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A Case Study of Vibration in Positive Displacement Pump Systems

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Experience

Trenton Cook

- *FEA of machinery piping systems*
- *Field pulsation and vibration assessment of piping systems*
- *Modal and forced response analysis of mechanical systems*

Sarah Simons

- *Almost 10 years of experience in flow and acoustic analysis of pump systems*
- *Leads research on fluid property testing, and flow and pulsations in combined machinery types*

Abstract

Positive displacement pump systems can experience high piping vibrations. System vibration can have many root causes- including underdamped fluid pulsations, mechanical resonance, and poor skid design. This case study shows the mechanical and acoustic assessment of a reciprocating pumping system which had multiple vibration induced failures. Poor support stiffness, coupled with inadequate pulsation dampener performance resulted in high amplitude piping vibration- requiring both mechanical and acoustic analyses. Collected field pulsation and vibration data are presented, along with follow-up acoustic and finite element modeling results to showcase a solution to pulsation induced vibration in this particular pump system.

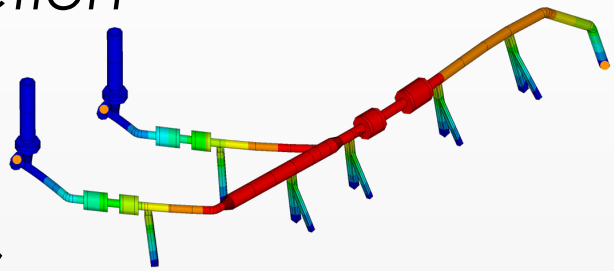
Problem

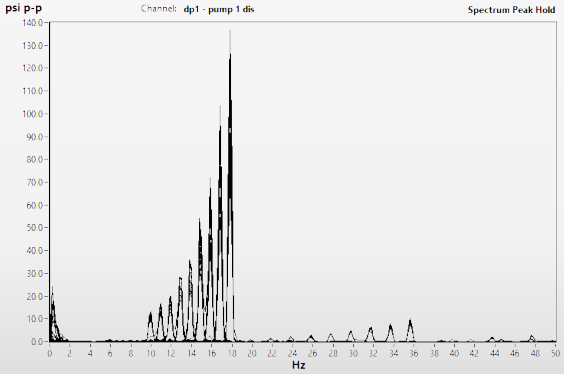
- *Reciprocating pump installation for salt water disposal*
- *Multiple reported piping failures*
- *Failure of pulsation dampener bladders*
- *Reported piping/skid vibration*

Location of Previous Failure

Solution Overview

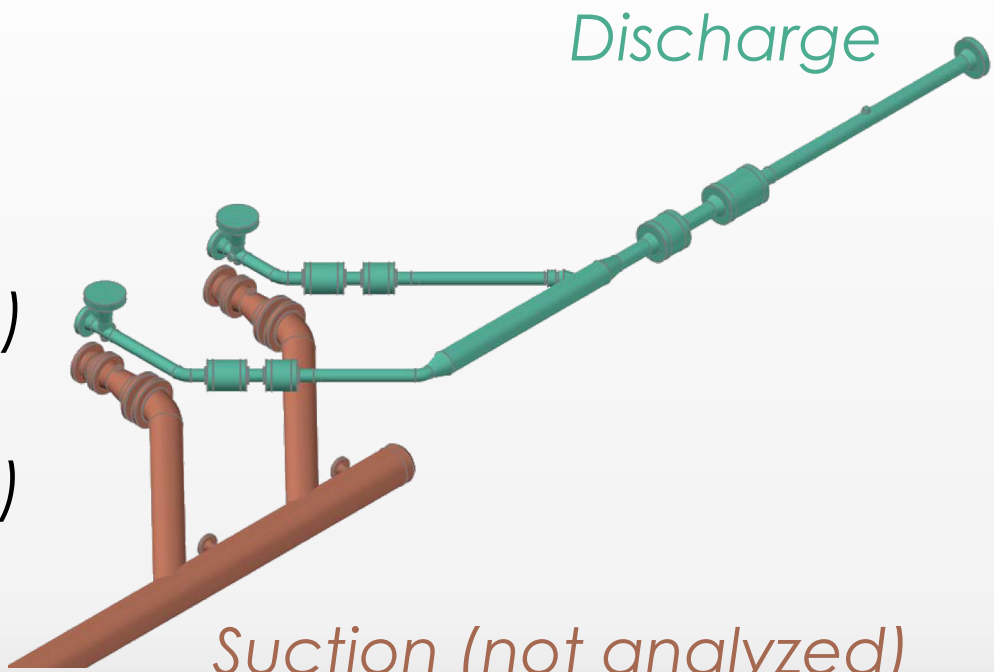
- *Field Data Collection*
- *Modal Analysis*
- *FEA Analysis*
- *Pulsation Analysis*
- *Design Changes:*
  - *Mechanical*
  - *Acoustic*





