Journal Bearing

**Introduction**

Journal bearings are used to carry radial loads, for example, to support a rotating shaft.

A simple journal bearing consists of two rigid cylinders. The outer cylinder (bearing) wraps the inner rotating journal (shaft). Normally, the position of the journal center is eccentric with the bearing center. A lubricant fills the small annular gap or clearance between the journal and the bearing. The amount of eccentricity of the journal is related to the pressure that will be generated in the bearing to balance the radial load. The lubricant is supplied through a hole or a groove and may or may not extend all around the journal.

Under normal operating conditions, the gases dissolved in the lubricant cause cavitation in the diverging clearance between the journal and the bearing. This happens because the pressure in the lubricant drops below the saturation pressure for the release of dissolved gases. The saturation pressure is normally similar to the ambient pressure. The following model does not account for cavitation and therefore predicts sub-ambient pressures. Such sub-ambient pressures are the result of the so-called Sommerfeld boundary condition. For practical purposes, these sub-ambient pressures should be neglected. Future versions of the Lubrication Shell physics interface will offer additional tools for modeling cavitation.

**Model Definition**

The pressure in the lubricant (SAE 10 at 70°C) is governed by the Reynolds equation. For an incompressible fluid with no-slip condition, the stationary Reynolds equation in the continuum range is given by

\[
\nabla_T \cdot \left( \frac{-\rho h^3}{12\eta} \nabla_T p + \frac{\rho h}{2} (v_a + v_b) \right) - \rho ( (\nabla_T b \cdot v_b) - (\nabla_T a \cdot v_a) ) = 0
\]

In this equation, \( \rho \) is the density (kg/m\(^3\)), \( h \) is the lubricant thickness (m), \( \eta \) is the viscosity (Pa·s), \( p \) is the pressure (Pa), \( a \) is the location (m) of the channel base, \( v_a \) is the tangential velocity (m/s) of the channel base, \( b \) is the location (m) of the solid wall, and \( v_b \) is the tangential velocity (m/s) of the solid wall. Here the rotating journal is considered to be the solid wall. Figure 1 shows the rotating journal wall on which you solve the Reynolds equation. Because the pressure is constant through the lubricant
film thickness, COMSOL uses the tangential projection of the gradient operator, $\nabla_T$, to calculate the pressure distribution on the lubricant surface. Note that in this case the term $\rho((\nabla_T b \cdot v_b) - (\nabla_T a \cdot v_a))$ equates to 0, so the governing equation simplifies to

$$\nabla_T \cdot \left( \frac{-\rho h^3}{12 \eta} \nabla_T p + \frac{\rho h}{2} (v_a + v_b) \right) = 0 \tag{2}$$

The lubricant thickness, $h$, is defined as

$$h = c(1 + \varepsilon \cos \theta)$$

where $c \equiv R_B - R_J$ is the difference between the bearing radius and the journal radius, $\varepsilon$ is the eccentricity, and $\theta$ is the polar angular coordinate of a point on the lubricant. Figure 2 shows the converging and diverging lubricant thickness around the journal.

Figure 1: Geometry (cylindrical journal) showing the velocity direction with black arrows.
Figure 2: The lubricant thickness around the rotating journal.

**Border Conditions**

The pressure at the ends of the cylindrical journal is assumed to be similar to the ambient pressure. Therefore, the border conditions are

\[ p = 0 \text{ at } z = 0, L \]  

where \( L \) is the length of the cylindrical journal.

**Results and Discussion**

Figure 3 shows the calculated pressure distribution and pressure contours. As expected, the maximum pressure is reached in a region closer to the minimum lubricant thickness. Sub-ambient or negative pressure also results due to approximate boundary conditions. For a more accurate modeling of pressure distribution, gaseous cavitation has to be taken into account.
Figure 3: Pressure distribution and pressure contours on the journal.

