Impact of RCF Analysis on Operation of Pipeline Vertical Booster Pumps

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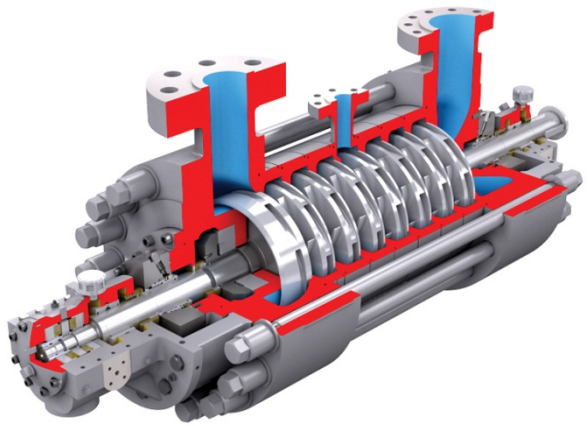
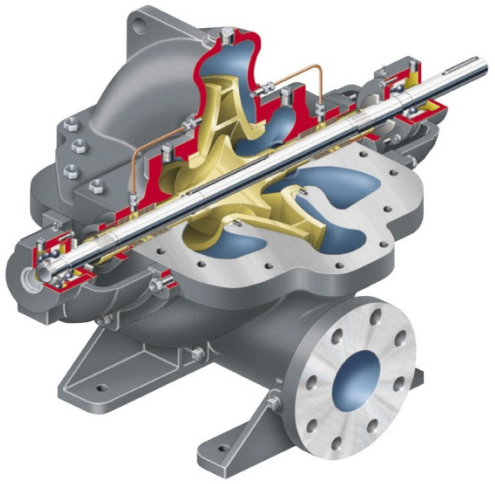
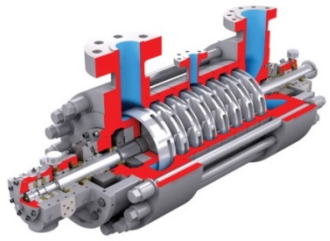
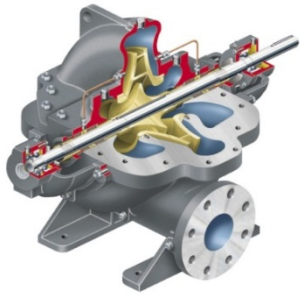




Presenters

Hemanth Satish	**Bio** **Hemanth Satish currently works for TransCanada Pipelines Ltd as a Senior Mechanical Engineer in their Major Equipment Engineering and Turbine Fleet group. He has over 12 years of Engineering experience working mainly in the areas of Rotating Machinery, Heat Transfer and Stress Analysis. He is a registered Professional Engineer with APEGA and holds a Bachelor's and Master's degree in Mechanical Engineering. He has professional background working in the areas of gas turbine & centrifugal compressors, large centrifugal pumps operation and trouble shooting, root cause failure analysis of rotating machinery, research and development in pulsation and vibration analysis of reciprocating compressors, design & operation of heat transfer equipment & high performance composite materials.** **Hemanth has published journal papers and presented in a number of conferences. He currently sits on the PRCI (Pipeline Research Council International) compressor and pump technical committee and part of API 610 12th Ed Task Force.**

