



MEEN 459/659 – Spring 2019

Adventures in Field Vibration Testing

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Dustin Pavelek is a Sr. Consultant with Kelm Engineering, LLC where he is responsible for conducting analytical studies and field vibration testing for rotating and reciprocating machinery.

He previously served as a member of corporate Machinery Engineering and Predictive Maintenance groups in the petrochemical and power generation industries. He is a proud graduate of Texas A&M University and holds a B.S. (2004) and an M.S. (2006) in Mechanical Engineering.

Pavelek is a registered professional engineer in the States of Texas and Louisiana and is a Certified ISO Category IV Vibration Analyst through the Vibration Institute.

What to Expect Today

- A handful of case studies from actual field or shop vibration tests
- An honest description of how some things have (or could have) gone wrong
- A few tips to keep in your tool box for the future
- Some discussion on choosing a career path

Case Study 1: Alignment and Field Balancing

- Machine Type: Multistage Centrifugal Compressor
- Plant Type: Coal-fired Power Plant
- Application: Soot Blowing Air Compressor



Case Study 1: Alignment and Field Balancing

- Instrumentation:
 - Plant proximity probes and monitoring system
 - Temporary magnet-mounted accelerometers
 - Laser tachometer
- Test Plan:
 - Visual Inspection
 - Alignment
 - Operating Test
 - Balancing
 - Mechanical Verification



Case Study 1: Alignment and Field Balancing

- Challenges
 - The plant personnel installed the machines
 - A gearbox OEM representative provided oversight for the onsite gearbox overhaul
 - A machine with a history of things going very, very bad
- Results
 - The machine tripped on high vibration on multiple start attempts
 - Vibration data showed high speed gearbox was the culprit

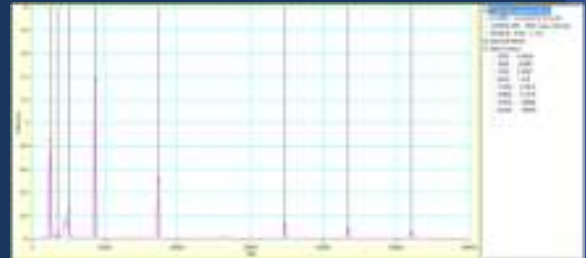
Case Study 1: Alignment and Field Balancing

- Vibration trends from prox probes show high speed gearbox vibration was excessive



Case Study 1: Alignment and Field Balancing

- Vibration spectra show high 1X and gear mesh vibration on the high speed gearbox



Case Study 1: Alignment and Field Balancing

- Gearbox bearings were suspected
- HSGB has an “upmesh”

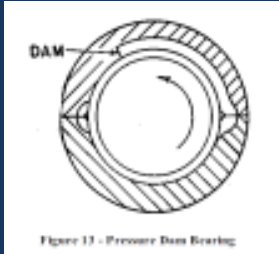
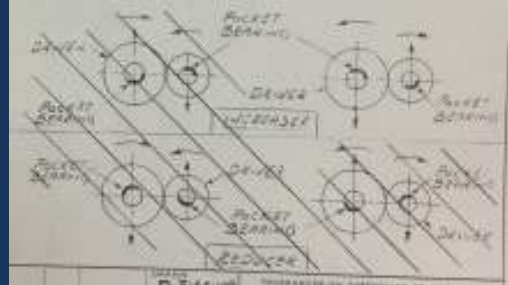


Figure 13 - Pericone Dam Bearing



Case Study 1: Alignment and Field Balancing

- Gearbox output shaft bearings were installed upside down



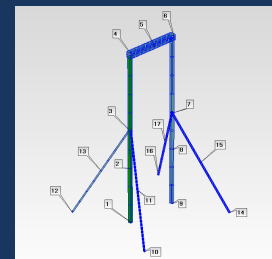
Case Study 2: Structural Modal Test

- Fall protection harness manufacturer
- Drop test rig certification testing
- Lower limit of 200 Hz for fixture structural natural frequencies
- Static deflection limits for structure



