CASE STUDY ON RESOLVING OIL WHIRL ISSUES ON GAS COMPRESSOR

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Abstract

• This case is a site vibration issue on a Gas compressor module. When machine was running at partial load condition, vibration at compressor DE and NDE bearings suddenly increased and tripped the machine.
• This case study outlines how the high vibration issue was successfully diagnosed using shaft relative vibration data.
• The high vibration of 346 um pp (14 mil pp), higher than nominal bearing clearances, was due to subsynchronous 0.37X component forward precession. Significant shaft centerline thermal influence was detected.
• Oil Whirl condition, was diagnosed at compressor bearings.
• Bearing modification was suggested to the OEM. Length/Diameter bearings ratio was decreased by pads machining from both sides. Follow-up tests after bearing modification confirmed no vibration issue afterwards at any load condition.
Machine Information
## Machine Information

### Compressor Mechanical Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Speed</td>
<td>1497 rpm</td>
</tr>
<tr>
<td>Compressor Speed</td>
<td>5877 rpm</td>
</tr>
<tr>
<td><strong>Compressor 1(^{st}) Lateral Critical Speed</strong></td>
<td>2786 rpm</td>
</tr>
<tr>
<td>Compressor 2(^{nd}) Lateral Critical Speed</td>
<td>9042 rpm</td>
</tr>
<tr>
<td>Rotating Direction View from Drive End</td>
<td>Clockwise</td>
</tr>
<tr>
<td>Shaft Seal Type</td>
<td>Labyrinth</td>
</tr>
<tr>
<td>DE Bearing Clearance</td>
<td>0.250-0.293 mm</td>
</tr>
<tr>
<td>NDE Bearing Clearance</td>
<td>0.190-0.233 mm</td>
</tr>
<tr>
<td>Compressor Bearing Type</td>
<td>Plane Sleeve</td>
</tr>
<tr>
<td>Balance Piston Seal Clearance</td>
<td>0.85-1.07 mm</td>
</tr>
</tbody>
</table>

### Design Operating Condition:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate</td>
<td>168685 m3/h (224144 kg/h)</td>
</tr>
<tr>
<td>Suction Pressure</td>
<td>0.99 Bar abs.</td>
</tr>
<tr>
<td>Suction Temperature</td>
<td>35 deg C</td>
</tr>
<tr>
<td>Discharge Pressure</td>
<td>3.063 Bar abs</td>
</tr>
<tr>
<td>Discharge Temperature</td>
<td>169 deg C</td>
</tr>
</tbody>
</table>
Design Operating Curve
Problem Description
Background

When machine was running at partial load condition, vibration at compressor DE and NDE suddenly increased and tripped machine.

Example condition before the first tripped on 29th Dec 2015
- Discharge pressure : 0.86 Barg
- Air Flow Rate : about 182000 kg/hour
- Discharge Temperature : about 125 deg C
- Suction Temperature : about 33 deg C

Example condition before the first tripped on 15th January 2016 (after realignment)
- Discharge pressure : 1.14 Barg
- Air Flow Rate : about 287000 kg/hour
- Discharge Temperature : about 152 deg C
- Suction Temperature : about 33 deg C
Process condition during trip events

Machine tripped at different operating conditions.
## Shaft Speed Trend

The chart illustrates the trend of shaft speed over time, with notable data points recorded.

### Data Points:

- **KT-5350252**
  - From 24NOV2015 08:00:00 to 25JAN2016 11:52:00
  - RPM
  - Historical
  - 26NOV2015 16:03:36
  - 59 rpm
  - Alarm + Transient + Trend

- **KT-5350350**
  - Historical
  - 26NOV2015 16:03:27
  - 233 rpm
  - Alarm + Transient + Trend

### Graphical Representation:

The graph shows a timeline from 24NOV2015 to 19JAN2016, with amplitude levels indicating varying shaft speeds. The data is segmented into 48-hour divisions, with specific timeframes marked for analysis.

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**Imagination at Work**

GE

May 23, 2017
Compressor Overall Vibration (Abnormal)

Diagnosis

Fixed
Gearbox Overall Vibration (Normal)
Data Analysis
Overview

Air Blower data from 27 Nov 2015
- Bower Vibration
- rpm
- Bower Vib
- Bower orbit
- Bower Brg Temp
- Bower Shaft Centerline
- Bower Shaft Axial Position

Air Blower data 01 DEC 2015 no Trip
Air Blower data 02 DEC 2015 No Trip
Air Blower data 05 DEC 20151100-1145 (TRIP)
Air Blower data 05 DEC 2015 1424-1645 (Not Trip)
Air Blower data 16 DEC 2015 0910 (Trip)
Air Blower data 16 DEC 2015 1730-1930 (Trip NDE Y)
Air Blower data 21 DEC 2015
Air Blower data 28 DEC 2015 2108 (Trip)
Air Blower data 29 DEC 2015 1707 (first trip)
Air Blower data 29 DEC 2015 1707 (second trip)
Air Blower data 29 DEC 2015 1707 (third trip)