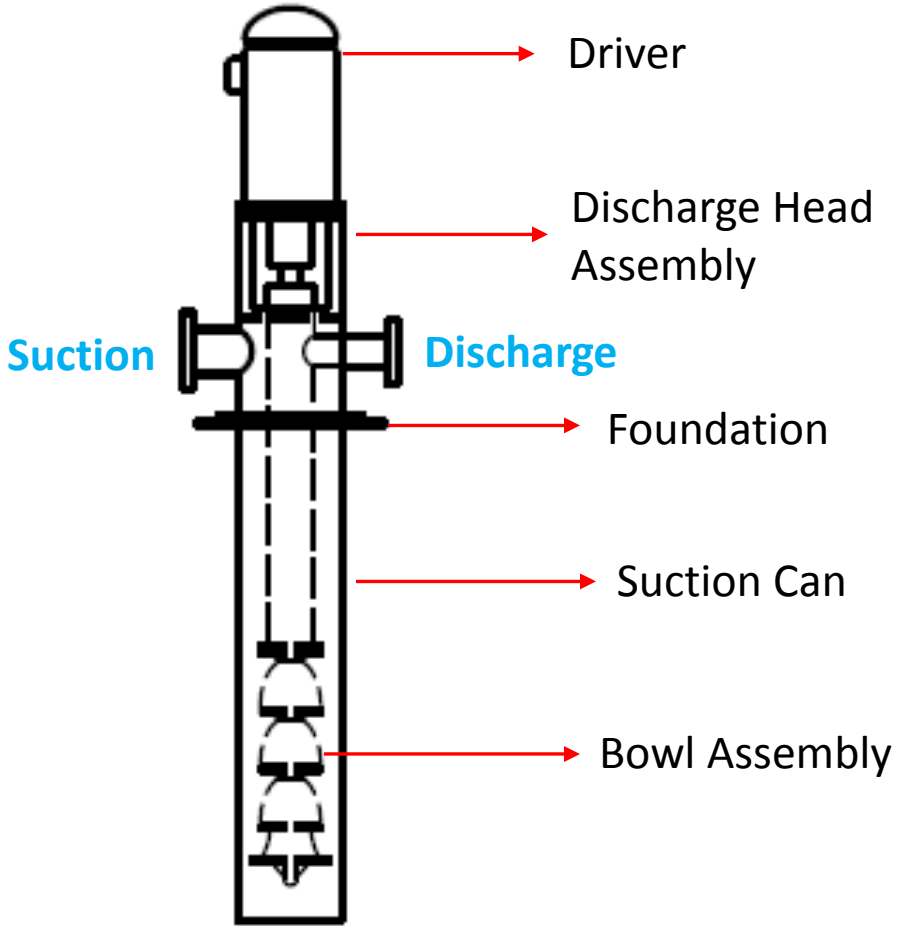




Presentation Outline

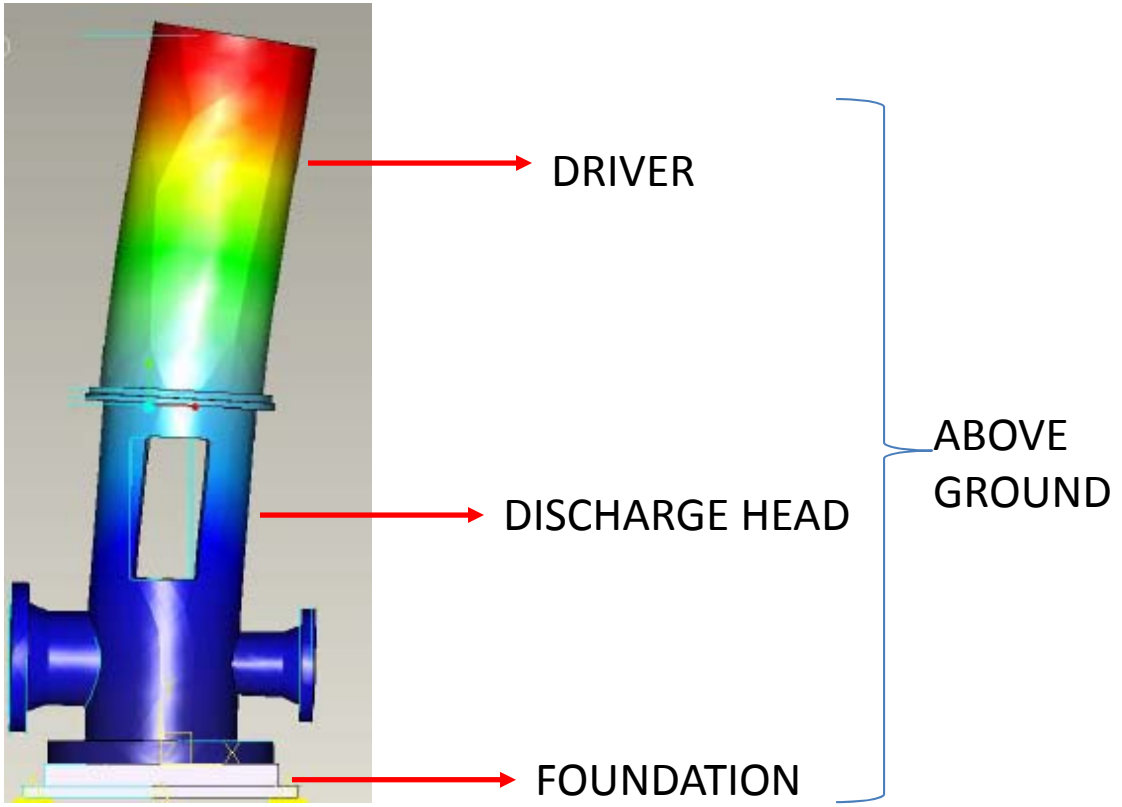
- Introduction;
- Reed Critical Frequency (RCF) Overview;
- RCF & Rotor Dynamic Analysis Distinction;
- Importance of Performing RCF Analysis;
- Basic Elements of Performing RCF;
- Field Verification and Fixes;
- Summary;
- Questions.

