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BB3 Structural Vibration Problem Resolved Using Analytical Methods

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Installation

- 3 stage BB3 type
- Water injection service (1200 GPM @ 2650 ft)
- Driven through gearbox by natural-gas engine
- 3560 to 6000 RPM continuous operating speed range

Problem

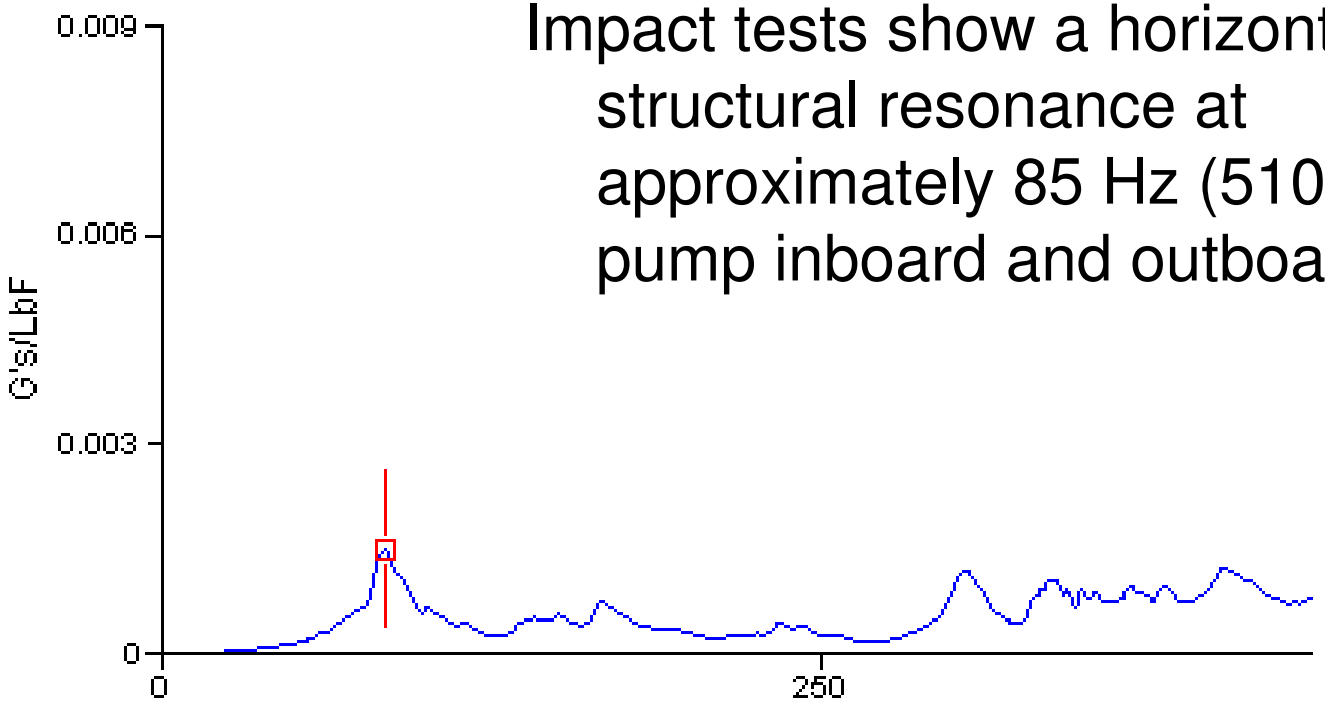
Vibration Performance

- High bearing housing and casing vibrations showed after the pumps were relocated and put into a new service (Ran fine in previous life)

- Same problem with 3 identical units
- Horizontal vibration (~0.6 in/sec) at or above 5200 RPM
- Not able to reach full speed (6000 RPM)

Root Cause Analysis

Structural Resonance – Impact Testing



PIH

Impact tests show a horizontal structural resonance at approximately 85 Hz (5100 cpm) on pump inboard and outboard end

