Angular Velocity

The Analysis of the RPM

Physics

- The rate of change of angular displacement and is a vector quantity which specifies the angular speed of an object and the axis about which the object is rotating.

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Simplified

- The RPM displayed in a 0 to 360/720 degree plot and measured degree-by-degree so that slight RPM changes can be detected.

Angular Velocity's Sensor Point

- Records the rise and fall of the RPM in a phased plot
- Can record in units of RPM and Hz
- Only requires the encoder

Angular Velocity’s Tools

- Derivatives and Spectrum window
- Smoothing
- Cursor
- Group/Waterfall Plots

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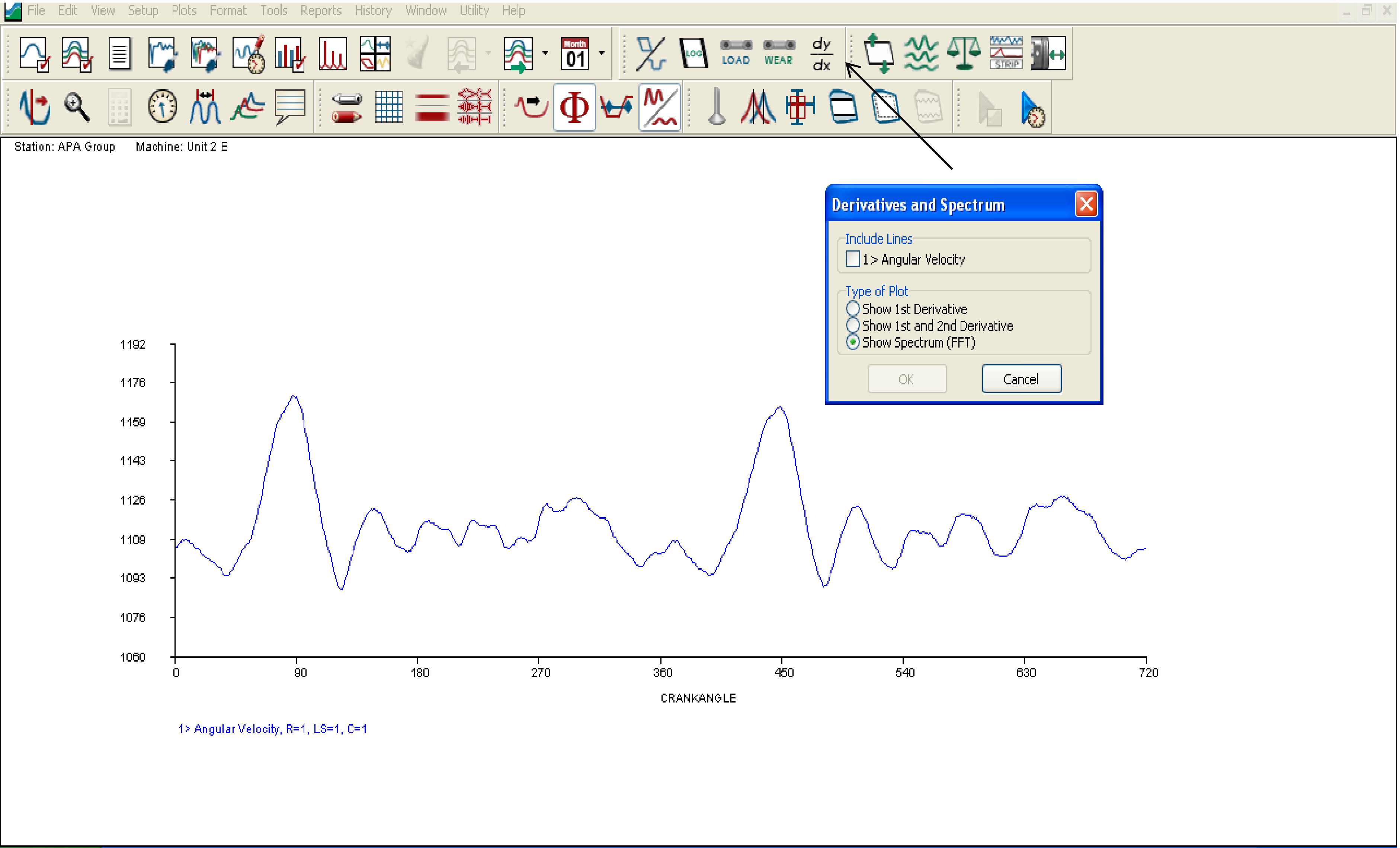
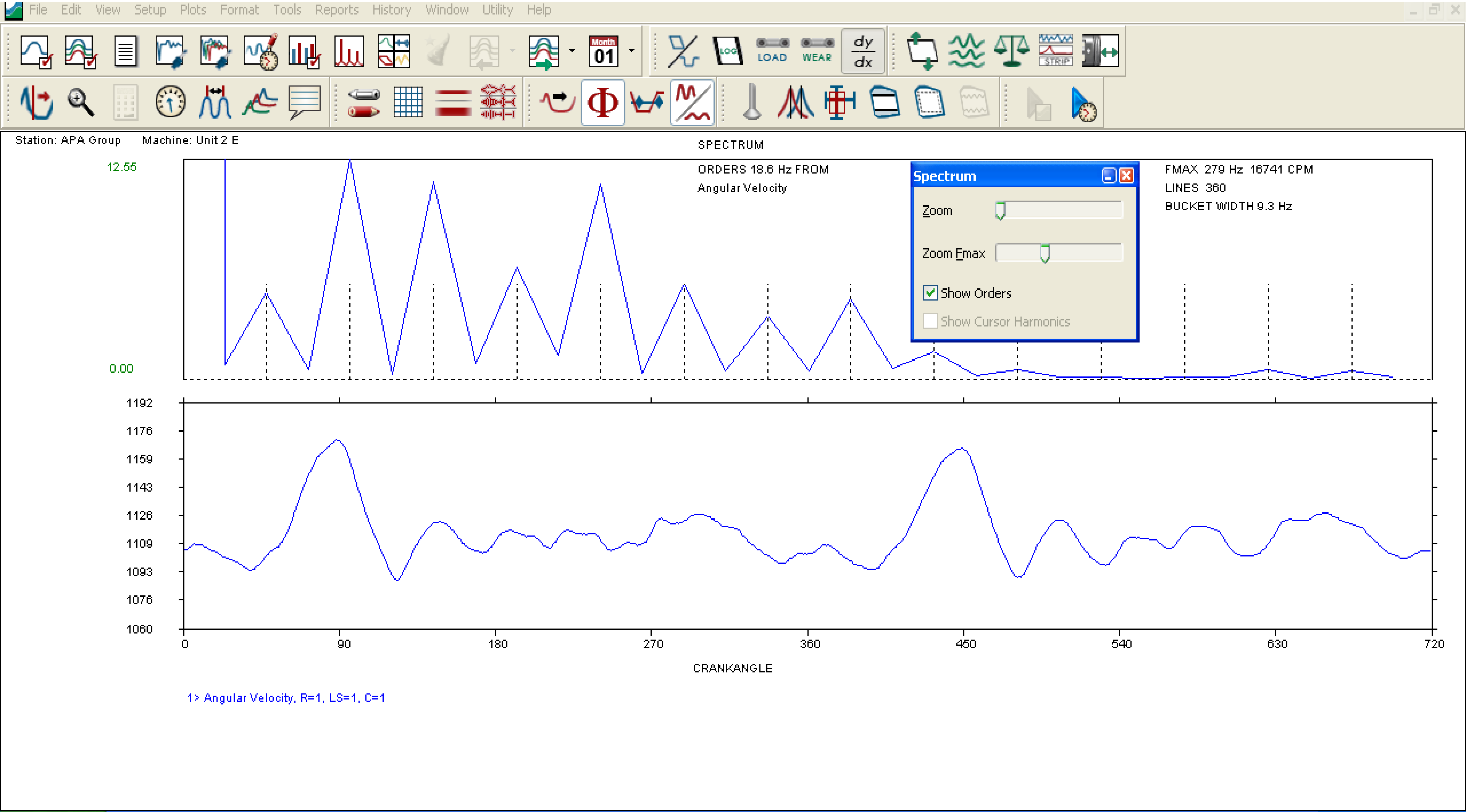
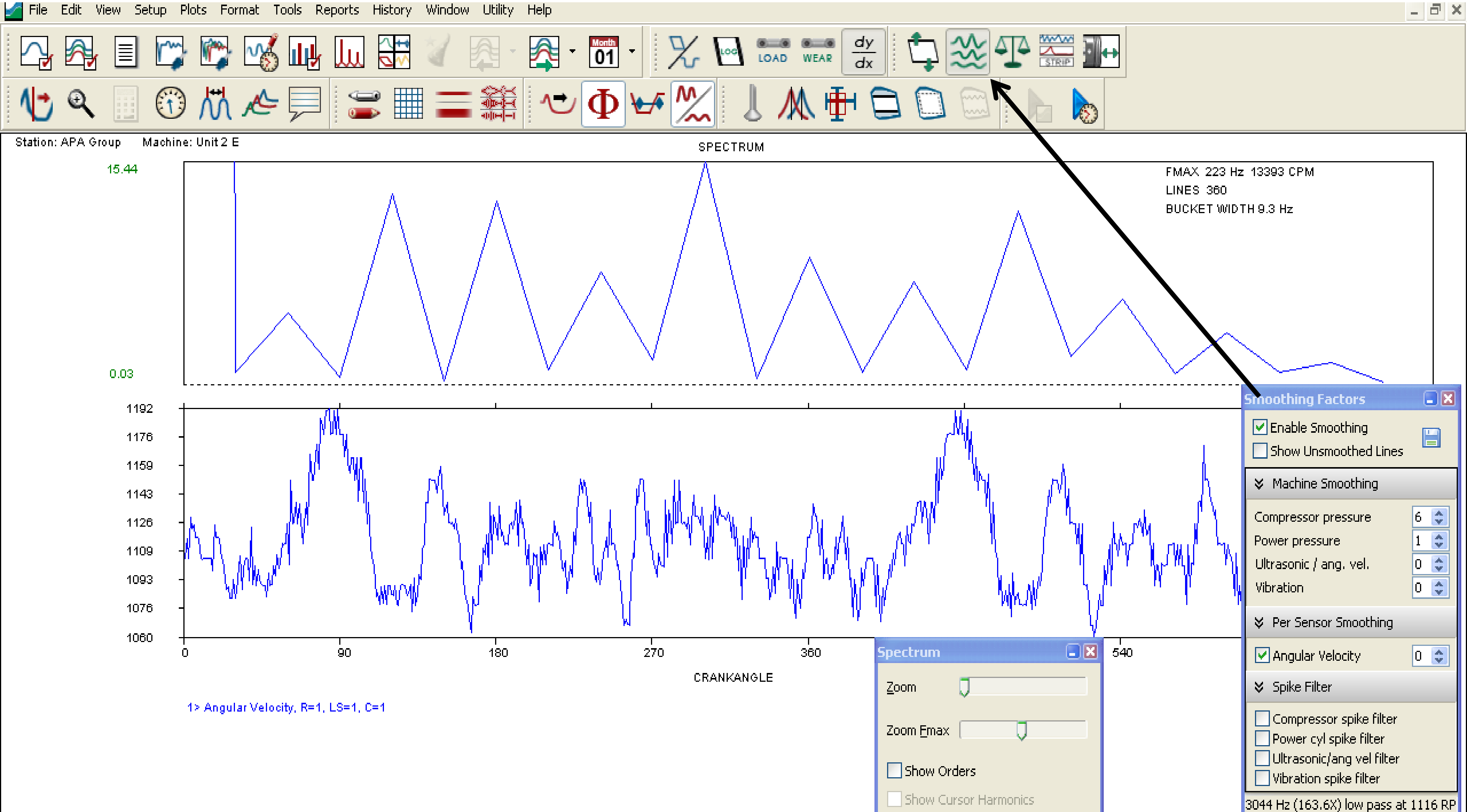
Derivatives and Spectrum Window