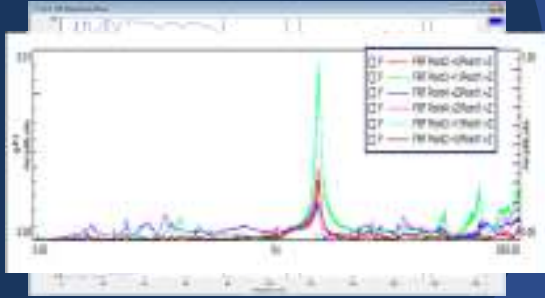
Case Study 2: Structural Modal Test

- Test Plan
 - Pre-test
 - Where do we hit?
 - Response measurement locations?
 - Conduct modal test
 - Triaxial Accels
 - Instrumented Hammer
 - Multi-channel DAQ
 - Conduct static deflection test
 - Calibrated load cell
 - Dial indicator
 - Proximity probe



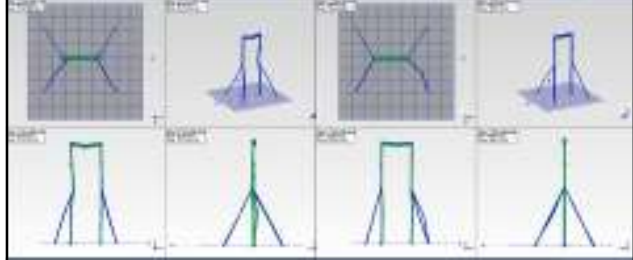
Case Study 2: Structural Modal Test

- So... how'd it go?



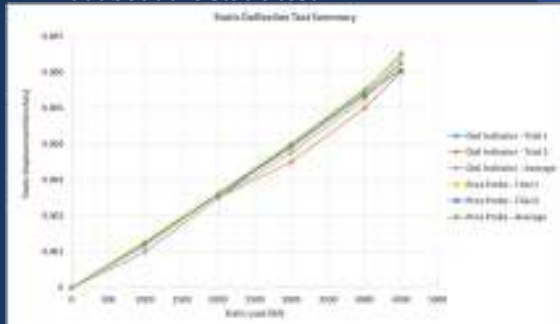
Case Study 2: Structural Modal Test

- So... how'd it go?



Case Study 2: Structural Modal Test

- What about the static test?



Case Study 2: Structural Modal Test

- What went wrong?



Case Study 3: Multiplane Balancing and Testing

- Machine Type: Steam Turbine-Generator
- Plant Type: Combined Cycle Power Plant
- Problem: High vibration during startup



Case Study 3: Multiplane Balancing and Testing

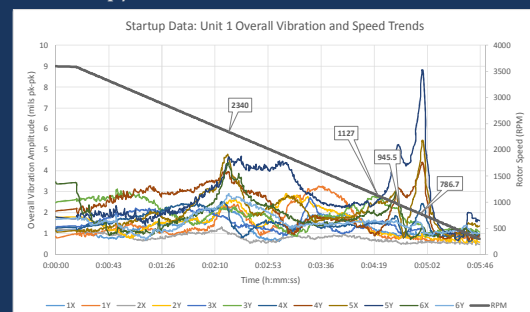
- Test Plan:
 - Startup/coast down vibration
 - Permanent/temporary proximity probes
 - Temporary accelerometers
 - Tach/Phase reference
 - Bearing housing impact testing
 - Rotordynamic study

Case Study 3: Multiplane Balancing and Testing



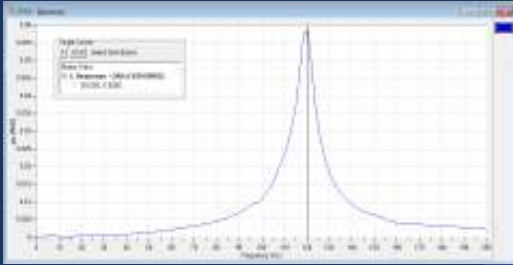
Case Study 3: Multiplane Balancing and Testing

- Startup/Coast Down Vibration



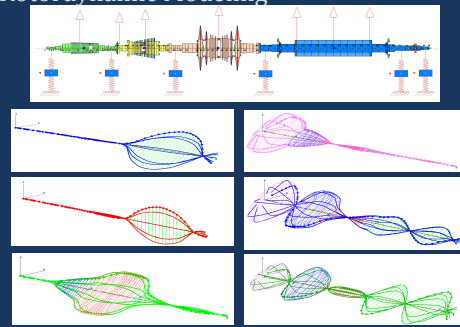
Case Study 3: Multiplane Balancing and Testing