Introduction



RCF Overview

- First natural frequency of the upper portion of the vertical pump;



RCF Overview (Cont..)

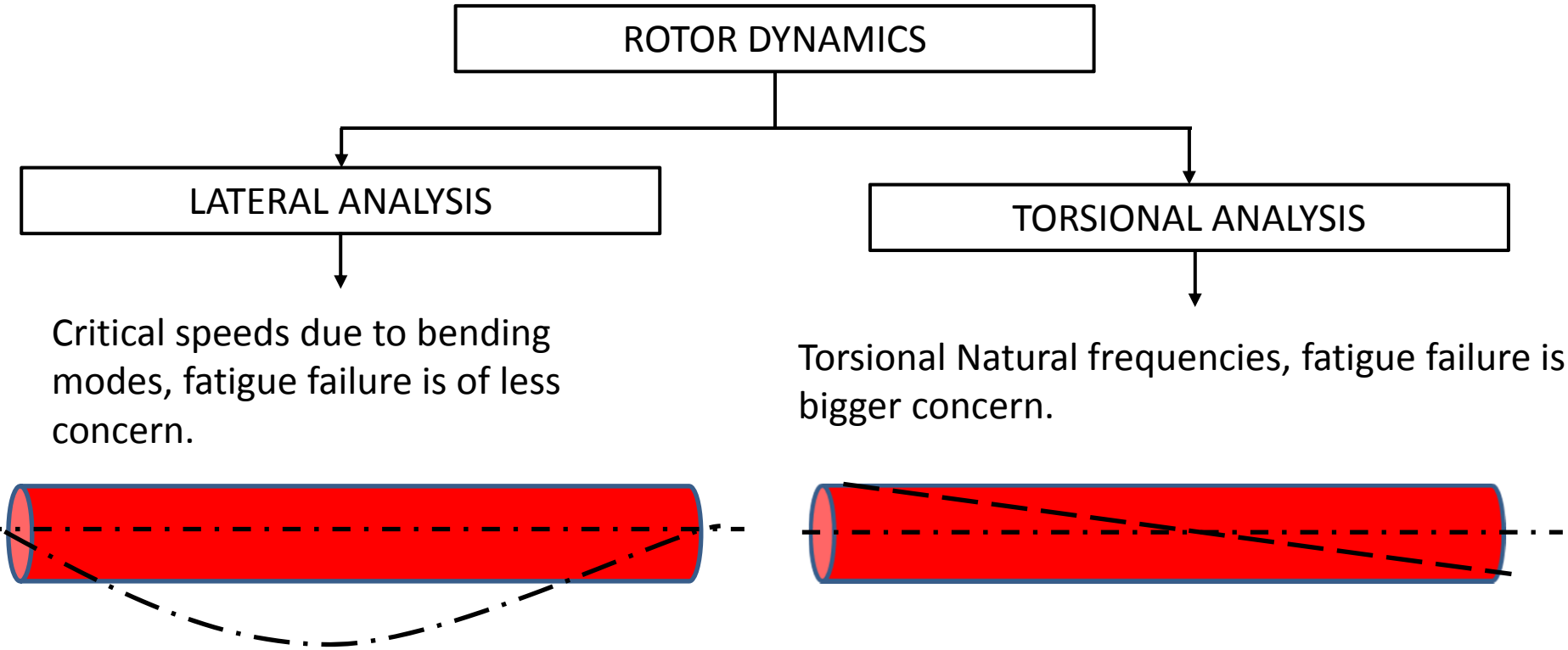
- RCF is a structural Mechanical Natural Frequency (MNF);
- Interference of run speed and RCF results in resonant condition, leading to excessive vibration;
- Could potentially excite sub sync whirl ;
- Variable speed pumps are more susceptible;
- 20% or greater Separation Margin (SM) is recommended per HI;

