46TH TURBOMACHINERY & 33RD PUMP SYMPOSIA
HOUSTON, TEXAS | DECEMBER 11-14, 2017
GEORGE R. BROWN CONVENTION CENTER

Torsional Failure on Reciprocating Compressor Package

Ken Atkins
James Clark
Engineering Dynamics, Inc.
San Antonio, Texas

ENGINEERING DYNAMICS

TEES TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

TEXAS A&M UNIVERSITY

Ken Atkins is a Senior Staff Engineer at Engineering Dynamics, Incorporated (EDI). He has over 35 years of experience with rotating machinery and structural dynamics and has lectured frequently at the Turbomachinery and Pump Symposia, including tutorials and short courses.

Mr. Atkins received a B.S. Degree in Engineering Science from Trinity University in 1978, graduating as a University Scholar. He is a member of ASME, several API committees, and is a Registered Professional Engineer in the State of Texas.

James Clark is a Project Engineer at Engineering Dynamics, Incorporated (EDI). He joined EDI in 2008 as an engineering intern, receiving his BSME from The University of Texas at San Antonio in 2010.

Mr. Clark is involved in both field and analytical studies for a wide range of rotating machinery and structures. He has conducted numerous field tests involving torsional vibration measurements for reciprocating machinery and turbomachinery. He is a member of ASME and Tau Beta Pi.

ABSTRACT

This case history describes a vibration problem on a skid mounted high-speed reciprocating compressor package. The initial concern was high vibration on the motor. When the coupling guard was removed for further testing, a 45-degree crack was noticed on the motor shaft. This is a classic indication of a torsional fatigue failure.

A spare motor was installed and torsional measurements were made. This confirmed the problem as a torsional resonance. The flywheel was modified to de-tune the resonance. Follow-up testing was conducted and confirmed the success of the modifications.

Typical Skid Mounted Package

- Motor-driven reciprocating compressor
- 4-cylinder, 3-stage compressor
- Motor rated for 2750 HP, VFD 600 – 900 RPM
- Commonly used in gas gathering and gas processing services
- Often re-purposed more than once in their lifetime

Installation Photos

Initial Problem

- High vibration, motor drive end
- Radial vibration sensor caused unit to trip
- Inspected motor and compressor, nothing found
- Vibration trips persisted