- Impact Data



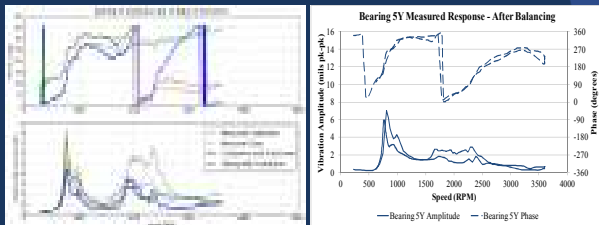
Case Study 3: Multiplane Balancing and Testing

- Rotordynamic Modeling



Case Study 3: Multiplane Balancing and Testing

- Balancing Results



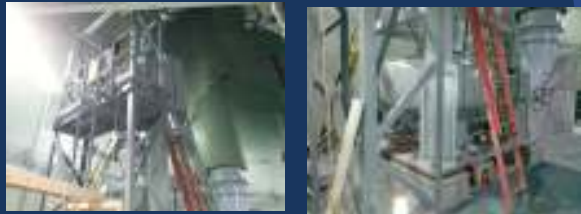
Case Study 4: Vertical Pump

- Machine Type: VFD Motor Driven Vertical Pump-2000HP
- Plant Type: Sewage Treatment
- Problem: Acceptance Testing
- Speed Range: 270-395 RPM



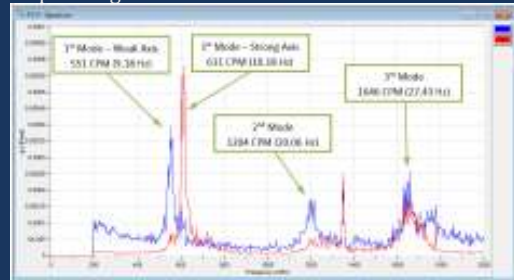
Case Study 4: Vertical Pump

- Test Plan:
 - Impact Tests
 - Operating vibration measurement

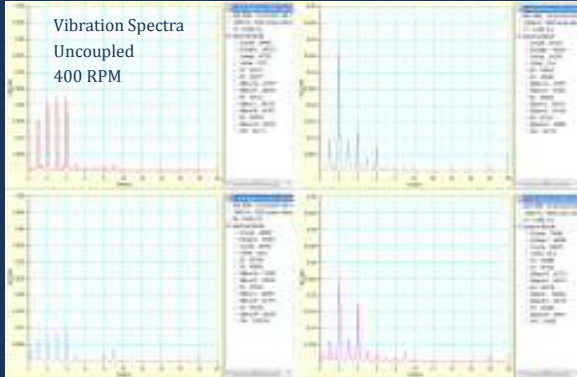


Case Study 4: Vertical Pump

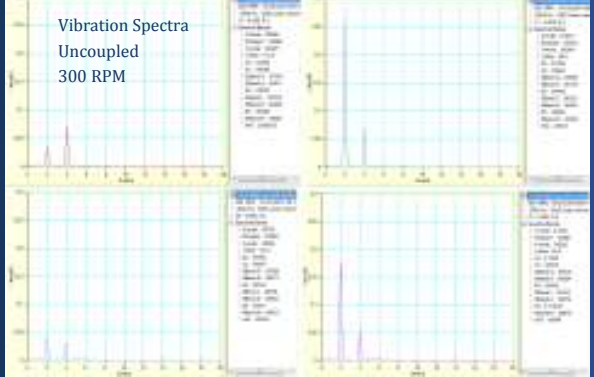
- Test Plan:
 - Impact Tests – No impact hammer!
 - Operating vibration measurement

