Disturbance Rejection in a Web Transport System Using a Pendulum Dancer

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Outline

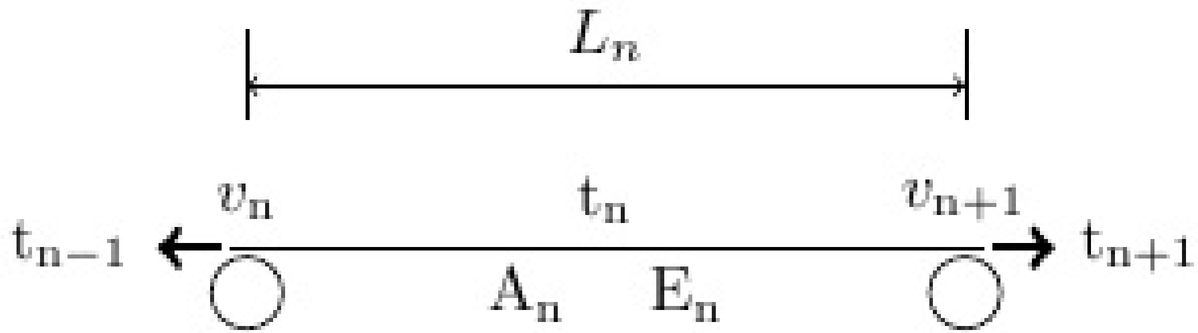
- Motivation
- Primitive Elements
- The Euclid Web Line
- Disturbance Results
- Conclusions

Motivation

- Increase awareness of Dancer utility
- Create a mathematical model of a physical web line to allow simulation
- Study disturbance rejection capability of a dancer

Primitive Elements

- The Span
  - Conservation of mass
  - Linearized



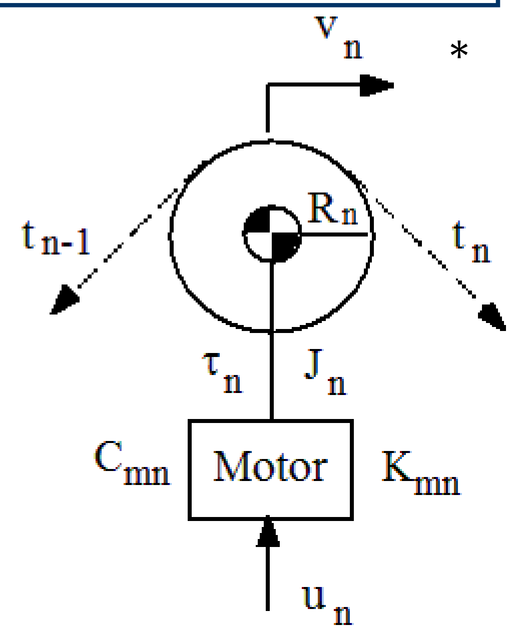
*

$$L_n(t)\frac{dt_n(t)}{dt} = \mathrm{E_n A_n}(v_{\mathrm{n+1}} - v_{\mathrm{n}}) - V_{\mathrm{n+1}}\mathrm{t_n(t)} + V_{\mathrm{n}}\frac{\mathrm{E_n A_n}}{\mathrm{E_{n-1} A_{n-1}}}\mathrm{t_{n-1}(t)}$$

*K.-H. Shin, Distributed control of tension in multi-span web transport systems, Stillwater, OK: Ph.D, Oklahoma State University, 1991.

Primitive Elements

- The Driven Roller
  - Torque Balance
  - Remove Motor constant and damping for idle roller
  - Linearized