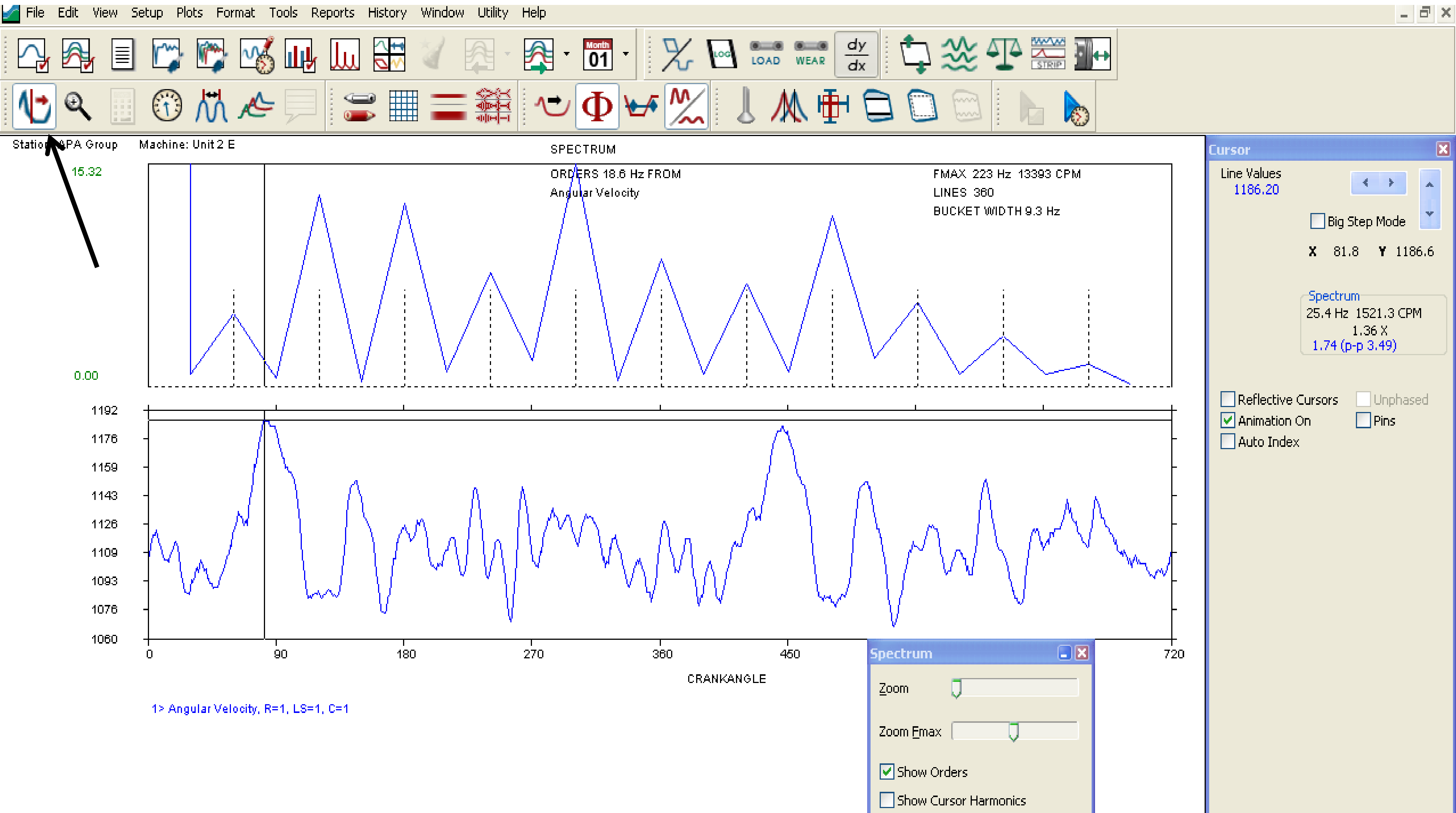
Change to an FFT Plot



Smoothing

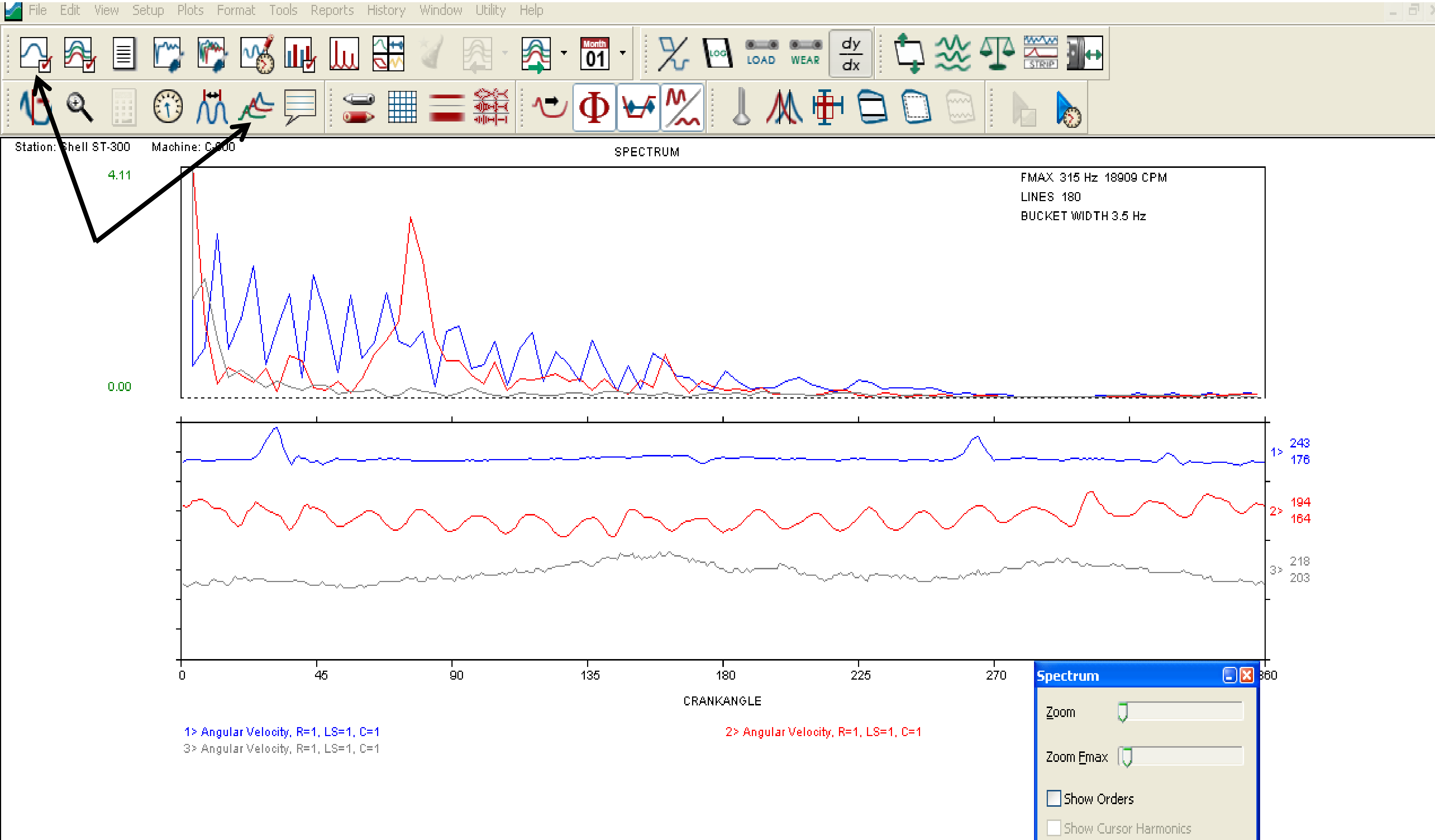

File Edit View Setup Plots Format Tools Reports History Window Utility Help
Station: APA Group Machine: Unit 2 E
SPECTRUM
FMAX 223 Hz 13393 CPM
LINES 360
BUCKET WIDTH 9.3 Hz
15.44
0.03
CRANKANGLE
1> Angular Velocity, R=1, LS=1, C=1
Smoothing Factors
Enable Smoothing
Show Unsmoothed Lines
Machine Smoothing
Compressor pressure 6
Power pressure 1
Ultrasonic / ang. vel. 0
Vibration 0
Per Sensor Smoothing
Angular Velocity 0
Spike Filter
Compressor spike filter
Power cyl spike filter
Ultrasonic/ang vel filter
Vibration spike filter
Spectrum
Zoom
Zoom Fmax
Show Orders
Show Cursor Harmonics

Cursor



File Edit View Setup Plots Format Tools Reports History Window Utility Help
LOAD
WEAR
dy
dx
Month
01
STRIP
Station: APA Group
Machine: Unit 2 E
SPECTRUM
ORDERS 18.6 Hz FROM
Angular Velocity
FMAX 223 Hz 13393 CPM
LINES 360
BUCKET WIDTH 9.3 Hz
15.32
0.00
1192
1176
1159
1143
1126
1109
1093
1076
1060
0
90
180
270
360
450
720
CRANKANGLE
1> Angular Velocity, R=1, LS=1, C=1
Cursor
Line Values
1186.20
Big Step Mode
X 81.8 Y 1186.6
Spectrum
25.4 Hz 1521.3 CPM
1.36 X
1.74 (p-p 3.49)
Reflective Cursors
Unphased
Animation On
Pins
Auto Index
Spectrum
Zoom
Zoom Fmax
Show Orders
Show Cursor Harmonics

Plots


File Edit View Setup Plots Format Tools Reports History Window Utility Help
Station: Shell ST-300
SPECTRUM
4.11
0.00
FMAX 315 Hz 18909 CPM
LINES 180
BUCKET WIDTH 3.5 Hz
1> 243 176
2> 194 164
3> 218 203
