APPENDIX H

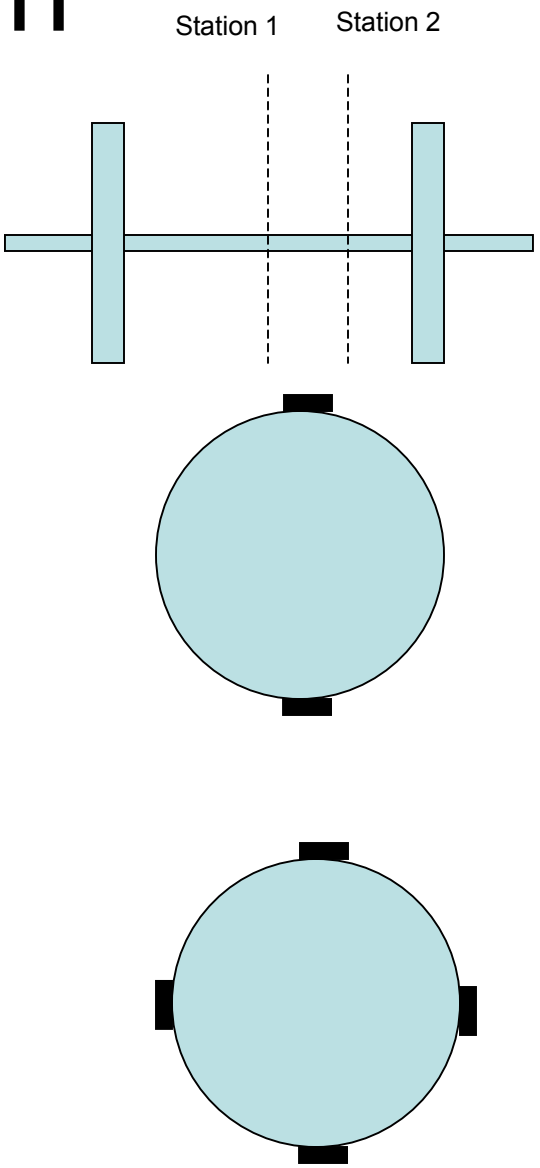
Axle Strains

Appendix H

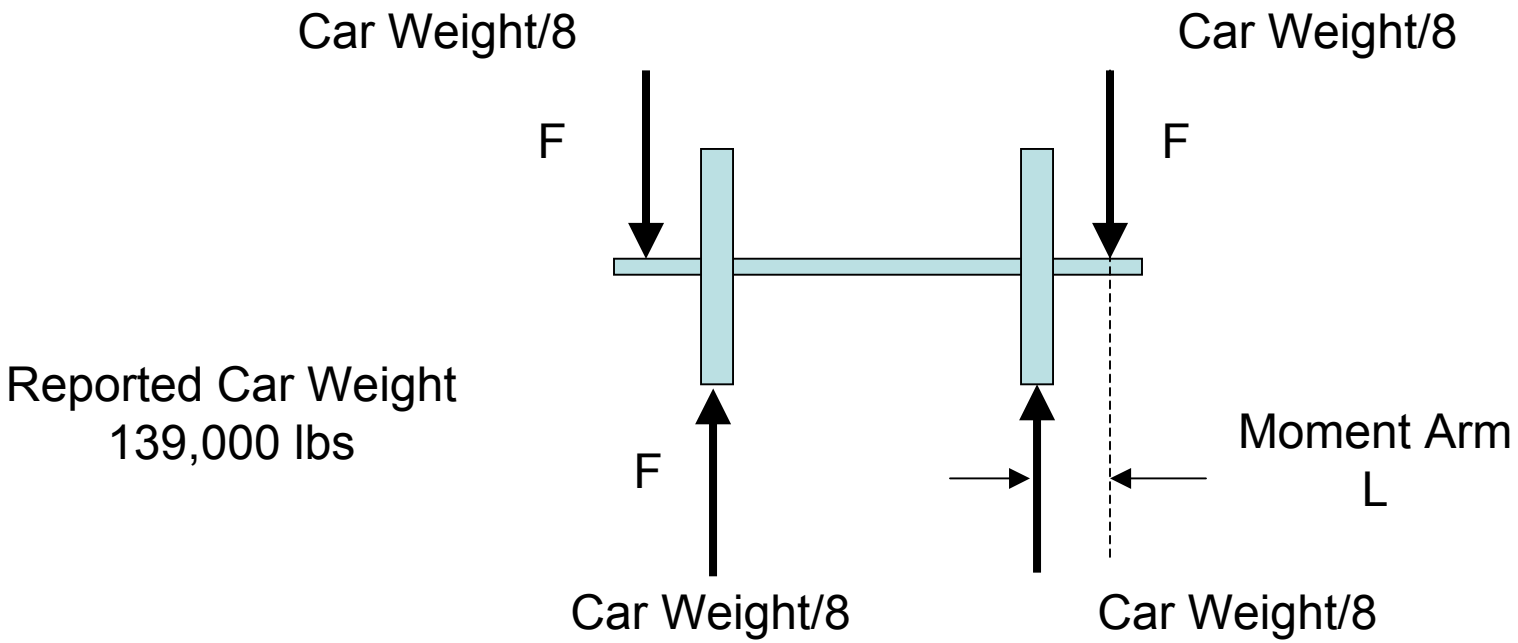
Axle Strain

Axle Strain

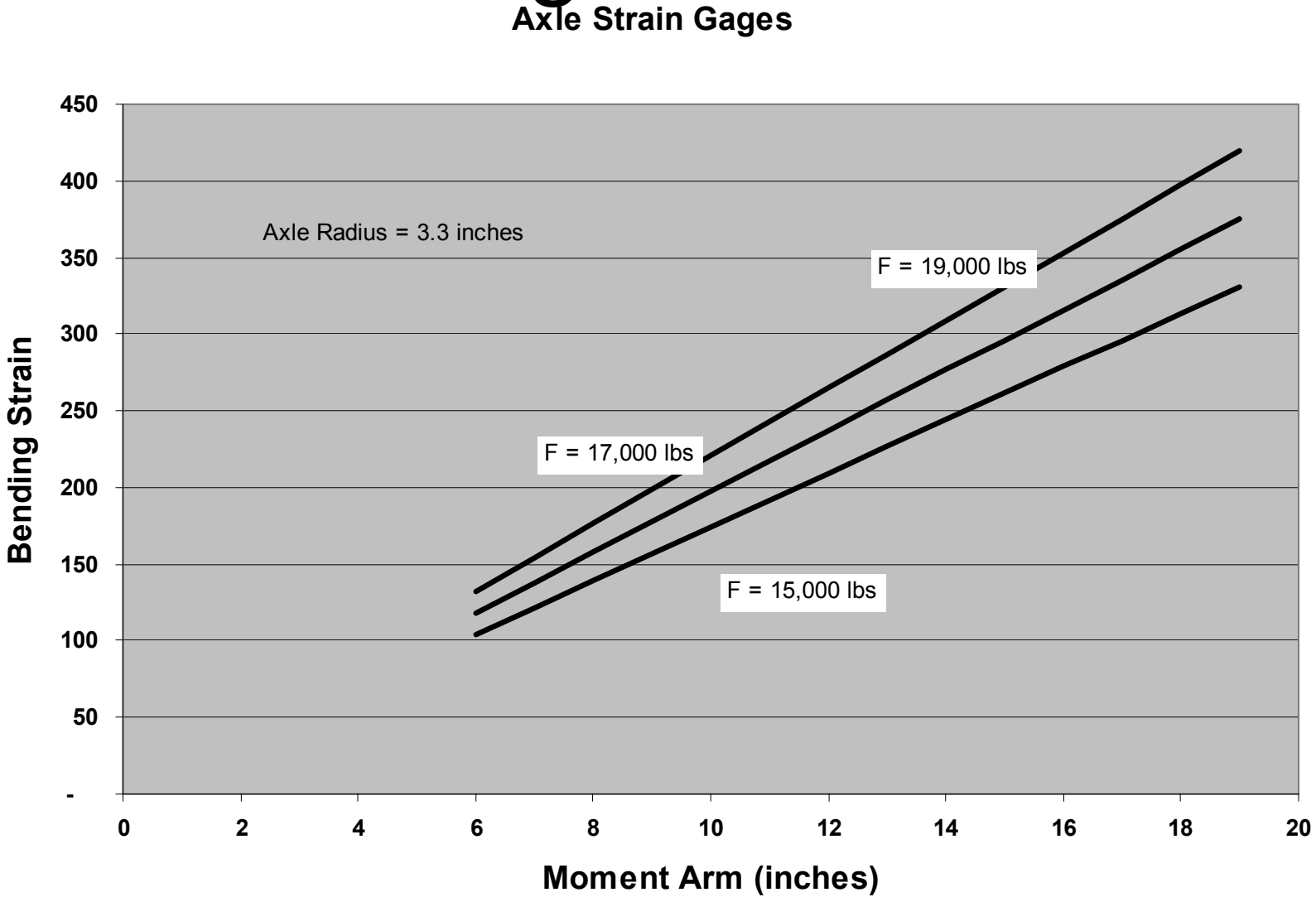
- Axle With WABTEC/SAB-WABCO Discs
  - At Two Stations Along Axle
  - Two Gages Per Station
  - 180^{o} Difference In Circumferential Location
- Axle with Knorr Discs
  - At Two Stations Along Axle
  - Two Gages at One Station
  - Four Gages At the Other Station
  - 180^{o} And 90^{o} Difference In Circumferential Location



Axle Strain Analysis



Bending Axle Strain



PSD of Strain Signals

- The PSD's of Strain Gage Signals Revealed Little Information for Either Axle
- Both Showed a Peak at the Wheel Revolution Frequency
- Co-processing of Two Channels of Bending Signals May Provide a More Accurate PSD