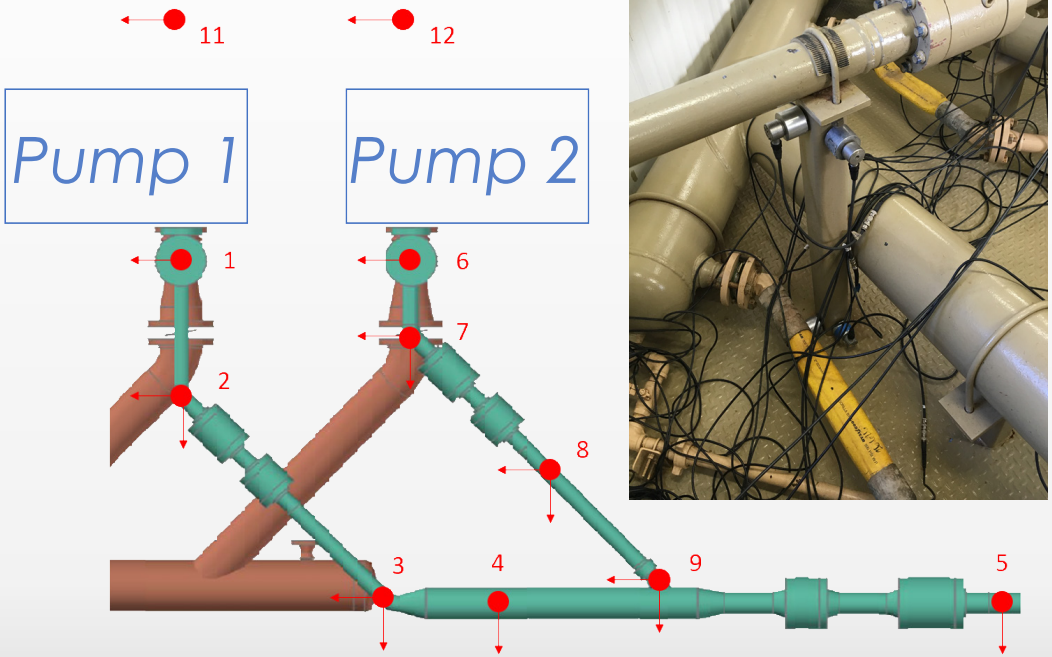
System Overview

- *(2) Triplex pumps, skid mounted on soil pad*
- *200-400 RPM*
- *800-1400 psi (discharge)*
- *Pulsation dampeners (discharge and suction)*



Field Data Collection

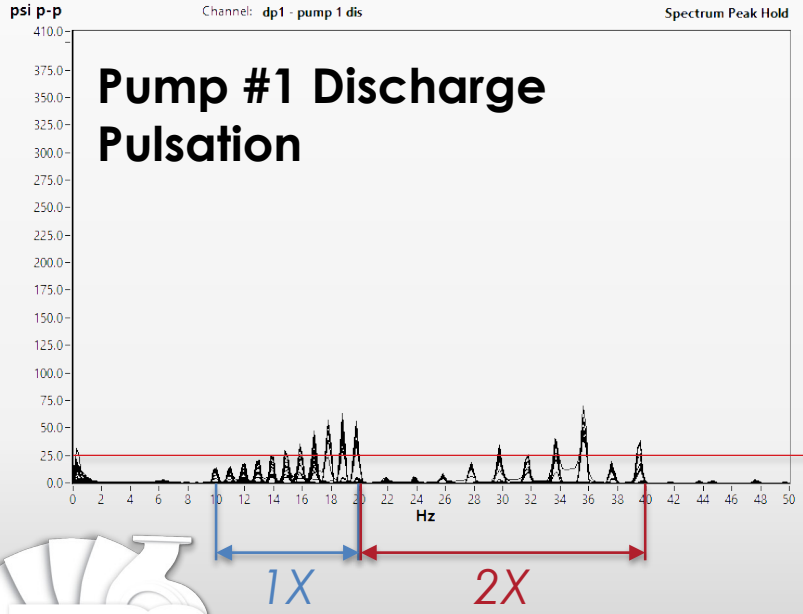
- *Independent and parallel operation of Pumps #1 and #2*
- *Speed sweep (200-400 RPM)*
- *Multiple pulsation dampeners tested*
- *Accelerometers*
- *Pulsation transducers*



Vibration Test Locations

Test Case - 1

- *Parallel operation and speed sweep (200-400 RPM) of Pumps #1 and #2- in original configuration*