0 45 90 135 180 225 270
CRANKANGLE
1> Angular Velocity, R=1, LS=1, C=1
2> Angular Velocity, R=1, LS=1, C=1
3> Angular Velocity, R=1, LS=1, C=1
Spectrum
Zoom
Zoom Fmax
Show Orders
Show Cursor Harmonics

Why Use Angular Velocity?

- Some OEMs will recommend maximum peak RPM in a revolution, aka RPM Velocity Limit
- Crankshaft Torsional Vibration
  - Alternating torques are generated by the slider-crank mechanism of the crankshaft, connecting rod, and piston.
  - The motion of the piston mass and connecting rod mass generate alternating torques, often referred to as "inertia" torques.
  - The cylinder pressure due to combustion is not constant through the combustion cycle.
  - The slider-crank mechanism does not output a smooth torque, even if the pressure is constant (e.g., at top dead center there is no torque generated).

Continue

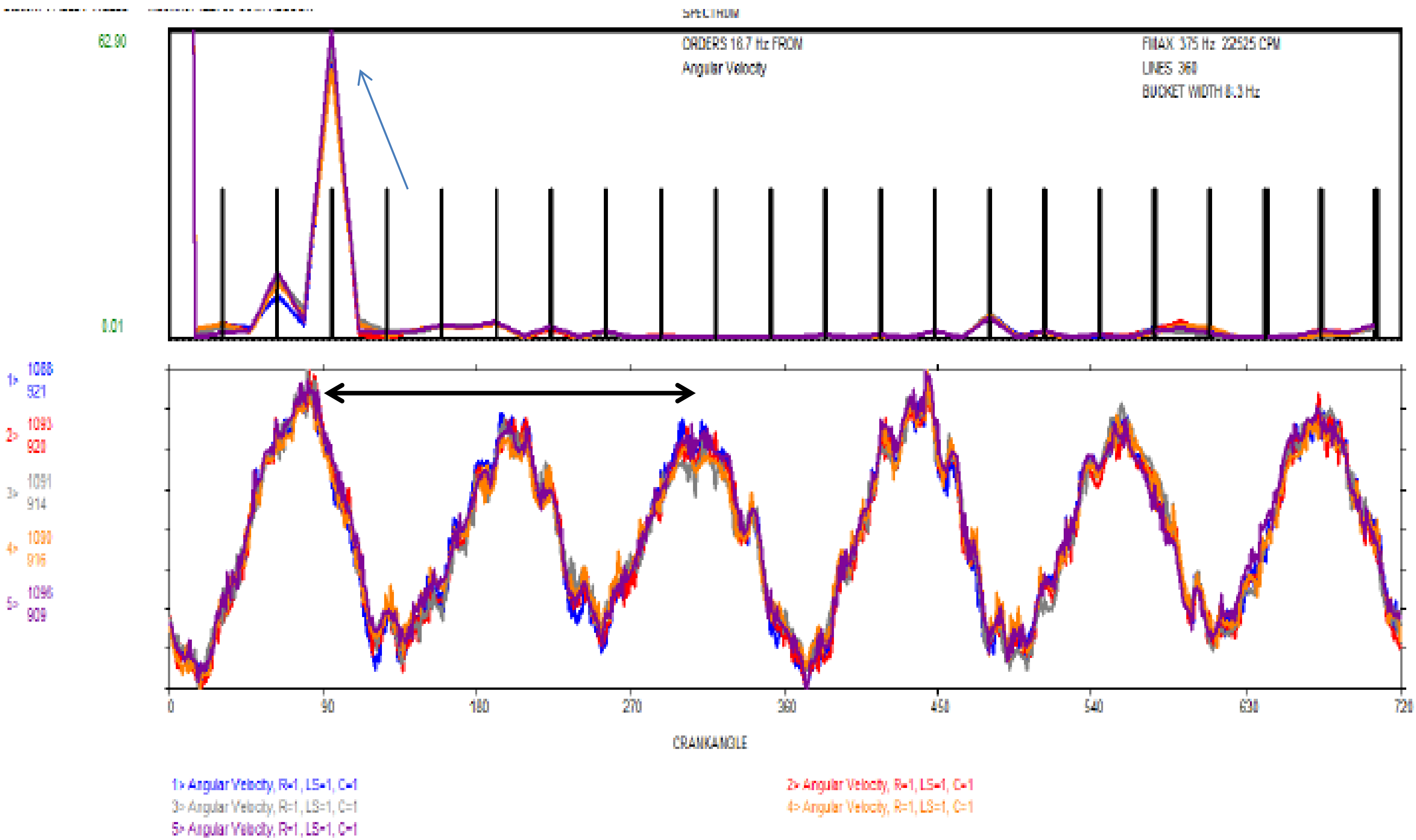
- Machines with several cylinders can have very flexible crankshafts due to their long length.
- There is inherently little damping in a crankshaft to reduce the vibration.
- If torsional vibration is not controlled in a crankshaft, it can cause failure of the crankshaft or any accessories that are being driven by the crankshaft (typically, at the front of the machine, the inertia of the flywheel normally reduces the motion at the rear of the machine).
- This potentially damaging vibration is often controlled by a torsional damper that is located at the front nose of the crankshaft (in automobiles, it is often integrated into the front pulley).

