

Comparison of Different Hydrodynamic Bearings

Introduction

This example compares the load bearing abilities of different hydrodynamic bearings. The simulation is performed using the Rotordynamics Module's Hydrodynamic Bearing interface. This interface solves the Reynold equation to compute the pressure developed in a thin fluid film for different bearing types. The bearings included in this example are of cylindrical, elliptical, split-halves, and multilobe type (2, 3, and 4 lobes).

Model Definition

Eight bearings are compared: one each of cylindrical, elliptical, and split-halves type, and five different multilobe bearings. The latter are one two-lobe bearing and two three-lobe and four-lobe bearings. The two three-lobe bearings differ from each other in their relative orientation with respect to the applied load direction, as do the two four-lobe bearings.

The journals rotate inside the bearing with an angular speed of Ω (rad/s). The static position of the journal is obtained such that the net force due to the fluid film in the horizontal direction is zero whereas that in the vertical direction balances the journal weight, W .

The bearing configuration is shown in [Figure 1](#) below.

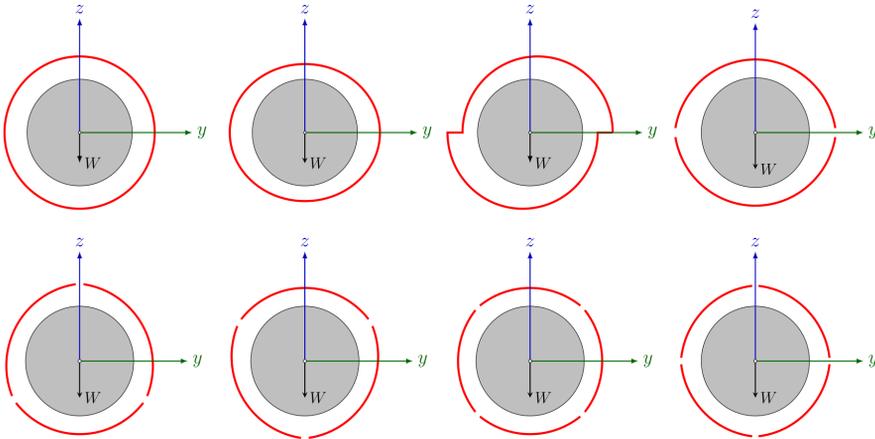


Figure 1: Bearing configuration. Top row: Cylindrical, elliptical, split halves, two-lobe. Bottom row: Three-lobe (LOP), three-lobe (LBP), four-lobe (LOP), four-lobe (LBP).

On the fluid side, the parameters needed for the computation are the dynamic viscosity, the density at cavitation pressure, and the compressibility. The fluid parameters, whose

values are summarized in [Table 1](#), are close to those of lubricating oils used in real bearings.

TABLE 1: FLUID PROPERTIES.

PROPERTY	VALUE
Density ρ	1000 kg/m ³
Dynamic viscosity μ	0.072 Pa·s
Compressibility β	10 ⁻⁷ Pa ⁻¹

BEARING DATA

The maximum and minimum clearance, C_{\max} and C_{\min} , respectively, of all the bearings are set to the same values in order to make them equivalent.

The initial clearance, h_b , assuming that the journal is located at the center of the bearing, is listed in [Table 2](#).

TABLE 2: INITIAL FILM THICKNESS.

BEARING	INITIAL FILM THICKNESS
Cylindrical	$h_b = C$
Elliptical	$h_b = C_{\min} + (C_{\max} - C_{\min}) \cos \theta$
Split halves	$h_b = C + \text{sign}(\sin \theta) d \cos \theta$
Multilobe	$h_b = C + d \cos(\theta - \alpha_m), \alpha_m = \frac{\pi}{N} + \frac{2\pi}{N} \left\lfloor \frac{\theta N}{2\pi} \right\rfloor$

The objective is to obtain various parameters in [Table 2](#) for different bearings by setting maximum and minimum values to C_{\max} and C_{\min} , respectively. The following sections provide these expressions.

Cylindrical Bearing

Because the initial thickness is uniform, the best choice of C for the cylindrical bearing is $C = (C_{\max} + C_{\min})/2$.

Elliptical Bearing

The maximum and minimum clearance C_{\max} and C_{\min} are known.

Split-halves Bearing

For split-halves bearings, $C_{\min} = C - d$, $C_{\max} = C + d$, from which one finds $C = (C_{\max} + C_{\min})/2$ and $d = (C_{\max} - C_{\min})/2$.

Multilobe Bearings

For multilobe bearings, $C_{\max} = C + d$ and $C_{\min} = C + d \cos(\pi/N)$.

Hence, it follows that $C = (C_{\min} - \cos(\pi/N)C_{\max})/(1 - \cos(\pi/N))$, and $d = (C_{\max} - C_{\min})/(1 - \cos(\pi/N))$.

Results and Discussion

Figure 2 below shows the fluid pressure profile on the bearing.

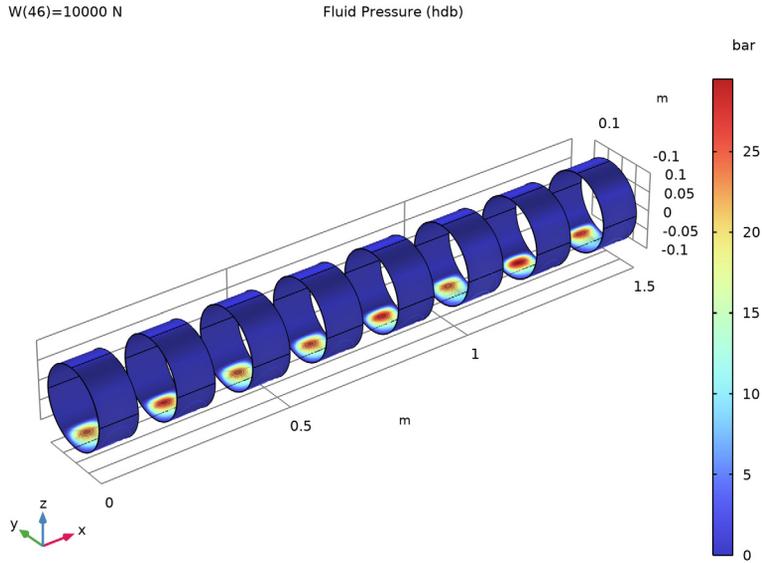


Figure 2: Fluid-film pressure profile.

Several results from the simulation provide valuable information about bearing performance. Figure 3 shows a plot of journal eccentricity versus load. The journals that exhibit lower eccentricity are the better ones. From the plot, it seems that the split-halves and 3-lobe LBP (load between pad) bearings have optimum eccentricity in the operating range. For loads higher than 5000 N, the 4-lobe bearing with load on pad (LOP) has the

largest eccentricity, while the 4-lobe LBP has the smallest one. The performances of the other bearings lie somewhere in between.

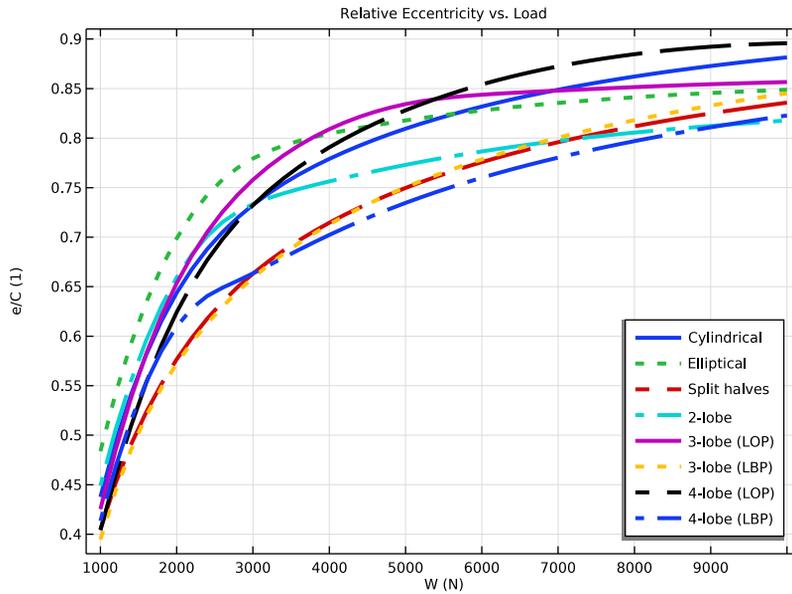


Figure 3: Eccentricity vs. load.