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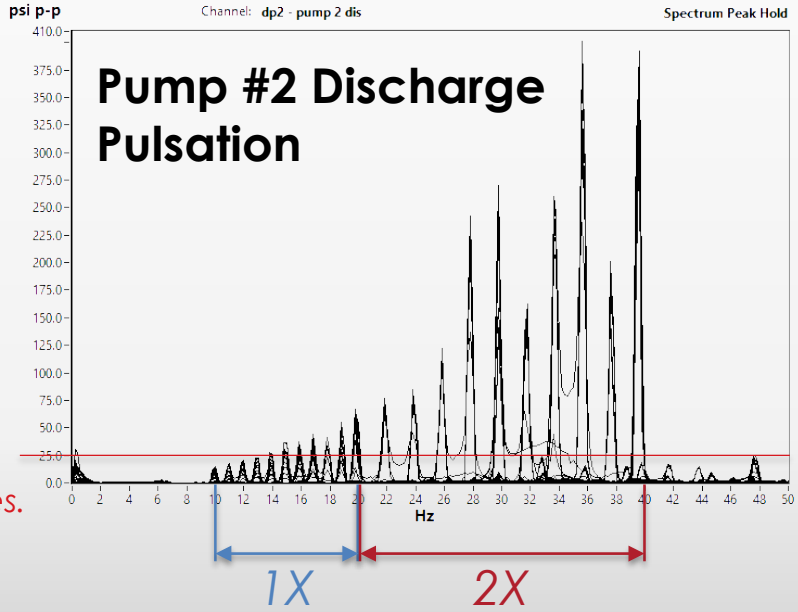
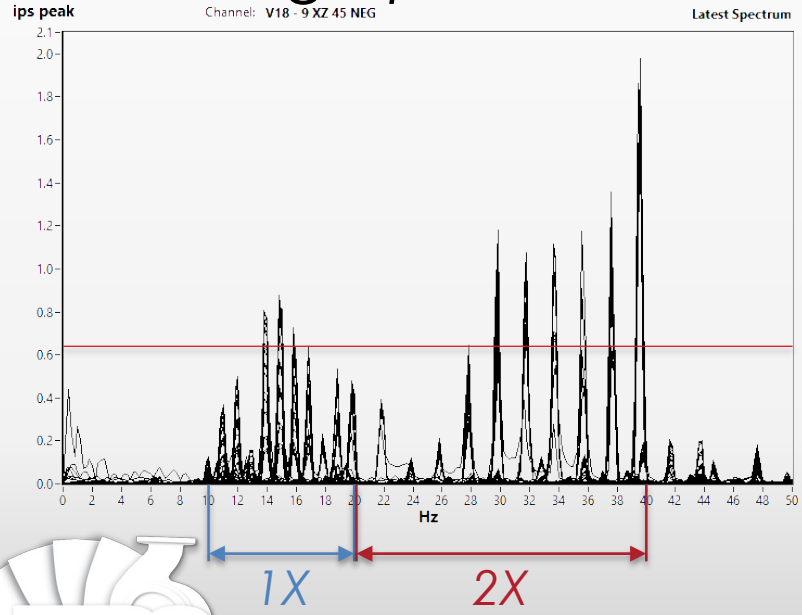


Test Case - 1

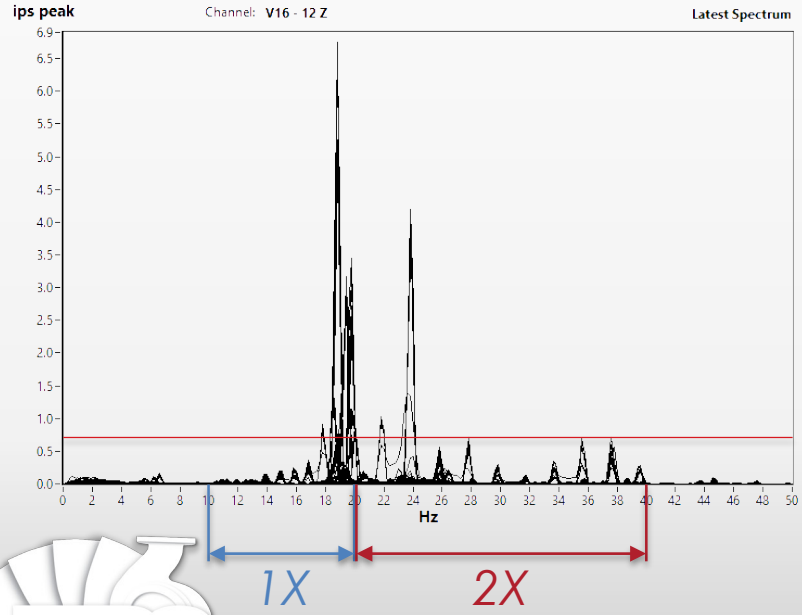
- *Vibration at wye (location of previous failures)*
- *Vibration frequencies consistent with Pump#2 discharge pulsations*



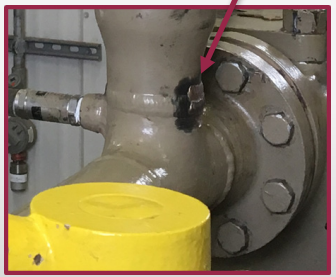
Previous Failure

Test Case - 1

- *Vibration of Pump #2 pulsation dampener (top)*
- *Mechanical resonance near 19 Hz*