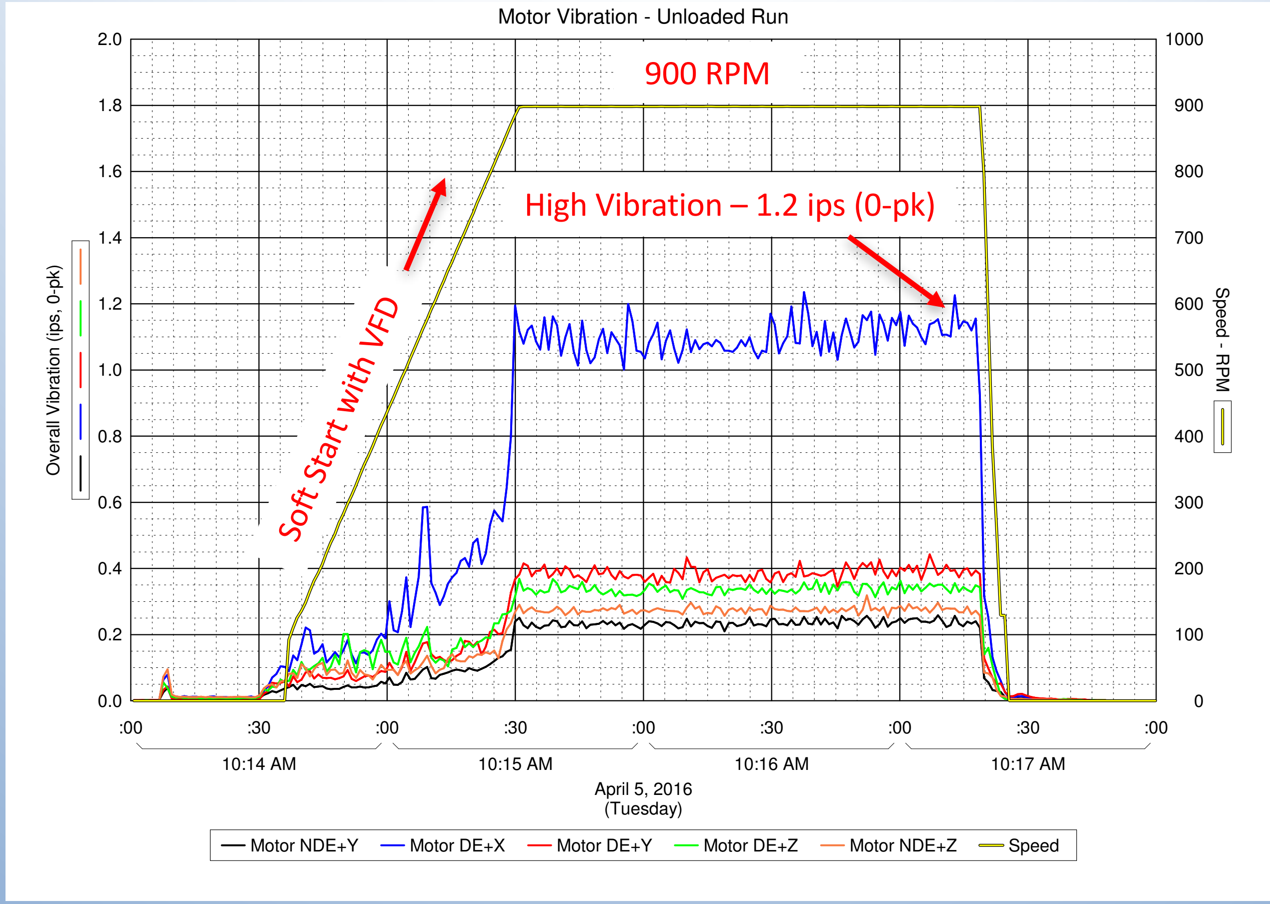
Initial Problem (cont'd)

- Vibration sensor was questioned
- Trip was disabled, new sensor ordered
- With new sensor installed, vibration trips continued
- Comprehensive field tests then pursued

Instrumentation

- Tri-axial accelerometers, motor and compressor
- In-cylinder pressure transducers (8 each)
- Cylinder head-end vibration (all cylinders)
- Keyphasor – 32 Channels total
- Continuous recording, high-speed DAQ