The equilibrium position of the journals is shown in Figure 4 with increasing load W . The y -coordinate of the journal position is plotted on the x -axis, and the z -coordinate is plotted on the y -axis. When the load W is small, all journals tend to move more in the y direction while the movement in the z direction is small. However, as the load increases, they move significantly in the negative z direction and touch the bottom part of the bearing. In the hydrodynamic bearing, two types of forces act on the journal. One, a radial force due to the pressure distribution in the film and other, a tangential viscous force due to the shear in the film. The journal equilibrium position depends on the relative magnitude of these forces. If the shear force is dominant and is enough to support the weight of the journal, equilibrium position is more toward the horizontal direction. For a large journal weight,

shear force alone cannot support the journal and a radial force is also needed. In such a case, journal equilibrium position will move in the negative z direction.

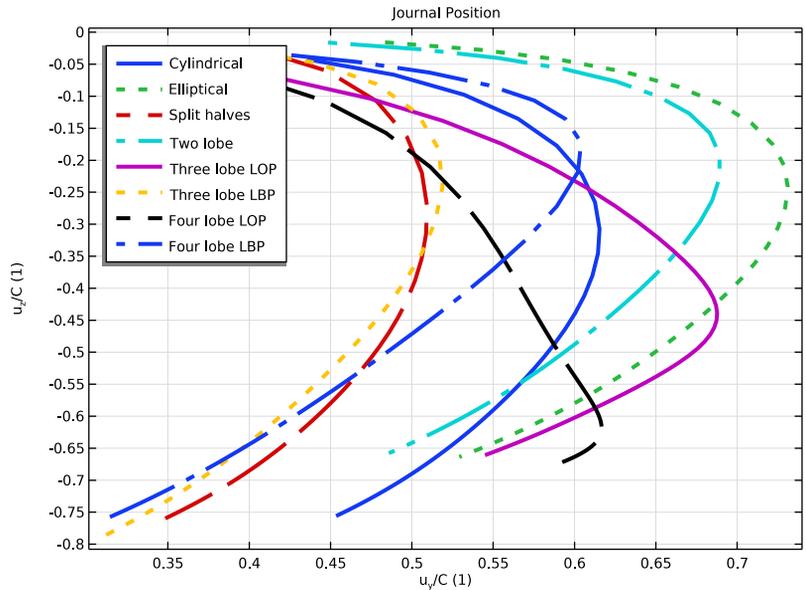


Figure 4: Journal position.

Figure 5 shows the plot of the fluid thickness profile when the journal is concentric with the bearing. The geometric parameters of bearings are set in such a way that the minimum

and maximum clearances are the same for all bearings except for the cylindrical bearing, which is kept at the mean position.

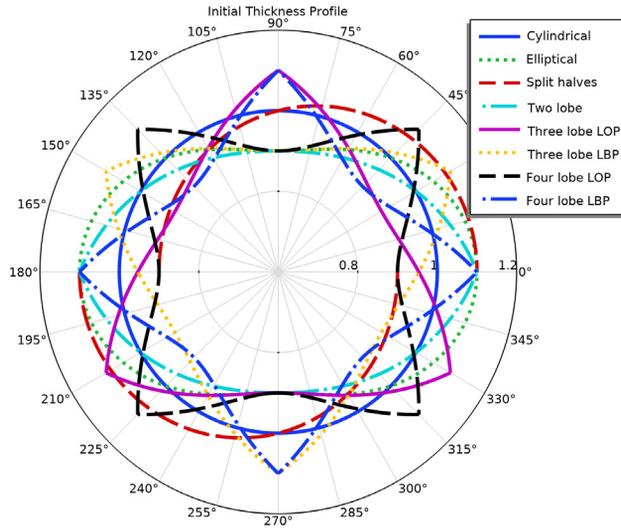


Figure 5: Initial thickness profile.

Figure 6 shows a plot of the steady-state (current) thickness profile of the fluid.

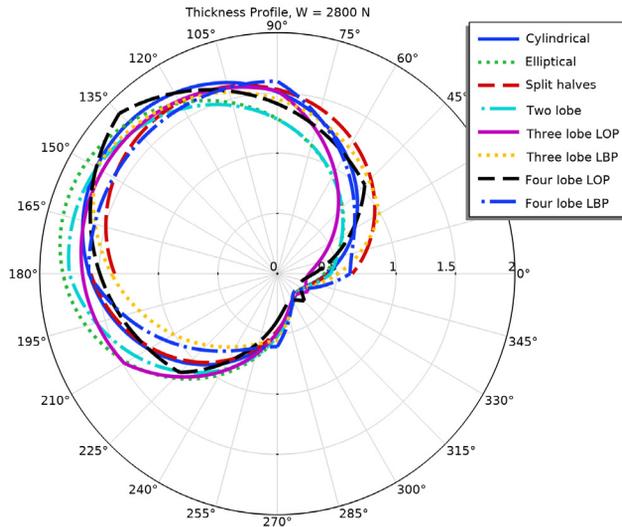


Figure 6: Current thickness profile.

In [Figure 7](#), the fluid-film pressure profile is unwrapped from the bearing surface and the resulting surface is compared between the eight different bearing types. Similarly, [Figure 8](#) compares the unwrapped velocity fields.

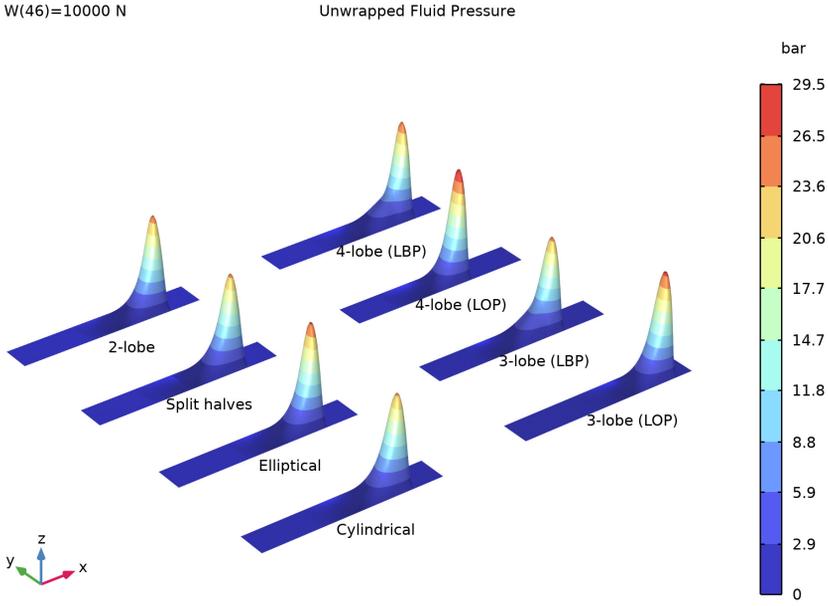


Figure 7: Unwrapped fluid-film pressure profile.

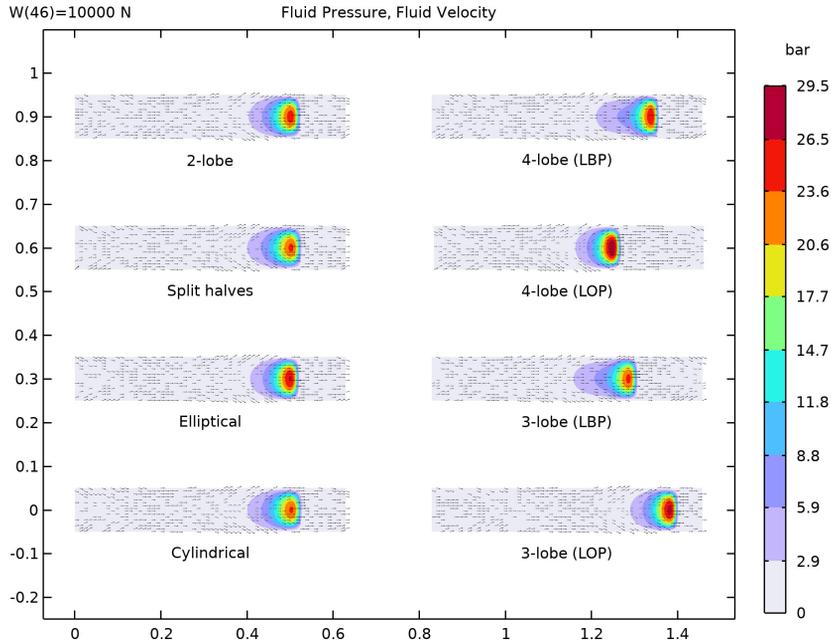


Figure 8: Unwrapped fluid-film pressure and velocity field.