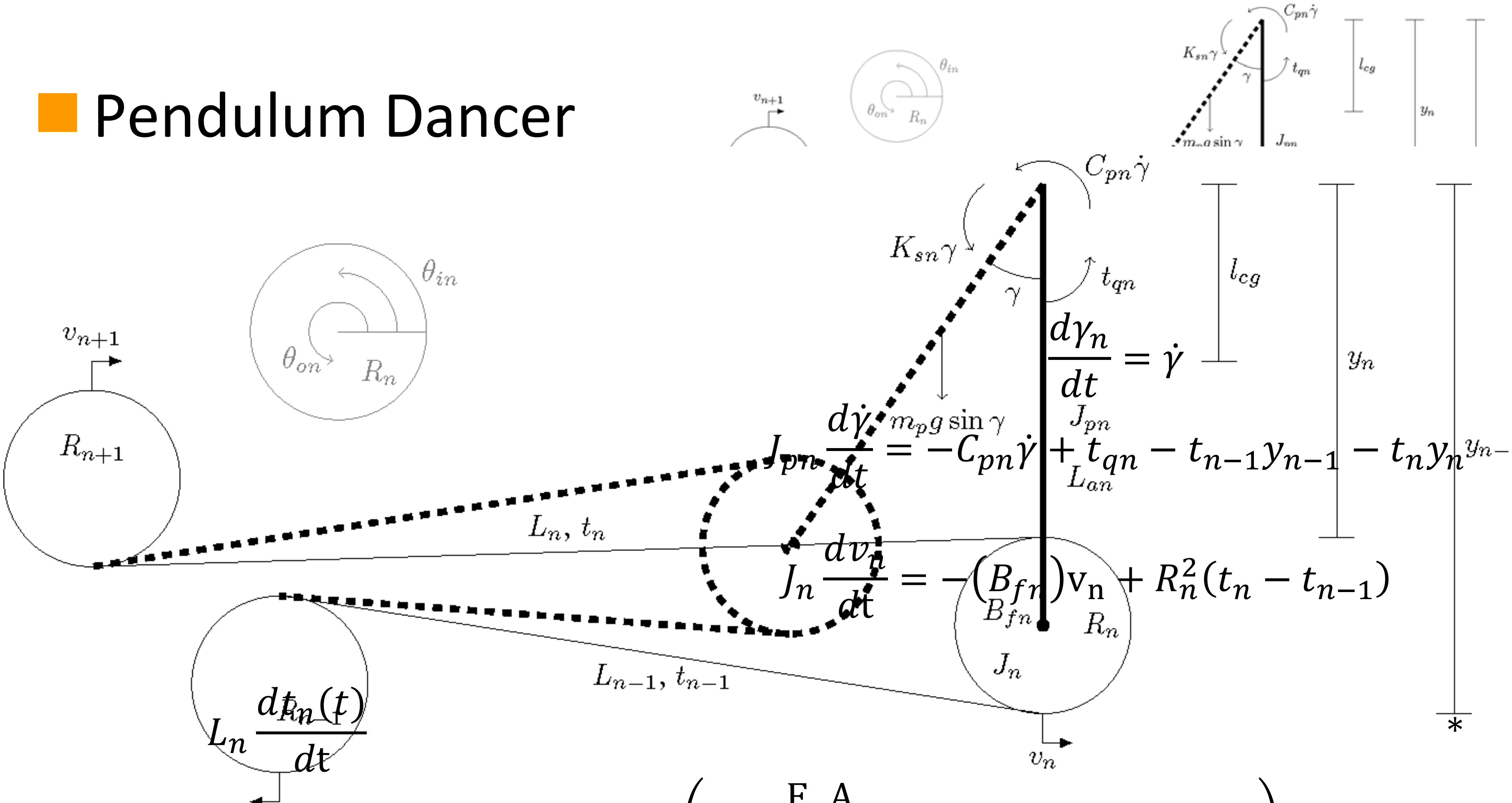


$$J_n \frac{dv_n}{dt} = -\left(B_{fn} + C_{bn}\right)v_n + R_n^2\left(t_n - t_{n-1}\right)$$
$$-R_n K_{bn} u_n + \mathrm{R_n M}_n \mathrm{ge_n} \sin(\omega_n \mathrm{t} + \phi_{n0})$$ *

*K.-H. Shin, Distributed control of tension in multi-span web transport systems, Stillwater, OK: Ph.D, Oklahoma State University, 1991.

Primitive Elements

- Pendulum Dancer



$$\frac{d\gamma_n}{dt} = \dot\gamma$$

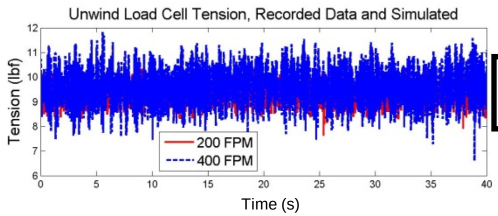
$$J_{pn}\frac{d\dot\gamma}{dt} = -C_{pn}\dot\gamma + t_{qn} - t_{n-1}y_{n-1} - t_n y_n$$