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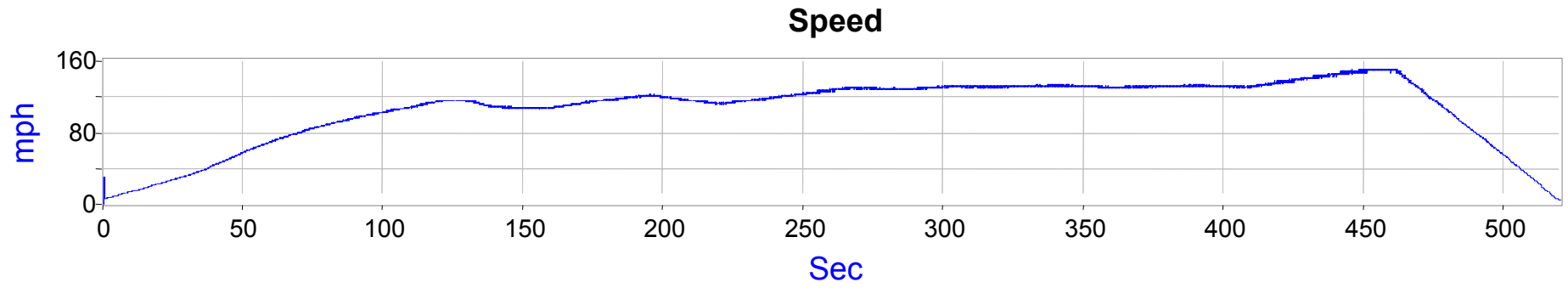
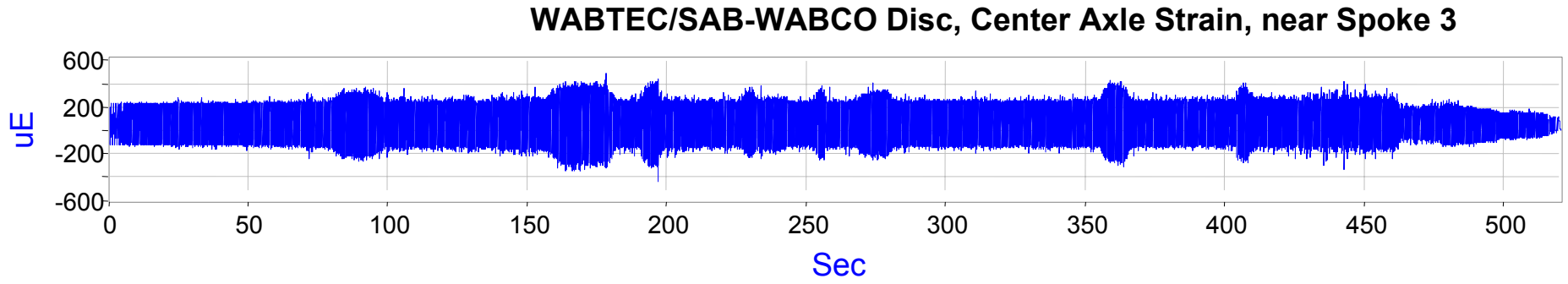
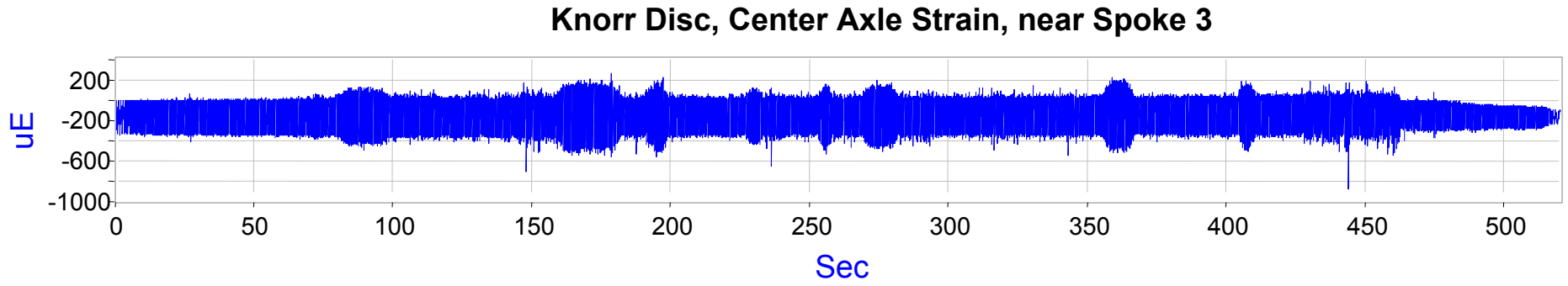

Speed
160
80
0
mph
0
50
100
150
200
250
300
350
400
450
500
Sec


WABTEC/SAB-WABCO Disc, Center Axle Strain, near Spoke 3
600
200
-200
-600
uE
0
50
100
150
200
250
300
350
400
450
500
Sec


Knorr Disc, Center Axle Strain, near Spoke 3
200
-200
-600
-1000
uE
0
50
100
150
200
250
300
350
400
450
500
Sec