Notes About the COMSOL Implementation

In the computation, use an **Auxiliary sweep** study extension on the load applied by the journal on the bearing to automatically run a loop over the parameter. The Auxiliary sweep functionality is activated in the study step settings.

Application Library path: Rotordynamics_Module/Tutorials/hydrodynamic_bearings_comparison

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click  **Model Wizard**.

MODEL WIZARD

- 1 In the **Model Wizard** window, click .
- 2 In the **Select Physics** tree, select **Structural Mechanics > Rotordynamics > Hydrodynamic Bearing (hdb)**.
- 3 Click **Add**.
- 4 Click  **Study**.
- 5 In the **Select Study** tree, select **General Studies > Stationary**.
- 6 Click  **Done**.

GLOBAL DEFINITIONS

Parameters I

- 1 In the **Model Builder** window, under **Global Definitions** click **Parameters I**.
- 2 In the **Settings** window for **Parameters**, locate the **Parameters** section.
- 3 In the table, enter the following settings:

Name	Expression	Value	Description
Rj	0.1[m]	0.1 m	Radius of journal
H	0.1[m]	0.1 m	Height of journal
C	0.001[m]	0.001 m	Mean bearing clearance
d	0.1*C	1E-4 m	Pad center offset
Cmax	C+d	0.0011 m	Maximum bearing clearance
Cmin	C-d	9E-4 m	Minimum bearing clearance
Ow	200[rad/s]	200 rad/s	RPS
W	100[N]	100 N	Load on bearing, z-component
mu	0.072[Pa*s]	0.072 Pa*s	Dynamic viscosity

GEOMETRY I

Cylinder I (cyl1)

- 1 In the **Geometry** toolbar, click  **Cylinder**.
- 2 In the **Settings** window for **Cylinder**, locate the **Size and Shape** section.
- 3 In the **Radius** text field, type Rj.

- 4 In the **Height** text field, type H.
- 5 Locate the **Axis** section. From the **Axis type** list, choose **x-axis**.
- 6 Locate the **Object Type** section. From the **Type** list, choose **Surface**.
- 7 Click  **Build Selected**.

Array 1 (arr1)

Replicate 7 more cylinders along the x direction by executing the following commands.

- 1 In the **Geometry** toolbar, click  **Transforms** and choose **Array**.
- 2 Select the object **cyl1** only.
- 3 In the **Settings** window for **Array**, locate the **Size** section.
- 4 In the **x size** text field, type 8.
- 5 Locate the **Displacement** section. In the **x** text field, type $2 \cdot H$.

Form Union (fin)

- 1 In the **Geometry** toolbar, click  **Build All**.
- 2 Click the  **Zoom Extents** button in the **Graphics** toolbar.

DEFINITIONS

Cylindrical bearing

- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 In the **Settings** window for **Explicit**, type **Cylindrical bearing** in the **Label** text field.
- 3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Boundary**.
- 4 Select **Boundary 1** only.
- 5 Select the **Group by continuous tangent** checkbox.

Selecting this checkbox allows automatic selection of multiple surfaces across which the tangent is continuous.

Elliptical bearing

- 1 Right-click **Cylindrical bearing** and choose **Duplicate**.
- 2 In the **Settings** window for **Explicit**, type **Elliptical bearing** in the **Label** text field.
- 3 Locate the **Input Entities** section. Click  **Clear Selection**.
- 4 Select **Boundaries 5–8** only.

Explicit Selections

- 1 Repeat above sequence of commands to add more **Explicit** selections using the information given in the following table:

Name	Selection
Split halves bearing	9, 10, 11, 12
Two lobe bearing	13, 14, 15, 16
Three Lobe bearing (LOP)	17, 18, 19, 20
Three lobe bearing (LBP)	21, 22, 23, 24
Four lobe bearing (LOP)	25, 26, 27, 28
Four lobe bearing (LBP)	29, 30, 31, 32

The table above displays the entire selection for each bearing. But to create for example the **Hydrodynamic Journal Bearing (Split halves)** selection, selecting surface 9 is enough. This is so because you duplicate the existing selection to create the new ones and the **Group by continuous tangent** checkbox is already selected within the old.

- 2 In the **Model Builder** window, collapse the **Definitions** node.

HYDRODYNAMIC BEARING (HDB)

- 1 Click the  **Show More Options** button in the **Model Builder** toolbar.
- 2 In the **Show More Options** dialog, in the tree, select the checkbox for the node **Physics > Advanced Physics Options**.
- 3 In the tree, select **Physics > Stabilization**.
- 4 In the tree, select the checkbox for the node **Physics > Stabilization**.
- 5 Click **OK**.
- 6 In the **Model Builder** window, under **Component 1 (comp1)** click **Hydrodynamic Bearing (hdb)**.
- 7 In the **Settings** window for **Hydrodynamic Bearing**, locate the **Physical Model** section.
- 8 From the **Fluid type** list, choose **Liquid with cavitation**.
You can change the compressibility β inside the bearing node.
- 9 Click to expand the **Inconsistent Stabilization** section. In the $\delta_{artificial}$ text field, type 20.
The tuning parameter is increased to improve the stabilization in the cavitated film.

Hydrodynamic Journal Bearing (Cylindrical)

- 1 In the **Model Builder** window, under **Component 1 (comp1) > Hydrodynamic Bearing (hdb)** click **Hydrodynamic Journal Bearing 1**.

- 2 In the **Settings** window for **Hydrodynamic Journal Bearing**, type Hydrodynamic Journal Bearing (Cylindrical) in the **Label** text field.
- 3 Locate the **Bearing Properties** section. In the C text field, type C .
- 4 Locate the **Journal Properties** section. From the **Specify** list, choose **Load**.
- 5 Specify the \mathbf{W}_j vector as

0	x
0	y
-W	z

- 6 Specify the \mathbf{u}_{j0} vector as

0	x
0	y
-0.1*C	z

- 7 In the Ω text field, type $0w$.
- 8 Locate the **Fluid Properties** section. From the μ list, choose **User defined**. In the associated text field, type μ .
- 9 Locate the **Bearing Properties** section. From the \mathbf{X}_c list, choose **From geometry**.

Hydrodynamic Journal Bearing (Elliptical)

- 1 Right-click **Hydrodynamic Journal Bearing (Cylindrical)** and choose **Duplicate**.
- 2 In the **Settings** window for **Hydrodynamic Journal Bearing**, type Hydrodynamic Journal Bearing (Elliptical) in the **Label** text field.
- 3 Locate the **Boundary Selection** section. From the **Selection** list, choose **Elliptical bearing**.
- 4 Locate the **Bearing Properties** section. From the **Bearing type** list, choose **Elliptical**.
- 5 In the C_{\min} text field, type C_{\min} .
- 6 In the C_{\max} text field, type C_{\max} .
- 7 From the \mathbf{X}_c list, choose **From geometry**.

Hydrodynamic Journal Bearing (Split halves)

- 1 Right-click **Hydrodynamic Journal Bearing (Elliptical)** and choose **Duplicate**.
- 2 In the **Settings** window for **Hydrodynamic Journal Bearing**, type Hydrodynamic Journal Bearing (Split halves) in the **Label** text field.
- 3 Locate the **Boundary Selection** section. From the **Selection** list, choose **Split halves bearing**.

- 4 Locate the **Bearing Properties** section. From the **Bearing type** list, choose **Split halves**.
- 5 In the C text field, type C .
- 6 From the **Preload factor** list, choose **Compute from offset**.
- 7 In the d text field, type d .
- 8 From the X_c list, choose **From geometry**.