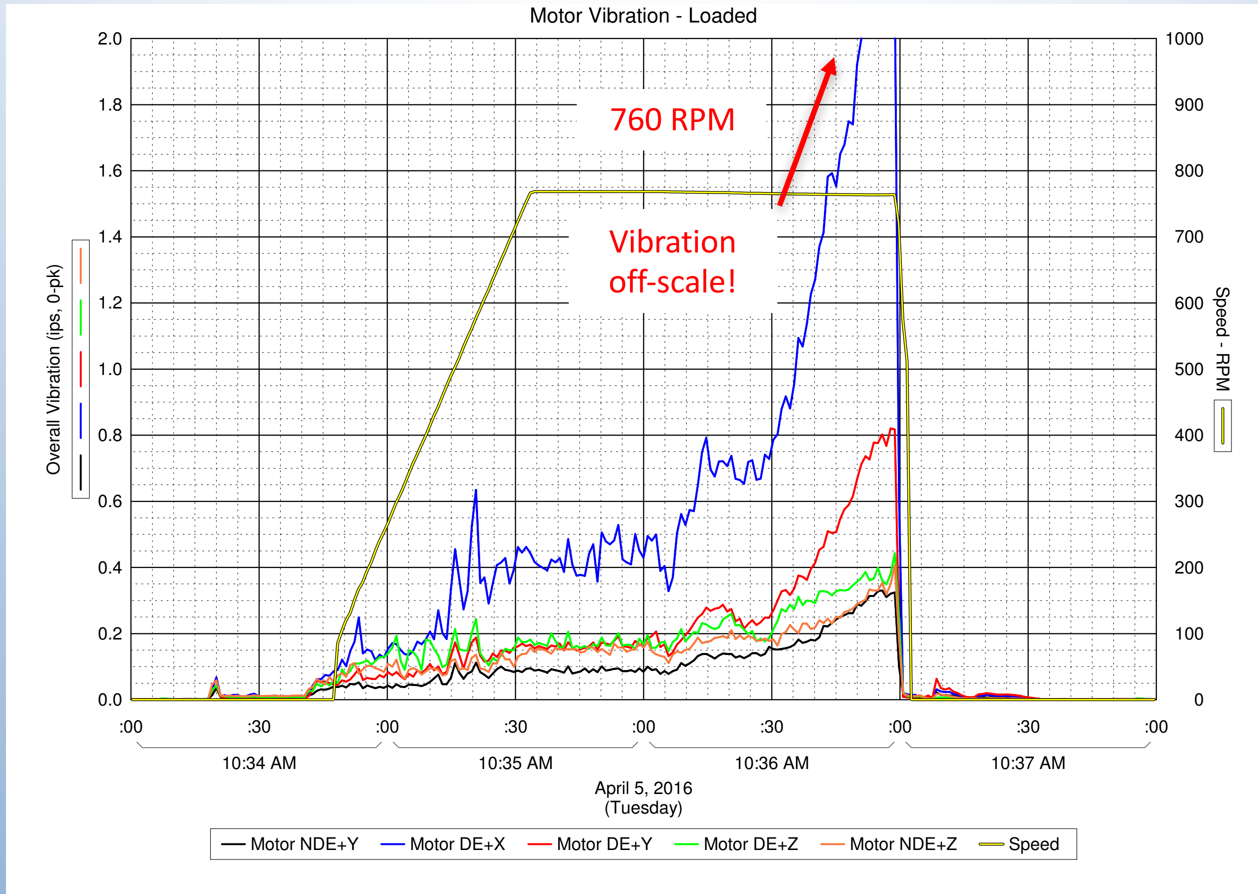
1st Run - Unloaded



1^{st} Run – Unloaded (cont'd)

- High vibration on motor drive end – axial direction (1 – 1.2 ips, 0-pk)
- Vibration in other directions and on Motor NDE bearing in the 0.2 – 0.4 ips, 0-pk range