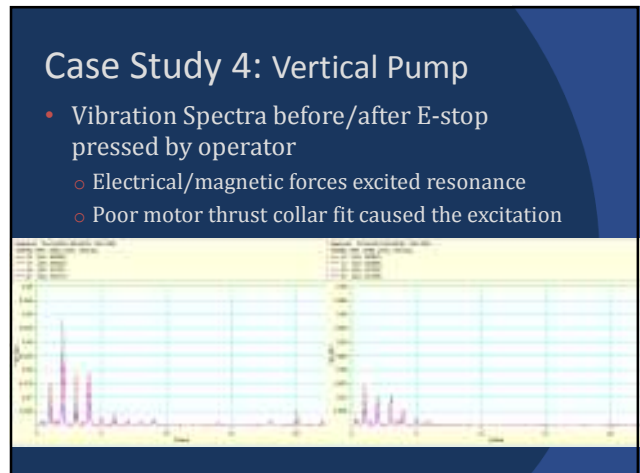
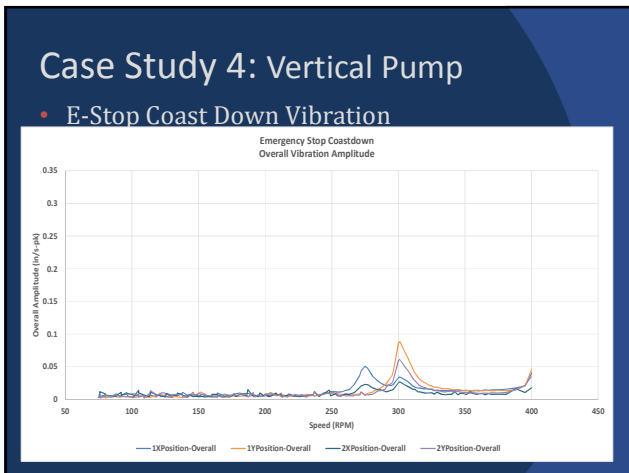
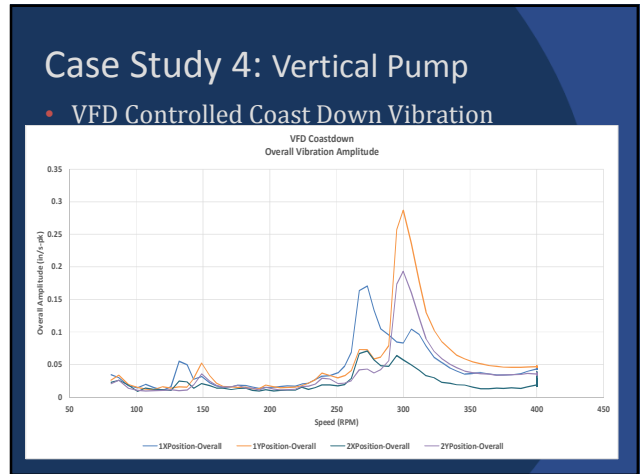
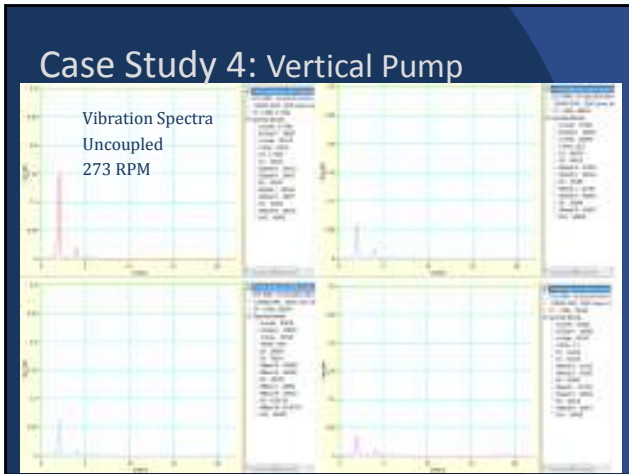


Case Study 4: Vertical Pump



Case Study 4: Vertical Pump



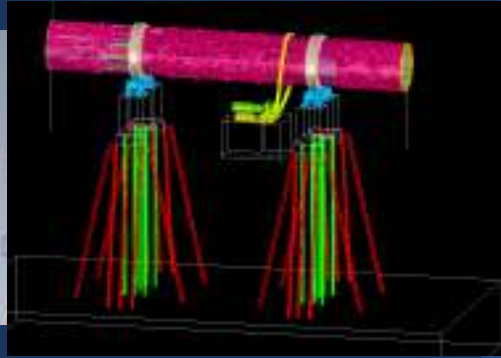


Case Study 5: Paper Mill Debarker

- Extensive foundation work done to reduce vibration. Test to document results.
- Challenge: Transient vibration.
- Solution: Time-based ODS