Hydrodynamic Journal Bearing (2-lobe)

- 1 Right-click **Hydrodynamic Journal Bearing (Split halves)** and choose **Duplicate**.
- 2 In the **Settings** window for **Hydrodynamic Journal Bearing**, type Hydrodynamic Journal Bearing (2-lobe) in the **Label** text field.
- 3 Locate the **Boundary Selection** section. From the **Selection** list, choose **Two lobe bearing**.
- 4 Locate the **Bearing Properties** section. From the **Bearing type** list, choose **Multilobe**.
- 5 In the C text field, type C_{max} .
- 6 From the **Preload factor** list, choose **Compute from offset**.
- 7 In the d text field, type $2*d$.
- 8 From the X_c list, choose **From geometry**.

Hydrodynamic Journal Bearing (3-lobe LOP)

- 1 Right-click **Hydrodynamic Journal Bearing (2-lobe)** and choose **Duplicate**.
- 2 In the **Settings** window for **Hydrodynamic Journal Bearing**, type Hydrodynamic Journal Bearing (3-lobe LOP) in the **Label** text field.
- 3 Locate the **Boundary Selection** section. From the **Selection** list, choose **Three Lobe bearing (LOP)**.
- 4 Locate the **Bearing Properties** section. In the C text field, type $2*C_{max} - C_{min}$.
- 5 In the d text field, type $4*d$.
- 6 In the N text field, type 3.
- 7 From the X_c list, choose **From geometry**.

Hydrodynamic Journal Bearing (3-lobe LBP)

- 1 Right-click **Hydrodynamic Journal Bearing (3-lobe LOP)** and choose **Duplicate**.
- 2 In the **Settings** window for **Hydrodynamic Journal Bearing**, type Hydrodynamic Journal Bearing (3-lobe LBP) in the **Label** text field.
- 3 Locate the **Boundary Selection** section. From the **Selection** list, choose **Three lobe bearing (LBP)**.
- 4 Locate the **Bearing Properties** section. From the X_c list, choose **From geometry**.

Hydrodynamic Journal Bearing (4-lobe LOP)

- 1 Right-click **Hydrodynamic Journal Bearing (3-lobe LBP)** and choose **Duplicate**.
- 2 In the **Settings** window for **Hydrodynamic Journal Bearing**, type Hydrodynamic Journal Bearing (4-lobe LOP) in the **Label** text field.
- 3 Locate the **Boundary Selection** section. From the **Selection** list, choose **Four lobe bearing (LOP)**.
- 4 Locate the **Bearing Properties** section. In the C text field, type $(\sqrt{2} * C_{max} - C_{min}) / (\sqrt{2} - 1)$.
- 5 In the d text field, type $\sqrt{2} * (C_{max} - C_{min}) / (\sqrt{2} - 1)$.
- 6 In the N text field, type 4.
- 7 From the X_c list, choose **From geometry**.

Hydrodynamic Journal Bearing (4-lobe LBP)

- 1 Right-click **Hydrodynamic Journal Bearing (4-lobe LOP)** and choose **Duplicate**.
- 2 In the **Settings** window for **Hydrodynamic Journal Bearing**, type Hydrodynamic Journal Bearing (4-lobe LBP) in the **Label** text field.
- 3 Locate the **Boundary Selection** section. From the **Selection** list, choose **Four lobe bearing (LBP)**.
- 4 Locate the **Bearing Properties** section. From the X_c list, choose **From geometry**.

Next set the orientation of the bearings using the following instructions.

Bearing Orientation Hydrodynamic Journal Bearing (3-lobe LOP)

- 1 In the **Physics** toolbar, click  **Boundaries** and choose **Bearing Orientation**.
- 2 In the **Settings** window for **Bearing Orientation**, type Bearing Orientation Hydrodynamic Journal Bearing (3-lobe LOP) in the **Label** text field.
- 3 Locate the **Boundary Selection** section. From the **Selection** list, choose **Three Lobe bearing (LOP)**.
- 4 Locate the **Bearing Orientation** section. In the ϕ text field, type $-\pi/6$.

Bearing Orientation Hydrodynamic Journal Bearing (3-lobe LBP)

- 1 Right-click **Bearing Orientation Hydrodynamic Journal Bearing (3-lobe LOP)** and choose **Duplicate**.
- 2 In the **Settings** window for **Bearing Orientation**, type Bearing Orientation Hydrodynamic Journal Bearing (3-lobe LBP) in the **Label** text field.
- 3 Locate the **Boundary Selection** section. From the **Selection** list, choose **Three lobe bearing (LBP)**.

4 Locate the **Bearing Orientation** section. In the ϕ text field, type $\pi/6$.

Bearing Orientation Hydrodynamic Journal Bearing (4-lobe LOP)

1 Right-click **Bearing Orientation Hydrodynamic Journal Bearing (3-lobe LBP)** and choose **Duplicate**.

2 In the **Settings** window for **Bearing Orientation**, type Bearing Orientation Hydrodynamic Journal Bearing (4-lobe LOP) in the **Label** text field.

3 Locate the **Boundary Selection** section. From the **Selection** list, choose **Four lobe bearing (LOP)**.

4 Locate the **Bearing Orientation** section. In the ϕ text field, type $\pi/4$.

MESH I

Mapped I

1 In the **Mesh** toolbar, click  **More Generators** and choose **Mapped**.

2 In the **Settings** window for **Mapped**, locate the **Boundary Selection** section.

3 From the **Selection** list, choose **All boundaries**.

Distribution I

1 Right-click **Mapped I** and choose **Distribution**.

2 In the **Settings** window for **Distribution**, locate the **Edge Selection** section.

3 From the **Selection** list, choose **All edges**.

4 Locate the **Distribution** section. In the **Number of elements** text field, type 15.

5 In the **Model Builder** window, right-click **Mesh I** and choose **Build All**.

STUDY I

Step I: Stationary

1 In the **Model Builder** window, under **Study I** click **Step I: Stationary**.

2 In the **Settings** window for **Stationary**, click to expand the **Study Extensions** section.

Use following instructions to add an **Auxiliary sweep** on load W .

3 Select the **Auxiliary sweep** checkbox.

4 Click  **Add**.

5 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
W (Load on bearing, z-component)	range (1000 , 200 , 10000)	N

6 In the **Study** toolbar, click  **Compute**.

Set preferred units for the pressure by following the instructions below.

RESULTS

Preferred Units I

- 1 In the **Results** toolbar, click  **Configurations** and choose **Preferred Units**.
- 2 In the **Settings** window for **Preferred Units**, locate the **Units** section.
- 3 Click  **Add Physical Quantity**.
- 4 In the **Physical Quantity** dialog, type `pres` in the text field.
- 5 In the tree, select **General > Pressure (Pa)**.
- 6 Click **OK**.
- 7 In the **Settings** window for **Preferred Units**, locate the **Units** section.
- 8 In the table, enter the following settings:

Quantity	Unit	Preferred unit
Pressure	Pa	bar

9 Click  **Apply**.

Fluid Pressure (hdb)

- 1 In the **Model Builder** window, under **Results** click **Fluid Pressure (hdb)**.
- 2 In the **Settings** window for **3D Plot Group**, click to expand the **Title** section.
- 3 From the **Title type** list, choose **Label**.
- 4 Locate the **Color Legend** section. Select the **Show units** checkbox.

The dependent variable `pfilm` in the default plot does not represent the physical pressure and can have a negative value in the cavitated zone. Use physics scope variable `hdb.p` instead to show the physical pressure in the bearings.

Surface I

- 1 In the **Model Builder** window, expand the **Fluid Pressure (hdb)** node, then click **Surface I**.
- 2 In the **Settings** window for **Surface**, locate the **Expression** section.

3 In the **Expression** text field, type `hdb.p`.

Contour I

- 1 In the **Model Builder** window, click **Contour I**.
- 2 In the **Settings** window for **Contour**, locate the **Expression** section.
- 3 In the **Expression** text field, type `hdb.p`.
- 4 In the **Fluid Pressure (hdb)** toolbar, click  **Plot**.
- 5 Click the  **Zoom Extents** button in the **Graphics** toolbar.

Use the following instructions to plot the eccentricity of the journals against the load as shown in [Figure 3](#).

Relative Eccentricity vs. Load

- 1 In the **Results** toolbar, click  **ID Plot Group**.
- 2 In the **Settings** window for **ID Plot Group**, type `Relative Eccentricity vs. Load` in the **Label** text field.
- 3 Click to expand the **Title** section. From the **Title type** list, choose **Label**.
- 4 Locate the **Plot Settings** section.
- 5 Select the **x-axis label** checkbox. In the associated text field, type `W (N)`.
- 6 Select the **y-axis label** checkbox. In the associated text field, type `e/C (1)`.