RCF Overview (Cont..)

- When is an RCF analysis required?
  - ✓ High power pump (>500 HP)
  - ✓ VFD driven pumps
  - ✓ Deep suction can (>25ft)
  - ✓ If required by operator
  - ✓ When motor RCF does not meet required SM
  - ✓ non proven pump design, unusual operations;
  - ✓ When a very flexible foundation is anticipated;
  - ✓ Relatively novice OEM

RCF & Rotor Dynamic Analysis Distinction

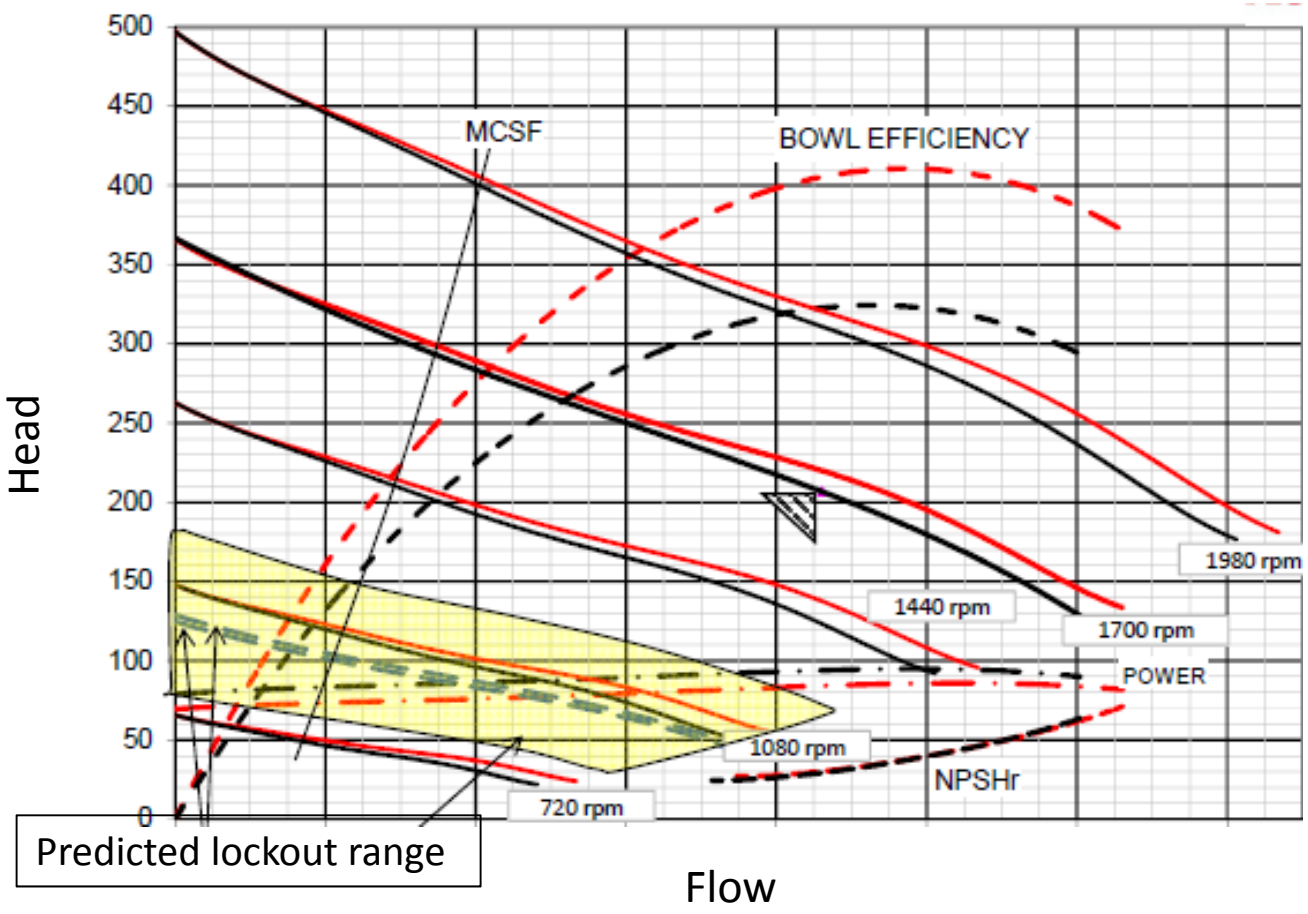
- RCF Analysis and Rotor Dynamic Analyses are not the same;