Root Cause Analysis

Pump Lateral Rotordynamics

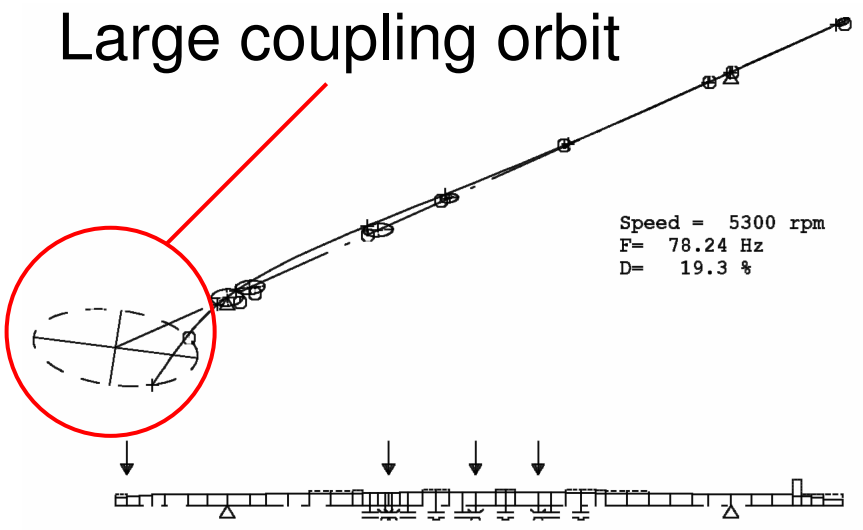
- High speed operation. (6000 RPM)
- Heavy coupling. (~100 lbs total)
- Long shaft span at drive end.
- Nearest seal is eye of suction impeller.

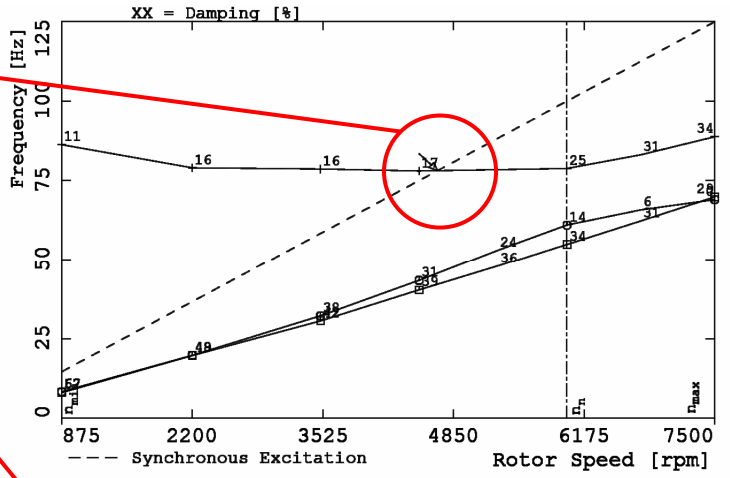
Root Cause Analysis

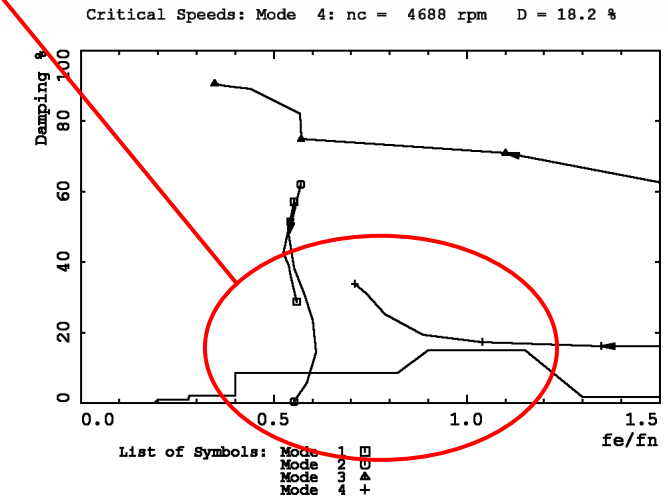
Overhung mode critical speed
(~4700 RPM)

