Understanding Dancer Tension Control Systems

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System Types

- Manual systems
- Automatic systems
  - Open loop
  - Closed loop
Load Cell System

Sensor measures tension
Control adjusts brake torque up or down
Dancer Systems

Typical dancer control system
Why Use Dancers?

- Accumulation for Out-of-Round Rolls
- Accumulation for Indexing Applications
- Accumulation for Zero Speed Splicing
How Dancers Work

1st Commandment
• The load on the dancer sets the tension!

2nd Commandment
• The load on the dancer must not change!
Forces (F) on a Dancer

\[ 2T = L + MA + DV + KX \]

Ideal Condition: \( 2T = L \)

How do we get there?

\( T = \) Web Tension
\( L = \) Load Set by Loading Device + Dancer Weight
\( M = \) Mass
\( A = \) Acceleration
\( D = \) Damping Factor
\( V = \) Velocity
\( K = \) Spring Rate
\( X = \) Deflection
Loading Dancers

- 1 - Clutch and cable
  - Magnetic Particle 😊
1. Clutch and cable
   - Magnetic Particle

2. Pneumatic cylinder and regulator
   - Use a rolling diaphragm type cylinder
     - Bellafram
     - Illinois Pneumatic
     - Control Air

Quick relieving

Loading Dancers
1 - Clutch and cable
   Magnetic Particle

2 - Pneumatic cylinder and regulator
   Use a rolling diaphragm type cylinder

3 - Springs
   Load changes as spring is stretched from rest position

4 - Weights (Counter balance)
   They add mass

5 - Shock absorbers
   Load changes with velocity of dancer
Dancer Arm:
• Should be long enough
• Should be positioned far enough away from adjacent idler rolls so the load on the dancer arm does not change
• Arcs of 30°- 90° are common

Loading Device should be:
• Independent of position
• Independent of velocity
• Independent of direction of motion

Effect of Position, Velocity & Direction of Motion on Dancer
Air Cylinder & Regulator

- Velocity affects air cylinder & regulator combination
- Pressure regulator can make or break dancer system
- Must have sensitive relieving regulator (grab dancer arm & pull up quickly)

Recommended: Add an air reservoir between the regulator and cylinder. The reservoir volume must be much larger than the cylinder volume.
Gain Affects on Dancer Position

- Assume 1° of Dancer rotation results in an output/torque change of 5 (lb-ft)....”Gain”
- What happens to Tension?

\[ \Delta T = \frac{5 \text{ (lb-ft)}}{1 \text{ (ft)}} = 5 \text{ lb @ Full Roll} \]
Gain Affects on Dancer Position

- Assume 1° of Dancer rotation results in an output/torque change of 5 (lb-ft)…”Gain”
- What happens to Tension?

\[ \Delta T = \frac{5 \text{(lb - ft)}}{0.25 \text{ (ft)}} = 20 \text{lb @ Core} \]
Summary of Gain Affects on Dancer Position

Review Roll Dimensions

- Full Roll Diameter of 1 (ft)
- Core Diameter of 0.25 (ft)

Roll Build
Ratio of 4:1

Tension Change Due to Roll Diameter Reduction

- 5 lb @ Full Roll
- 20 lb @ Core

Tension Changes by the Roll Build Ratio, but Inertia
(Unwind Gain) Changes by $R^3$, or 1:64

Larger Roll Build Ratios are Common!
Evolution of Gain
(System Gain = Control Gain + Unwind Gain)

“The Past”

The graph shows the evolution of gain without gain compensation. The x-axis represents the diameter, and the y-axis represents the gain. The graph compares different gain components, including:

- System Gain w/o Compensation
- Control Gain w/o Compensation
- Unwind Gain
Methods to Minimize Gain Affects

- Reduce the Roll Build Ratio
  - Impossible!!!!

- Operate Dancer Control with Low Gain
  - Slow Response (Sluggish)
  - Dancer May Hit Stops

- Set Gain Proportionate to Roll Size
  - Use a Gain Compensating Dancer Control
Evolution of Gain
(System Gain = Control Gain + Unwind Gain)

“The Past”

“Today”
Summary

- Use Dancer Systems for Accumulation
  - Out-of-Round Rolls
  - Indexing
  - Zero Speed Splicing
- Use a Quality “Non-Stick” Rolling Diaphragm Air Cylinder
- Make the Arm as Light as possible
- No Springs, Dampers or Weights
- For Large Roll Builds use a Gain Compensating Control
Thank you!

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Please remember to turn in your evaluation sheet...