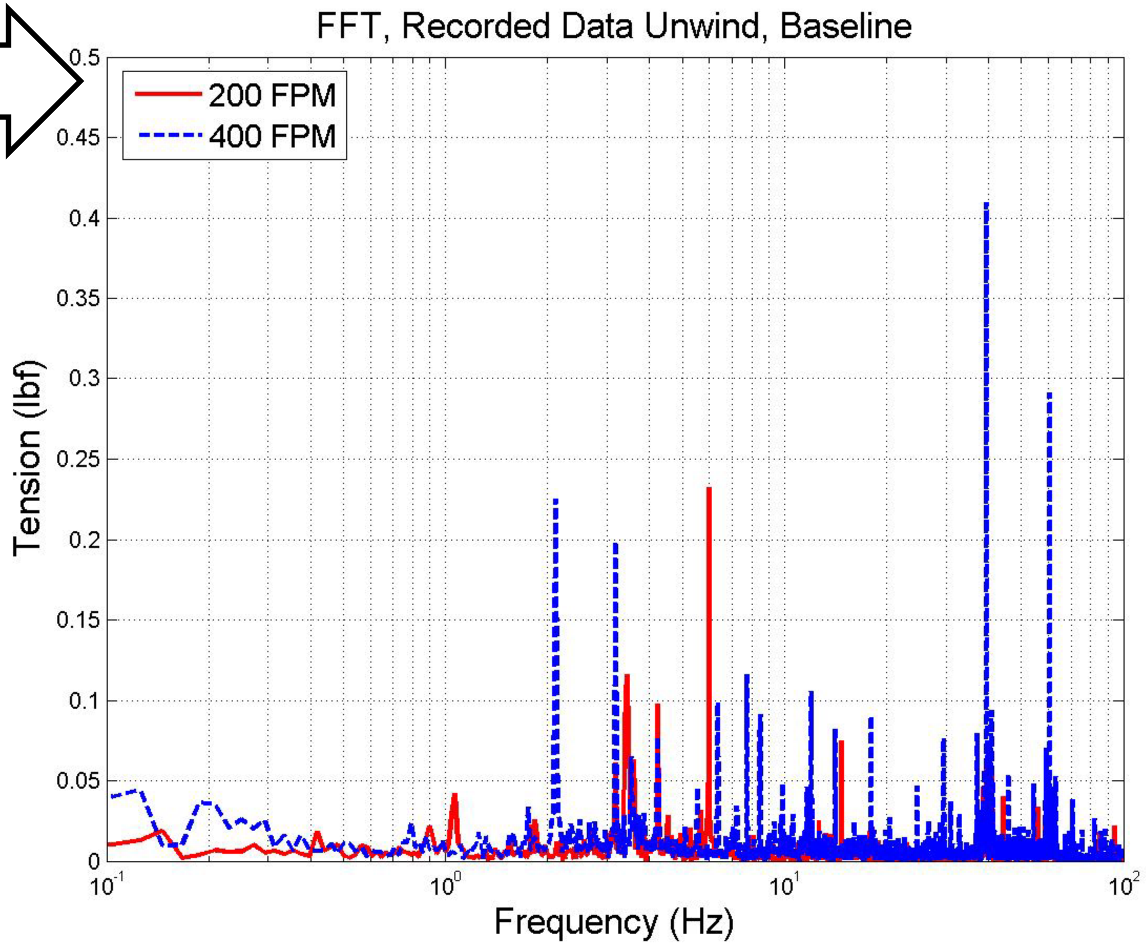
$$J_n\frac{dv_n}{dt} = -(B_{fn})\mathrm{v_n} + R_n^2(t_n - t_{n-1})$$

$$L_n\frac{dt_n(t)}{dt} = \mathrm{E_nA_n}\big(v_{n+1}(\mathrm{t}) - v_{\mathrm{n}}(\mathrm{t})\big) + \left(V_n\frac{\mathrm{E_nA_n}}{\mathrm{E_{n-1}A_{n-1}}}\,\mathrm{t_{n-1}(t)} - V_{n+1}t_n(\mathrm{t})\right) + (\mathrm{E_nA_n} - t_n)L_{an+1}\dot\gamma_{\mathrm{n+1}}\sin(\theta_{in+1})$$

*K.-H. Shin, Distributed control of tension in multi-span web transport systems, Stillwater, OK: Ph.D, Oklahoma State University, 1991.