Previous Failure

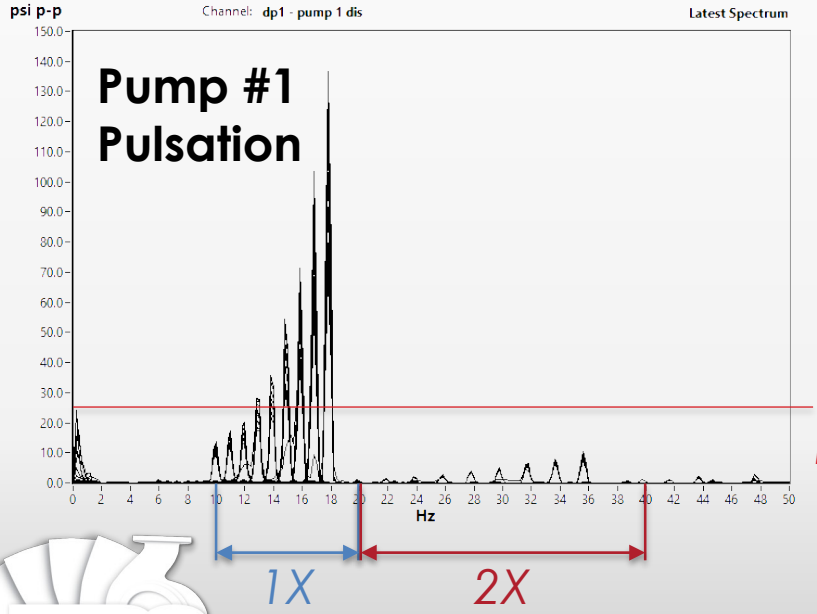


Test Case - 1

- *Pump #2 pulsation dampener had failed- would not hold charge*
- *High amplitude pulsations (undamped) caused high amplitude piping vibration across operating range*
- *Multiple mechanical piping/support modes excited by high amplitude pulsations*
- *Next Test-- replacing Pump #2 pulsation dampener with alternative model- at site from previous use*

Test Case - 6

- *Parallel operation and speed sweep (200-400 RPM) of Pumps #1 and #2- alternative dampener on Pump #2*



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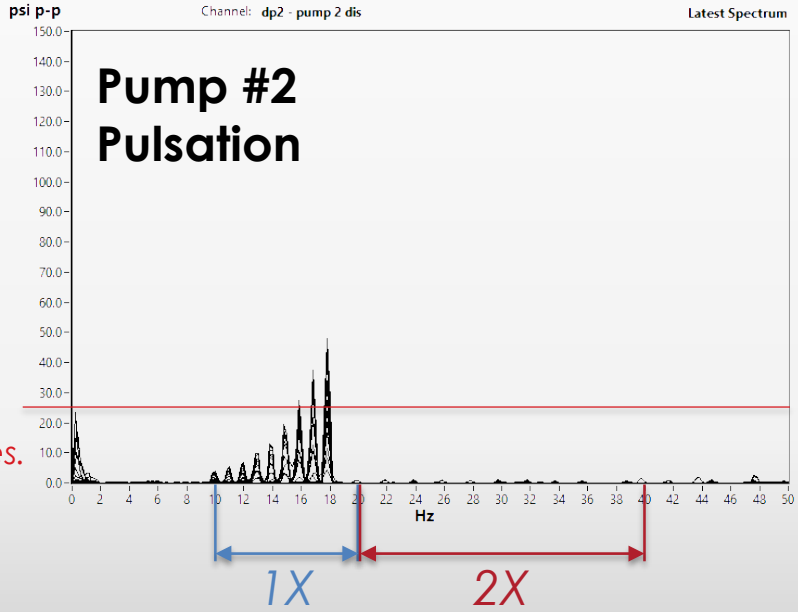
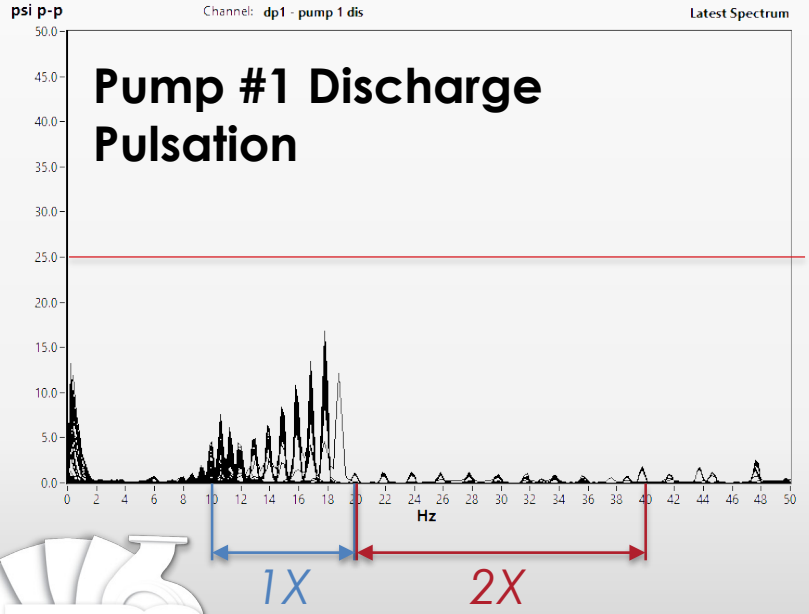