Low damping

Large coupling orbit



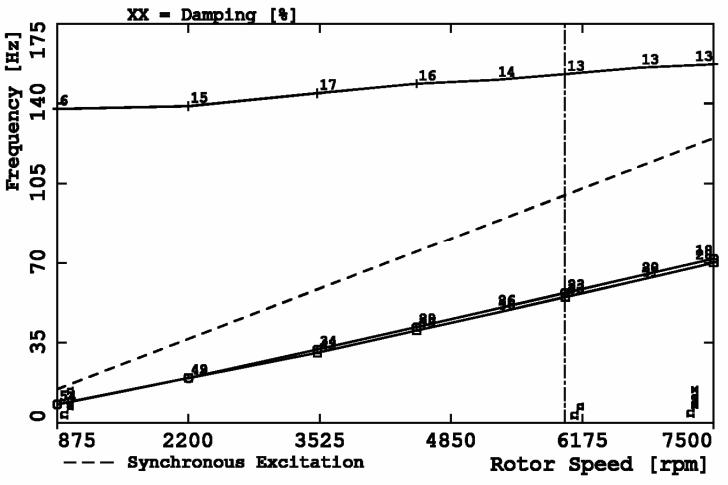


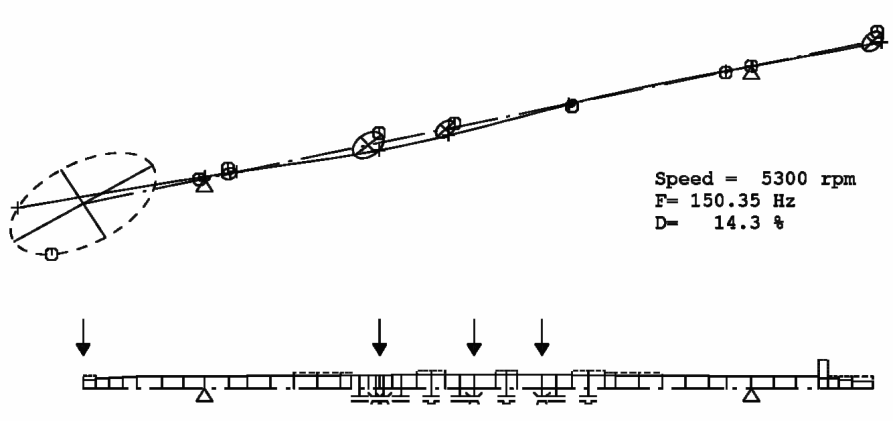


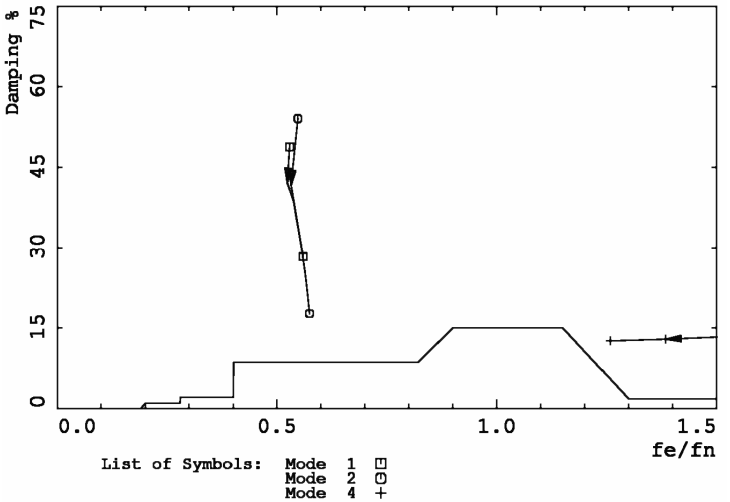
Root Cause Analysis

Recommendations

- Replace coupling
- Lateral stability improved