Global I

- 1 Right-click **Relative Eccentricity vs. Load** and choose **Global**.
- 2 In the **Settings** window for **Global**, click **Replace Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component I (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (Cylindrical) > Eccentricity and attitude angle > hdb.hjb1.ec_rel - Relative eccentricity - I**.
- 3 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component I (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (Elliptical) > Eccentricity and attitude angle > hdb.hjb2.ec_rel - Relative eccentricity - I**.
- 4 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component I (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (Split halves) > Eccentricity and attitude angle > hdb.hjb3.ec_rel - Relative eccentricity - I**.
- 5 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component I (comp1) > Hydrodynamic Bearing >**

Hydrodynamic Journal Bearing (2-lobe) > Eccentricity and attitude angle > hdb.hjb4.ec_rel - Relative eccentricity - I.

6 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component I (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (3-lobe LOP) > Eccentricity and attitude angle > hdb.hjb5.ec_rel - Relative eccentricity - I.**

7 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component I (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (3-lobe LBP) > Eccentricity and attitude angle > hdb.hjb6.ec_rel - Relative eccentricity - I.**

8 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component I (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (4-lobe LOP) > Eccentricity and attitude angle > hdb.hjb7.ec_rel - Relative eccentricity - I.**

9 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component I (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (4-lobe LBP) > Eccentricity and attitude angle > hdb.hjb8.ec_rel - Relative eccentricity - I.**

10 Locate the **y-Axis Data** section. In the table, enter the following settings:

Expression	Unit	Description
hdb.hjb1.ec_rel	1	Cylindrical
hdb.hjb2.ec_rel	1	Elliptical
hdb.hjb3.ec_rel	1	Split halves
hdb.hjb4.ec_rel	1	2-lobe
hdb.hjb5.ec_rel	1	3-lobe (LOP)
hdb.hjb6.ec_rel	1	3-lobe (LBP)
hdb.hjb7.ec_rel	1	4-lobe (LOP)
hdb.hjb8.ec_rel	1	4-lobe (LBP)

11 Click to expand the **Coloring and Style** section. Find the **Line style** subsection. From the **Line** list, choose **Cycle**.

12 From the **Width** list, choose **3**.

Relative Eccentricity vs. Load

1 In the **Model Builder** window, click **Relative Eccentricity vs. Load**.

2 In the **Settings** window for **ID Plot Group**, locate the **Legend** section.

- 3 From the **Position** list, choose **Lower right**.
- 4 In the **Relative Eccentricity vs. Load** toolbar, click  **Plot**.
- 5 Click the  **Zoom Extents** button in the **Graphics** toolbar.
- 6 In the **Model Builder** window, collapse the **Relative Eccentricity vs. Load** node.

Use the following instructions to plot the attitude angle against the load.

Attitude Angle vs. Load

- 1 In the **Results** toolbar, click  **ID Plot Group**.
- 2 In the **Settings** window for **ID Plot Group**, type Attitude Angle vs. Load in the **Label** text field.
- 3 Locate the **Title** section. From the **Title type** list, choose **Label**.
- 4 Locate the **Plot Settings** section.
- 5 Select the **x-axis label** checkbox. In the associated text field, type W (N).
- 6 Select the **y-axis label** checkbox. In the associated text field, type ϕ (degree).

Global 1

- 1 Right-click **Attitude Angle vs. Load** and choose **Global**.
- 2 In the **Settings** window for **Global**, click **Replace Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component 1 (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (Cylindrical) > Eccentricity and attitude angle > hdb.hjb1.phia - Attitude angle - rad**.
- 3 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component 1 (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (Elliptical) > Eccentricity and attitude angle > hdb.hjb2.phia - Attitude angle - rad**.
- 4 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component 1 (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (Split halves) > Eccentricity and attitude angle > hdb.hjb3.phia - Attitude angle - rad**.
- 5 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component 1 (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (2-lobe) > Eccentricity and attitude angle > hdb.hjb4.phia - Attitude angle - rad**.
- 6 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component 1 (comp1) > Hydrodynamic Bearing >**

- Hydrodynamic Journal Bearing (3-lobe LOP) > Eccentricity and attitude angle > hdb.hjb5.phia - Attitude angle - rad.**
- 7 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component I (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (3-lobe LBP) > Eccentricity and attitude angle > hdb.hjb6.phia - Attitude angle - rad.**
 - 8 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component I (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (4-lobe LOP) > Eccentricity and attitude angle > hdb.hjb7.phia - Attitude angle - rad.**
 - 9 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component I (comp1) > Hydrodynamic Bearing > Hydrodynamic Journal Bearing (4-lobe LBP) > Eccentricity and attitude angle > hdb.hjb8.phia - Attitude angle - rad.**
- 10 Locate the **y-Axis Data** section. In the table, enter the following settings:

Expression	Unit	Description
hdb.hjb1.phia	deg	Cylindrical
hdb.hjb2.phia	deg	Elliptical
hdb.hjb3.phia	deg	Split halves
hdb.hjb4.phia	deg	2-lobe
hdb.hjb5.phia	deg	3-lobe (LOP)
hdb.hjb6.phia	deg	3-lobe (LBP)
hdb.hjb7.phia	deg	4-lobe (LOP)
hdb.hjb8.phia	deg	4-lobe (LBP)

- 11 Locate the **Coloring and Style** section. Find the **Line style** subsection. From the **Line** list, choose **Cycle**.
- 12 From the **Width** list, choose **3**.

Attitude Angle vs. Load

- 1 In the **Model Builder** window, click **Attitude Angle vs. Load**.
- 2 In the **Attitude Angle vs. Load** toolbar, click  **Plot**.
- 3 Click the  **Zoom Extents** button in the **Graphics** toolbar.
- 4 In the **Model Builder** window, collapse the **Attitude Angle vs. Load** node.

Use the following instructions to plot the journal position versus load as shown in [Figure 4](#).

Journal Position

- 1 In the **Results** toolbar, click  **ID Plot Group**.
- 2 In the **Settings** window for **ID Plot Group**, type **Journal Position** in the **Label** text field.
- 3 Locate the **Title** section. From the **Title type** list, choose **Label**.
- 4 Locate the **Plot Settings** section.
- 5 Select the **x-axis label** checkbox. In the associated text field, type $u_{y/C}$.
- 6 Select the **y-axis label** checkbox. In the associated text field, type $u_{z/C}$.

Cylindrical

- 1 Right-click **Journal Position** and choose **Global**.
- 2 In the **Settings** window for **Global**, type **Cylindrical** in the **Label** text field.
- 3 Locate the **y-Axis Data** section. In the table, enter the following settings:

Expression	Unit	Description
$hdb.hjb1.uJz/C$	1	

- 4 Locate the **x-Axis Data** section. From the **Parameter** list, choose **Expression**.
- 5 In the **Expression** text field, type $hdb.hjb1.uJy/C$.
- 6 Locate the **Coloring and Style** section. Find the **Line style** subsection. From the **Line** list, choose **Cycle**.
- 7 From the **Width** list, choose **3**.
- 8 Click to expand the **Legends** section. Find the **Include** subsection. Clear the **Solution** checkbox.
- 9 Clear the **Description** checkbox.
- 10 Select the **Label** checkbox.

Elliptical

- 1 Right-click **Cylindrical** and choose **Duplicate**.
- 2 In the **Settings** window for **Global**, type **Elliptical** in the **Label** text field.
- 3 Locate the **y-Axis Data** section. In the table, enter the following settings:

Expression	Unit	Description
$hdb.hjb2.uJz/C$	1	

4 Locate the **x-Axis Data** section. In the **Expression** text field, type `hdb.hjb2.uJy/C`.

Global Display Nodes

Similarly add six more **Global** display nodes using the information given in the following table:

Name	y axis Data	x axis Data	Legends
Split halves	<code>hdb.hjb3.uJz/C</code>	<code>hdb.hjb3.uJy/C</code>	Split halves
Two lobe	<code>hdb.hjb4.uJz/C</code>	<code>hdb.hjb4.uJy/C</code>	Two lobe
Three lobe LOP	<code>hdb.hjb5.uJz/C</code>	<code>hdb.hjb5.uJy/C</code>	Three lobe LOP
Three lobe LBP	<code>hdb.hjb6.uJz/C</code>	<code>hdb.hjb6.uJy/C</code>	Three lobe LBP
Four lobe LOP	<code>hdb.hjb7.uJz/C</code>	<code>hdb.hjb7.uJy/C</code>	Four lobe LOP
Four lobe LBP	<code>hdb.hjb8.uJz/C</code>	<code>hdb.hjb8.uJy/C</code>	Four lobe LBP

Journal Position

- 1 In the **Model Builder** window, click **Journal Position**.
- 2 In the **Settings** window for **ID Plot Group**, locate the **Legend** section.
- 3 From the **Position** list, choose **Upper left**.
- 4 In the **Journal Position** toolbar, click  **Plot**.
- 5 Click the  **Zoom Extents** button in the **Graphics** toolbar.
- 6 In the **Model Builder** window, collapse the **Journal Position** node.

