Acoustical and Bearing Housing Resonant Vibration on a Centrifugal Pump

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24th International Pump Users Symposium
- Pine Bend, Minnesota, 2000 hp, 3600 rpm
- 6x8x13, 5/4 stage centrifugal pump, 4th stage is removed and 7 vanes on all impellers

- Power optimization study shows a VFD will pay for itself in a short period of time the way this pump is operated
6x8x13 5/4 stage Pump, 2000 hp
Pine Bend, MN
Acoustical Resonance
Centrifugal Pumps

- Acoustical resonance can develop within the hydraulic passageways of the pump, especially in the long cross-overs. It occurs when the affective hydraulic passageway length, is the same length as the sound wave length produced by the vane pass pressure pulsations, thus generating a standing wave.

  - The amplitude of the standing wave is greatly amplified in this condition and creates large pressure pulsations and extremely high vibration levels.

- Acoustic wave length = \((60 \times 12)xc / (N \times n)\)
  - C= speed of sound for product pumped, ft/sec
  - N= pump speed, rpm
  - n= number of vanes on impeller
Old Method of Cross Over Length Measurement for Acoustic Resonance Calculations (Volute Lip to Impeller Entrance)
New Method of Cross Over Length Measurement for Accoustical Resonance Calculations (longer than old method since it includes length of impeller vane)
Sectional Drawing 6x8x13, 5/4 stage pump
Acoustical Resonance

- Crossover length, old method = 56 inches as determined by pump manufacturer’s engineer by reviewing pump hydraulic drawings passage lengths (volute lip to impeller entrance)
- Cross over length, new method = 79.5 inches (closed loop method includes distance around impeller periphery and across next impeller eye)
- Speed of sound in product used for this analysis:
  - Diesel fuel – 4264 ft/sec
  - Gasoline – 3837 ft/sec
  - Butane – 3184 ft/sec
- Different sources provide different speeds so results can be different
Acoustical Analysis of existing 7 vane impellers, shows problem at higher speeds

![Graph showing wavelength vs. pump speed for diesel, gasoline, and cross over length.](image)

- **Diedel**
- **Gasoline**
- **Cross over length**

**Pump speed, rpm**

**Wavelength, inches**
Acoustical Analysis of proposed 5 vane impeller, shows separation margin

**Acoustical Resonance**

- **Wavelength, inches**
  - 0
  - 25
  - 50
  - 75
  - 100
  - 125
  - 150

- **Pump speed, rpm**
  - 2,160
  - 2,340
  - 2,520
  - 2,700
  - 2,880
  - 3,060
  - 3,240
  - 3,420
  - 3,600
  - 3,780
  - 3,960

Lines for:
- **diesel**
- **gasoline**
- **cross over length**
HIGH VIBRATION with 5 vane impeller
2.8 in/sec (over all, unfiltered, peak) on gasoline but not on diesel

- The modified pump and VFD were installed and everyone said it ran great for about a year. Then the seal flush tubing failed and a more thorough analysis was conducted and determined the pump had high vibration levels when pumping gasoline at higher speeds.

- The pump ran smooth on diesel fuel but rough on gasoline indicating an acoustical resonance problem. The bump test indicated that the inboard bearing housing in the vertical direction had a natural frequency which was also excited by the 5 vane impeller.
VFD installation with pump modification

The original pump had 7 vane on all impellers and the impeller feeding the cross over was changed to 5 vane to avoid an acoustical resonance condition

- The pump ran smooth while pumping diesel fuel but ran extremely rough when pumping gasoline at higher speeds.
- **Data while pumping diesel fuel (.86 SG), inboard vertical**
  - VFD%    Pump Speed    Vibration, in/sec
    - Rpm    Over all, unfiltered, peak
    - 80      2890      .02
    - 90      3240      .13
    - 95      3420      .16
    - 100     3590      .16
    - 107     3820      .19 (peak at 5X)
- **Data while pumping gasoline (.73 SG), inboard vertical**
  - 85      3085      .02
  - 100     3590      1.0 (peak at 5X)
  - 105     3800      2.8 (peak at 5X)
  - 110     3980      .48 (peak at 5X)
Acoustical Analysis of proposed 4 vane impeller, shows greater separation margin

Accoustical Resonance

Wavelength, inches

Pump speed, rpm

- diesel
- gasoline
- cross over length
- butane
Bearing Housing Bump Test Analysis
natural frequency = 305 Hz = 18,300 cpm
5 vane shows a problem at 3600 rpm
VFD installation with 2\textsuperscript{nd} pump modification

The impeller feeding the cross over (2\textsuperscript{nd} stage) was changed from a 5 vane to 4. All other impellers are still 7 vane (same as original pump from factory).

- All problems are now resolved and the pump runs with low vibration levels at all speeds while pumping all products.

- Data while pumping diesel fuel (.86 SG), inboard vertical
  - VFD\%   Pump Speed   Vibration, in/sec
  - Rpm    Over all, unfiltered, peak
  - 100  3590     .10

- Data while pumping gasoline (.73 SG), inboard vertical
  - 100  3590     .15
Summary

- Installing VFDs on pumps that were formerly constant speed pumps can cause new vibration problems to be encountered.

- Acoustical resonance conditions can occur in the long cross over. New methods of measuring acoustical cross over lengths is now available that provide better results.

- In some situations, vane pass frequencies can excite bearing housing natural frequencies and create a resonate conditions.

- Variable speed centrifugal pumps have a much higher chance of having vibration problems and a lot of analysis and field testing needs to be performed to avoid problems.