Test Case - 6

- *Replacing the Pump #2 failed pulsation dampener with alternative dampener significantly reduced pulsation amplitudes in system*
- *Pump #1 still had high amplitude pulsations and vibration still persisted, despite general reduction in amplitudes*
- *Next Test--replacing Pump #1 pulsation dampener with alternative model- to match Pump #2*

Test Case - 7

- *Parallel operation and speed sweep (200-400 RPM) of Pumps #1 and #2- with alternative dampeners*



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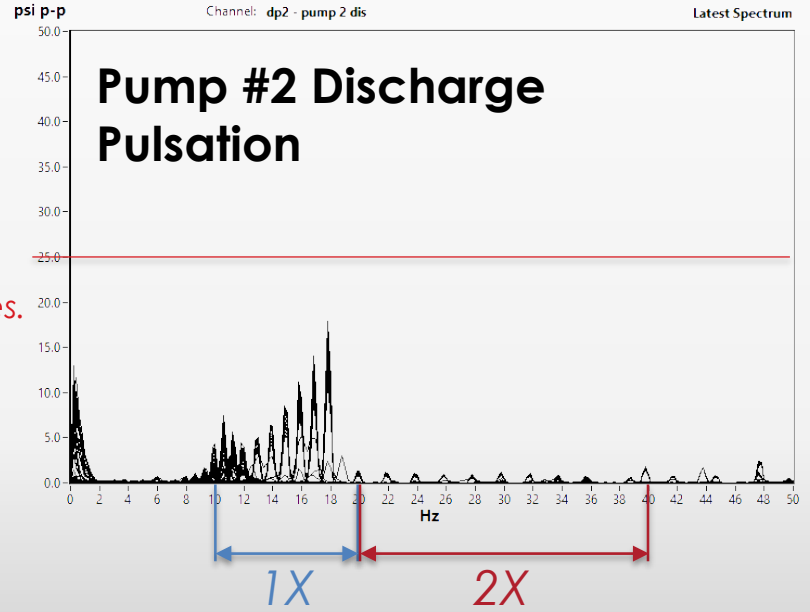
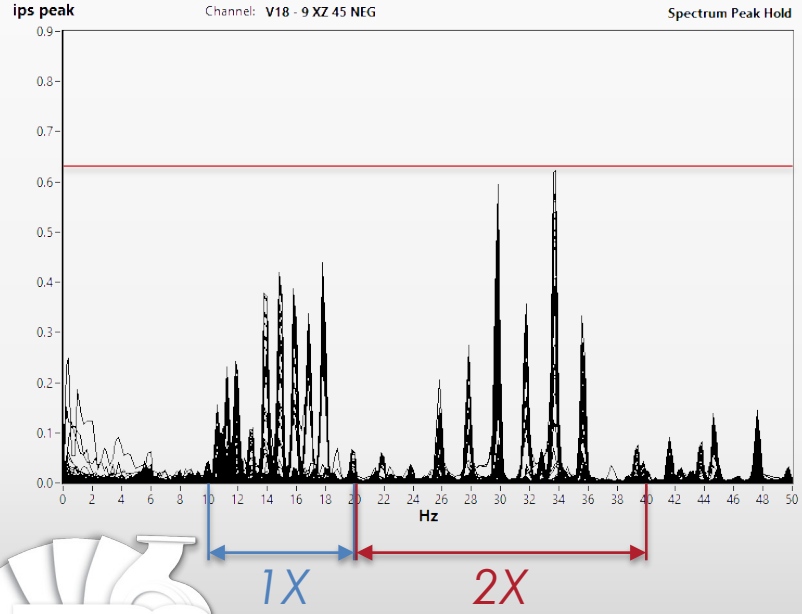


Test Case - 7

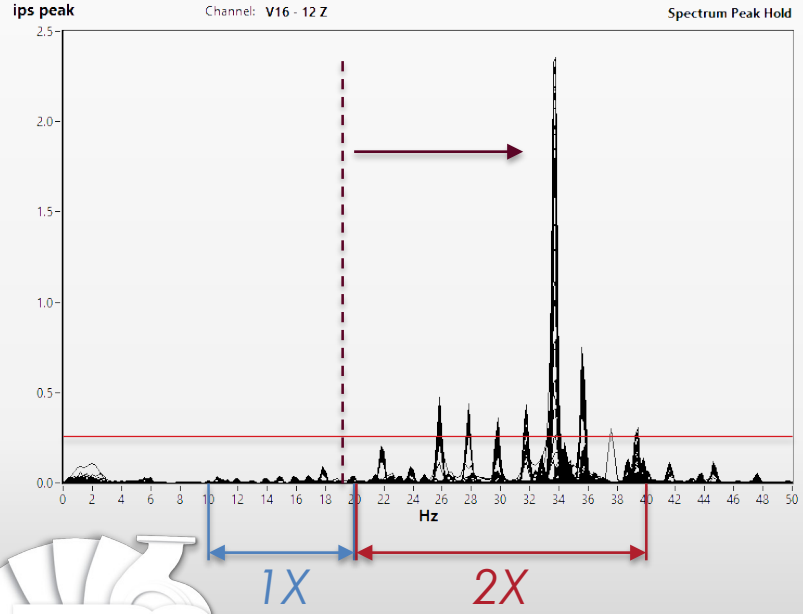
- *Vibration at wye significantly reduced*
- *Potential mechanical resonances still at 2X*