Root Cause Analysis

Support Structure Modal FEA

Not every seam welded

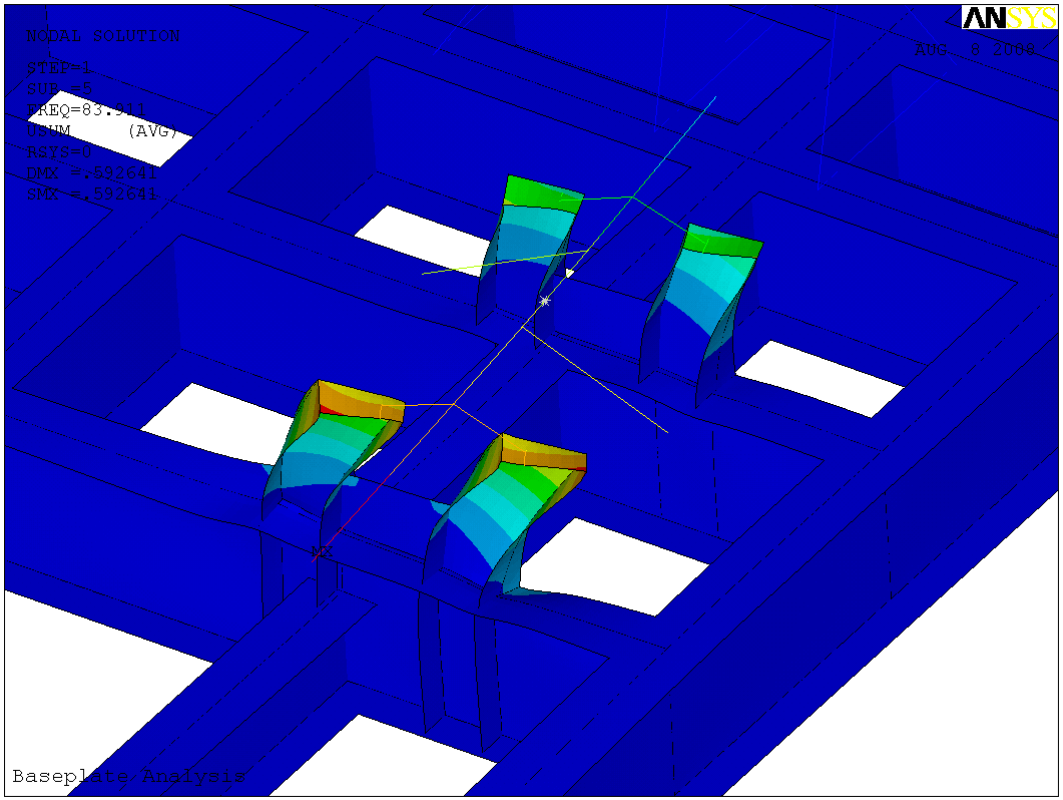
Uncertain hold-down locations

Root Cause Analysis

Support Structure Modal FEA

Horizontal pump mode
84Hz [5040 cpm]

