Case Study: Fast Response Vibration Interlock of High Pressure Reciprocating Compressor

Donald Easterwood  
*Control Engineer*  
*Invista Sabine River Works*

Joseph Reimers  
*Mechanical Engineer*  
*Invista Sabine River Works*
Background

• Plunger Pump Failure
  – Pull rod failure
  – Loss of containment
  – Fire
  – Significant production loss

• Subsequent Study of Synthesis Pumps & Compressors
  – Performed risk assessments for identified hazard events
  – Recommended: For reciprocating machines, a safety interlock system based on vibration be installed to detect mechanical failure and automatically shutdown the machines.

• Installed High Speed Vibration Interlock System on 6 Reciprocating Machines
Vibration Interlock System

- Designed for Reciprocating Machines
- Crank-Angle-Based Vibration Analysis
- High Speed Threshold Interlock Monitoring
- Offered More Capability Than Other Options
Vibration Interlock System

- Suction valve opens
- Intake phase
- Suction valve closes
- Compression phase
- Discharge valve opens
- Discharge phase
Vibration Interlock System

Segment Intlk Settings
H2 Compressor Rod Failures

• Sudden Catastrophic 2nd Stage Rod Failure on H2 compressor
  • Bent Crankshaft to Crosshead Connecting Rod

• 3 Weeks Later
  – Sudden Catastrophic 2nd Stage Rod Failure on other H2 compressor
  – Identical (carbon copy) in nature to first failure

• Vibration Interlock System
  – Shutdown Both Compressors Within 1 Second
H2 Compressor Rod Failures

- Sudden Catastrophic 2nd Stage Rod Failure on H2 compressor
  - Bent Crankshaft to Crosshead Connecting Rod
- 3 Weeks Later
  - Sudden Catastrophic 2nd Stage Rod Failure on other H2 compressor
  - Identical (carbon copy) in nature to first failure
- Vibration Interlock System
  - Shutdown Both Compressors Within 1 Second

Diagram:
- Acceleration-Sensors on crosshead-guides
- 2nd stage (damaged)
- 1st stage
- 3rd stage north
- 3rd stage south
H2 Compressor Rod Failures

<table>
<thead>
<tr>
<th>Machine</th>
<th>Measuring Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOBILE</td>
<td>2nd St. CH</td>
</tr>
</tbody>
</table>

1 Revolution Before

Rod Break Revolution

158.0°
H2 Compressor Rod Failures

Short-term-trend (Minutely average-value) of Peak-Values on CH Cyl. 2 for one day prior to failure
Rod Failure Analysis

Rod - Side View

Rod - End View

Piston - Side View
Rod Failure Analysis

Rod Fracture Point
Rod Failure Analysis

Cracks originated at the 3rd or 4th thread from the bottom of the stud holes toward the center of the rod.

During assembly:
- Studs were bottomed out in rod
- Put maximum stress on the inside of the 3rd thread due to the thread depth taper at the bottom.

Short distance between diameter transition and the rod threads causes additional stress on the internal side of the rod.
Pictures
Failure Analysis Summary

• Items considered
  • Changes in process conditions
  • Rod / Piston assembly
  • Metallurgy & Rod QA
  • Length of service

• Key Factors
  – Rod & piston installation assembly
    • Torquing threaded stud into bottom of stud holes caused excessive stress in threads
  – Rod Taper / stud hole proximity
    • Close proximity accentuated the stress level in the threads
Upgrades Implemented

• QA Check Sheet for New Rods
  – Correct metallurgy
  – Meets specifications

• Rod & Piston Assembly Procedure
  – Detailed instructions
  – Manufacturer input to proper assembly

• 3 Year Rod Change Out
  – Removed rods are tested and re-furbished if no wear evidence is detected
Learnings

• Validation of the Vibration Interlock System
  – Fast reaction time (Less that 1 second)
  – Provided data for determination of second break

• Rod & Piston Assembly Procedure
  – Critical to proper assembly of components
Questions?