**Model Library path:** CFD_Module/Tutorial_Models/journal_bearing

**Modeling Instructions**

**MODEL WIZARD**

1. Go to the Model Wizard window.
2. Click Next.
3. In the Add Physics tree, select Fluid Flow>Thin-Film Flow>Lubrication Shell (tffs).
4. Click Next.
5. In the Studies tree, select Preset Studies>Stationary.
6. Click Finish.
GLOBAL DEFINITIONS

Parameters

1. In the Model Builder window, right-click Global Definitions and choose Parameters.
2. Go to the Settings window for Parameters.
3. Locate the Parameters section. In the Parameters table, enter the following settings:

<table>
<thead>
<tr>
<th>NAME</th>
<th>EXPRESSION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>0.03[m]</td>
<td>Journal radius</td>
</tr>
<tr>
<td>H</td>
<td>0.05[m]</td>
<td>Journal height</td>
</tr>
<tr>
<td>c</td>
<td>0.03[mm]</td>
<td>Clearance between the bearing and the journal</td>
</tr>
<tr>
<td>omega</td>
<td>1500/60<em>2</em>pi[rad/s]</td>
<td>Journal angular velocity</td>
</tr>
</tbody>
</table>

GEOMETRY 1

Cylinder 1

1. In the Model Builder window, right-click Model 1>Geometry 1 and choose Cylinder.
2. Go to the Settings window for Cylinder.
3. Locate the Object Type section. From the Type list, select Surface.
4. Locate the Size and Shape section. In the Radius edit field, type R.
5. In the Height edit field, type H.
6. In the Model Builder window, right-click Cylinder 1 and choose Build All.
7. Click the Zoom Extents button on the Graphics toolbar.

DEFINITIONS

Variables 1

1. In the Model Builder window, right-click Model 1>Definitions and choose Variables.
2. Go to the Settings window for Variables.
3. Locate the Variables section. In the Variables table, enter the following settings:

<table>
<thead>
<tr>
<th>NAME</th>
<th>EXPRESSION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>angle</td>
<td>atan2(y,x)[rad]</td>
<td>Angle along circumference</td>
</tr>
<tr>
<td>h</td>
<td>c*(1+0.6*cos(angle))</td>
<td>Lubricant film thickness</td>
</tr>
<tr>
<td>u</td>
<td>-omega<em>R</em>sin(angle)</td>
<td>x-component of journal velocity</td>
</tr>
<tr>
<td>v</td>
<td>omega<em>R</em>cos(angle)</td>
<td>y-component of journal velocity</td>
</tr>
</tbody>
</table>
**LUBRICATION SHELL**

*Fluid-Film Properties 1*

1. In the Model Builder window, expand the Model 1>Lubrication Shell node, then click Fluid-Film Properties 1.

2. Go to the Settings window for Fluid-Film Properties.

3. Locate the Fluid Properties section. From the ρ list, select User defined. In the associated edit field, type 860 [kg/m^3].

4. From the µ list, select User defined. In the associated edit field, type 0.01 [Pa*s].

5. Click to expand the Gap Properties section.

6. In the h₀ edit field, type h.

7. From the uₜ, w list, select User defined. Specify the associated vector as

<table>
<thead>
<tr>
<th>u</th>
<th>x</th>
</tr>
</thead>
<tbody>
<tr>
<td>v</td>
<td>y</td>
</tr>
<tr>
<td>0</td>
<td>z</td>
</tr>
</tbody>
</table>

8. Click to collapse the Gap Properties section.

9. Click to expand the Rarefaction Effects section.

10. From the Qₜch list, select No slip.

**Border 1**

As you can see in the Border Settings section, the default condition that applies at the cylinder ends is Zero pressure.

**MESH 1**

*Free Triangular 1*

1. In the Model Builder window, right-click Model 1>Mesh 1 and choose More Operations>Free Triangular.

2. Go to the Settings window for Free Triangular.

3. Locate the Boundaries section. From the Selection list, select All boundaries.

4. Click the Build Selected button.

**STUDY 1**

In the Model Builder window, right-click Study 1 and choose Compute.
RESULTS

3D Plot Group 1

The first of the two default plot group shows the pressure field as a surface plot. Add a contour plot of the same quantity to reproduce the plot in Figure 3.

1. In the Model Builder window, right-click Results>3D Plot Group 1 and choose Contour.
2. Go to the Settings window for Contour.
3. Locate the Coloring and Style section. From the Color table list, select GrayScale.
4. Clear the Color legend check box.

To see the bearing from different angles just click and drag in the Graphics window.