Case Study 5: Paper Mill Debarker



Case Study 5: Paper Mill Debarker



Case Study 5: Paper Mill Debarker

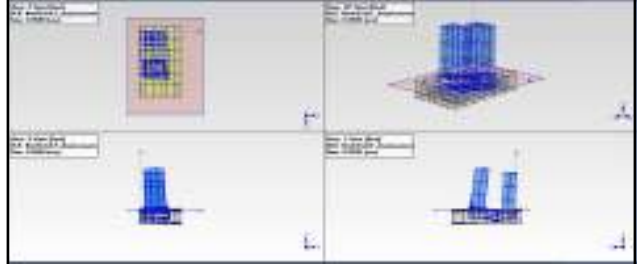


Case Study 5: Paper Mill Debarker



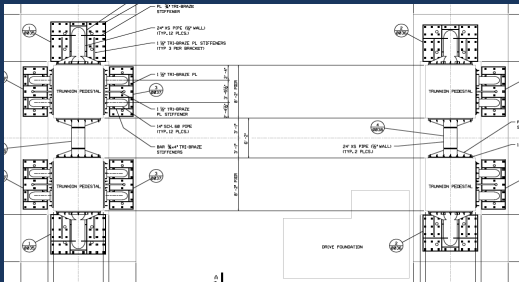
Case Study 5: Paper Mill Debarker

- Transient ODS Results



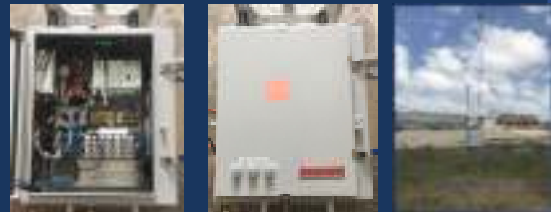
Case Study 5: Paper Mill Debarker

- Final Solution: More Steel!



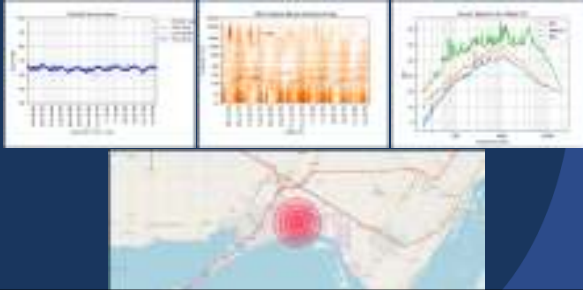
Case Study 6: Industrial Noise Measurement

- Sound measurement:
 - Useful for machinery troubleshooting
 - Also useful for keeping the neighbors happy!
 - IIoT Solution for Remote Monitoring



Case Study 6: Industrial Noise Measurement

- Overall levels, Octave band filtering, attenuation from weather conditions



Case Study 7: Wind Tunnel Torsional Test

- Application: Wind Tunnel Synchronous Motor
- Scope:
 - Document Static/Dynamic Torque
 - Document Power
 - Document TNF's
 - Measure Vibration
- Test Plan:
 - Strain Gages
 - Radio Telemetry
 - Laser Tachometer
 - Accelerometers

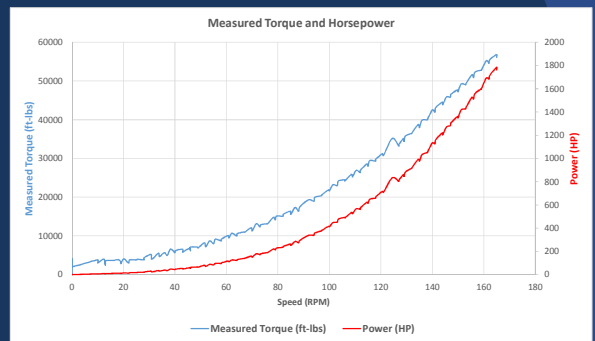


Case Study 7: Wind Tunnel Torsional Test

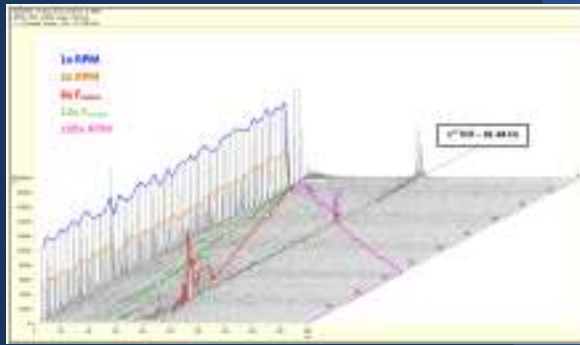
- Careful surface preparation and calibration procedure required for strain gage application