Use the following instructions to plot the initial thickness profile of the fluid film as shown in [Figure 5](#).

Initial Thickness Profile

- 1 In the **Results** toolbar, click  **Polar Plot Group**.
- 2 In the **Settings** window for **Polar Plot Group**, type Initial Thickness Profile in the **Label** text field.
- 3 Locate the **Data** section. From the **Parameter selection (W)** list, choose **First**.
- 4 Click to expand the **Title** section. From the **Title type** list, choose **Label**.
- 5 Locate the **Axis** section. Select the **Manual axis limits** checkbox.
- 6 In the **r minimum** text field, type 0.6.
- 7 In the **r maximum** text field, type 1.2.

Cylindrical

- 1 Right-click **Initial Thickness Profile** and choose **Line Graph**.

- 2 Select Edges 1, 2, 4, and 6 only.
- 3 In the **Settings** window for **Line Graph**, click **Replace Expression** in the upper-right corner of the **r-Axis Data** section. From the menu, choose **Component 1 (comp1) > Hydrodynamic Bearing > Journal and bearing properties > Film thickness and clearance > hdb.hi_rel - Relative film thickness, initial - I**.
- 4 Locate the **r-Axis Data** section.
- 5 Select the **Description** checkbox. In the associated text field, type *Cylindrical*.
- 6 Locate the θ **Angle Data** section. From the **Parameter** list, choose **Expression**.
- 7 In the **Expression** text field, type `hdb.Th+hdb.ang_bearing`.
- 8 Click to expand the **Coloring and Style** section. Find the **Line style** subsection. From the **Line** list, choose **Cycle**.
- 9 From the **Width** list, choose **3**.
- 10 Click to expand the **Legends** section. Select the **Show legends** checkbox.
- 11 Find the **Include** subsection. Clear the **Solution** checkbox.
- 12 Select the **Label** checkbox.
- 13 In the **Label** text field, type *Cylindrical*.

Elliptical

- 1 Right-click **Cylindrical** and choose **Duplicate**.
- 2 In the **Settings** window for **Line Graph**, type *Elliptical* in the **Label** text field.
- 3 Locate the **Selection** section. Click  **Clear Selection**.
- 4 Select Edges 13, 14, 16, and 18 only.
- 5 Locate the **r-Axis Data** section. In the **Description** text field, type *Elliptical*.

Line graph Nodes

Similarly add more **Line Graph** nodes using the information given in the following table:

Name	Selection	r-Axis Data: Expression	Legends
Split halves	25, 26, 28, 30	Split halves	Split halves
Two lobe	37, 38, 40, 42	Two lobe	Two lobe
Three lobe LOP	49, 50, 52, 54	Three lobe LOP	Three lobe LOP
Three lobe LBP	61, 62, 64, 66	Three lobe LBP	(As is)
Four lobe LOP	73, 74, 76, 78	Four lobe LOP	Four lobe LOP
Four lobe LBP	85, 86, 88, 90	Four lobe LBP	Four lobe LBP

Initial Thickness Profile

- 1 In the **Model Builder** window, click **Initial Thickness Profile**.
- 2 In the **Initial Thickness Profile** toolbar, click  **Plot**.

Use the following instructions to plot the current thickness profile of the fluid film as shown in [Figure 6](#) using the following instructions.

Initial Thickness Profile I

Right-click **Initial Thickness Profile** and choose **Duplicate**.

Initial Thickness Profile

In the **Model Builder** window, collapse the **Results > Initial Thickness Profile** node.

Current Thickness Profile

- 1 In the **Model Builder** window, under **Results** click **Initial Thickness Profile I**.
- 2 In the **Settings** window for **Polar Plot Group**, type Current Thickness Profile in the **Label** text field.
- 3 Click to expand the **Title** section. From the **Title type** list, choose **Manual**.
- 4 In the **Title** text area, type Thickness Profile, W = 2800 N.

Line graph Nodes

- 1 Edit the existing **Line Graph** nodes under **Polar: Current Thickness Profile** using the information given in the following table:

Name	r-Axis Data: Expression	theta angle data: Expression
Cylindrical	$hdb.h_rel$	$mod(hdb.Th + hdb.ang_bearing, 2 * \pi)$
Elliptical	$hdb.h_rel$	$mod(hdb.Th + hdb.ang_bearing, 2 * \pi)$
Split halves	$hdb.h/C$	$mod(hdb.Th + hdb.ang_bearing, 2 * \pi)$
Two lobe	$hdb.h_rel$	$mod(hdb.Th + hdb.ang_bearing, 2 * \pi)$
Three lobe LOP	$hdb.h_rel$	$mod(hdb.Th + hdb.ang_bearing, 2 * \pi)$
Three lobe LBP	$hdb.h_rel$	$mod(hdb.Th + hdb.ang_bearing, 2 * \pi)$

Name	r-Axis Data: Expression	theta angle data: Expression
Four lobe LOP	<code>hdb.h_re1</code>	<code>mod(hdb.Th+hdb.ang_bearing,2*pi)</code>
Four lobe LBP	<code>hdb.h_re1</code>	<code>mod(hdb.Th+hdb.ang_bearing,2*pi)</code>

- 2 In the **Model Builder** window, expand the **Current Thickness Profile** node, then click **Results > Current Thickness Profile**.
- 3 Locate the **Data** section. From the **Parameter selection (W)** list, choose **Manual**.
- 4 In the **Parameter indices (1-46)** text field, type 15.
- 5 Locate the **Axis** section. In the **r minimum** text field, type 0.0.
- 6 In the **r maximum** text field, type 2.0.
- 7 In the **Current Thickness Profile** toolbar, click  **Plot**.
- 8 In the **Model Builder** window, collapse the **Results > Current Thickness Profile** node.

RESULT TEMPLATES

Add unwrapped plots for all the bearings, to create the associated datasets.

- 1 In the **Results** toolbar, click  **Result Templates** to open the **Result Templates** window.
- 2 Go to the **Result Templates** window.
- 3 In the tree, select **Study 1/Solution 1 (sol1) > Hydrodynamic Bearing > Unwrapped Plots (hjb1)**, **Study 1/Solution 1 (sol1) > Hydrodynamic Bearing > Unwrapped Plots (hjb2)**, **Study 1/Solution 1 (sol1) > Hydrodynamic Bearing > Unwrapped Plots (hjb3)**, **Study 1/Solution 1 (sol1) > Hydrodynamic Bearing > Unwrapped Plots (hjb4)**, **Study 1/Solution 1 (sol1) > Hydrodynamic Bearing > Unwrapped Plots (hjb5)**, **Study 1/Solution 1 (sol1) > Hydrodynamic Bearing > Unwrapped Plots (hjb6)**, **Study 1/Solution 1 (sol1) > Hydrodynamic Bearing > Unwrapped Plots (hjb7)**, and **Study 1/Solution 1 (sol1) > Hydrodynamic Bearing > Unwrapped Plots (hjb8)**.
- 4 Click the **Add Result Template** button in the window toolbar.
- 5 In the **Results** toolbar, click  **Result Templates** to close the **Result Templates** window.

RESULTS

Unwrapped Plots (hjb1)

In the **Model Builder** window, under **Results** right-click **Unwrapped Plots (hjb1)** and choose **Ungroup**.