Previous Failure

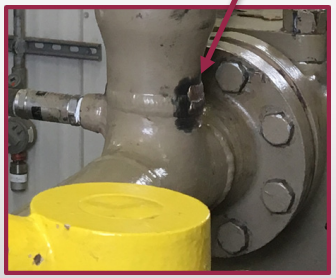
Test Case - 7

- *Vibration of Pump #2 pulsation dampener (top)*
- *Mechanical resonance near 34 Hz (shifted)*



Alt Dampener

Previous Failure

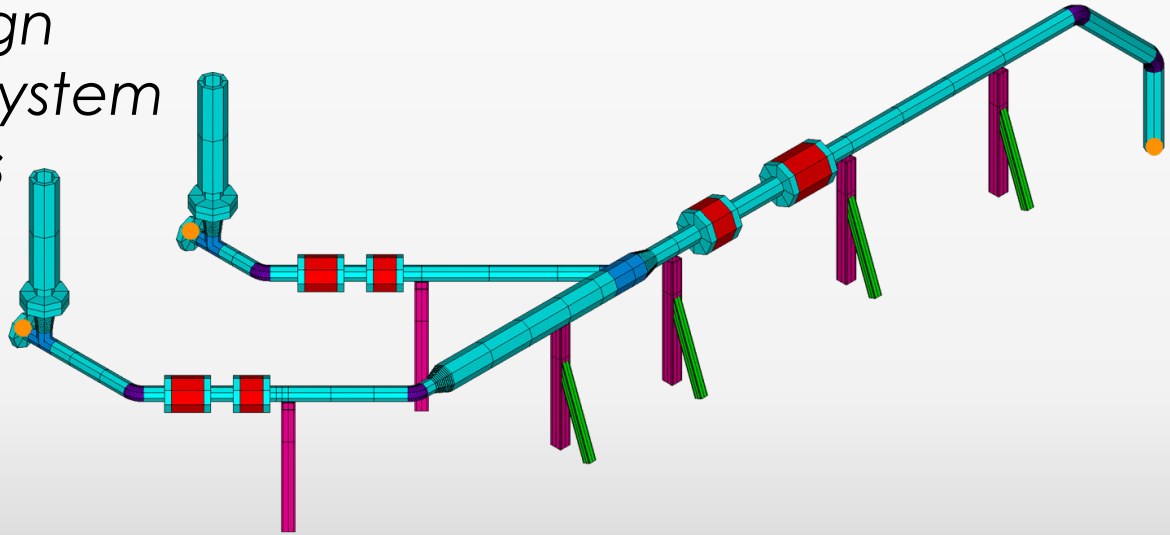


Test Case - 7

- *Replacing both Pump #1 and #2 dampeners with alternative design reduced the system pulsation amplitudes within acceptable limits*
- *System vibration amplitudes significantly reduced with alternative dampeners*
- *Some high amplitude vibration still persistent- associated with mechanical resonances*
- *Pulsation dampeners recommended to be re-sized*
- *Additional modal analysis and bracing recommended*

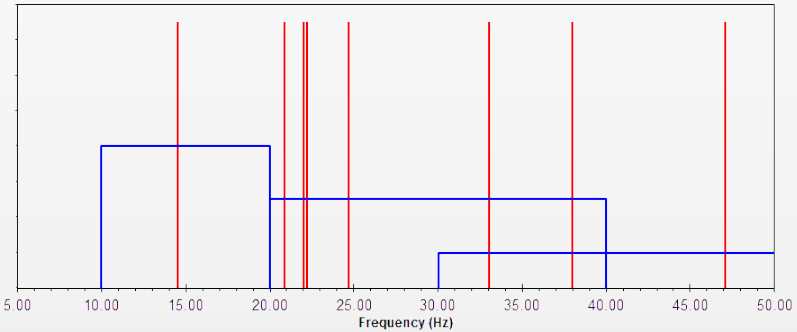
Modal Analysis

- *Finite Element model built to perform modal analysis of piping system*
- *Results used to design additional support system to place key modes beyond range of operating speed*