Case Study 7: Wind Tunnel Torsional Test



Case Study 7: Wind Tunnel Torsional Test



Case Study 7: Wind Tunnel Torsional Test

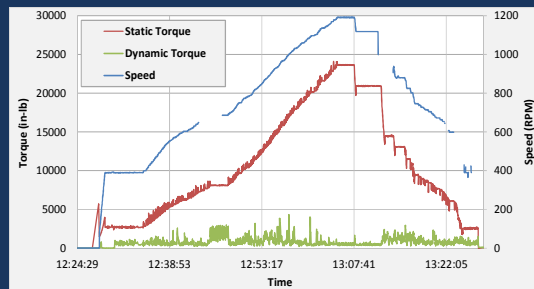


Case Study 8: ID Fan Torque Measurement

- ID Fan in an air separation facility
 - Document static/dynamic torque during startup and operation
 - Identify torsional natural frequencies using strain gages
 - Validate analytical model of torsional system
- Test Plan:
 - Strain Gages
 - Radio Telemetry
 - Laser Tachometer

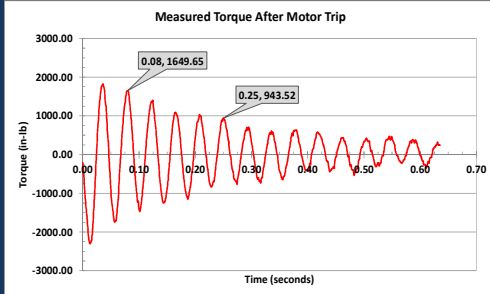
Case Study 8: ID Fan Torque Measurement

- Static/Dynamic Torque Data Looks Great!



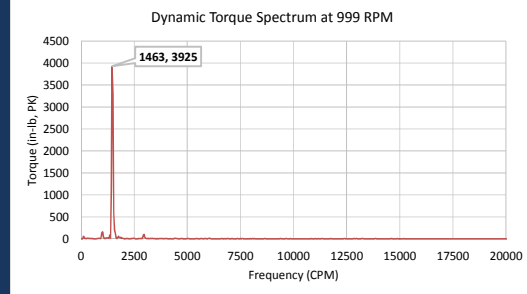
Case Study 8: ID Fan Torque Measurement

- TNF matches prediction very well!



Case Study 8: ID Fan Torque Measurement

- Dynamic Torque below acceptable limit!



Case Study 8: ID Fan Torque Measurement



Case Study 8: ID Fan Torque Measurement

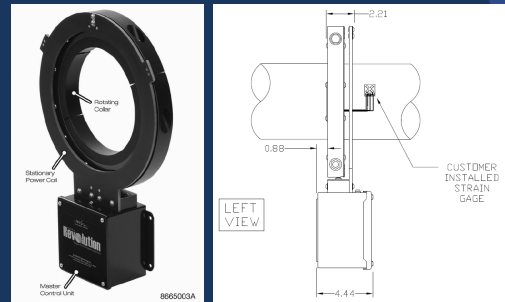
- Lesson Learned:
 - Regardless of any real or perceived schedule pressure, SAFETY must be your #1 priority during a test
 - Rotating machinery **CAN BE** hazardous
 - Broken rotating machinery **IS** hazardous!

Case Study 9: Online Torque Monitoring

- Problem:
 - Integrally Geared Air Compressor Driven by a Synchronous Motor
 - Multiple coupling failures had previously occurred
 - Client wanted an online monitoring device to measure static and dynamic torque
- Solution:
 - Off-the-shelf strain gages/transmitter/reciever
 - Custom Labview software
 - Verify instrumentation/data with known hardware

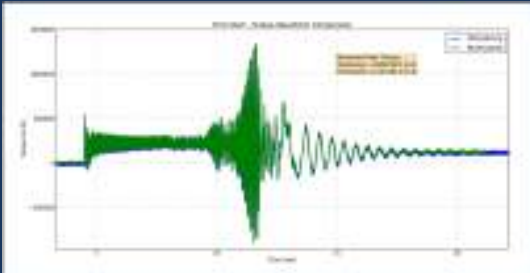
Case Study 9: Online Torque Monitoring

- Hardware:



Case Study 9: Online Torque Monitoring

- How did the online system compare to known temporary instrumentation... GREAT!