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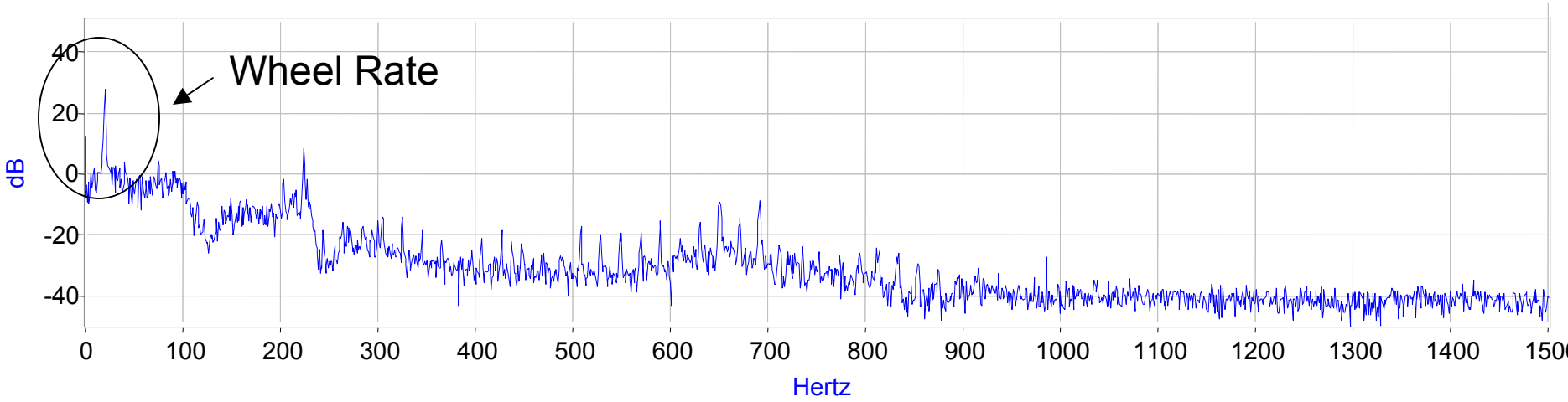
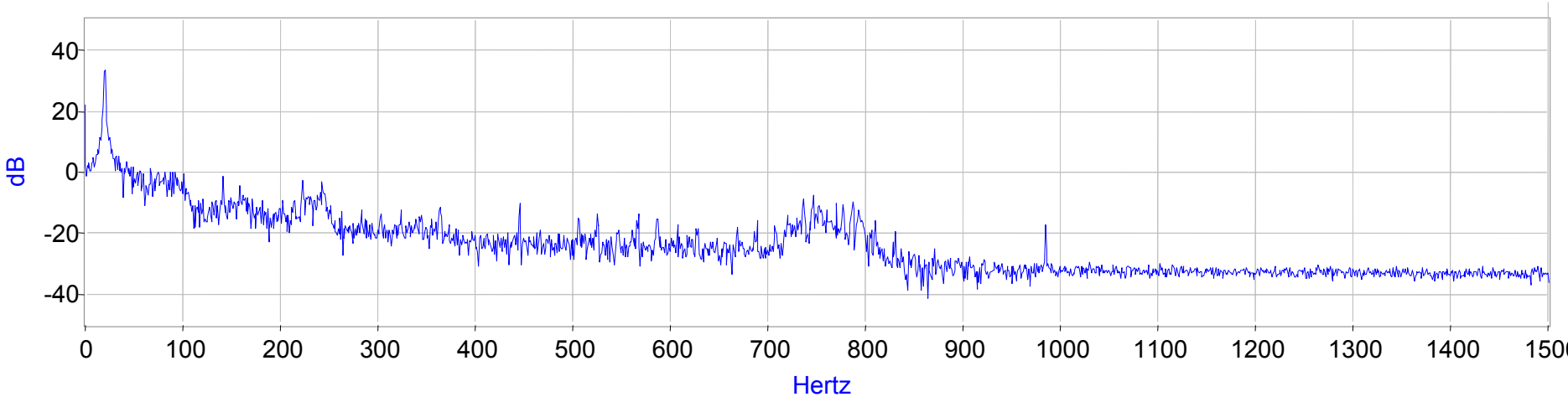
**PSD of WABTEC/SAB-WABCO Disc Axle Strain near Spoke 3,
16384 points, 5 point moving avg, t = 300s, speed = 130 mph**