Unwrapped Fluid Pressure

- 1 In the **Model Builder** window, under **Results** click **Unwrapped Fluid Pressure (hjb1)**.
- 2 In the **Settings** window for **2D Plot Group**, type Unwrapped Fluid Pressure in the **Label** text field.
- 3 Click to expand the **Title** section. From the **Title type** list, choose **Label**.
- 4 Locate the **Color Legend** section. Select the **Show units** checkbox.
- 5 Click to expand the **Plot Array** section. Select the **Enable** checkbox.
- 6 From the **Array shape** list, choose **Square**.
- 7 From the **Padding** list, choose **Absolute**.
- 8 In the **Row padding length** text field, type 3*H.
- 9 In the **Column padding length** text field, type 3*H.

Pressure (Cylindrical)

- 1 In the **Model Builder** window, expand the **Unwrapped Fluid Pressure** node, then click **Surface 1**.
- 2 In the **Settings** window for **Surface**, type Pressure (Cylindrical) in the **Label** text field.

Pressure (Elliptical)

- 1 Right-click **Pressure (Cylindrical)** and choose **Duplicate**.
- 2 In the **Settings** window for **Surface**, type Pressure (Elliptical) in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb2)**.
- 4 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 5 Click to expand the **Plot Array** section. Select the **Manual indexing** checkbox.
- 6 In the **Row index** text field, type 1.

Pressure (Split Halves)

- 1 Right-click **Pressure (Cylindrical)** and choose **Duplicate**.
- 2 In the **Settings** window for **Surface**, type Pressure (Split Halves) in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb3)**.
- 4 Locate the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 5 Locate the **Plot Array** section. Select the **Manual indexing** checkbox.
- 6 In the **Row index** text field, type 2.

Pressure (2-lobe)

- 1 Right-click **Pressure (Cylindrical)** and choose **Duplicate**.
- 2 In the **Settings** window for **Surface**, type Pressure (2-lobe) in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb4)**.
- 4 Locate the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 5 Locate the **Plot Array** section. Select the **Manual indexing** checkbox.
- 6 In the **Row index** text field, type 3.

Pressure (3-lobe LOP)

- 1 Right-click **Pressure (Cylindrical)** and choose **Duplicate**.
- 2 In the **Settings** window for **Surface**, type Pressure (3-lobe LOP) in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb5)**.
- 4 Locate the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 5 Locate the **Plot Array** section. Select the **Manual indexing** checkbox.
- 6 In the **Column index** text field, type 1.

Pressure (3-lobe LBP)

- 1 Right-click **Pressure (Cylindrical)** and choose **Duplicate**.
- 2 In the **Settings** window for **Surface**, type Pressure (3-lobe LBP) in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb6)**.
- 4 Locate the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 5 Locate the **Plot Array** section. Select the **Manual indexing** checkbox.
- 6 In the **Row index** text field, type 1.
- 7 In the **Column index** text field, type 1.
- 8 In the **Unwrapped Fluid Pressure** toolbar, click  **Plot**.

Pressure (4-lobe LOP)

- 1 Right-click **Pressure (Cylindrical)** and choose **Duplicate**.
- 2 In the **Settings** window for **Surface**, type Pressure (4-lobe LOP) in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb7)**.
- 4 Locate the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 5 Locate the **Plot Array** section. Select the **Manual indexing** checkbox.
- 6 In the **Row index** text field, type 2.
- 7 In the **Column index** text field, type 1.

Pressure (4-lobe LBP)

- 1 Right-click **Pressure (Cylindrical)** and choose **Duplicate**.
- 2 In the **Settings** window for **Surface**, type Pressure (4-lobe LBP) in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb8)**.
- 4 Locate the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 5 Locate the **Plot Array** section. Select the **Manual indexing** checkbox.
- 6 In the **Row index** text field, type 3.
- 7 In the **Column index** text field, type 1.

Unwrapped Fluid Pressure

In the **Model Builder** window, click **Unwrapped Fluid Pressure**.

Table Annotation 1

- 1 In the **Unwrapped Fluid Pressure** toolbar, click  **More Plots** and choose **Table Annotation**.
- 2 In the **Settings** window for **Table Annotation**, locate the **Data** section.
- 3 From the **Source** list, choose **Local table**.
- 4 In the table, enter the following settings:

x-coordinate	y-coordinate	Annotation
$R_j \cdot \pi$	$-3 \cdot H/2$	Cylindrical
$R_j \cdot \pi$	$5 \cdot H/2$	Elliptical
$R_j \cdot \pi$	$13 \cdot H/2$	Split halves
$R_j \cdot \pi$	$21 \cdot H/2$	2-lobe
$3 \cdot R_j \cdot \pi + 3 \cdot H$	$-3 \cdot H/2$	3-lobe (LOP)
$3 \cdot R_j \cdot \pi + 3 \cdot H$	$5 \cdot H/2$	3-lobe (LBP)
$3 \cdot R_j \cdot \pi + 3 \cdot H$	$13 \cdot H/2$	4-lobe (LOP)
$3 \cdot R_j \cdot \pi + 3 \cdot H$	$21 \cdot H/2$	4-lobe (LBP)

- 5 Locate the **Coloring and Style** section. Clear the **Show point** checkbox.
- 6 From the **Anchor point** list, choose **Center**.
- 7 In the **Unwrapped Fluid Pressure** toolbar, click  **Plot**.
- 8 Click the  **Go to Default View** button in the **Graphics** toolbar.
- 9 Click the  **Zoom Extents** button in the **Graphics** toolbar.

Unwrapped Fluid Pressure

In the **Model Builder** window, collapse the **Results > Unwrapped Fluid Pressure** node.

Unwrapped Velocity

- 1 In the **Model Builder** window, under **Results** click **Unwrapped Velocity (hjb1)**.
- 2 In the **Settings** window for **2D Plot Group**, type Unwrapped Velocity in the **Label** text field.
- 3 Click to expand the **Title** section. From the **Title type** list, choose **Manual**.
- 4 In the **Title** text area, type Fluid Pressure, Fluid Velocity.
- 5 Locate the **Color Legend** section. Select the **Show units** checkbox.
- 6 Click to expand the **Plot Array** section. Select the **Enable** checkbox.
- 7 From the **Array shape** list, choose **Square**.
- 8 From the **Padding** list, choose **Absolute**.
- 9 In the **Row padding length** text field, type 2*H.
- 10 In the **Column padding length** text field, type 2*H.

Pressure (Cylindrical)

- 1 In the **Model Builder** window, expand the **Unwrapped Velocity** node, then click **Pressure**.
- 2 In the **Settings** window for **Surface**, type Pressure (Cylindrical) in the **Label** text field.
- 3 Click to expand the **Plot Array** section. Select the **Manual indexing** checkbox.

Velocity (Cylindrical)

- 1 In the **Model Builder** window, click **Velocity**.
- 2 In the **Settings** window for **Arrow Surface**, type Velocity (Cylindrical) in the **Label** text field.
- 3 Click to expand the **Plot Array** section. Select the **Manual indexing** checkbox.

Pressure (Cylindrical), Velocity (Cylindrical)

- 1 In the **Model Builder** window, under **Results** > **Unwrapped Velocity**, Ctrl-click to select **Pressure (Cylindrical)** and **Velocity (Cylindrical)**.
- 2 Right-click and choose **Duplicate**.

Pressure (Elliptical)

- 1 In the **Settings** window for **Surface**, type Pressure (Elliptical) in the **Label** text field.
- 2 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb2)**.
- 3 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 4 Locate the **Plot Array** section. In the **Row index** text field, type 1.

Velocity (Elliptical)

- 1 In the **Model Builder** window, under **Results** > **Unwrapped Velocity** click **Velocity (Cylindrical) 1**.
- 2 In the **Settings** window for **Arrow Surface**, type **Velocity (Elliptical)** in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb2)**.
- 4 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Velocity (Cylindrical)**.
- 5 Locate the **Plot Array** section. In the **Row index** text field, type 1.
- 6 In the **Unwrapped Velocity** toolbar, click  **Plot**.

Pressure (Cylindrical), Velocity (Cylindrical)

- 1 In the **Model Builder** window, under **Results** > **Unwrapped Velocity**, Ctrl-click to select **Pressure (Cylindrical)** and **Velocity (Cylindrical)**.
- 2 Right-click and choose **Duplicate**.

Pressure (Split Halves)

- 1 In the **Settings** window for **Surface**, type **Pressure (Split Halves)** in the **Label** text field.
- 2 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb3)**.
- 3 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 4 Locate the **Plot Array** section. In the **Row index** text field, type 2.