Fast-Fourier Transform

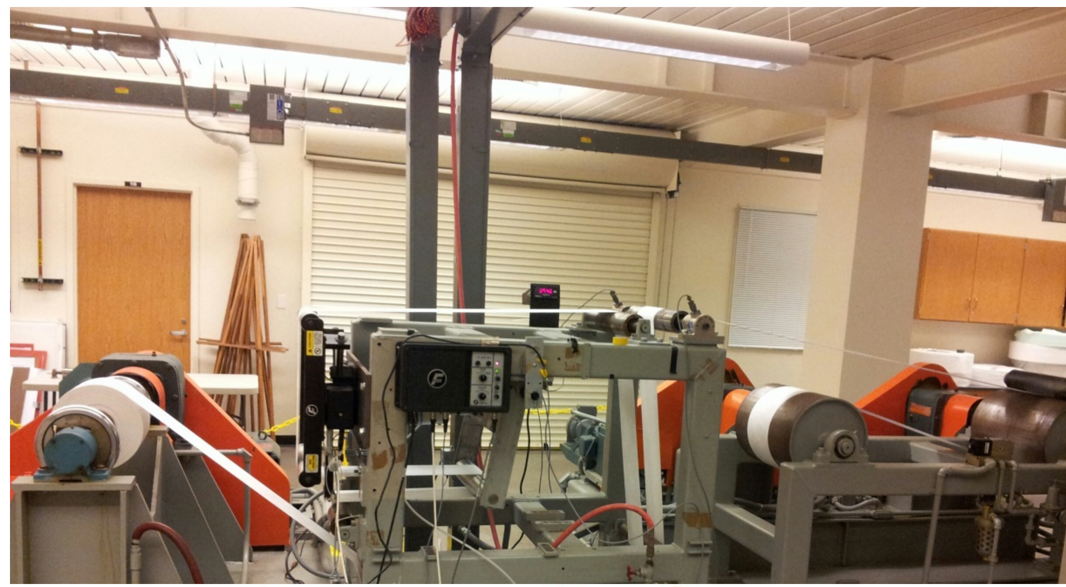


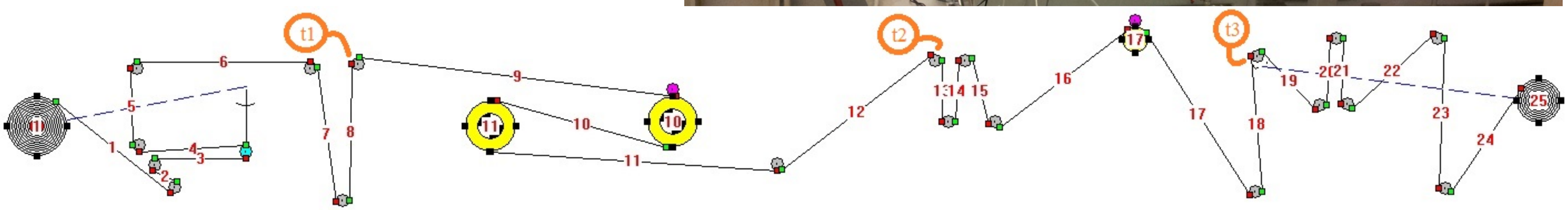


- Fits a large group of sinusoids to raw data
- Returns magnitude and frequency
- Excel can do this

Euclid Web Line

- High tension, low speed research line
- Tyvek material
- 4 sections
  - Unwind
  - S-wrap
  - Process
  - Rewind

