenance, power savings and energy conservation gives AC regen drives a clear advantage over mechanical brakes.

- **Energy Savings**
  - Return Tension Energy to the line. (AFE ~ 1.0 PF)

- **Maintenance**
  - AC motor
Zone Tension Control Challenges

Modern drive system systems can provide a high degree of performance, but they depend on the quality of the power transmission mechanics.

Poor mechanical characteristics, compliance and lost motion between load and motor, limit tension control performance.

Power transmission components should be evaluated for mechanical stiffness including coupling, shafts, and core chucks / shafts.
Zone Tension control – The Turret Unwind

The tension control system on turret unwinds and rewinds should take into consideration the velocity changes to the web as the turret indexes.

The addition (+/-) of web velocity should be included as a feed forward to the tension control system rather than letting the PID control determine and eliminate the error.
Zone Tension control

Consideration should be given to selecting the lead section or master, typically the closest driven section to the unwind or the section that requires the highest level of speed regulation accuracy.

Sections should follow the web velocity or position setpoints rather than actual values.
Tension Control Modes

- Open Loop Tension Control
- Closed Loop Tension Control
Open Loop Tension Control

- Used when tension control accuracy is not critical
- Cost considerations
- Typical accuracy: >(+/-) 10%
- Improved by: accurate inertia and friction compensation, use of synchronous motors
Open Loop Tension Control

Draw / Velocity Ratio Control

Used where the web has an acceptable and predictable modulus of elasticity.
Closed Loop Tension Control

- Controlled tension via feedback device
- Increased tension accuracy
- Torque limiting or speed setpoint correction control
- Loop Gain adaptation, inertia compensation for large build ratios (Unwinds / Rewinds)
Closed Loop Tension Control - Feedback Devices

Load Cells

Dancer Roll System
A dancer roll system is a free moving idler, loaded with a force that is imparted to the web as tension as a result of the web positioning the dancer.
Dancer Mechanical Configuration: Linear or Pivoting - (single wrap)

Linear

Horizontal pivot

Vertical top pivot

Vertical bottom pivot
Dancer Mechanical Configuration: Multi-wrap

Multi Wrap Pivoting

Center Pivot Rotary
Dancer Systems – Design Criteria

- **Low Mass**: The dancer is a position controlled device
- **Eliminate Friction**: Friction affects tension

A change in web velocity without a change in dancer position will create a tension disturbance.
Traditionally a \textit{geared} analog sensor or potentiometer.

**Optical Encoder (Sin/Cos)**

- High Resolution – 22 bit sin/cos (+4Mppr)
- Absolute Position (single turn)
- No gearing required
- Zero Noise
- Accurate starting diameter calculation
Rolling Diaphragm Cylinders provide a low friction conversion of pneumatic pressure to linear force.

- Highly sensitive to force changes
- No line lubrication required
- Low friction - (circulating ball bearing)
- No pneumatic leakage
- Wide range of sizes
Dancer Systems – Supplying the Cylinder pressure

A change in dancer position will affect the pressure in the cylinder.

**Electro-Pneumatic Regulator**

- Requirement: High forward and reverse flow
- Remote tension adjustment
- Enables taper tension
- Voltage or current commands
- Output pressure ~ pseudo tension indication

*Courtesy of Proportion Air*
Dancer System Overview

- Typically uses on Unwind / Rewind
- Not a sensor
- Position controlled via web length change
- Dancer force = Web Tension
- Pivoting type the most common (+/- 30 degrees)

**Advantages**
- Storage / Absorb tension transients
- Starting diameter calculation

**Disadvantages**
- Design critical for functionality
- Tension indication
- Tension range
Accumulators

- Used for storage when stopping a section (roll change / splice, etc.)
- Types: Loaded & Driven
- Driven type - offers best tension control
Tension Sensors – Load Cell Styles / Options

- Cartridge
  - Dead Shaft

- Compact
  - Live Shaft

- Pillow Block / Heavy Duty
  - Live Shaft

- In Roll / Cantilevered
  - Cantilevered
Tension Sensors – Strain Gauge Functionality

Bridge Output (mv)

Load Cell Half #1

Load Cell Half #2

Tension

Compression

Load Cell

Excitation

WEB TENSION FORCE

Tension Signal Output

Tension

Compression

Tension

Compression
Load Cells – Connecting to the Controller

Traditionally used with analog amplifiers (mv in to 10vdc output).
Most load cell manufacturers produce amplifiers that support the popular industrial networks.
Load Cells – Connecting to the Controller

Optimal Solution: Load Cell amplifier in a machine located remote I/O module

Measuring technology seamlessly integrated into the automation system
Tension Sensors - Strain Gauge Load Cell

**Advantages**
- Accuracy
- Direct Measurement
- Ranges: 15-20:1 Cartridge
  50:1 Compact
  Dual Load cell option to +200:1

**Disadvantages**
- Low voltage signal (mv) – requires amplification
- Noise / may require filtering
- Subject to overload
- Calibration
- Potential temperature drift
Tension Sensors - LVDT

- LVDT, (Linear Variable Displacement Transformer)
- High Signal Level output
- Pillow Block Style Mounting
- Used for higher tension ranges
Tension Control – Closed Loop control Options

- TORQUE LIMITATION CONTROL
- SPEED SETPOINT CONTROL
Tension Control in the Winder – Closed Loop Torque Control

- Mass
- Diameter & Tension
- Friction & Mech. Losses
- Changing Diameter
Tension Control in the Winder – Speed Setpoint Correction

Diagram showing the control system with various components such as load cell, actual tension, web transport, and gain adapt. The diagram illustrates the interaction between the tension set, taper tension, diameter & tension, and inertia calculation.
Tension control – Mode Selection

The selection of the tension control mode can be influenced by several factors, including machine specifications or design, the type of tension sensor used.

A major determining factor will be the compliance of the web.

The modes of torque control / limiting are commonly implemented when the web material has a very low compliance or is “non-extensible”, e.g. heavy paper, steel, aluminum, other metals or foils.

The mode of tension regulation via speed correction is ideally implemented when the web is compliant or “extensible”.
Thanks for your attention!

* Contact us for a Converting Toolbox Flash Drive

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