**PSD of Knorr Disc Axle Strain near Spoke 3,
16384 points, 5 point moving avg, t = 300s, speed = 130 mph**



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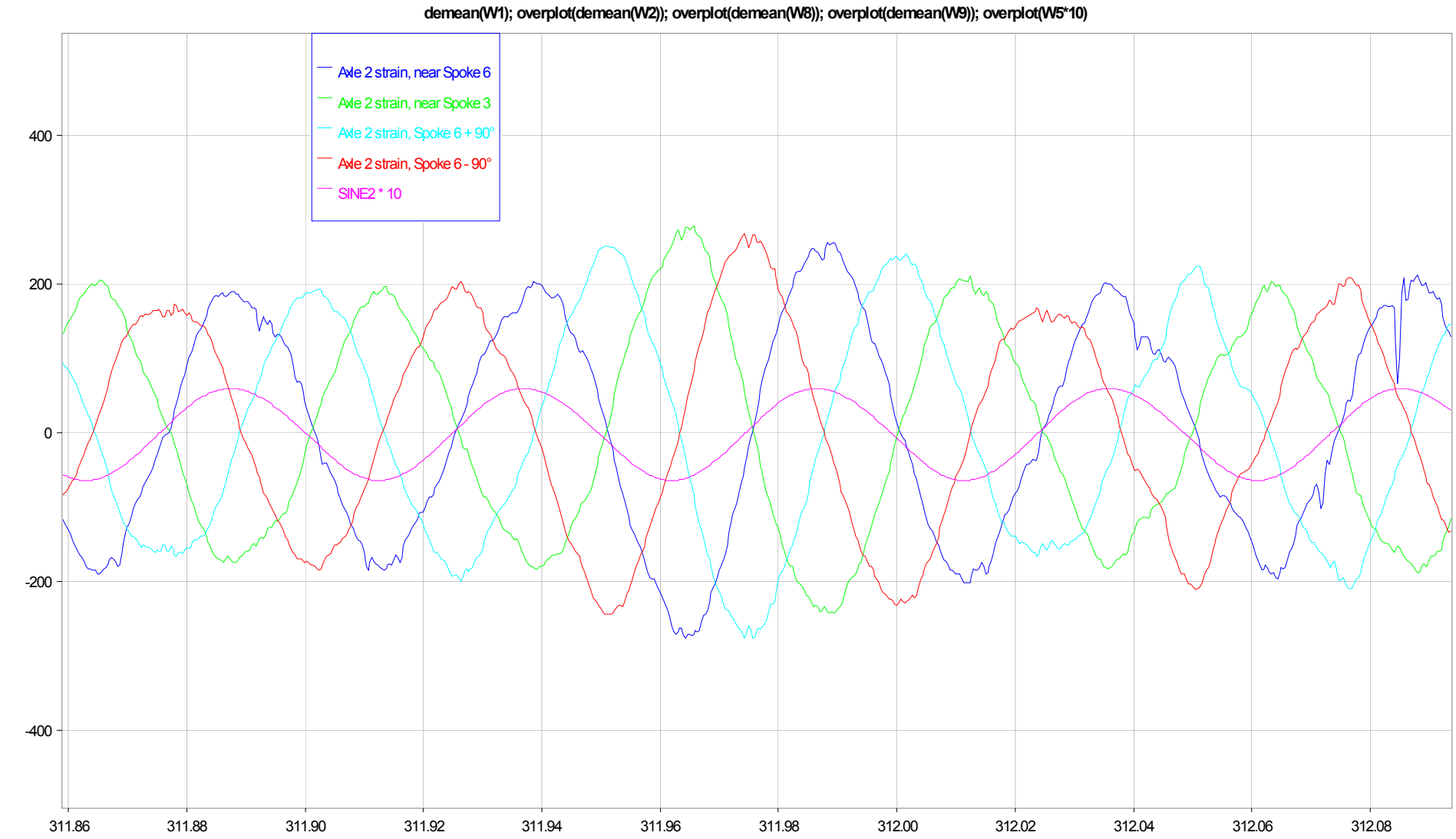
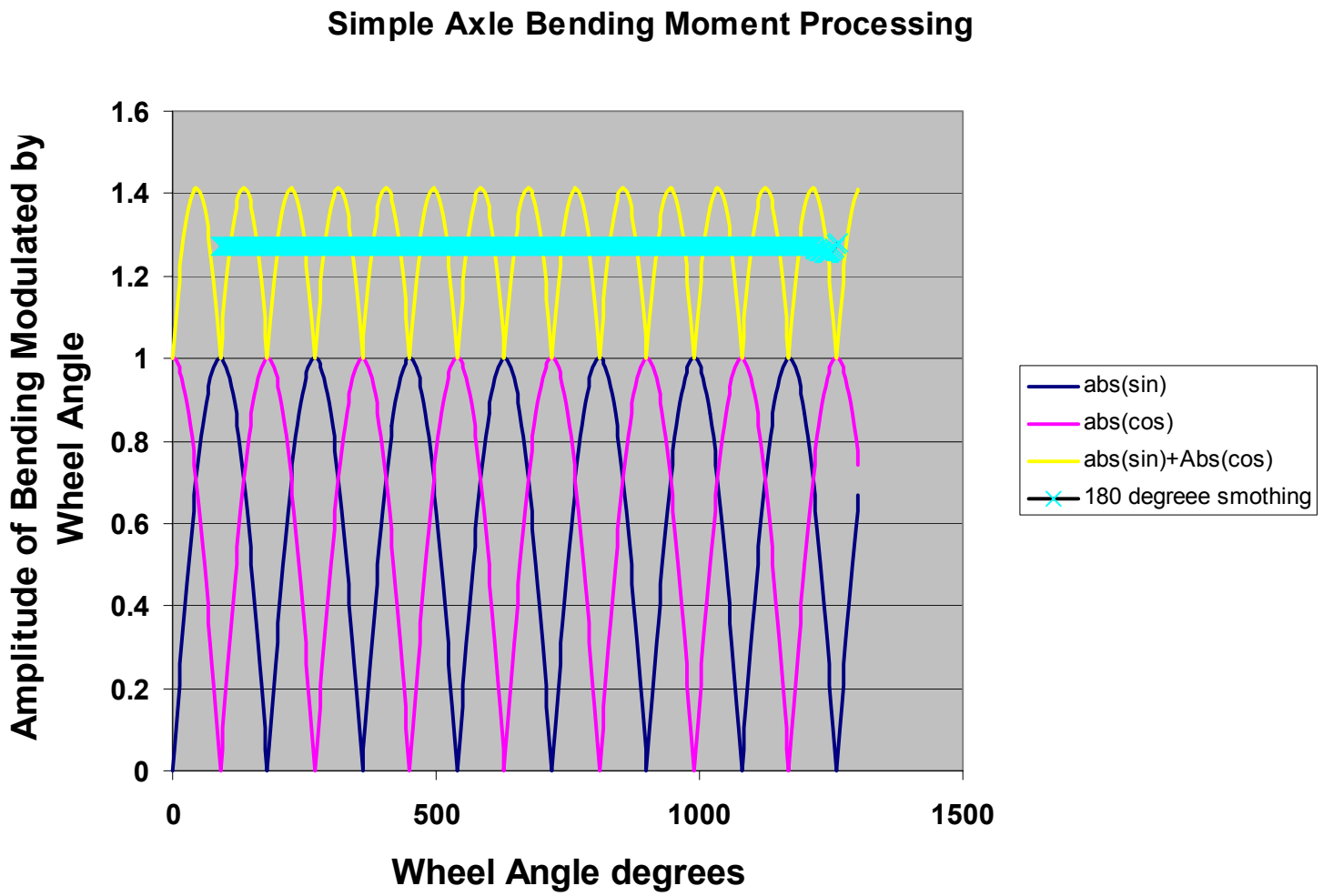

demean(W1); overplot(demean(W2)); overplot(demean(W8)); overplot(demean(W9)); overplot(W5*10)
Axle 2 strain, near Spoke 6
Axle 2 strain, near Spoke 3
Axle 2 strain, Spoke 6 + 90°
Axle 2 strain, Spoke 6 - 90°
SINE2 * 10
400
200
0
-200
-400
311.86
311.88
311.90
311.92
311.94
311.96
311.98
312.00
312.02
312.04
312.06
312.08

