Investigation and Resolution of Governing Valve Linkage Failure for Compressor Drive Steam Turbine

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The rod end bearing failure occurred in 2017 after the Turbine had been in operation for 9 years.
Similar trouble had happened around 2006 in other plants. Countermeasure ➔ Bearing size up from M8 to M16.

<table>
<thead>
<tr>
<th>Size</th>
<th>Static Limit Load</th>
<th>Radial Static Ultimate Load</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Radial (kN)</td>
<td>Axial (kN)</td>
<td></td>
</tr>
<tr>
<td>M16</td>
<td>8.33</td>
<td>N/A</td>
<td>3.5 times larger area than M8.</td>
</tr>
<tr>
<td>M8</td>
<td>2.69</td>
<td>N/A</td>
<td>11.76</td>
</tr>
</tbody>
</table>

This turbine reconfigured the bearing size to M16 in 2008. ➔ The M16 bearing failed in 2017 after 9 years of operation.
Rod-end Bearing Design

Material specification:
M8 and M16 are same design
They are comprised of the same materials.

<table>
<thead>
<tr>
<th>Material</th>
<th>PARTS</th>
<th>Hardness (HV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martensitic stainless</td>
<td>Ball</td>
<td>≥ 653</td>
</tr>
<tr>
<td>Austenitic stainless</td>
<td>Body</td>
<td>≤ 200</td>
</tr>
<tr>
<td>PTFE</td>
<td>Liner</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Worn out thickness was roughly 2mm and striation pattern was observed which helped us identify high cycle fatigue fracture.
### Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible Causes</th>
<th>Possibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing failure</td>
<td>High shock load</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Improper strength at design stage</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Corrosive fracture under severe environment</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Vibratory stress</strong></td>
<td></td>
<td><strong>High</strong></td>
</tr>
</tbody>
</table>

- Strength and shock load were verified to be within criteria.
Fatigue fracture pattern and vibration analysis indicated that the 4th resonance mode falls in the Turbine operation range.
Scenario

- PTFE liner wore out due to resonance vibration (4th mode).
- Bending stress occurred due to resonance vibration.

Worn out

f (Hz)

Ball and body doesn’t slip

Failed due to repeated bending stress
Excitation force was estimated using motion analysis with the help of static force.

Output data
(Sliding velocity and force)

Input value
Measured Vibration on pedestal.
1. Excited force was estimated with motion analysis.
2. Damping at resonance frequency was confirmed with hammering test.

Slip velocity (5.6 mm/sec), Lh = 16,644 hr (1.9 years)

Under resonance condition, PTFE liner will wear out within 1.9 years of operation.
The peak stress points due to vibration at resonant frequency was found using FEA. They match the crack origin point of the failed bearing.
Recommendations

- **Plan 1:** Provide separation margin from resonant excitation frequency. -> (it is no longer operation range.)
- **Plan 2:** Improve system integrity using a redundant system.

Apply multiple rod end bearings
Recommendations

- Plan 3: Replace with Direct-drive actuator (Linkages are minimized).
As a result of modification (Plan 1), turbine operation speed is far away from the resonance frequency. No issues experienced after the maintenance.

Plan 2 will be carried out during next Turbine maintenance.

Plan 3 with Direct Drive Actuators.
Lessons Learned

• Bearing Life should be considered at the design stage and bearing should be replaced at every maintenance.

• Understand dynamic behavior of linkage system and enforce sufficient separation margin (Authors recommend 5% for similar situations) on damaging modes.

• Root cause analysis and Motion Analysis to know the dynamic force for multiple linkage is an useful tool in understanding the failure modes of Linkages and bearings.
Thank You...

Questions???
For Q and A

Bearing Life to be determine

Highly depends on contact stress, slip velocity & frequency