Two Types of Dampers

- Viscous dampers consist of an inertia ring in a viscous fluid. The torsional vibration of the crankshaft forces the fluid through narrow passages that dissipates the vibration as heat. The viscous torsional damper is similar to the hydraulic shock absorber in a car's suspension.

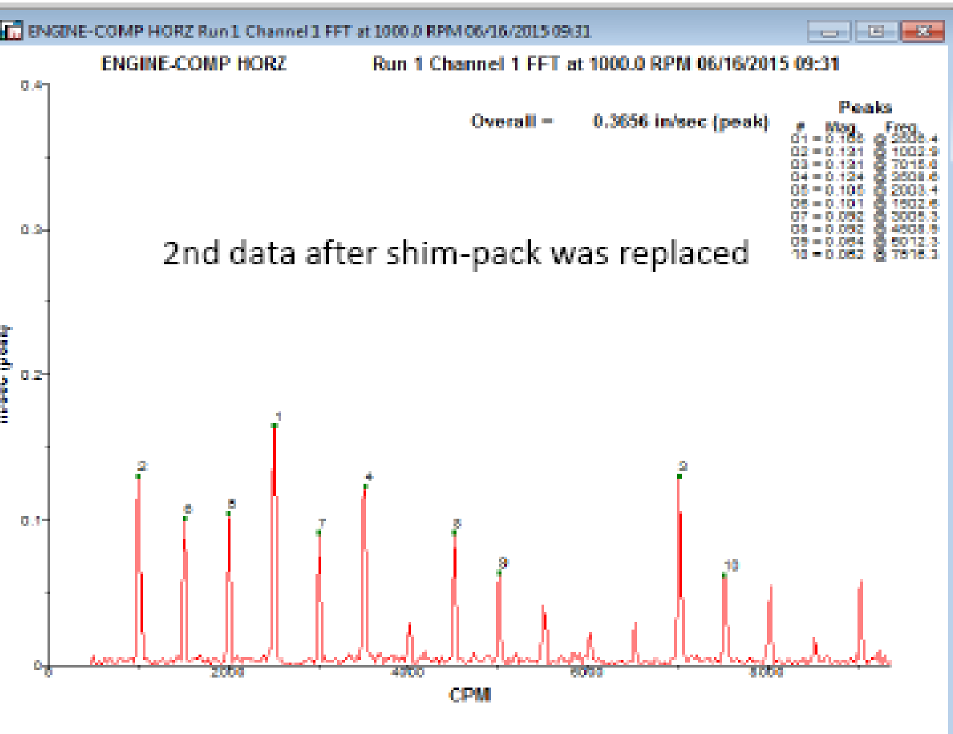
- Tuned absorber-type of "dampers" are often referred to as a harmonic dampers or harmonic balancers (even though it technically does not dampen or balance the crankshaft). This damper uses a spring element (often rubber in automobile engines) and an inertia ring that is typically tuned to the first torsional natural frequency of the crankshaft. This type of damper reduces the vibration at specific engine speeds, when an excitation torque excites the first natural frequency of the crankshaft but not at other speeds. This type of damper is similar to the tuned mass dampers used in skyscrapers to reduce the building motion during an earthquake.