2nd Run



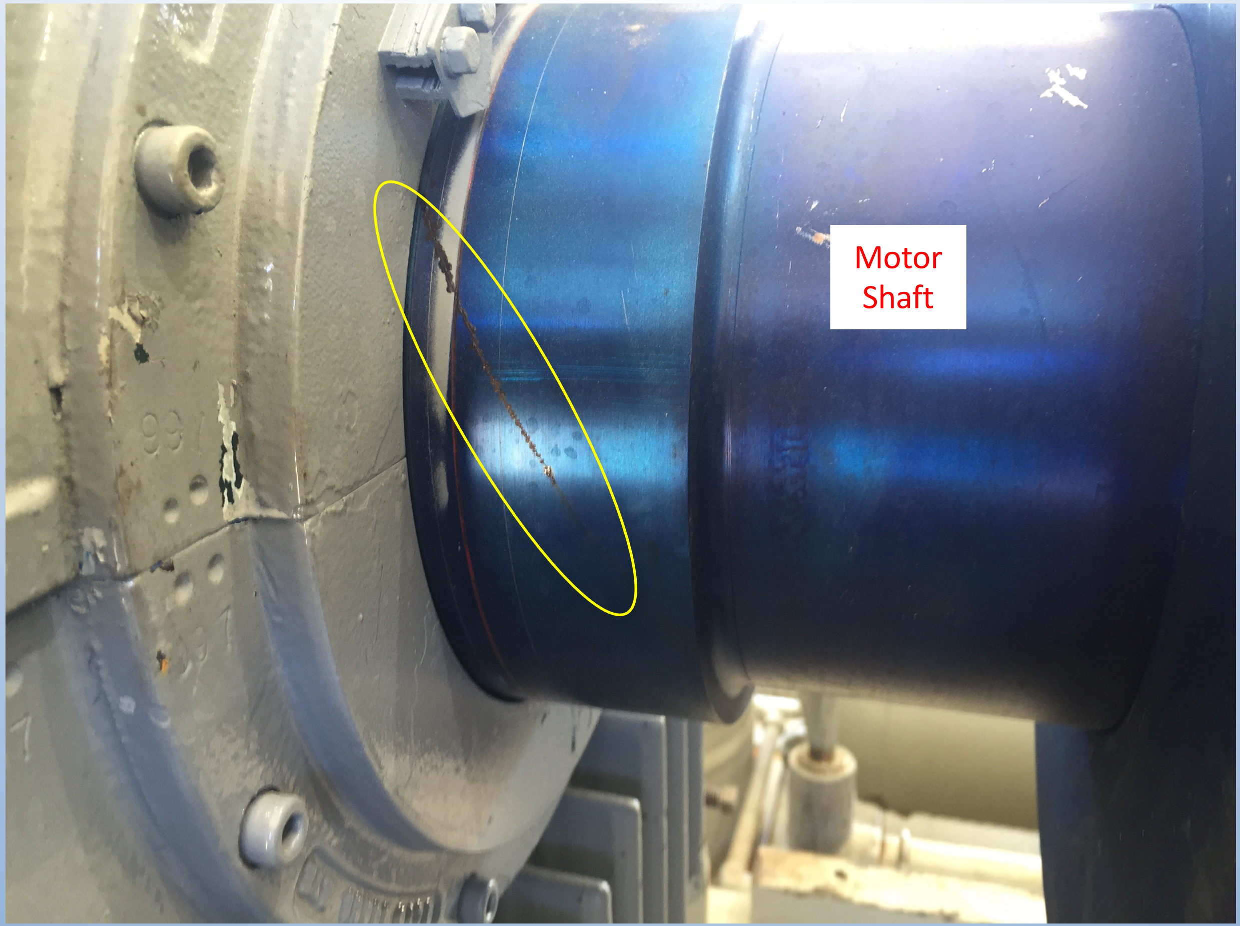
Motor Vibration - Loaded
760 RPM
Vibration off-scale!
Overall Vibration (ips, 0-pk)
Speed - RPM
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1000
900
800
700
600
500
400
300
200
100
0
:00
:30
:00
:30
:00
:30
:00
:30
:00
10:34 AM
10:35 AM
10:36 AM
10:37 AM
April 5, 2016
(Tuesday)
Motor NDE+Y
Motor DE+X
Motor DE+Y
Motor DE+Z
Motor NDE+Z
Speed

2nd Run (cont'd)

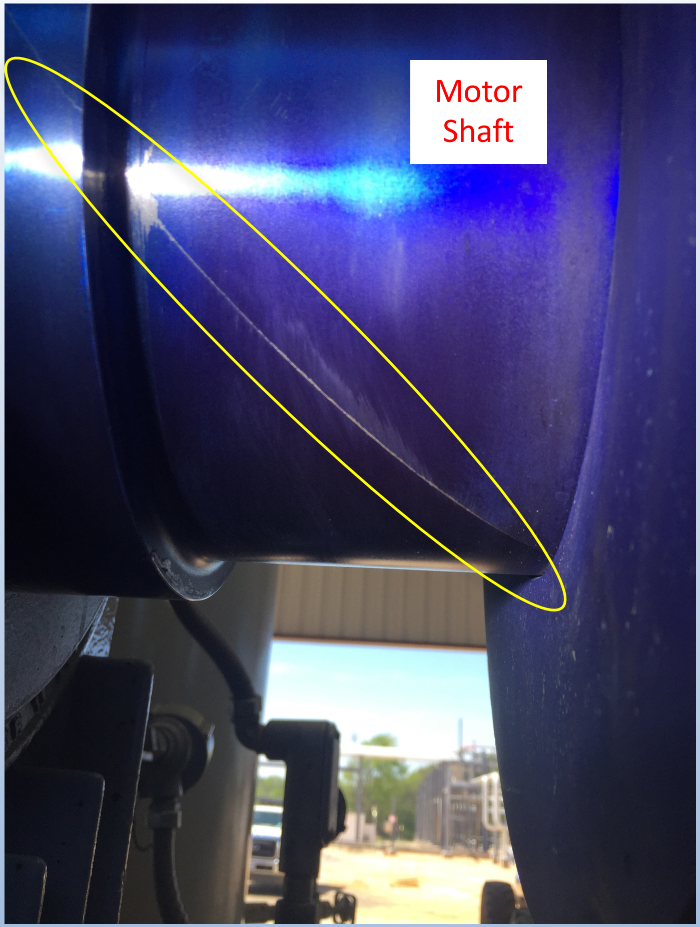
- Speed run to ~760 RPM, then load
- Motor DE bearing vibration excessive
- Shutdown to inspect system