Importance of Performing RCF Analysis

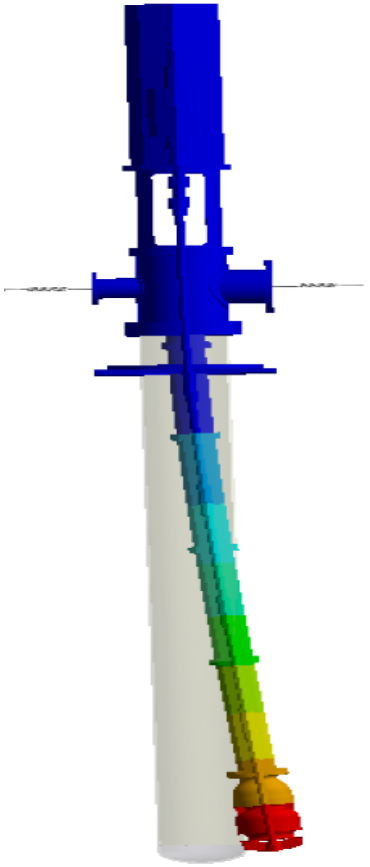
- To know the resonance points and set appropriate lock out speeds;
- Avoid excessive vibration;
- At design stage make modifications to narrow the lock out speeds;
- Plan for contingency within operations if lock out speeds are inevitable.
- Operational constraints leading to throughput loss and increased costs could be mitigated.

Importance of Performing RCF Analysis(cont..)