General Observations

- Modulated By Wheel Rate
- Long Term Envelope Established By Unbalance On Curves
- This Envelope Can Be Determined By The Following Method
- Add The Absolute Values Of Two Bending Moment Stains That Are 90^{o} Separated And Average Over Several Wheel Cycles
- Resultant Equals the Average Bending Moment Times ~ 1.2
- See Following Example

Axle Bending Moment



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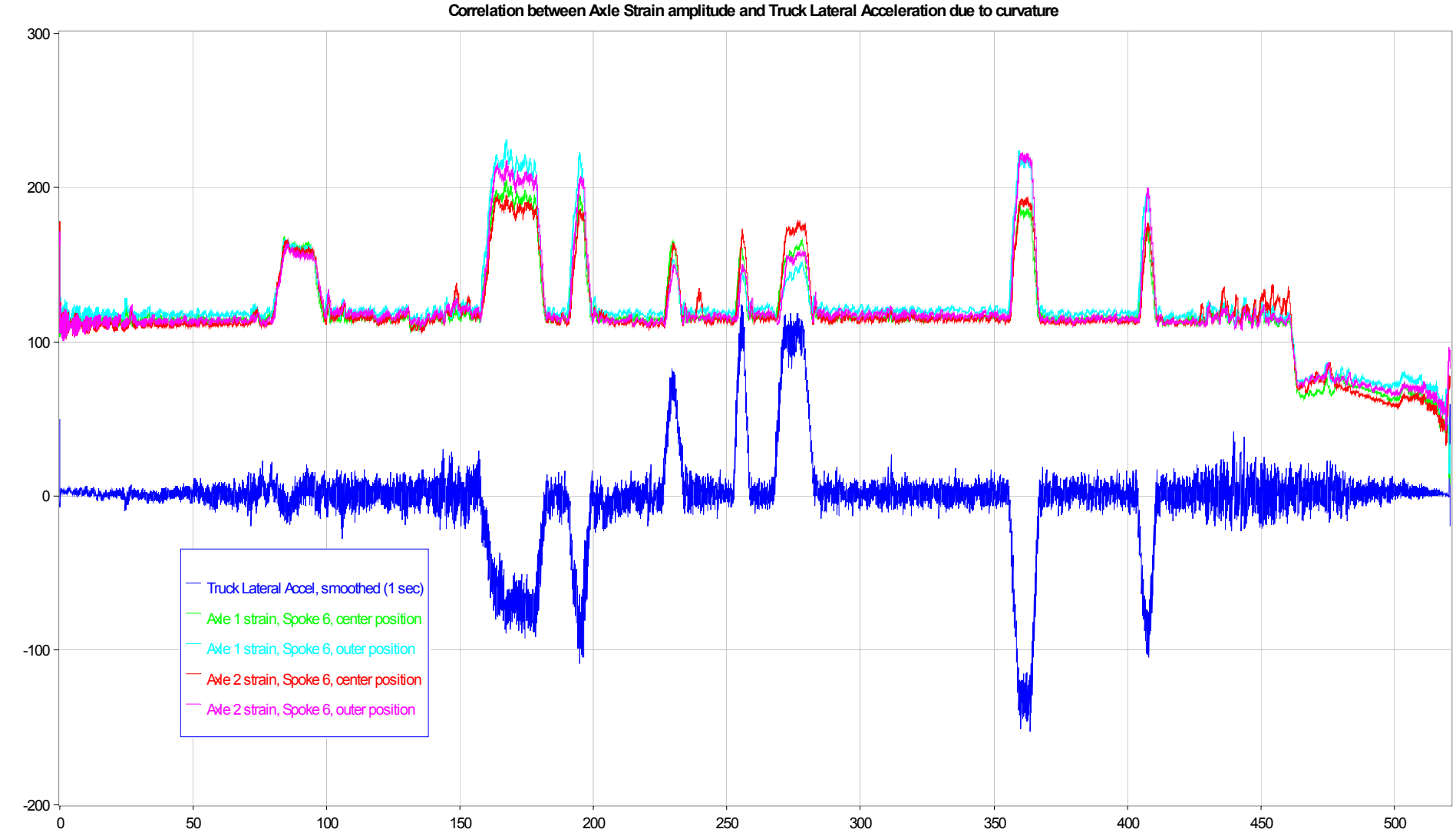
Bending Moment Envelope