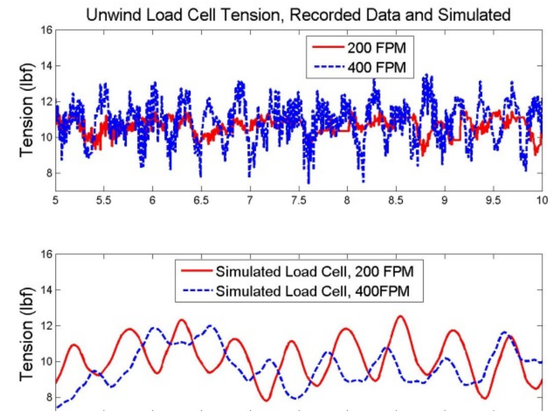


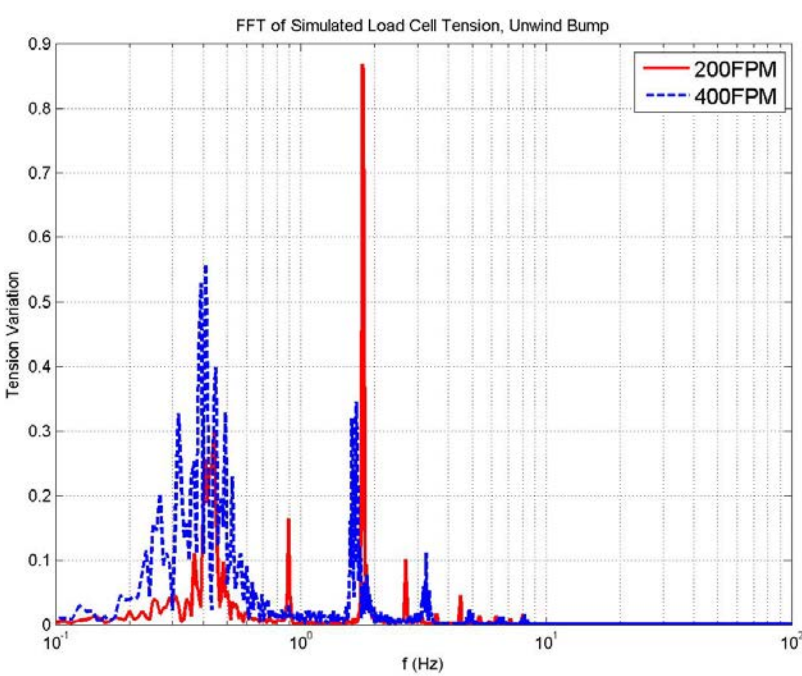


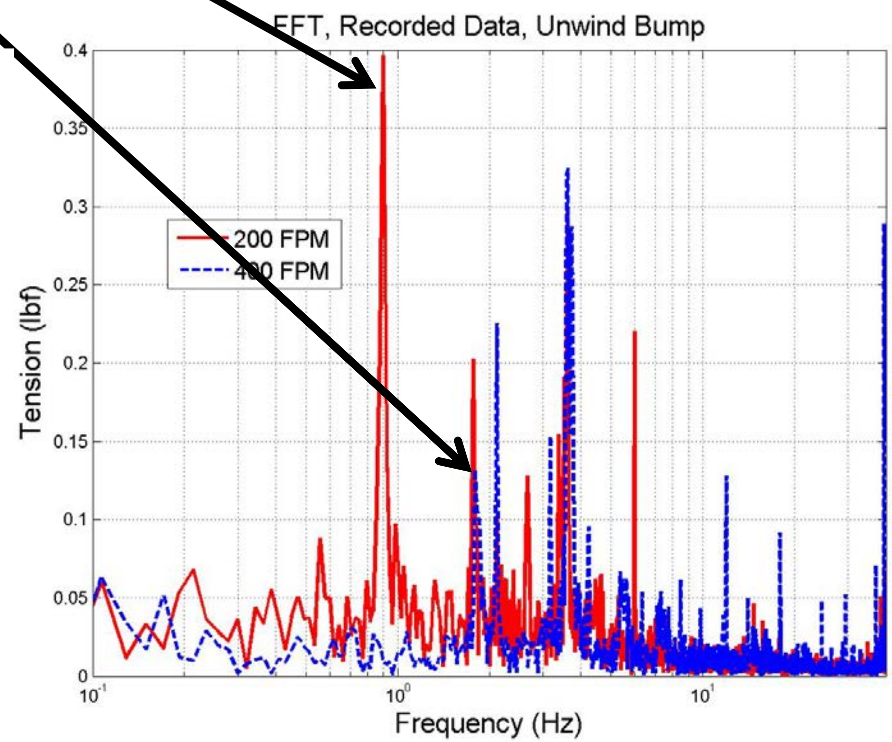
DISTURBANCES

Unwind Bump Disturbance

- 0.75in bump added
- 0.91Hz for 200FPM
- 1.82Hz for 400FPM

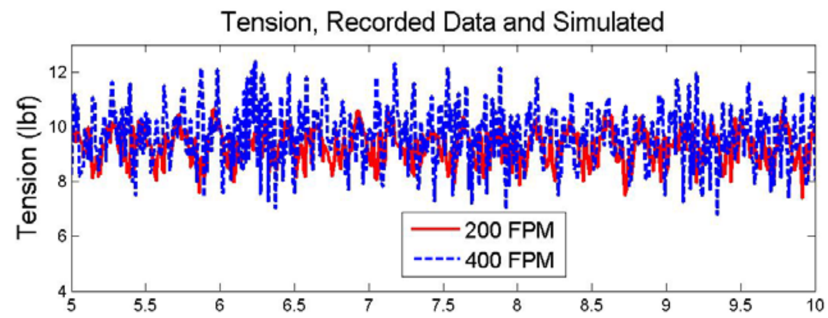


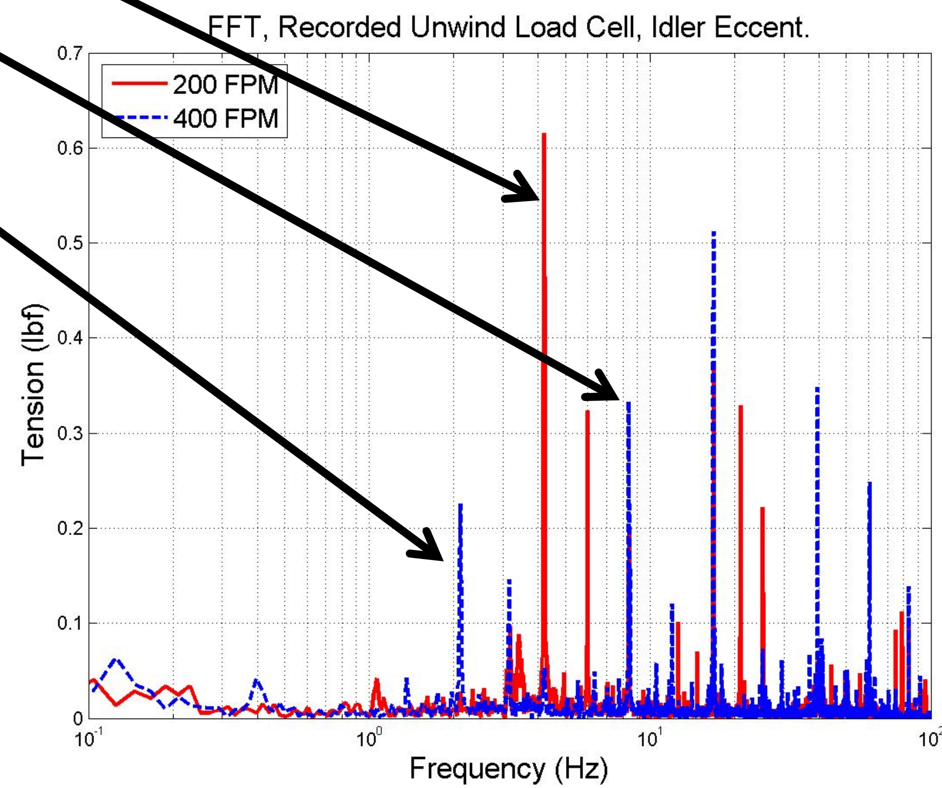




Upstream Eccentric Idler Disturbance

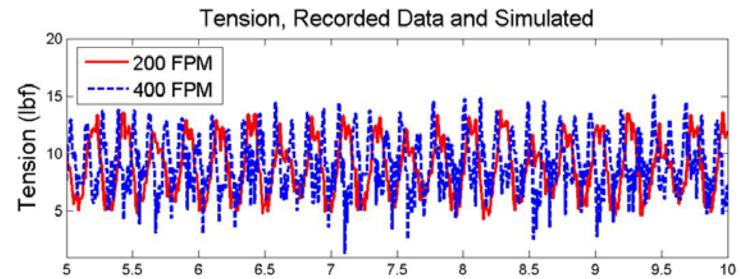
- 0.1in eccentricity
- 4.2Hz for 200FPM
- 8.4Hz for 400FPM
- 2.1Hz for 400FPM
  S-wrap roller