Air Blower data 29 DEC 2015 1707 (three cycle)
Air Blower orbit
Air Blower Brg Temp
Air Blower Shaft Centerline w rpm stamp
Air Blower Shaft Axial Position
Air Blower Shaft Centerline w Time stamp
Air Blower Shaft Centerline

Air Blower data current value
Air Blower data 20150115 SU Alignment transient
Franze Plot Session 1 Current Value
Franze Plot Session 1 Historical Value
Shaft Speed vs. Vibration Amplitude Trends: Vibration suddenly increased

Shaft Speed

Overall Vibration Amplitude

Vibration suddenly increase and trip the machine
Vibration Amplitude: Higher than bearing Clearance (>293 um)

5th December 2015

346 um pp

Bearing Clearance = 293 um pp
Vibration Spectrum: 0.371X Dominant
Dynamic Shaft Movement (Orbit): Big, Elliptic, Forward Precession
DE and NDE orbits: In-Phase
Average Shaft Centerline: Significantly Different btw Cold and Hot Condition

- Startup from 233 rpm
- Coast down to 233 rpm

Cold Condition

Hot Condition
Lube oil temperature increased
Air Temperature increased (load up)
Run-up
Tripped
Coast down
X probe
Y probe
Diagnostics Summary
# Vibration Information Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Amplitude</strong></td>
<td>More than Bearing Clearance (293 um)</td>
</tr>
<tr>
<td><strong>Dominant Frequency</strong></td>
<td>0.37X (2175 cpm) (&lt; 1\textsuperscript{st} Res Freq.)</td>
</tr>
<tr>
<td><strong>nX Vector</strong></td>
<td>0.37X, DE and NDE are in-Phase.</td>
</tr>
<tr>
<td><strong>Shaft Position</strong></td>
<td>Near Bearing Center</td>
</tr>
<tr>
<td><strong>Orbit Shape</strong></td>
<td>Slightly Elliptical Shape, Forward Precession</td>
</tr>
</tbody>
</table>

**Fluid Induce Instability – Whirl**  
(most likely at DE bearing)
Fluid Whirl/Whip
Immediate Recommendations

1. Inspect Bearing and Seal Components

2. Check piping support, if any restriction.

3. Confirm Alignment / Correction
Piping Support inspection
Alignment Confirmation
Bearing Inspection

NDE side bearing clearance is 0.18~0.19 mm

This is upper casing

0.29~0.30 is DE side bearing clearance
What else to fix the problem?

**Excessive Bearing Clearance**

DE: 0.29-0.30 mm  
NDE: 0.18-0.19 mm  

**NO**

**Coupling Misalignment**

-0.42  
(-0.40)  
(-0.30)

-0.33  
(-0.33, fix)

+0.33

+0.40

**NO**

After adjust alignment, problem still existed.

**Bearing design issue**

Needs to consult with the OEM
Corrective Action
Corrective Action

A. Adjust External Alignment (btw Coupling): This would help if problem is not severe. >> Already tried, but not successful.

B. Change Lube Oil Temperature: not permanent solution. >> system could not further decrease oil temperature.

C. Decrease Lube Oil Flow Rate: Risk to damage other bearings.

D. Bearing Modification: must be designed and approved by machine manufacturer.
Bearing Design to break Circumferential Oil Flow Pattern

Two Axial-Groove

Three-Lobe

Elliptical

Offset Cylindrical

Tilting Pad

Pressure Dam
Solution

Bearing modification (suggested by OEM)
After bearing modification

Speed Trend

Startup

Normal shutdown then Re-startup
After bearing modification (Cont.)

Vibration Amplitude, 25 um pp (1 mil pp)

25 um pp maximum at NDE bearing
After bearing modification (Cont.)

Frequency, 1X dominant (normal)

5887 CPM (= 1X)
After bearing modification (Cont.)

Orbit plots shows normal dynamic shaft movement
After bearing modification (Cont.)
Discussions

• Oil whirl frequency tracks with speed, usually at < 0.5X (<50% running speed frequency). If the frequency is exactly ½ X, the instability is not oil whirl, instead it is parametric excitation (rub contact or bearing looseness).

• Oil whip frequency locks into one of the natural frequencies of rotor-bearing system, usually the lowest. As speed goes up, the frequency remains unchanged.

• Subsynchronous vibration could also be caused by aerodynamic instability such as stall or surge in compressors.

• Oil whirl/whip is affected by speed, bearing types and design, lube oil temperature and supply pressure, while aerodynamic instability in compressors is affected by flow condition.
The End

Thank You