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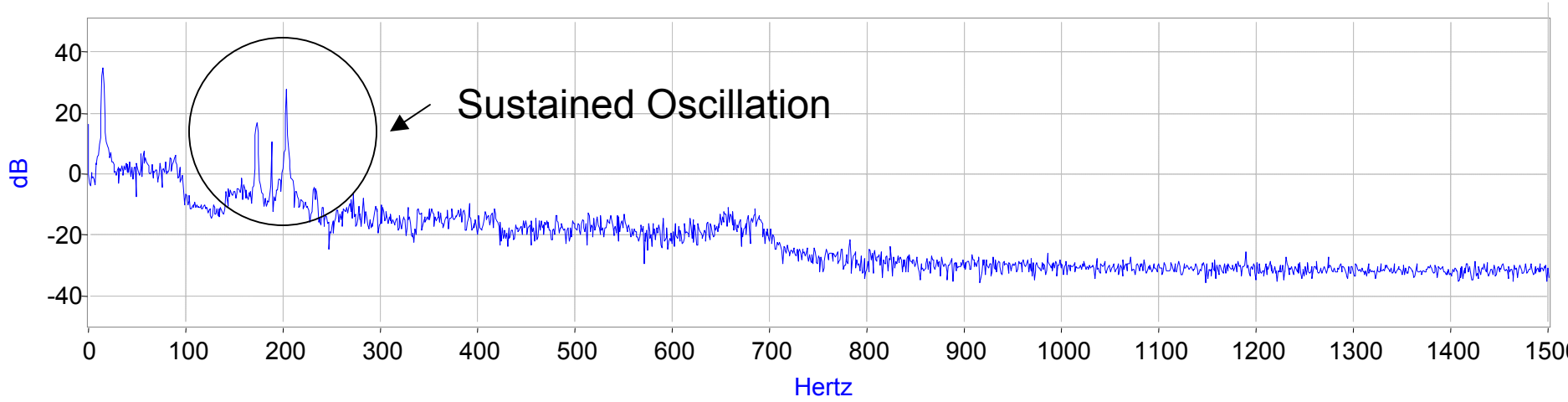
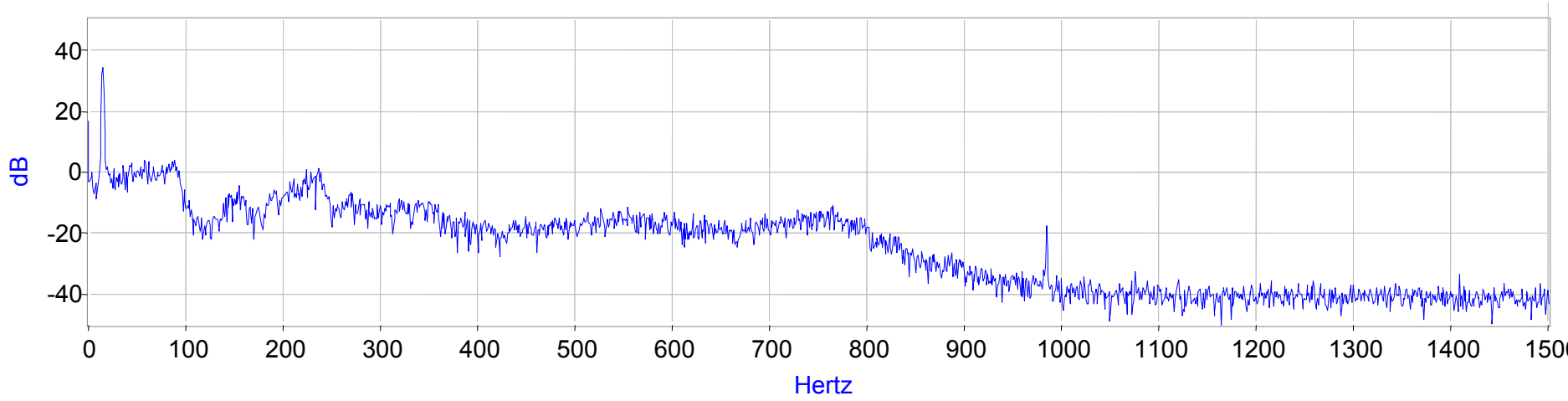
PSD of WABTEC/SAB-WABCO Disc Axle Strain near Spoke 3,
16384 points, 5 point moving avg, t = 480s, speed = 97 mph, during sustained oscill