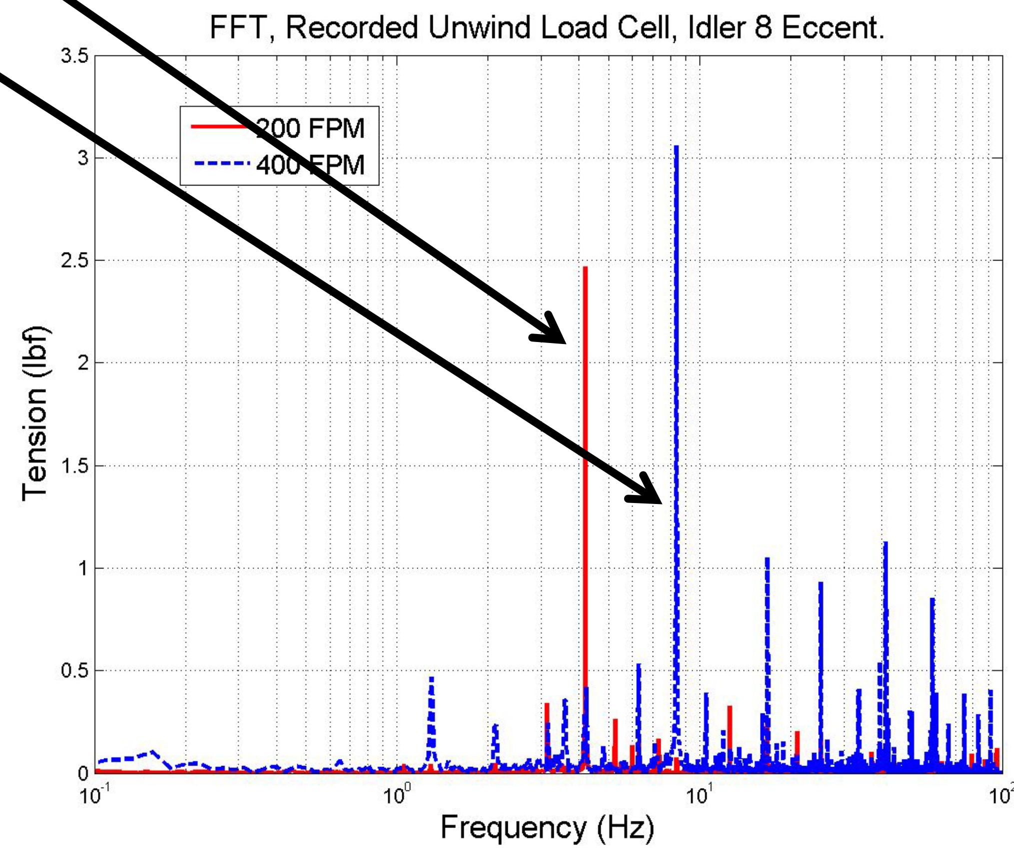




Downstream Eccentric Idler Disturbance

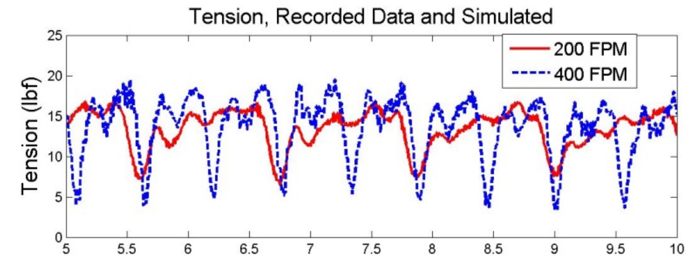
- 0.1 in eccentricity
- 4.2Hz for 200FPM
- 8.4Hz for 400FPM