Basic Elements of Performing RCF

RCF analysis – Above ground components



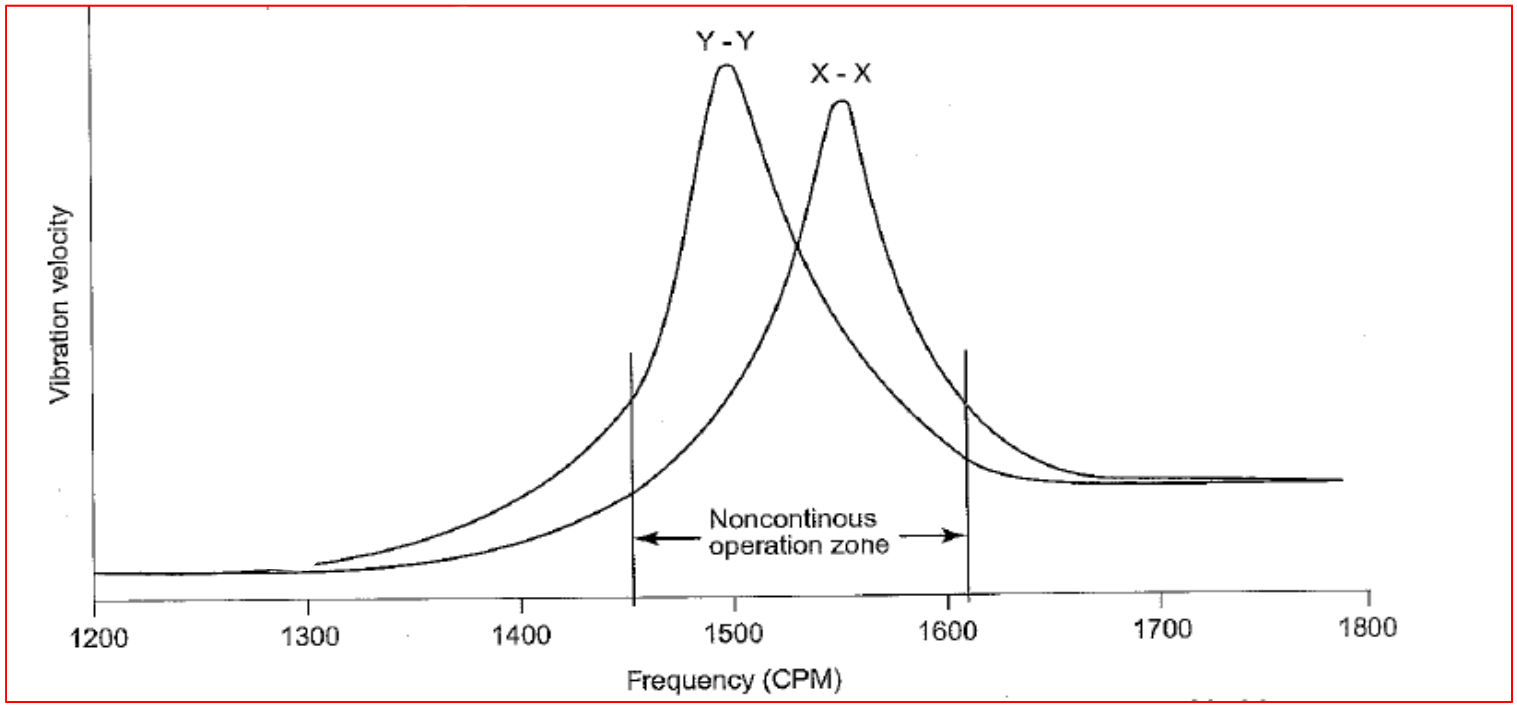
RCF analysis – Full train including below ground components.

Basic Elements of Performing RCF(cont..)

- Following information is required for RCF analysis
  - ✓ Motor information provided by motor OEM per NEMA MG1;
  - ✓ Motor RCF and corresponding deflection;
  - ✓ Foundation information if available (usually assumed rigid);
  - ✓ Operating speed and for VFD pumps full operating envelope;
  - ✓ Pump design parameters;
  - ✓ Piping attached if information is available;
  - ✓ Consider modeling with pumped fluid for accurate MNF.

Basic Elements of Performing RCF(cont..)

- Different lateral stiffness of discharge head results in atleast two different RCF;



Ref – Hydraulic Institute

Basic Elements of Performing RCF(cont..)

- Output of RCF analysis

Mode	Frequency (Hz)	SM at 1800 RPM (%)	SM at 1200 RPM (%)	Lock out speeds with 20% SM (RPM)
Mode1	17	43.4	15	816
Mode 2	18	40	10	1296
Mode 3	60	100	200	-
Mode 4	65	116.7	225	-

- There could be additional lockout speeds;

Basic Elements of Performing RCF(cont..)

- If RCF is an issue; Options during design stage to mitigate it?

✓ Modify pump design, Motor Support structure;

✓ Discharge head modification (add extra stiffness, increase wall thickness) – **Most Common**;

✓ Select driver with a different RCF;different mounting arrangement;

✓ Modify structural height, flexibility of joints (less feasible);

✓ Foundation modification(less feasible).