Case Study 9: Online Torque Monitoring



Case Study 9: Online Torque Monitoring

- Solution:
 - Parts shipped to manufacturer for repair
 - Collar re-installed with adhesive on the ID to maintain axial position



Case Study 10: Urea Conveyor Vibration

- Application: Granular urea conveyor in a fertilizer production facility
- Problem: Belt-driven conveyor experienced drive belt slipping from pulley
 - Plant attributed belt slippage to resonance problem
- Test Plan:
 - Impact Testing
 - Vibration Amplitude/Frequency Measurement
 - Try not to get too filthy!

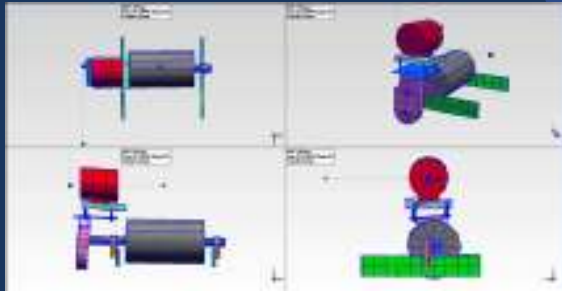
Case Study 10: Urea Conveyor Vibration



Case Study 10: Urea Conveyor Vibration

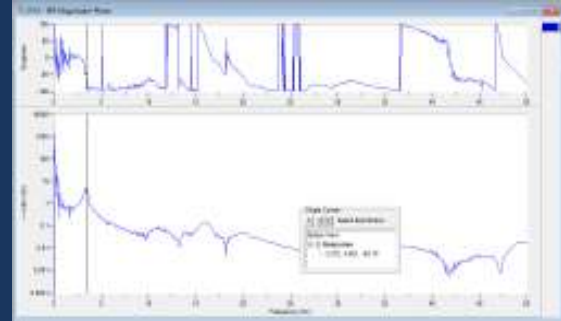


Case Study 10: Urea Conveyor Vibration



Case Study 10: Urea Conveyor Vibration

- Very low first natural frequency (<4 Hz)



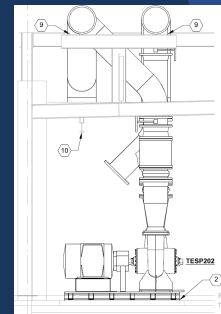
Case Study 10: Urea Conveyor Vibration

- Final Solution: Don't forget to tighten fasteners!



Case Study 11: Chilled Water Pumps

- Application: Chilled water pumps at a prominent university
- Problem: High 1x vibration
- Test Plan:
 - Impact Testing
 - Vibration Amplitude/Frequency Measurement
 - Field Balancing



Case Study 11: Chilled Water Pumps

- Highest vibration at 1X running speed
- Indication of excessive imbalance
- Maybe resonance... Let's Check!



Case Study 11: Chilled Water Pumps

- Source of imbalance was the improperly sized keys on the coupling
- The keys were too short to fill the void in the keyway
- Balance correction weights were installed at the same angle as the key to correct

Case Study 12: Condensate Pumps

- Application: A/B/C Condensate Pumps at a Combined Cycle Plant
- Problem: A-Pump keeps tripping on high vibration
- Test Plan:
 - Impact Testing - 3 pumps
 - Vibration Amplitude/Frequency Measurement on A Pump