Velocity (Split Halves)

- 1 In the **Model Builder** window, under **Results** > **Unwrapped Velocity** click **Velocity (Cylindrical) 1**.
- 2 In the **Settings** window for **Arrow Surface**, type **Velocity (Split Halves)** in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb3)**.
- 4 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Velocity (Cylindrical)**.
- 5 Locate the **Plot Array** section. In the **Row index** text field, type 2.
- 6 In the **Unwrapped Velocity** toolbar, click  **Plot**.

Pressure (Cylindrical), Velocity (Cylindrical)

- 1 In the **Model Builder** window, under **Results** > **Unwrapped Velocity**, Ctrl-click to select **Pressure (Cylindrical)** and **Velocity (Cylindrical)**.
- 2 Right-click and choose **Duplicate**.

Pressure (2-lobe)

- 1 In the **Settings** window for **Surface**, type Pressure (2-lobe) in the **Label** text field.
- 2 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb4)**.
- 3 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 4 Locate the **Plot Array** section. In the **Row index** text field, type 3.

Velocity (2-lobe)

- 1 In the **Model Builder** window, click **Velocity (Cylindrical) 1**.
- 2 In the **Settings** window for **Arrow Surface**, locate the **Data** section.
- 3 From the **Dataset** list, choose **Surface (hjb4)**.
- 4 In the **Label** text field, type Velocity (2-lobe).
- 5 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Velocity (Cylindrical)**.
- 6 Locate the **Plot Array** section. In the **Row index** text field, type 3.
- 7 In the **Unwrapped Velocity** toolbar, click  **Plot**.

Pressure (Cylindrical), Velocity (Cylindrical)

- 1 In the **Model Builder** window, under **Results** > **Unwrapped Velocity**, Ctrl-click to select **Pressure (Cylindrical)** and **Velocity (Cylindrical)**.
- 2 Right-click and choose **Duplicate**.

Pressure (3-lobe LOP)

- 1 In the **Settings** window for **Surface**, type Pressure (3-lobe LOP) in the **Label** text field.
- 2 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb5)**.
- 3 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 4 Locate the **Plot Array** section. In the **Column index** text field, type 1.

Velocity (3-lobe LOP)

- 1 In the **Model Builder** window, under **Results** > **Unwrapped Velocity** click **Velocity (Cylindrical) 1**.
- 2 In the **Settings** window for **Arrow Surface**, type Velocity (3-lobe LOP) in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb5)**.
- 4 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Velocity (Cylindrical)**.
- 5 Locate the **Plot Array** section. In the **Column index** text field, type 1.
- 6 In the **Unwrapped Velocity** toolbar, click  **Plot**.

Pressure (Cylindrical), Velocity (Cylindrical)

- 1 In the **Model Builder** window, under **Results** > **Unwrapped Velocity**, Ctrl-click to select **Pressure (Cylindrical)** and **Velocity (Cylindrical)**.
- 2 Right-click and choose **Duplicate**.

Pressure (3-lobe LBP)

- 1 In the **Settings** window for **Surface**, type Pressure (3-lobe LBP) in the **Label** text field.
- 2 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb6)**.
- 3 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 4 Locate the **Plot Array** section. In the **Row index** text field, type 1.
- 5 In the **Column index** text field, type 1.

Velocity (3-lobe LBP)

- 1 In the **Model Builder** window, under **Results** > **Unwrapped Velocity** click **Velocity (Cylindrical) I**.
- 2 In the **Settings** window for **Arrow Surface**, type Velocity (3-lobe LBP) in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb6)**.
- 4 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Velocity (Cylindrical)**.
- 5 Locate the **Plot Array** section. In the **Row index** text field, type 1.
- 6 In the **Column index** text field, type 1.
- 7 In the **Unwrapped Velocity** toolbar, click  **Plot**.

Pressure (Cylindrical), Velocity (Cylindrical)

- 1 In the **Model Builder** window, under **Results** > **Unwrapped Velocity**, Ctrl-click to select **Pressure (Cylindrical)** and **Velocity (Cylindrical)**.
- 2 Right-click and choose **Duplicate**.

Pressure (4-lobe LOP)

- 1 In the **Settings** window for **Surface**, type Pressure (4-lobe LOP) in the **Label** text field.
- 2 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb7)**.
- 3 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 4 Locate the **Plot Array** section. In the **Row index** text field, type 2.
- 5 In the **Column index** text field, type 1.

Velocity (4-lobe LOP)

- 1 In the **Model Builder** window, under **Results** > **Unwrapped Velocity** click **Velocity (Cylindrical) 1**.
- 2 In the **Settings** window for **Arrow Surface**, type **Velocity (4-lobe LOP)** in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb7)**.
- 4 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Velocity (Cylindrical)**.
- 5 Locate the **Plot Array** section. In the **Row index** text field, type 2.
- 6 In the **Column index** text field, type 1.
- 7 In the **Unwrapped Velocity** toolbar, click  **Plot**.

Pressure (Cylindrical), Velocity (Cylindrical)

- 1 In the **Model Builder** window, under **Results** > **Unwrapped Velocity**, Ctrl-click to select **Pressure (Cylindrical)** and **Velocity (Cylindrical)**.
- 2 Right-click and choose **Duplicate**.

Pressure (4-lobe LBP)

- 1 In the **Settings** window for **Surface**, type **Pressure (4-lobe LBP)** in the **Label** text field.
- 2 Locate the **Data** section. From the **Dataset** list, choose **Surface (hjb8)**.
- 3 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Pressure (Cylindrical)**.
- 4 Locate the **Plot Array** section. In the **Row index** text field, type 3.
- 5 In the **Column index** text field, type 1.

Velocity (4-lobe LBP)

- 1 In the **Model Builder** window, click **Velocity (Cylindrical) 1**.
- 2 In the **Settings** window for **Arrow Surface**, locate the **Data** section.
- 3 From the **Dataset** list, choose **Surface (hjb8)**.
- 4 In the **Label** text field, type **Velocity (4-lobe LBP)**.
- 5 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Velocity (Cylindrical)**.
- 6 Locate the **Plot Array** section. In the **Row index** text field, type 3.
- 7 In the **Column index** text field, type 1.

Unwrapped Velocity

In the **Model Builder** window, click **Unwrapped Velocity**.

Table Annotation 1

- 1 In the **Unwrapped Velocity** toolbar, click  **More Plots** and choose **Table Annotation**.

- 2 In the **Settings** window for **Table Annotation**, locate the **Data** section.
- 3 From the **Source** list, choose **Local table**.
- 4 In the table, enter the following settings:

x-coordinate	y-coordinate	Annotation
$Rj \cdot \pi$	-H	Cylindrical
$Rj \cdot \pi$	2*H	Elliptical
$Rj \cdot \pi$	5*H	Split halves
$Rj \cdot \pi$	8*H	2-lobe
$3 \cdot Rj \cdot \pi + 2 \cdot H$	-H	3-lobe (LOP)
$3 \cdot Rj \cdot \pi + 2 \cdot H$	2*H	3-lobe (LBP)
$3 \cdot Rj \cdot \pi + 2 \cdot H$	5*H	4-lobe (LOP)
$3 \cdot Rj \cdot \pi + 2 \cdot H$	8*H	4-lobe (LBP)

- 5 Locate the **Coloring and Style** section. Clear the **Show point** checkbox.
- 6 From the **Anchor point** list, choose **Center**.
- 7 In the **Unwrapped Velocity** toolbar, click  **Plot**.
- 8 Click the  **Zoom Extents** button in the **Graphics** toolbar.

Unwrapped Velocity

In the **Model Builder** window, collapse the **Results > Unwrapped Velocity** node.

Unwrapped Plots (hjb2), Unwrapped Plots (hjb3), Unwrapped Plots (hjb4), Unwrapped Plots (hjb5), Unwrapped Plots (hjb6), Unwrapped Plots (hjb7), Unwrapped Plots (hjb8)

Delete unnecessary plots.

- 1 In the **Model Builder** window, under **Results**, Ctrl-click to select **Unwrapped Plots (hjb2)**, **Unwrapped Plots (hjb3)**, **Unwrapped Plots (hjb4)**, **Unwrapped Plots (hjb5)**, **Unwrapped Plots (hjb6)**, **Unwrapped Plots (hjb7)**, and **Unwrapped Plots (hjb8)**.
- 2 Right-click and choose **Delete**.