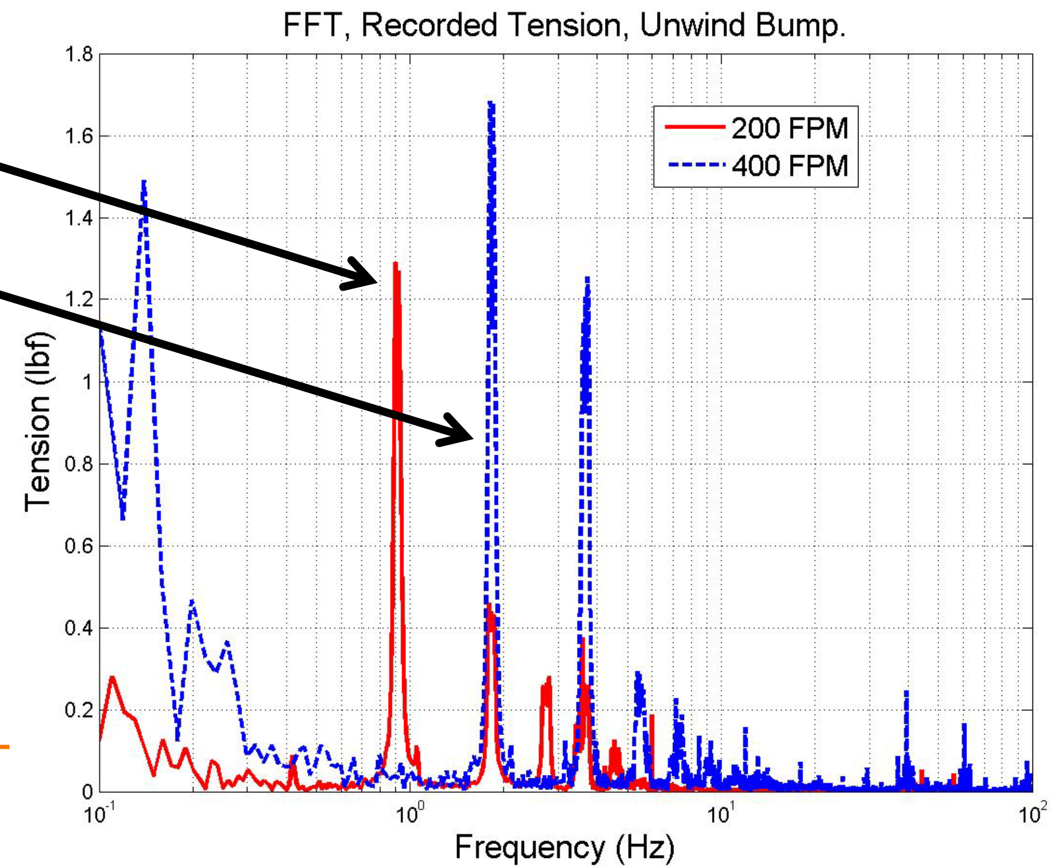




Load Cell Control (No Dancer)

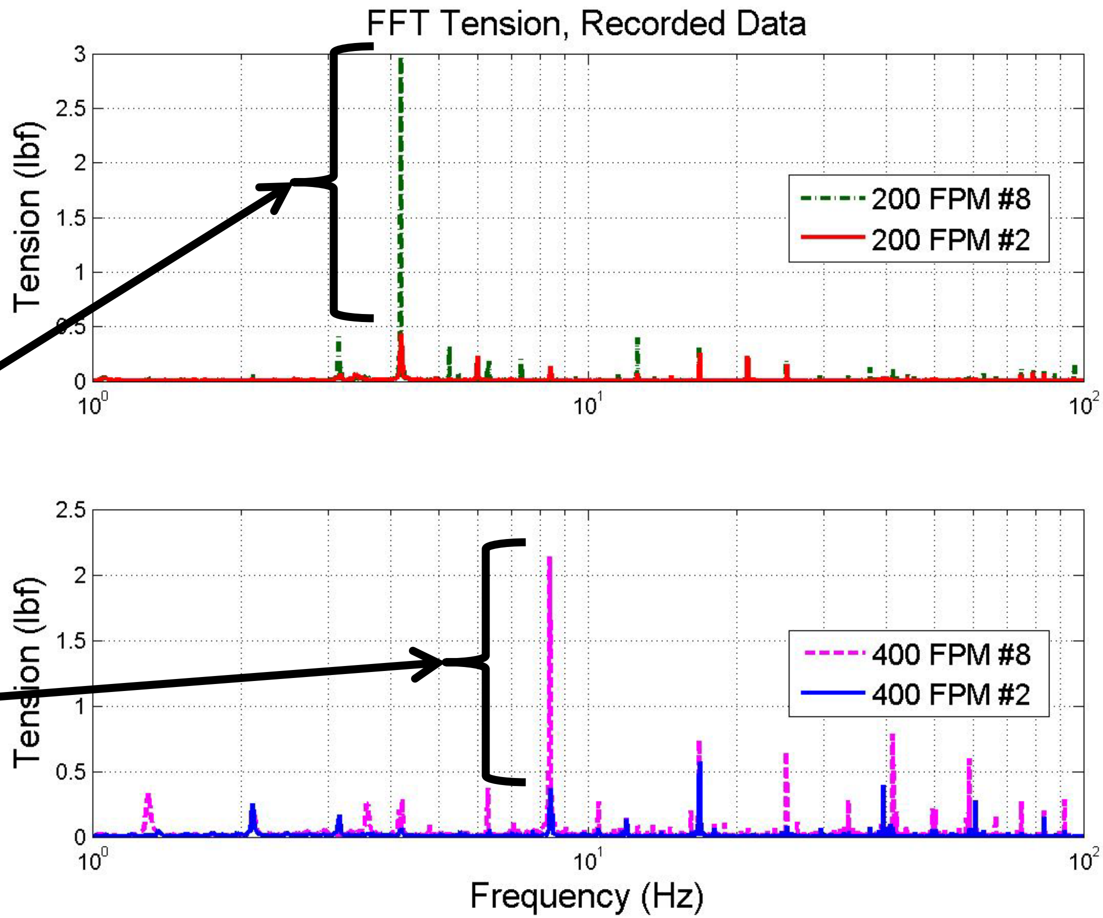
- Lock out the dancer
- Unwind Bump disturbance (0.75in)
- 0.91Hz for 200FPM
- 1.82Hz for 400FPM