TPS

Classical Torsional Failure



Classical Torsional Failure



Now What?

- Spare motor shaft procured
- Field measurements now focused on torsional vibration
- Torsional Vibration Analysis (TVA) report reviewed

TVA Predictions (by others)

- 1^{st} TNF = 4019 CPM (67 Hz)
- Excitation of concern was 5x at 804 RPM
- A flywheel was added to de-tune the system so that 5x was not resonant at 900 RPM
- Analysis assumed VFD used as soft start only

Torsional Measurements

Strain gage

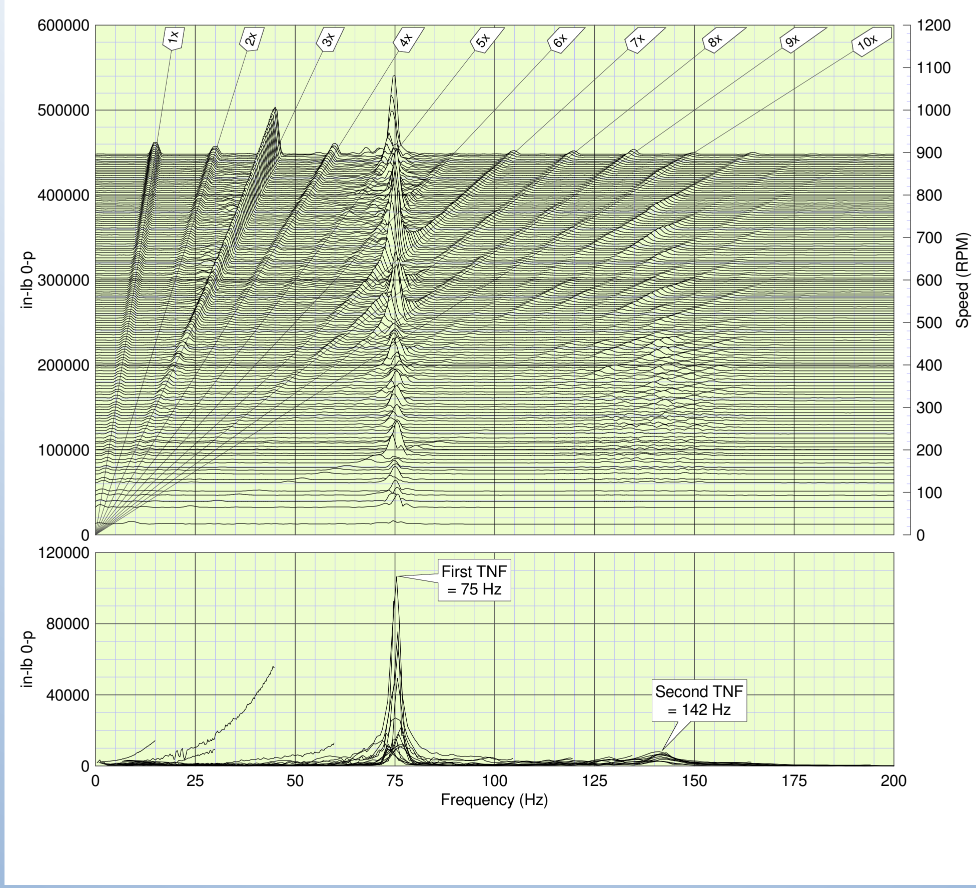
Telemetry System

Torsional Measurements

Encoder on
Auxiliary End

TPS

Torsional Measurements (cont'd)