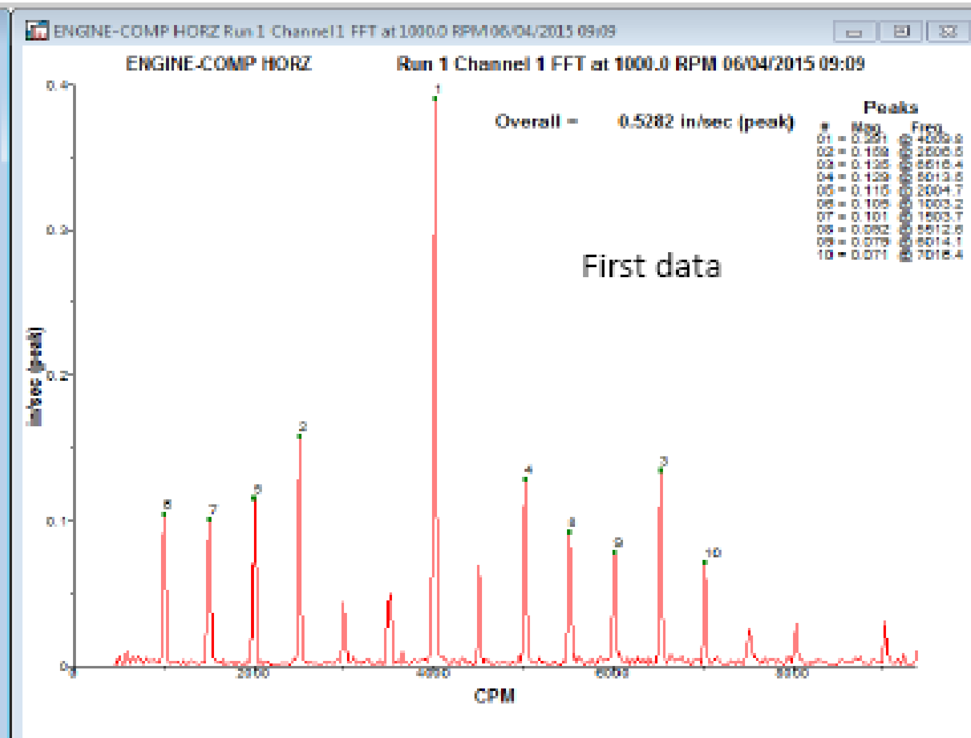
The Analysis



FFT, Guidelines and Trending

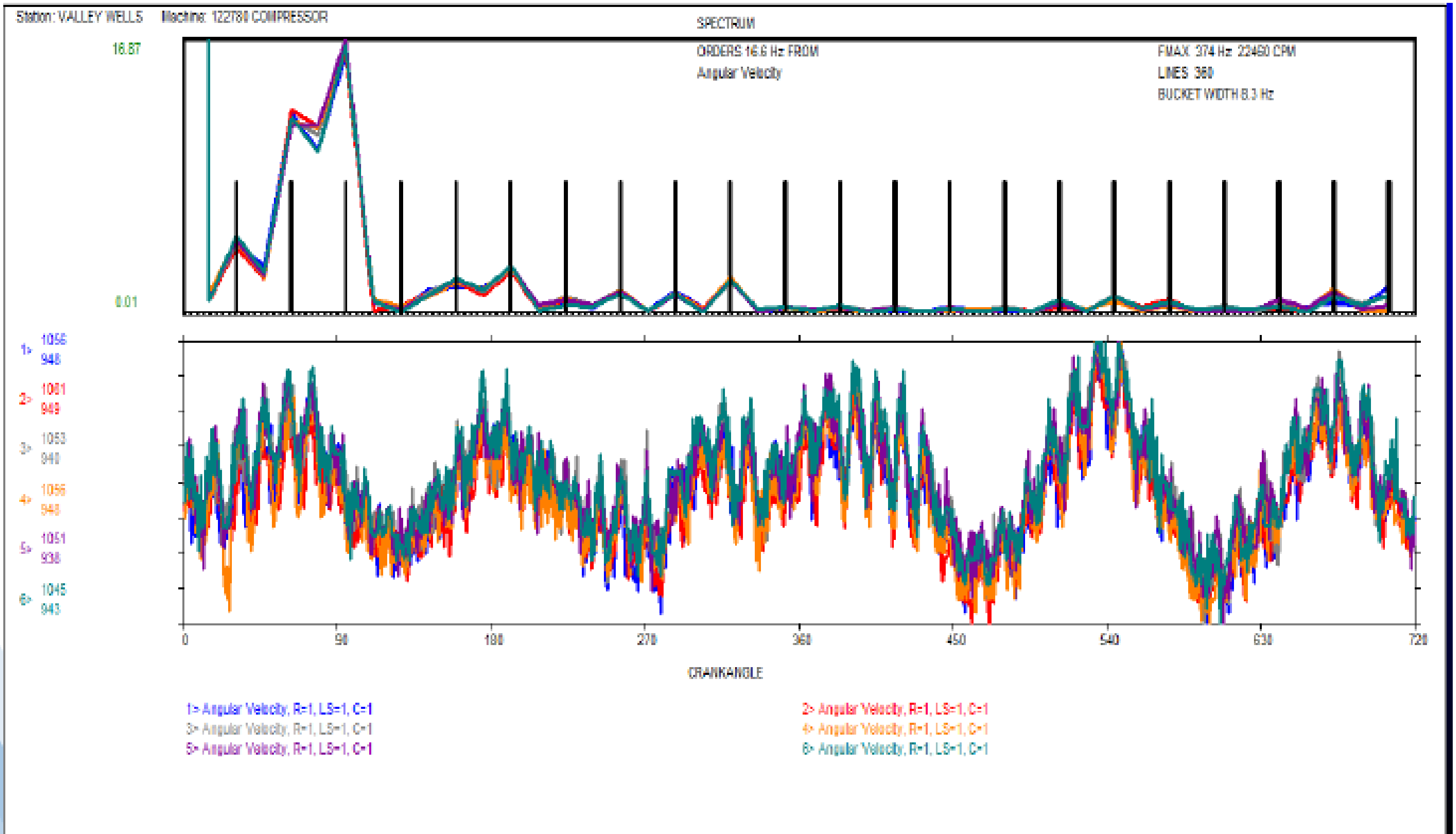
DATE	OBSERVATION	SPEED (rpm)	Mn Brg 1	Mn Brg 2	Mn Brg 3	Mn Brg 4	Mn Brg 5	Mn Brg 6	Mn Brg 7	Mn Brg 8	Mn Brg 9
6/16/2015	Current Data. After failure and new shim-pack. Low vibration peak at 4X run speed	1000	0.344	0.326	0.365	0.513	0.466	0.434	0.457	0.329	0.354
6/4/2015	**Previous Data.** Before the failure. **High misalignment** observed and coupling problem. **High vibration peak at 4X** run **speed**	1000	0.37	0.321	0.454	0.411	0.475	0.555	0.415	0.457	0.477





