THD Analysis of a Compliant Journal Bearing Considering Liner Deformation

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Introduction
A modern trend towards higher power densities in machines calls for better mechanical components that can carry higher loads while being the same or smaller in size. We have shown how load carrying capacity of tilting pad thrust bearings can be significantly improved by using PTFE as a substitute for white metal [1,2]. In this work, we focus on plain journal bearings to study the effect of a thin PTFE coating on their steady state characteristics.

Computational model and bearing geometry
The THD model used is based on the approach described in [3]. It includes Reynolds equation with a 3D viscosity variation, 3D energy and 3D heat transfer equations. Thermal expansions of the shaft and bearing are also considered. A deformation model used for the PTFE layer is based on the plain strain hypothesis. Zero boundary conditions are imposed at the bearing edges. The mesh grid contains from 256x33x42 up to 256x33x63 points. Convergence criteria are set to be $10^{-5}$ for pressure and $10^{-7}$ for temperature. A plain journal bearing with two oil supply grooves is considered. Main input parameters and bearing dimensions are given in the table below.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing inner radius, mm</td>
<td>190.5</td>
<td>Oil thermal conductivity, W/mK</td>
<td>0.15</td>
</tr>
<tr>
<td>Bearing outer radius, mm</td>
<td>297.5</td>
<td>Bearing thermal conductivity, W/mK</td>
<td>0.0625</td>
</tr>
<tr>
<td>Bearing length, mm</td>
<td>306</td>
<td>Air thermal conductivity, W/mK</td>
<td>0.025</td>
</tr>
<tr>
<td>Radial clearance, μm</td>
<td>237</td>
<td>PTFE thermal conductivity, W/mK</td>
<td>0.27</td>
</tr>
<tr>
<td>Shaft rotation speed, rpm</td>
<td>900-2700</td>
<td>PTFE elastic modulus, GPa</td>
<td>0.11</td>
</tr>
<tr>
<td>Load, kN</td>
<td>20-200</td>
<td>Steel elastic modulus, GPa</td>
<td>210</td>
</tr>
<tr>
<td>Oil viscosity grade</td>
<td>3VG2</td>
<td>Supply groove length, mm</td>
<td>60</td>
</tr>
<tr>
<td>Viscosity at 40°C, mm²/s</td>
<td>19.8</td>
<td>Supply groove width, degree</td>
<td>120</td>
</tr>
<tr>
<td>Viscosity at 100°C, mm²/s</td>
<td>1.3</td>
<td>PTFE thickness, mm</td>
<td>0.5-3</td>
</tr>
</tbody>
</table>

THD model verification
The THD model is verified against experimental data presented in [4]. A 100 mm diameter and 80 mm long plain journal bearing with two supply grooves has been analyzed for a number of load/speed combinations. A comparison of the measured and calculated pressure distributions along the central line of the bearing for a case with 3000 rpm shaft speed and 9 kN load is given in Fig. 1. It shows a good agreement between the computed and experimental data.

Results
White metal and PTFE lined bearings are compared in terms of the maximum temperature, maximum pressure, eccentricity and power loss. Representative results for the case of 900 rpm shaft speed only are given. Data is plotted as a function of the bearing load carrying capacity.

Eccentricity and power loss
Influence of the PTFE layer thickness on the bearing load carrying capacity is shown in Fig. 2. It can be seen that the load carrying capacity increases significantly with an increase in the PTFE layer thickness. The thicker the layer the higher the increase. Relative eccentricity is related to the cold clearance. Power loss becomes higher with an increase in the PTFE layer thickness, Fig. 3. To separate contributions of the thermal expansion and mechanical deformation of the PTFE layer to the total effect, additional cases (without PTFE expansion, without PTFE deformation and with an increased clearance) are plotted in Figs. 4.5. In all of these cases, the PTFE layer thickness is 2 mm. It can be seen that thermal expansion of the PTFE layer increases both load carrying capacity and power loss.

Mechanical deformation of the compliant PTFE layer has an opposite effect on both load carrying capacity and power loss. Thermal expansion reduces the radial clearance while mechanical deformation increases it. To reduce the negative effect of the PTFE thermal expansion on bearing power loss the radial clearance can be increased. The results clearly indicate that losses decrease. Compared to the reference white metal bearing, an 18% increase in clearance improves the load carrying capacity and reduces power loss. This increase in the radial clearance will also reduce maximum oil film pressure and temperature.

Maximum pressure and temperature
Variation in maximum oil film pressure with load and PTFE layer thickness is shown in Fig. 6. A significant reduction in maximum pressure for the compliant bearing can be observed for the same loading conditions. Influence of the PTFE layer thermal expansion and mechanical deformation is shown in Fig. 7. Mechanical deformation reduces maximum pressure.

Pressure and film thickness profiles
Fig. 10 shows pressure distributions in the circumferential direction along the bearing center line. Pressure distributions in the axial direction at 94 degree angle are presented in Fig. 11. Compliance of the PTFE layer changes pressure profiles resulting in a different shape of the oil film. Variation in the oil film thickness along the center line is shown in Fig. 12. It can be clearly seen that thermal expansion of the PTFE layer reduces radial clearance. A smaller clearance for the case with only mechanical deformation of the PTFE layer is due to the thermal expansion of the shaft and the housing. Fig. 13 shows oil film profiles at 219 degree angular position. A pocket is formed due to the deformation which is favorable for bearing performance especially when the radial clearance is increased.

Conclusions
• A compliant PTFE layer reduces maximum pressure and increases the load carrying capacity, temperature and power loss of a plain bearing.
• A slight increase in radial clearance in the PTFE lined bearing results in improved operating characteristics (higher load carrying capacity and lower power loss) compared to the white metal bearing.

References

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