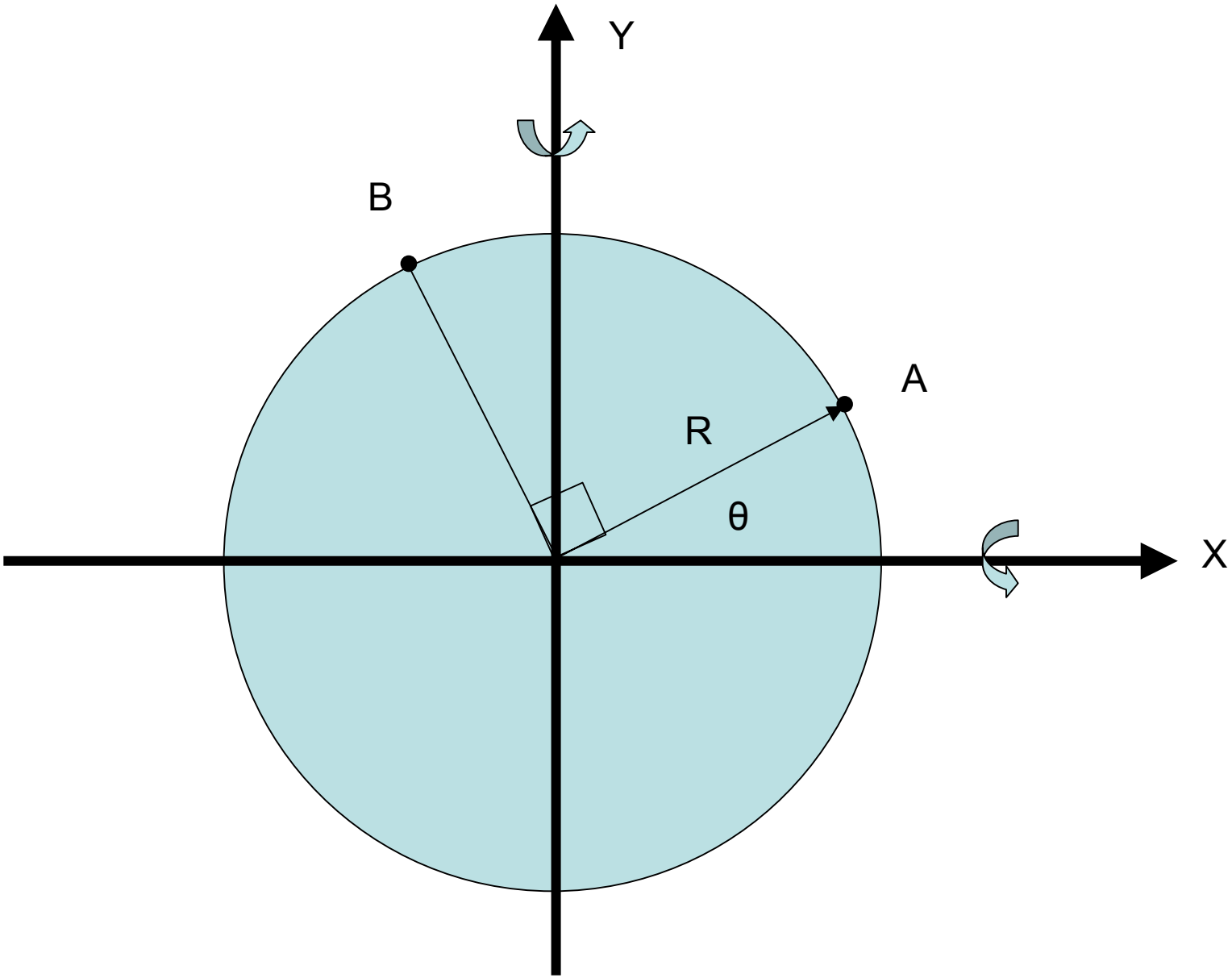


PSD of Knorr Disc Axle Strain near Spoke 3,
16384 points, 5 point moving avg, t = 480s, speed = 97 mph, during sustained oscill



Extracting the Two Orthogonal Bending Moments

- This Method Can Be Used When Two Bending Moment Gages Are 90^{o} Apart
- The First Bending Moment is in the Vertical Plane
- The Second Bending Moment is in the Horizontal Plane
- See the Next Series Of Slides For Method


Y
B
A
R
θ
X

Combined Bending Strain

$$\varepsilon_T = \varepsilon_x + \varepsilon_y$$

$$\varepsilon_x = \frac{-M_x X_A}{I}$$

$$\varepsilon_y = \frac{-M_y Y_A}{I}$$

$$\varepsilon_A = \frac{M_x X_A}{I} - \frac{M_y Y_A}{I}$$

$$\mathrm{X_A = R\sin\theta} \qquad \mathrm{Y_A = R\cos\theta}$$

$$\varepsilon_T = \frac{M_x R\sin\theta}{I} - \frac{M_y R\cos\theta}{I}$$

Strain At Points A and B

$$\varepsilon_A = \frac{M_x R \sin\theta}{I} - \frac{M_y R \cos\theta}{I}$$

$$\varepsilon_B = \frac{M_x R \sin(\theta + 90^o)}{I} - \frac{M_y R \cos(\theta + 90^o)}{I}$$

Given $\varepsilon_A, \varepsilon_B$ and θ

Two Equations and two Unknowns M_x and M_y

Combined Bending

$$\cos(\theta + 90^o) = \cos\theta\cos 90^o - \sin\theta\sin 90^o = -\sin\theta$$

$$\sin(\theta + 90^o) = \sin\theta\cos 90^o + \cos\theta\sin 90^o = \cos\theta$$

$$\varepsilon_A = \frac{M_x R\sin\theta}{I} - \frac{M_y R\cos\theta}{I}$$

$$\varepsilon_B = \frac{M_x R\cos\theta}{I} + \frac{M_y R\sin\theta}{I}$$

Combined Bending

$$\mathrm{M_x} = \left(\frac{I}{R}\right)(\varepsilon_A \sin\theta + \varepsilon_B \cos\theta)$$

$$\mathrm{M_Y} = \left(\frac{I}{R}\right)(+\varepsilon_A \cos\theta - \varepsilon_B \sin\theta)$$

Extracting the Two Orthogonal Bending Moments

- This Approach Has Not Been Implemented
- It Would Be Implemented to:
  - Observe the Full Dynamic Behavior of Disc Bending
  - Observe the Bending Modes of the Axle in Both the Horizontal and Vertical Plane
  - Since the BOP Mode during Braking has Maximum Displacement in the Horizontal Plane, this Information Could be Important to Understand the Axle Disc Interaction