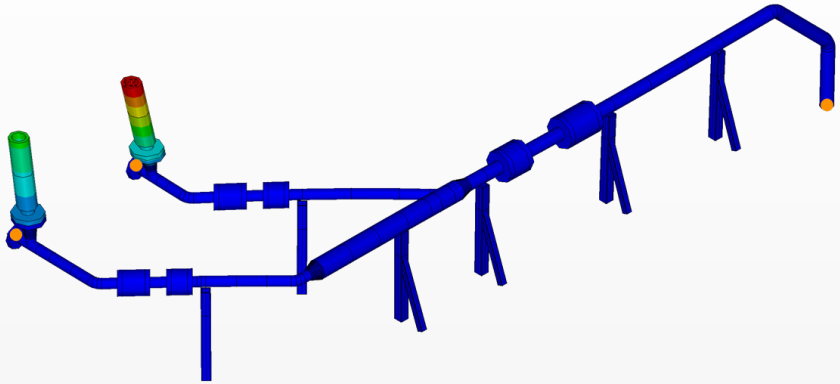


Modal Analysis

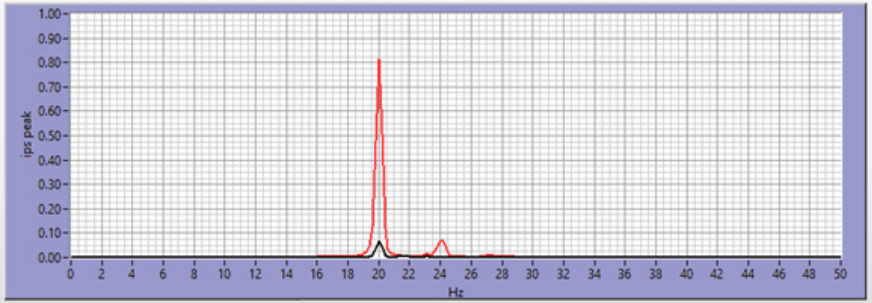
- *Impact test data collected in the field*
- *Modal analysis evaluated with FE model*



Modal Interference Plot



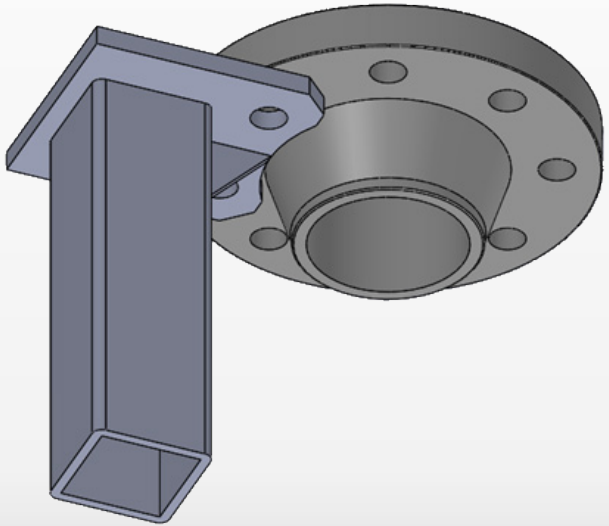
FEA Modal Results ~22 Hz



Field Bump Data ~20 Hz

Mechanical Recommendations

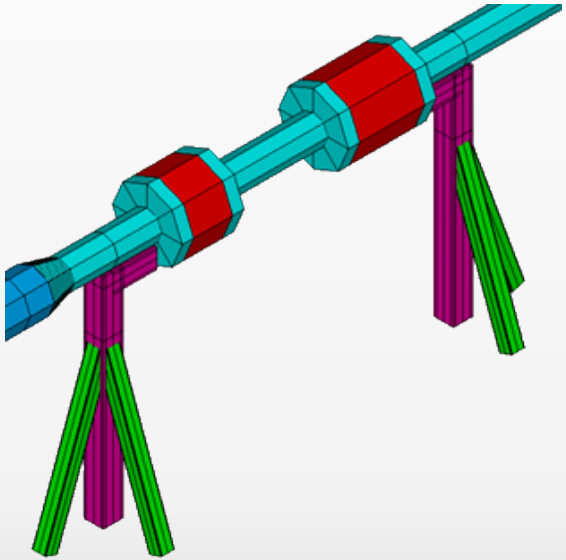
- *Additional bracing of pulsation dampener flange*

