Integrally Geared
Centrifugal Air Compressor
Vibration Analysis Case Studies

15-Feb-2008

By:
Timothy S. Irwin, P.E.
Senior Engineer
tsi@mbesi.com

Rotating Machinery Diagnostics & Instrumentation Solutions for... “Maintenance That Matters”
www.mbesi.com
Integrally Geared Air Compressors
Integrally Geared Air Compressors

How do we monitor these types of machines?

- What kind of components are we trying to monitor in these machines?
  - High speed gearing
  - High speed shafts / impellers
  - Low speed shafts
  - Geared couplings
  - Disc or shim-pack couplings
  - Sleeve bearings
  - Multi-segment tilt pad bearings

This does not include the driver which could be a motor or turbine of which either one can add more complexities to the setup of a monitoring route.
Integrally Geared Air Compressors

What parameters do we have available for monitoring the overall condition?

- Bearing temperatures
- Stage and drive gear vibration
- Stage inlet and outlet temperatures
- Stage inlet and outlet pressures
- Intercooler inlet and outlet temperatures
- Intercooler inlet and outlet pressures
- Motor amperage or kW

There are a lot of parameters that can be used including the above items and:

- Performance testing
- Oil Analysis
- And visual inspections
Integrally Geared Air Compressors

What do we use to monitor the vibration of the machine?

- Is there a permanent probe of some kind on each stage?
- Is there a permanent monitoring / vibration protection system installed?
- Or are our only options temporary accelerometers?

Many permanent monitoring systems will have proximity probes on each stage, are they?

- A single probe on the stage?
- Dual probes at 90 degrees?
- Any there permanent accelerometers?
- Can you ‘plug-in’ to obtain the raw signal in your portable data collector?
Integrally Geared Air Compressors

Vibration Analysis:

- Proximity probe use
- Magnetically mounted accelerometers
- High Frequency accelerometers

To use the above probes we need to figure out the expected fault frequencies so that we can set up the appropriate frequency spans and resolutions.

The following segments of the case studies will be on several Joy (Cameron Compression) MSG 4-stage machines.
Case Study #1 – Cameron Compression MSG

What are typical Fault Frequencies:
- Shaft Running Speeds
- Journal Bearing Issues
- Gear Mesh (and other gear fault frequencies)
- Vane Pass (diffuser vs. impeller)
- Coupling/Alignment

Motor
- Shaft Running Speeds
- Journal Bearing Issues
- Electrical Frequencies
Case Study #1 – Cameron Compression MSG

Example Fault Frequencies:

- **Shaft Speeds:**
  - Motor, Couplings, & Gear – 1781 rpm
  - Pinion Speeds – 14,385 & 21,372 rpm

- **Gears (420 teeth, 52 teeth, 35 teeth):**
  - Gear Mesh – 748,020 (12,467 Hz)
  - Assembly phase – 187,000 & 21,372 cpm
  - Hunting Tooth – 1198, 203 cpm

- **Vane Pass** – 362,100 cpm (for bladed diffuser)
# Case Study #1 – Cameron Compression MSG

Displacement – Velocity – Acceleration
What is an acceptable measurement frequency range:

<table>
<thead>
<tr>
<th></th>
<th>3600 rpm</th>
<th>20,000 rpm</th>
<th>750,000 cpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement (mils)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Velocity (in/s)</td>
<td>0.19</td>
<td>1.05</td>
<td>39.3</td>
</tr>
<tr>
<td>Acceleration (g)</td>
<td>0.18</td>
<td>5.68</td>
<td>7988</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>3600 rpm</th>
<th>20,000 rpm</th>
<th>750,000 cpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement (mils)</td>
<td>27</td>
<td>0.88</td>
<td>0.0006</td>
</tr>
<tr>
<td>Velocity (in/s)</td>
<td>5.1</td>
<td>0.921</td>
<td>0.025</td>
</tr>
<tr>
<td>Acceleration (g)</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
Case Study #1 – Cameron Compression MSG

Note the step changes in the trend plot
Case Study #1 – Cameron Compression MSG

Note the variations in amplitude over time
Case Study #1 – Cameron Compression MSG