Field Verification and Fixes

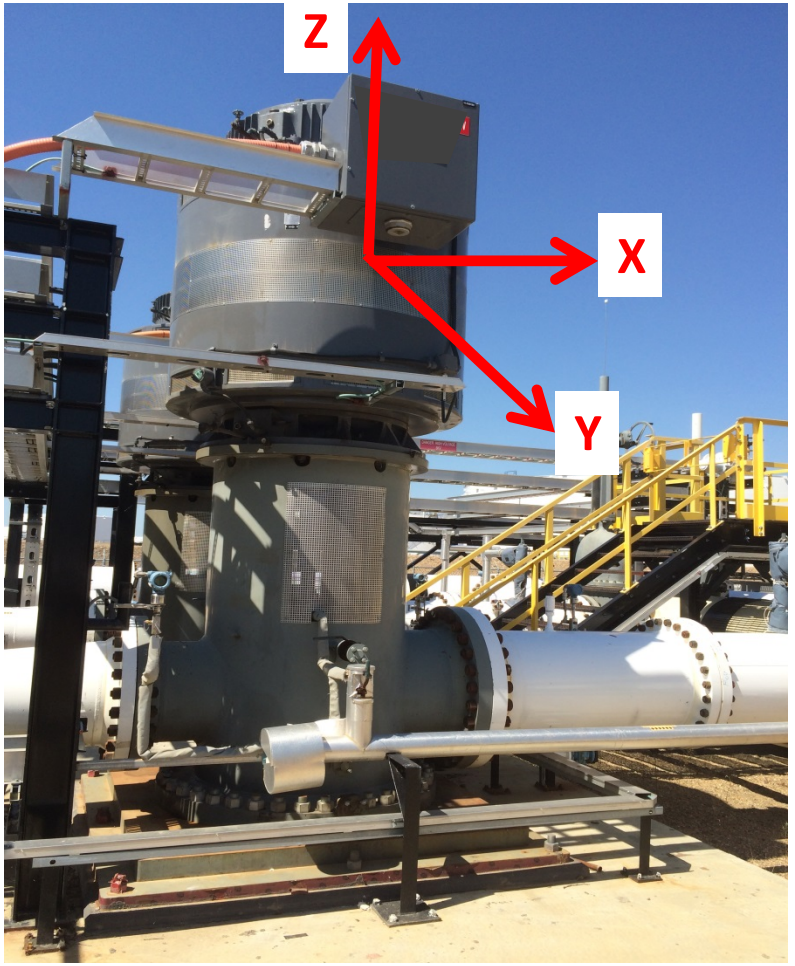
- It is recommended to measure the RCF in field

✓ If VFD driven, MNF data with vibration on speed sweep;

✓ If fixed speed, use variable speed shaker; or bump test on field;

Field Verification and Fixes (Cont..)

- Collect vibration Data along X and Y with a speed sweep on motor and near coupling;
- Collect data during ramp up and ramp down condition;
- Evaluate phase reversal for MNF determination;
- Evaluate vibration response – RISK ANALYSIS for acceptance;
- Make decision on lock out range and operating envelope



Field Verification and Fixes (Cont..)

- Lockout speeds could be narrowed down based on system response

✓ SM could be narrowed b/w 5 -10%. Needs risk assessment and depends on risk tolerance of end user.

✓ Needs periodic testing as a PM program to evaluate the SM and if MNF has changed;

✓ Advantage of increasing operating envelope;

Field Verification and Fixes (Cont..)

- Field fixes are last resort, expensive, time consuming and not always elegant;
- Modify the foundation stiffness, by modifying the baseplate design or altering anchor bolt torque;
- Add gussets or ribs to the discharge head;
- Modify Motor – Pump attachment stiffness;
- Add damping to the system; Eg: tie units together, add hydraulic dampers;

Field Verification and Fixes (Cont..)

- Use tuned spring mass system – dynamic absorber to alleviate vibrations ;
- Always check if other problems are created when trying to field fix MNF issue
  - For eg: altering base stiffness could lead to other turbulence related issues manifesting.

Summary

- RCF is a structural MNF – Vertical pump motor assemblies most susceptible;
- RCF and Rotor dynamic analysis are not the same;
- Operating at RCF will result in excessive vibration;
- Modeling System RCF accurately is paramount;
- A minimum 20% SM is recommended; field verification to narrow SM;
- Field fixes are available, not always feasible. Strive to design the system right;

Questions ?

Thank You !