Solving a Sever Vibration Problem in the Downstream Piping of a Gear Pump

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Abstract

A solution was developed for an extreme discharge piping vibration problem on an 80 hp gear pump piping system. Maximum field-measured vibration levels were over 4 ips 0-pk (200 mm/sec pk-pk). Most gear pumps are not equipped with the typical pulsation dampeners that are found on plunger pumps because the relatively high frequency pulsations that gear pumps generate typically do not result in piping vibration problems. Modeling predictions indicated that the vibrations were primarily driven by pulsations. After implementation of a new gas-liquid dampener, the system vibrations were significantly reduced.
Agenda

• Introduce System & Problem

• Steps taken to Solve Problem

• Summary & Lessons Learned
**Pump Description Details**

<table>
<thead>
<tr>
<th>Pumps Details</th>
<th>Pump Operating Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 pump (gear)</td>
<td>Suction Pressure: 11 psia (0.8 bara)</td>
</tr>
<tr>
<td>8 teeth</td>
<td>Discharge Pressure: 160 psia (11.2 bara)</td>
</tr>
<tr>
<td>Service: Turbine Oil</td>
<td>Temperature: 120-140°F (49-60°C)</td>
</tr>
<tr>
<td>750-945 rpm</td>
<td></td>
</tr>
<tr>
<td>62 gpm at 756 rpm</td>
<td></td>
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<tr>
<td>78 hp at 756 rpm</td>
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</tbody>
</table>
Problems

• High downstream piping vibration:
  – Excessively high amplitudes: >100 mm/sec RMS (>4 inches/sec RMS)
  – measured near 102.5 Hz
  – Client reported that vibration amplitudes increase as the speed increases beyond ~750 rpm

• Al-Bayroni needs to run the equipment at higher speeds; however, vibration levels are stopping them from proceeding
Steps Taken to Solve Problem

- Field investigation for problem characterization and diagnostics – vibration data measured by the client
- Pulsation and mechanical (modal) analysis conducted to develop potential solutions
- Gas liquid dampener and additional restraints recommended

Install the dampener near the pump
System Concerns:

- Complex piping system
- Pulsation control insufficient
- Few ‘rigid’ piping restraints
Summary of Initial Field Measured Vibrations

Peak values greater than 200 mm/s (8 in/s)

Key:
- **Peaks**
- **Average**

Average values near 75 mm/s (3 in/s)

# of points > screening criteria = 6 to 24
Field Vibration Data at Single Test Point

Reference point 6 (near support 7)

116 mm/s (4.6 in/s) RMS
OR
164 mm/s (6.5 in/s) 0-peak
@ 6150 cpm

6150 cpm / (60s/min) = 102.5 Hz
6150 cpm / 8 teeth = 769 cpm

118 mm/s (4.6 in/s) RMS OVERALL
Field Vibration on SwRI Vibration Screening Piping Vibration Severity Chart

Field measured vibrations in Danger region
Pulsation Model Results

Existing System Pulsation: 70 psi pk-pk at 8x (110 Hz) at pump outlet

3rd quarter wave mode

Average Line Pressure of 160 psia (11.2 bara)

Pulsation minimum is at lube oil reservoir

Quarter Point

~Half Point
Mechanical Analysis Recommended

- Dynamic support for dampener
- Pulsation & Mechanical mode shapes not coincident
- Dynamic support for rest of piping if vib. excessive after dampener installed
General Comments: Gas-Liquid Dampeners

- Pre charge gas filled bladder to fixed percentage of line pressure
- Pre-charged gas creates relatively large effective liquid volume to absorb pulsations
- Gas volume acts as spring compressing and expanding with line pressure changes
Gas Liquid Dampener

Note: Gas-liquid pulsation dampeners not previously attempted on this system, and not common on these types of systems

Recommended

• 12 Liters of N₂ gas
• 3” (full) diameter connection
• as close as possible to pump outlet

Dampener sized to attenuate pulsations at teeth-frequency (8x running speed; primary excitation measured in field data)
Pulsation Model Results – Before & After

**Existing System**
- 70 psi pk-pk at 8x

**Modified System**
- 11 psi pk-pk at 8x
Significant reductions in vibration amplitudes were observed after the gas-liquid dampener was installed.
Greater reductions in vib. amplitudes were observed after the gas-liquid dampener was installed closer.

**Graph:**
- **Vibration Level (mm/s)**: Average of 4.5 mm/s at 755 rpm
- **Peak Amplitude – below ‘preception’**

**Legend:**
- **Old Location**
- **New Location**

**Image:**
- shows a lube oil pump with labels indicating old and new locations.
Summary and Lessons Learned

• Pump System Problem
  – Excessive Vibration – 164 mm/s (6.5 in/s) 0-peak
  – Vibration amplitudes increase as the speed increases beyond ~750 rpm
  – Client needed to run at higher speeds

• Steps taken to Solve Problem
  – Field investigation – vibration measurements
  – Pulsation analysis and mechanical modal of piping
  – Field modifications and confirmed improvement

• Lesson Learned: When properly applied, gas-liquid dampener can significantly reduce pulsation and vibration amplitudes, even for gear pump piping system