Torsional Measurements (cont’d)

- 1st TNF = 4500 CPM (75 Hz)
- Excitation of concern was 5x (from TVA)
- 1st TNF excited by 5x @ 900 RPM
- Uh-oh!

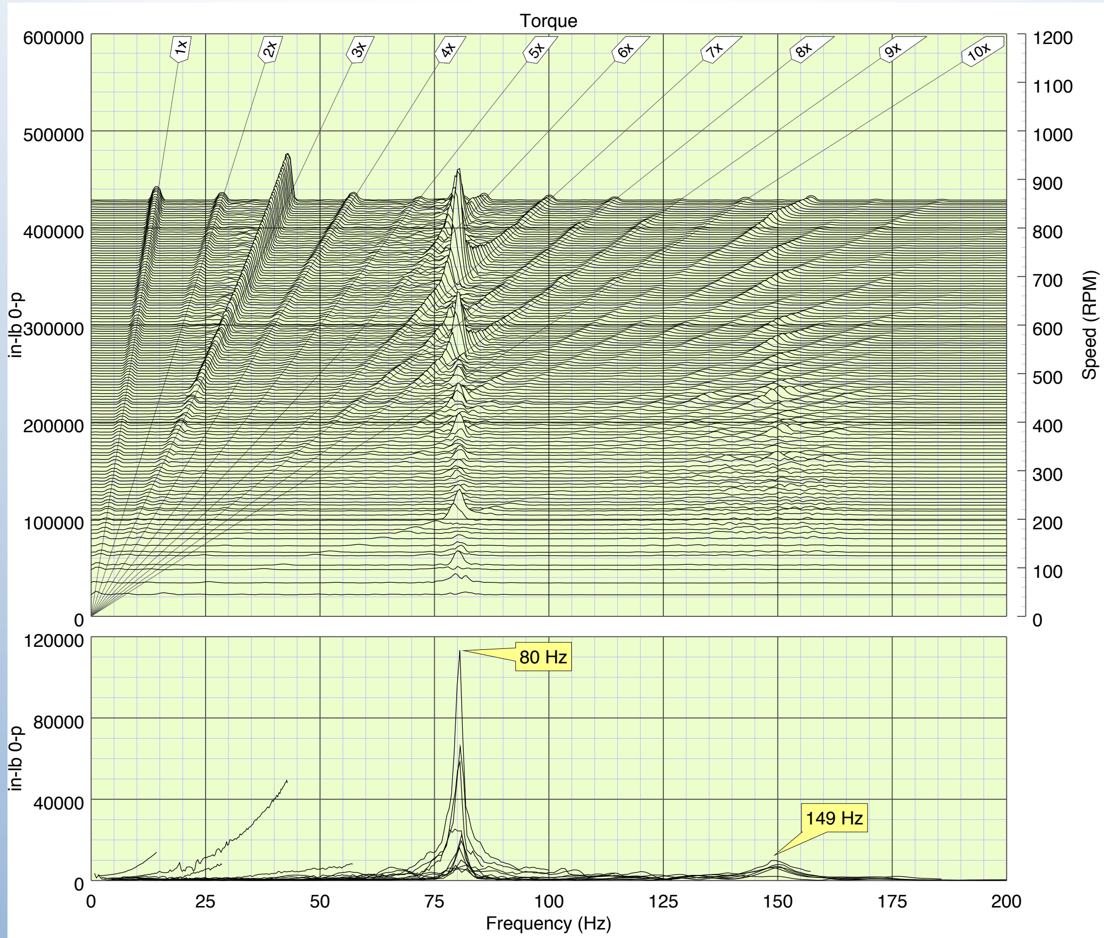
Now What?

