DyRoBeS©_BePerf Table of Contents

Other Topics

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Introduction

DyRoBeS©_BePerf computer program has been developed to analyze the **Be**aring steady state and dynamic **Perf**ormance of fixed lobe, flexural pad, and tilting pad hydrodynamic journal bearings, and gas lubricated journal bearings based on the Finite Element Method (FEM). In addition to journal bearing analysis, the program also performs thrust bearing analysis, lubricant properties analysis, and oil flow calculation. The acronym, DyRoBeS©, denotes **Dy**namics of **Ro**tor **Be**aring **S**ystems.

The program contains extensive modeling, analysis, and post-processing capabilities. This Window™ based software is very user friendly and easy to use. The operation is entirely consistent with industrial standard operation in Window environment. Help can be obtained at any time by pressing <F1> key.

The governing equation for pressure distribution in a fluid film journal bearing is incompressible Reynolds equation which is derived from the Navier-Stokes equation, as expressed below. The fluid film forces acting on the journal are determined by application of boundary conditions and integration of pressure distribution. It is an iterative process until the convergence criterion is satisfied. Once the static equilibrium is found, the bearing static performance, such as bearing eccentricity ratio, attitude angle, minimum film thickness, maximum film pressure, frictional power loss, oil flow rate, etc., can be easily determined. Under dynamic conditions, the journal is oscillating with small amplitudes around the static equilibrium position. The eight bearing dynamic coefficients (stiffness and damping) are obtained by solving the perturbed pressure equations.

$$\frac{\partial}{\partial x}\left(\frac{1}{G_x}\frac{h^3}{\mu}\frac{\partial P}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{1}{G_y}\frac{h^3}{\mu}\frac{\partial P}{\partial y}\right)=\frac{U_x}{2}\frac{\partial h}{\partial x}+\frac{U_y}{2}\frac{\partial h}{\partial y}+\frac{\partial h}{\partial t}$$

where x is in the axial direction and y is in the circumferential direction. Gx and Gy called the turbulent flow coefficients are the correctional terms of viscosity caused by the turbulent diffusion:

$$G_x = 12 + 0.0043\,\mathrm{Re}^{0.96} \quad \text{Axial direction}$$

$$G_y = 12 + 0.0136\,\mathrm{Re}^{0.90} \quad \text{Circumferential direction}$$

$$\mathrm{Re} = \frac{\rho U h}{\mu} \quad \text{Local Reynolds number}$$

For laminar flow, Gx = Gy = 12. A critical parameter affected by turbulence is the shear stress acting on the shaft.

$$\tau_s = C_f\frac{\mu U}{h}+\frac{h}{2}\frac{\partial P}{\partial y}$$

$$C_f = 1 + 0.0012\,\mathrm{Re}^{0.94}$$

where Cf is the turbulent Couette shear stress factor. For laminar flow, Cf = 1.

The boundary conditions in the axial coordinate are that the pressure is ambient at the edges of the bearing pad. The Swift-Stieber or Reynolds boundary conditions are applied in the circumferential coordinate. Film cavitation is considered and the transition boundary curve to the film rupture is determined by iteration.

The governing equation for pressure distribution in a gas/air lubricated journal bearing is compressible Reynolds equation.

$$\frac{\partial}{\partial x}\left(\frac{Ph^3}{12\mu}\frac{\partial P}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{Ph^3}{12\mu}\frac{\partial P}{\partial y}\right)=\frac{U}{2}\frac{\partial(Ph)}{\partial x}+\frac{\partial(Ph)}{\partial t}$$

This compressible Reynolds equation is more difficult to analyze due to the existence of the pressure (*P*) in each terms compared with the incompressible flow, which makes the problem non-linear. Weak formulation based on variational principle is applied for generating the finite element model for the boundary value problems. Since this is a nonlinear problem, Newton-Raphson's iterative scheme is utilized to solve the pressure increment, or pressure correction.

The solutions techniques for the incompressible and compressible Reynolds equation are discussed in the book – **Introduction to Dynamics of Rotor-Bearing Systems** by W. J. Chen and E. J. Gunter, 2005.

The BePerf program consists of seven primary functions:

1. Fixed Lobe Journal Bearing

2. Tilting Pad Journal Bearing

3. Floating Ring Bearing

4. Gas Journal Bearing

5. Thrust Bearing

6. Hydrostatic Bearing

7. Lubricant

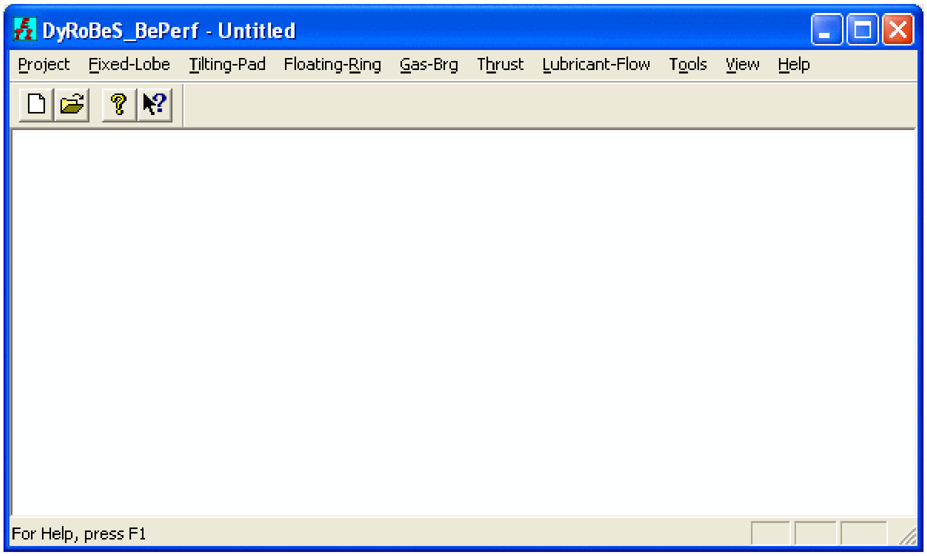
8. Flow Calculation

See also DyRoBeS©_Rotor.