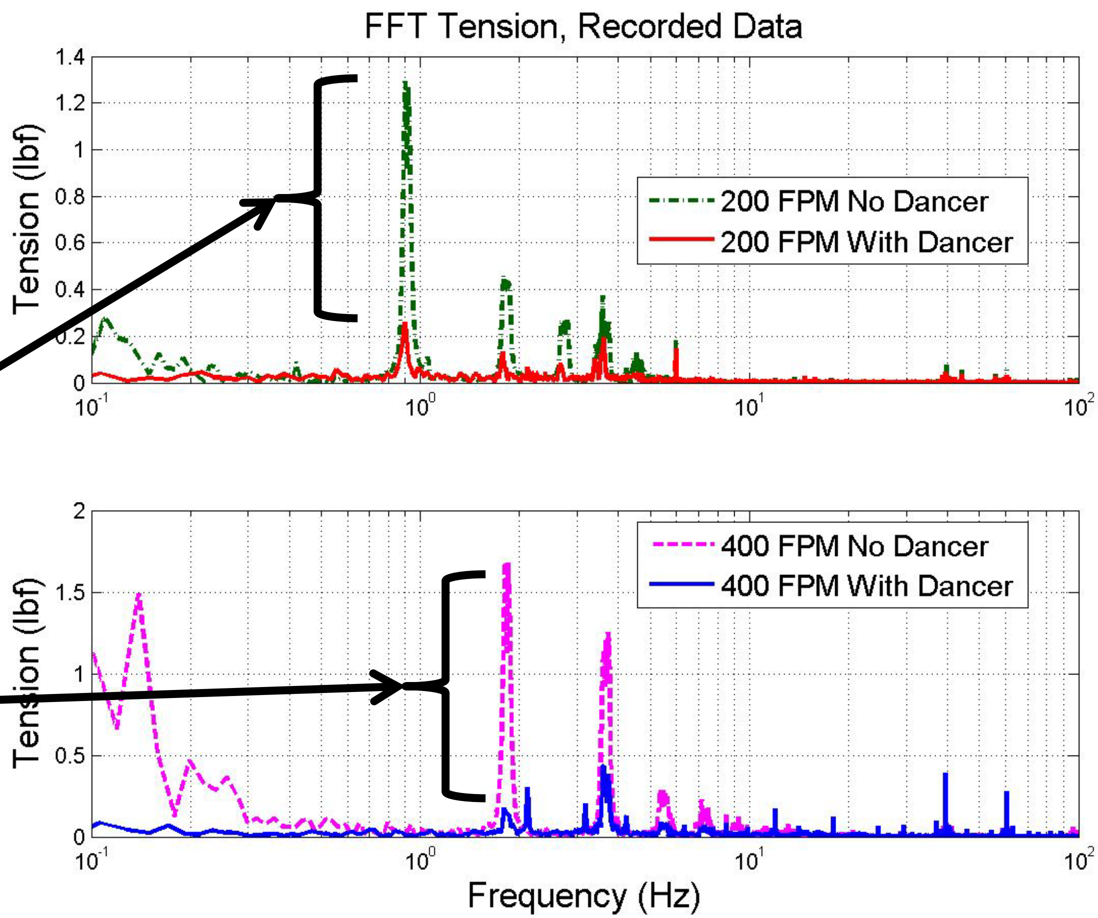
How Effective Is the Dancer?

- Compare Idle eccentricity
- Higher frequency driver
- 83% reduction in 200FPM 1-per-rev frequency magnitude
- 82% at 400FPM



How Effective Is the Dancer?

- Compare Unwind Bump with and without a dancer
- Lower frequency driver
- 83% reduction in 200FPM 1-per-rev frequency magnitude
- 82% at 400FPM



Conclusion

- Reviewed ‘primitive elements’ for modeling web handling lines
- Dancer disturbance rejection capability
  - 80% of 1-per-rev frequency magnitude for the eccentric idler removed compared to the magnitude without a dancer
  - 80% of 1-per-rev magnitude for the Unwind bump disturbance removed compared to not having a dancer
  - Compared results to simulations made with primitive elements

Questions?

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