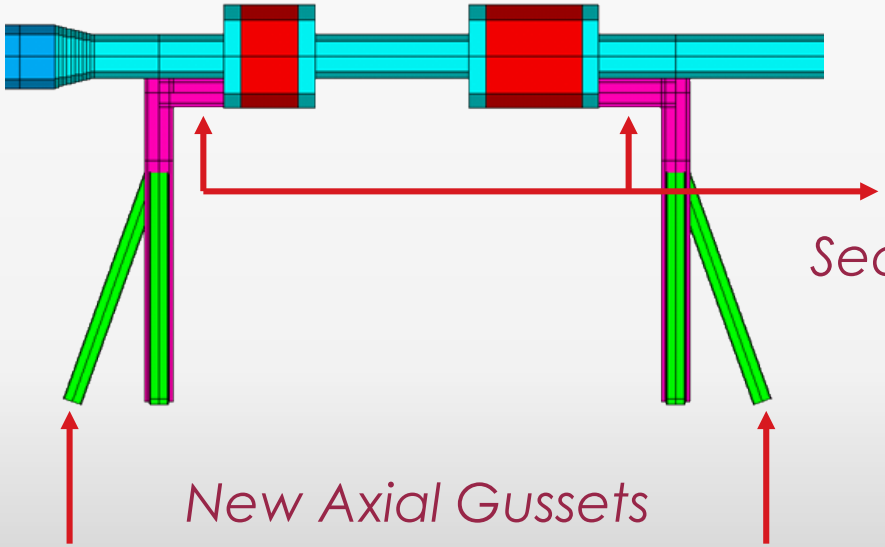


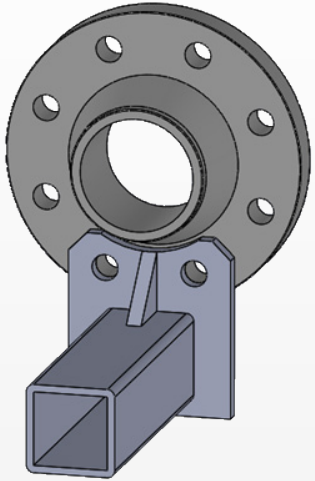
New Flange Support

Mechanical Recommendations

- *Additional bracing of discharge header*

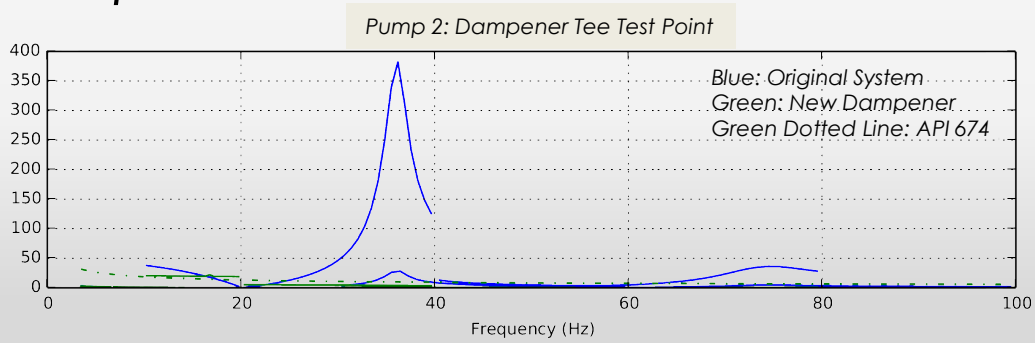






Pulsation Analysis

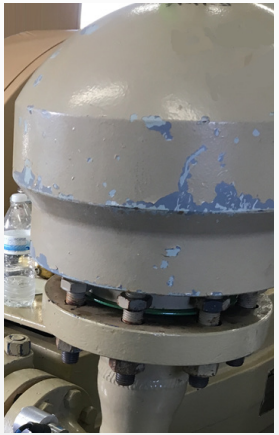
- *Alternate dampeners in the field not rated for long-term operation at the higher end of discharge pressure*
- *Pulsation analysis performed to size new dampeners designed for this application*
- *Initial model results matched well with field data and the model with the new dampener showed sufficient attenuation of the pump excitations, similar to Field Test Case 7 results.*



Dampener Evaluation

- *Dampeners need to be charged to 70-90% line pressure*
- *Avoid tall and heavy dampeners that have low MNFs*
- *Use bladder material suited for the application*

Original

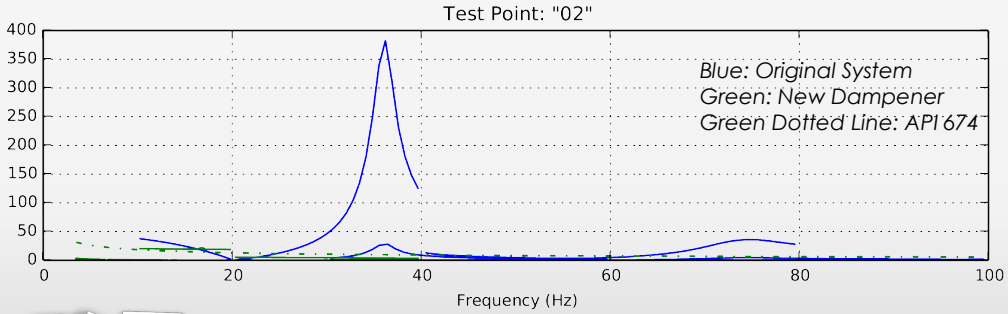


Tested

Final Installed

Solution Results

- *System operating without failures or excessive piping/support vibration*
- *Pulsation dampeners performing without failure*



Questions?