Here is a recent comparison to the other stages on the same machine

<table>
<thead>
<tr>
<th>Name</th>
<th>Data Source</th>
<th>Map Description</th>
<th>Value</th>
<th>Level</th>
<th>Status</th>
<th>Aut Plot Min</th>
<th>Plot Max</th>
<th>Units</th>
<th>Shift</th>
<th>TZ</th>
<th>Type</th>
<th>Period</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>J6VMM1.PV</td>
<td>MYRS60000</td>
<td>PMCA/diag/JOY 6 VIBRATION MON. #1</td>
<td>0.35</td>
<td>Good</td>
<td>Good</td>
<td>0</td>
<td>3</td>
<td>MILS</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>Best Fit</td>
<td>1 Hour</td>
</tr>
<tr>
<td>J6VMM2.PV</td>
<td>MYRS60000</td>
<td>PMCA/diag/J6 1STG VIBRATION Y PROB</td>
<td>0.34</td>
<td>Good</td>
<td>Good</td>
<td>0</td>
<td>3</td>
<td>MILS</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>Best Fit</td>
<td>1 Hour</td>
</tr>
<tr>
<td>J6VMM3.PV</td>
<td>MYRS60000</td>
<td>PMCA/diag/J6 2STG VIBRATION X PROB</td>
<td>0.95</td>
<td>Good</td>
<td>Good</td>
<td>0</td>
<td>3</td>
<td>MILS</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>Best Fit</td>
<td>1 Hour</td>
</tr>
<tr>
<td>J6VMM4.PV</td>
<td>MYRS60000</td>
<td>PMCA/diag/J6 2STG VIBRATION Y PROB</td>
<td>1.18</td>
<td>Good</td>
<td>Good</td>
<td>0</td>
<td>3</td>
<td>MILS</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>Best Fit</td>
<td>1 Hour</td>
</tr>
<tr>
<td>J6VMM5.PV</td>
<td>MYRS60000</td>
<td>PMCA/diag/J6 3STG VIBRATION X PROB</td>
<td>0.45</td>
<td>Good</td>
<td>Good</td>
<td>0</td>
<td>3</td>
<td>MILS</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>Best Fit</td>
<td>1 Hour</td>
</tr>
<tr>
<td>J6VMM6.PV</td>
<td>MYRS60000</td>
<td>PMCA/diag/J6 3STG VIBRATION Y PROB</td>
<td>0.45</td>
<td>Good</td>
<td>Good</td>
<td>0</td>
<td>3</td>
<td>MILS</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>Best Fit</td>
<td>1 Hour</td>
</tr>
<tr>
<td>J6VMM7.PV</td>
<td>MYRS60000</td>
<td>PMCA/diag/J6 4STG VIBRATION X PROB</td>
<td>0.88</td>
<td>Good</td>
<td>Good</td>
<td>0</td>
<td>3</td>
<td>MILS</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>Best Fit</td>
<td>1 Hour</td>
</tr>
<tr>
<td>J6VMM8.PV</td>
<td>MYRS60000</td>
<td>PMCA/diag/J6 4STG VIBRATION Y PROB</td>
<td>0.88</td>
<td>Good</td>
<td>Good</td>
<td>0</td>
<td>3</td>
<td>MILS</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>Best Fit</td>
<td>1 Hour</td>
</tr>
</tbody>
</table>
Case Study #1 – Cameron Compression MSG

Just after the startup
Case Study #1 – Cameron Compression MSG

This is only 6 days later
Case Study #1 – Cameron Compression MSG

NER - #6 JOY
#6 AIRCOMP-P2B, PANEL POINT TWO 2ND STAGE BOTTOM

1X Amplitudes at different samples: 0.793; 0.851; 0.709; 0.713; 0.862
Case Study #1 – Cameron Compression MSG
Case Study #2 – Cameron Compression MSG

Note the difference in the noise floor of a 10 mV/g vs. 100 mV/g
Case Study #2 – Cameron Compression MSG
Case Study #2 – Cameron Compression MSG
Case Study #2 – Cameron Compression MSG

Now we are at 20 kHz Frequency Span
Case Study #2 – Cameron Compression MSG

Now we are at 50 kHz
Case Study #2 – Cameron Compression MSG

Are the overall amplitudes really higher than expected?
Case Study #2 – Cameron Compression MSG

Differing time frames from the high frequency accel
Case Study #3 – Cameron Compression MSG

Raw Timebase or Waveform

High Frequency Enveloping
Case Study #4 – Ingersoll-Rand Centac II

Note the amplitudes
Case Study #4 – Ingersoll-Rand Centac II
Case Study #4 – Ingersoll-Rand Centac II

[Graphs showing vibration analysis for Ingersoll-Rand Centac II compressor]
Thank You – Any Questions?