Be Careful

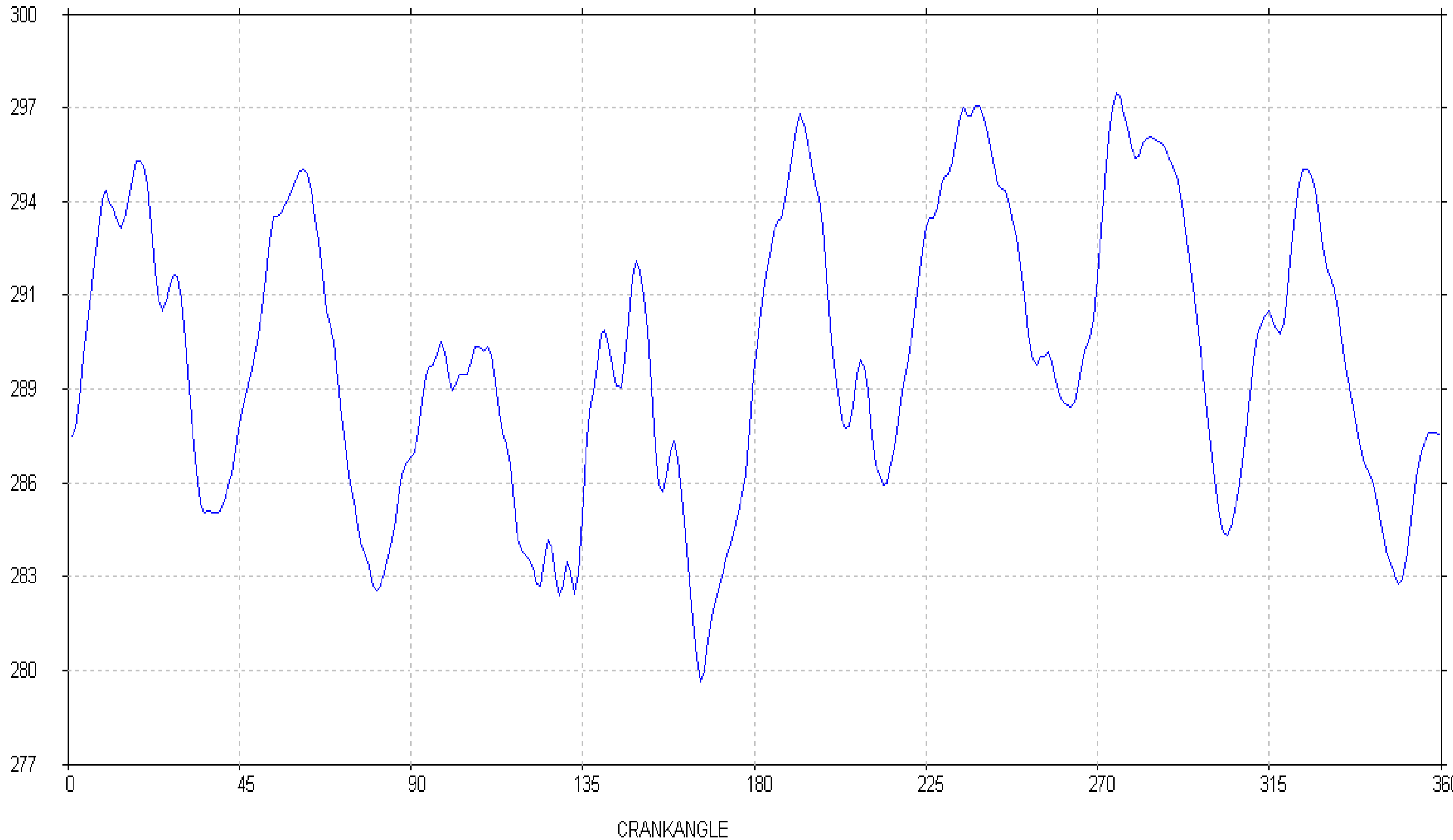
After single Damper was replaced for a Double Damper, the angular velocity went down to **16 rpm pk**. The maximum velocity limits for 6 throws and dual chain configuration is **40 rpm pk** recommended by Ariel



Due Diligence

- Garbage in, garbage out!
  - Encoder must be rigid, straight and free of obstacles
  - Plastic and rubber should not be used in the coupling or the tip of the encoder
  - Best Results would be a hex head bolt and socket or something comparable

Angular Velocity Example
(hex head drive on a TLA 6 at 289 RPM)