- Re-visit TVA
- Adjust mass-elastic data to match *measured* TNFs
  - Coupling stiffness
  - Motor inertia

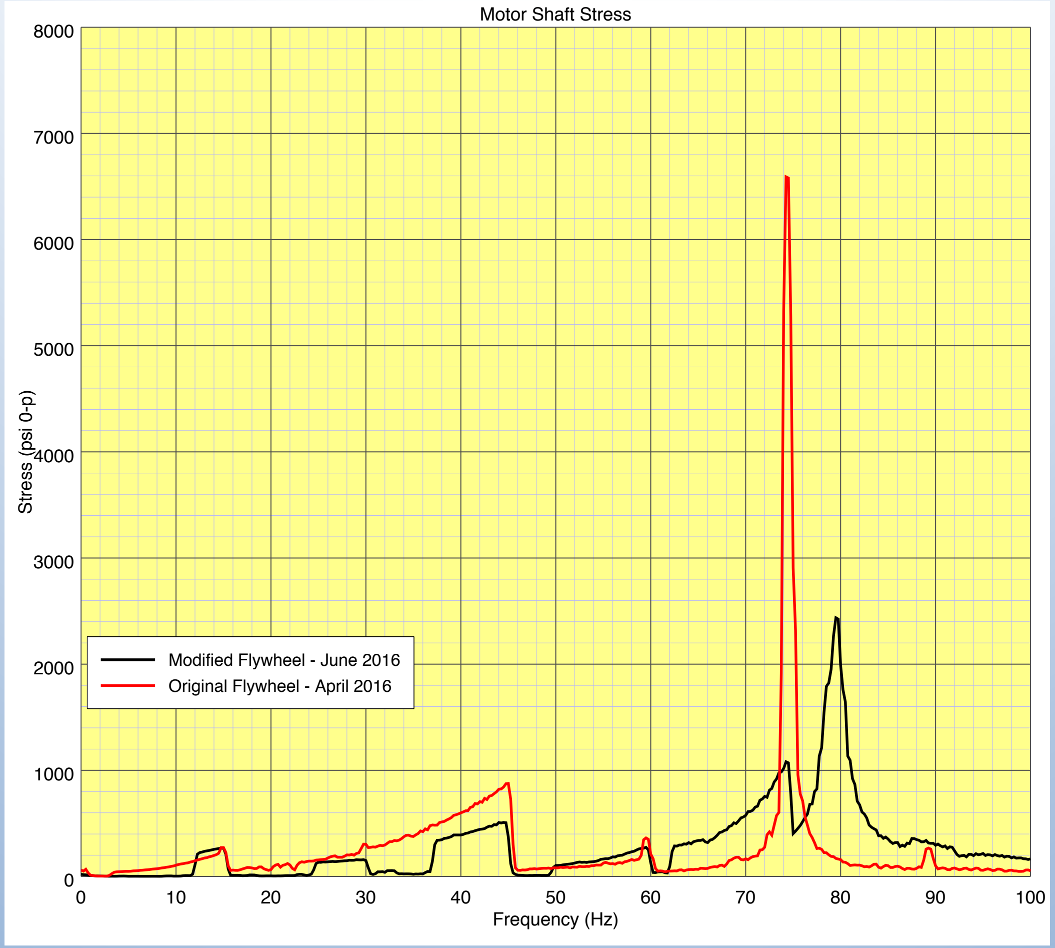
Recommendations

- Short Term:
  - Limit compressor speed to 750 – 850 RPM
- Long Term:
  - Trim flywheel to increase TNF (target ~80 Hz)

Results – 1st TNF Increased to 80 Hz



Results – Motor Shaft Stresses Reduced



Lessons Learned

- Don’t ignore vibration data, do what it takes to understand it
- Accuracy of TNF calculations are dependent on mass-elastic data provided by equipment OEM
- Measuring TNFs during commissioning is often justifiable. VFD operation increases chances of encountering torsional resonances