Mode shape offers
clues to detuning



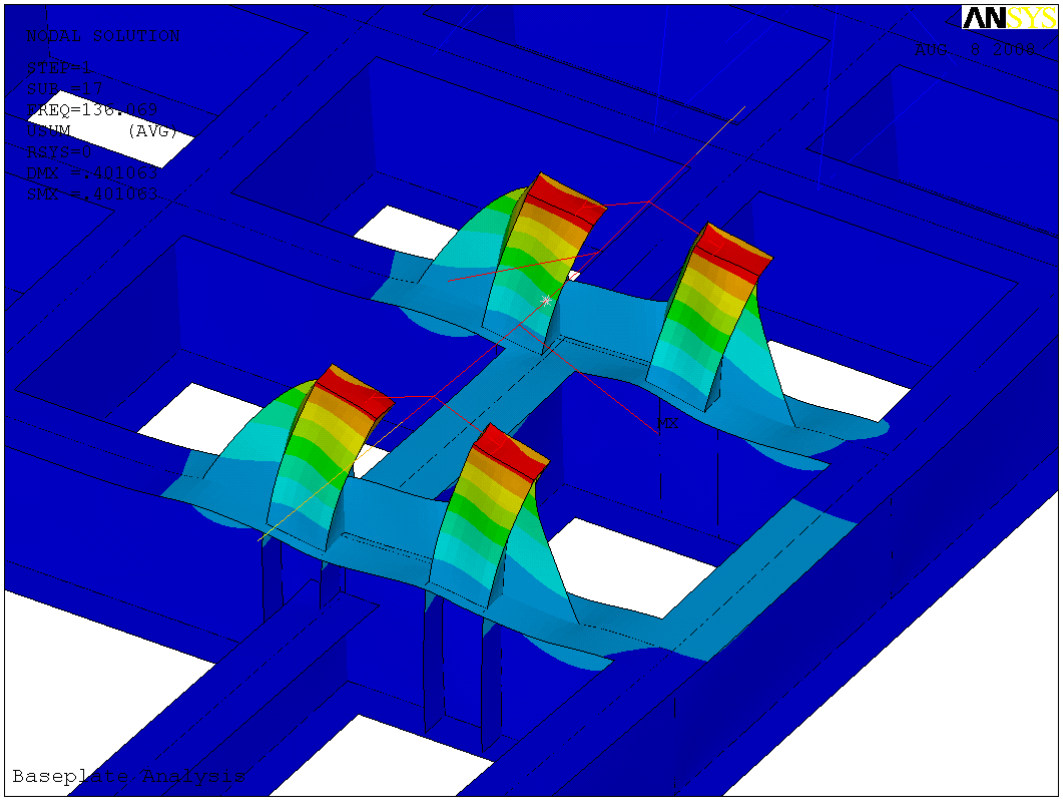
Root Cause Analysis

Recommendations

Add gussets / struts

Box the pedestals

Predicts increase in
natural frequency
136 Hz [8160 cpm]



Implementation

Bracing added to all four pedestals (as piping allowed)

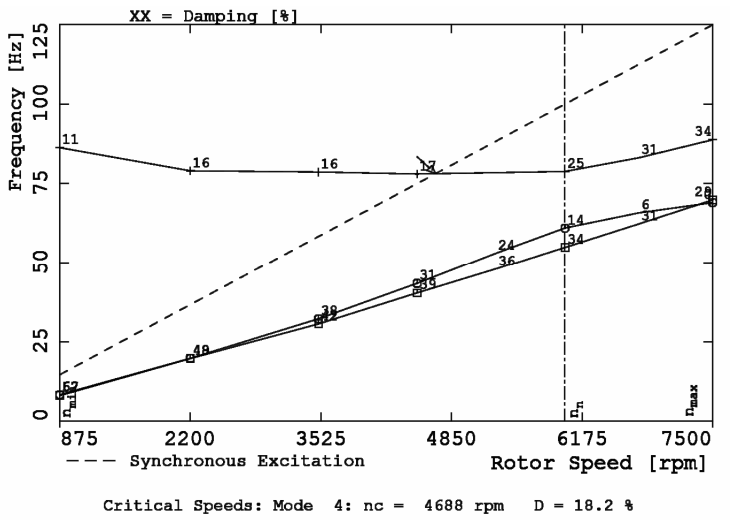
Implementation

Drive-end pedestals also
'Boxed' to reduce twisting

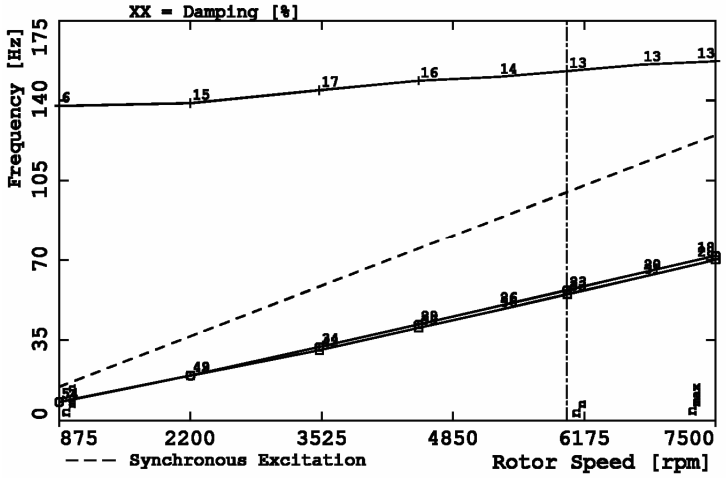
Implementation

Coupling Changes

- Original – 48 lbs (pump-side)
- Profiled – 36 lbs (pump-side)
- Field Balanced



- Entirely new
  13 lbs (pump-side)



Results

- Reduced Vibration
  - Original 0.60 in/sec @ 5200 RPM
  - Added Struts 0.28 in/sec @ 5800 RPM
  - Changed Coupling 0.19 in/sec @ 6100 RPM
- Ability to run through entire operating speed range

Lessons Learned

- Avoid unnecessarily heavy couplings.
- Open communication facilitates root cause analysis.
- Fix problems when found, as found.
- Relocating equipment and/or changing services –including speed range – can result in vibration issues.