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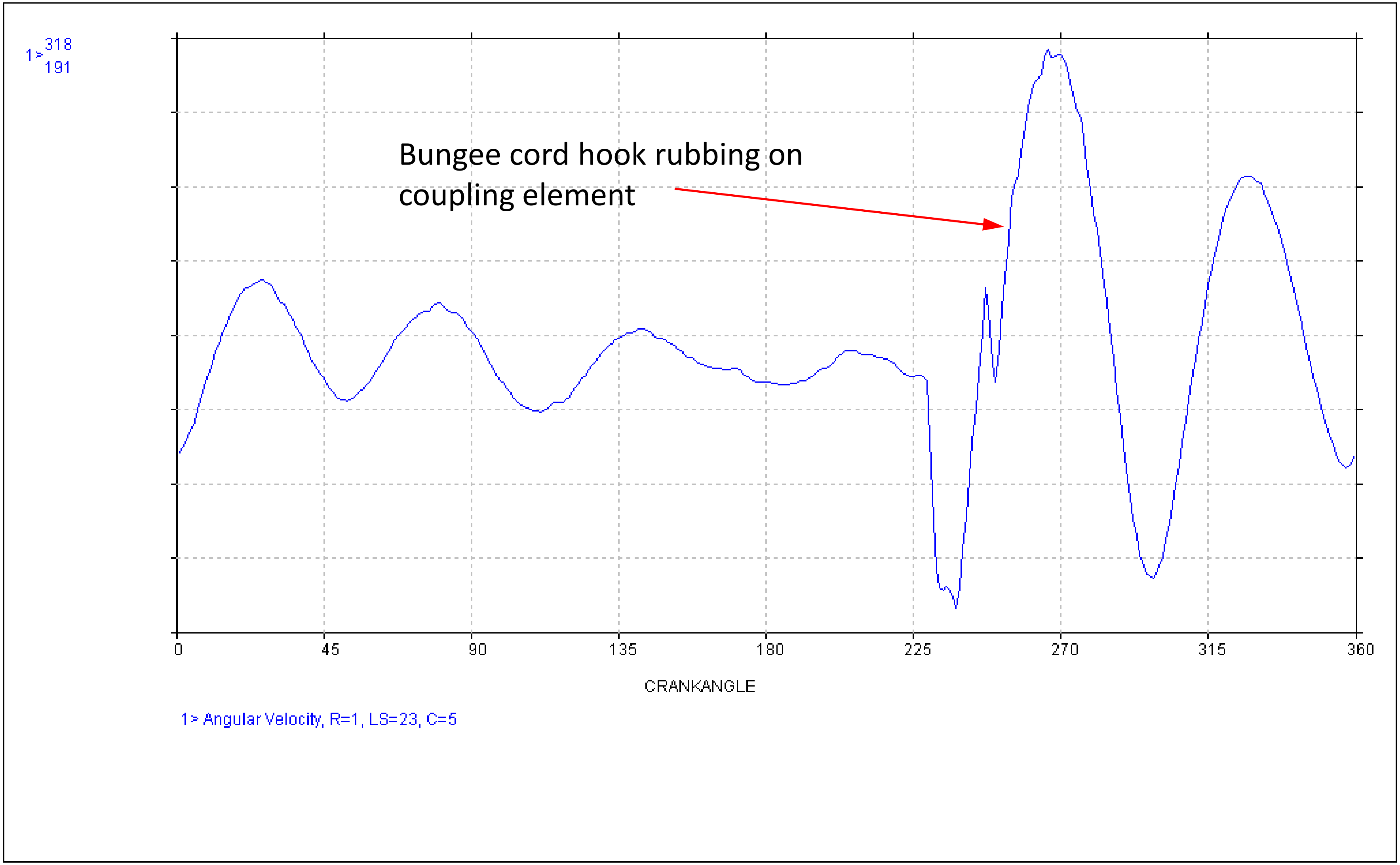
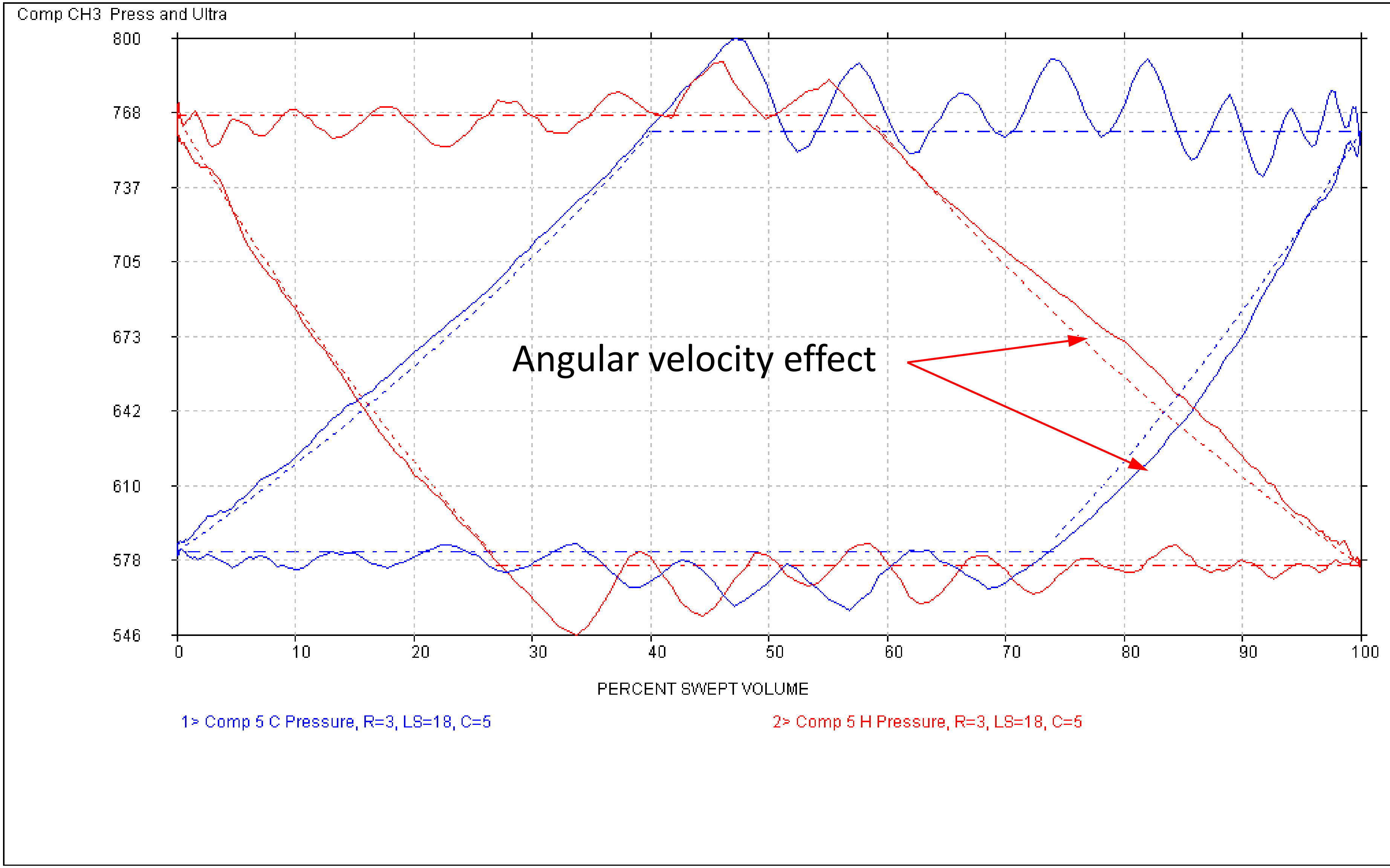
Angular Velocity





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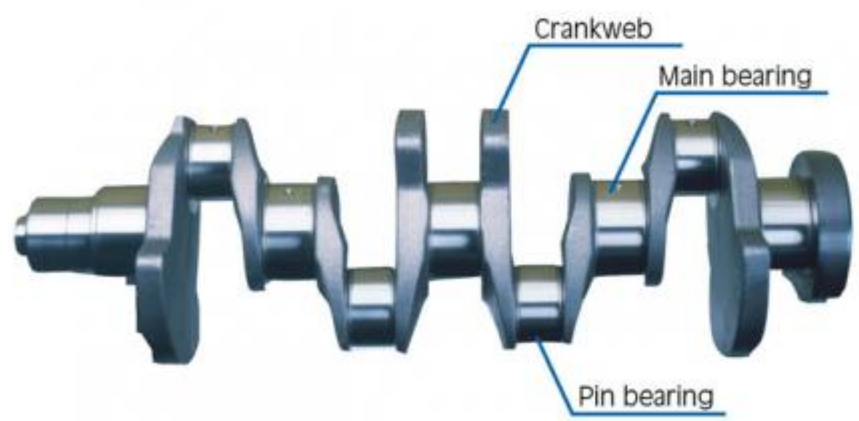
Conclusion

- Upside
  - The test point is very easy to collect
  - The analysis is easy if coupled to FFT data and/or guidelines

- Downside
  - There is some startup preparation needed
    - Machine may need to be down to install a hex head/bolt
  - Torsional issues are rare

Questions?



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