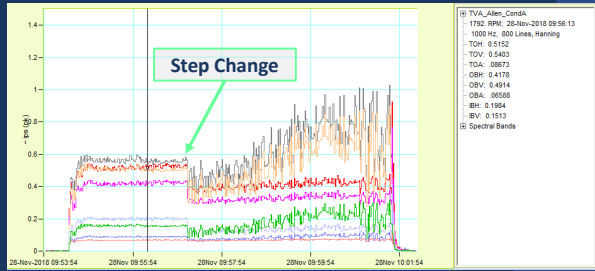
Case Study 12: Condensate Pumps

- Measurement Setup:
 - Accelerometers on motor bearings and pump upper bearing



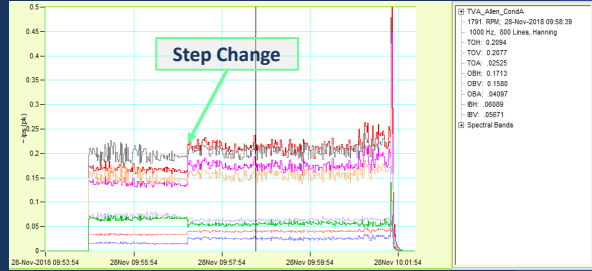
Case Study 12: Condensate Pumps

- Test Data – Overall Vibration Amplitude Trend



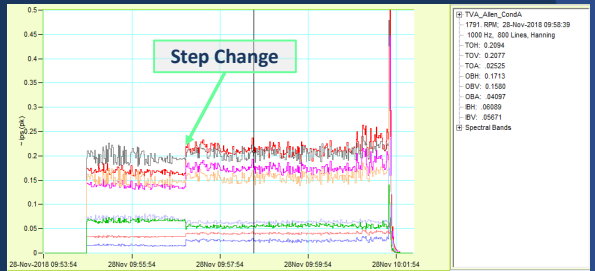
Case Study 12: Condensate Pumps

- Test Data – 1X Vibration Amplitude Trend



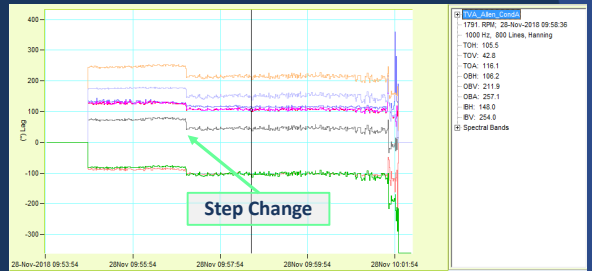
Case Study 12: Condensate Pumps

- Test Data – 1X Vibration Amplitude Trend



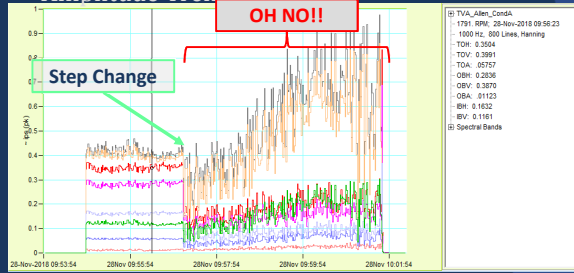
Case Study 12: Condensate Pumps

- Test Data – 1X Vibration Phase Trend



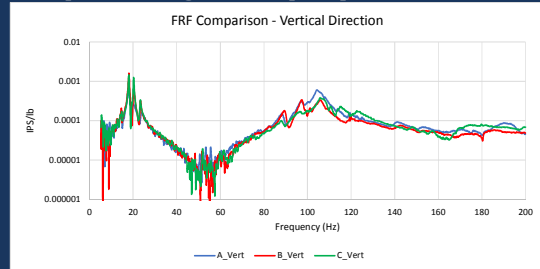
Case Study 12: Condensate Pumps

- Test Data – Subsynchronous Vibration Amplitude Trend



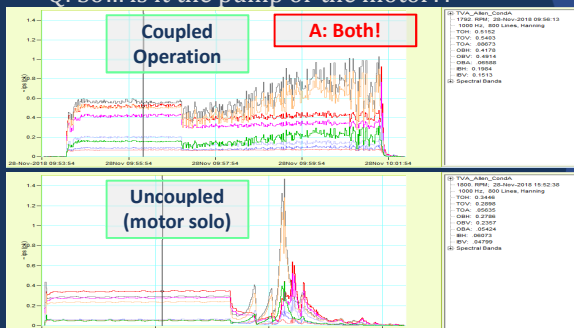
Case Study 12: Condensate Pumps

- Why is only A Pump bad? Structural?
- Impact testing on all 3 pumps...



Case Study 12: Condensate Pumps

- Q: So... is it the pump or the motor??



Case Study 12: Condensate Pumps

- So... What was wrong?
- Pump ingested foreign material
 - Caused pump impeller damage and excessive imbalance (High 1X) leading to excessive pump bearing clearance (High Subsynchronous)
 - Subsynchronous pump vibration excited structural natural frequencies
- What about the motor solo?
 - Motor was supplied with excessive imbalance