Getting Started

When you start the program, the following Main Frame Window appears on the screen. There are many ways to invoke a program. You can refer the Window Help manual for details. Depending upon your Window setup and the time when you execute the DyRoBeS©, your screen may possibly look different. The entire user’s manual can be viewed by click on the Help topics under the Help menu. Or you can press <F1> anywhere and anytime to get help. In the help, you can click on any **Green** font topic to lead you to that topic. Click on How to Use Help now to see how it works.

You can also use the Context Help command to obtain help on some portion of DyRoBeS©_BePerf. When you choose the Toolbar's Context Help button, the mouse pointer will change to an arrow and question mark. Then click somewhere in the DyRoBeS©_BePerf window, such as another Toolbar button. The Help topic will be shown for the item you clicked.



Help Topics

Use this command to display the opening screen of Help. From the opening screen, you can jump to step-by-step instructions for using DyRoBeS© and various types of reference information.

Once you open Help, you can click the **Contents** button to open the DyRoBeS© User's Manual.

The help offers you an **Index** to topics on which you can get help. You can also use **Find** to find any particular word that you like to get help. You can press <F1> at any time to get help.

Use the **Context Help** command to obtain help on some portion of DyRoBeS©. When you choose the Toolbar's Context Help button, the mouse pointer will change to an arrow and question mark. Then click somewhere in the DyRoBeS© window, such as another Toolbar button. The Help topic will be shown for the item you clicked.

When you are in the help screen, you can click on any **GREEN** font topics, this will lead you to that topic.

Project

A **Project** is also called a **File** or a **Document**, which contains the bearing geometric and operating data. All the options under the Project are self-explanatory. You can start with a new file, open an existing file, or close a file. These functions are also available in the analysis input dialog box. Eight most recently used files are listed for quick selection.

Since the program can perform fixed lobe and tilting pad, dimensional and non-dimensional analyses, floating ring bearing, gas bearing, and thrust bearing analyses. Several file extensions are used for different bearing types. They are:

LDI for Fixed Lobe Dimensional Analysis

LNI for Fixed Lobe Non-Dimensional Analysis

TDI for Tilting Pad Dimensional Analysis

TNI for Tilting Pad Non-Dimensional Analysis

FRB for Floating Ring Bearing

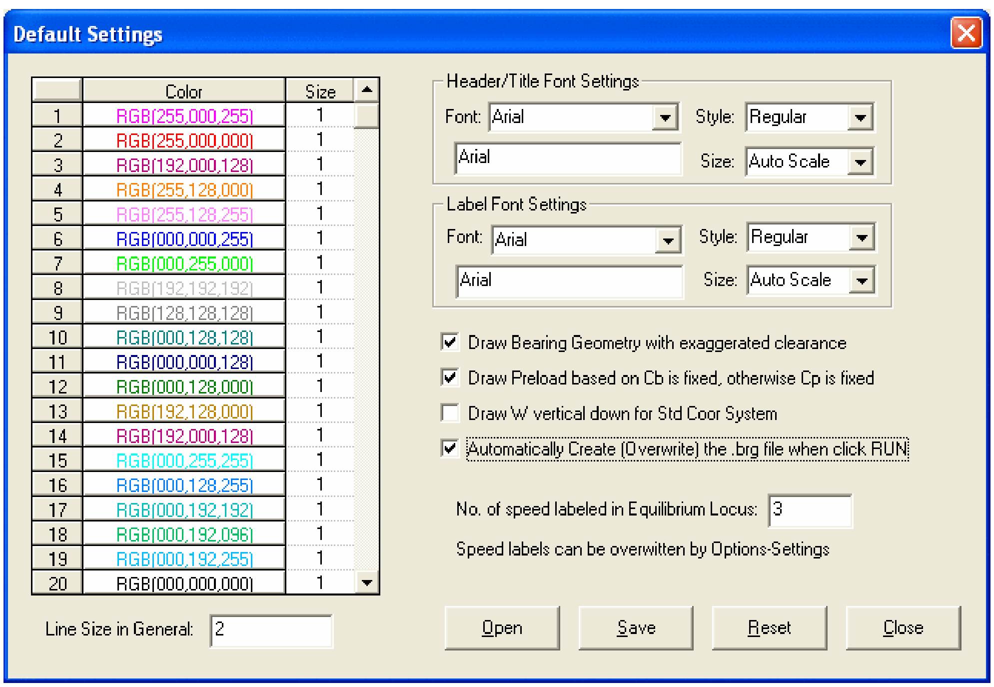
GDI for Gas Journal Bearing

TLT for tapered land Thrust Bearing

TPT for tilting pad Thrust Bearing

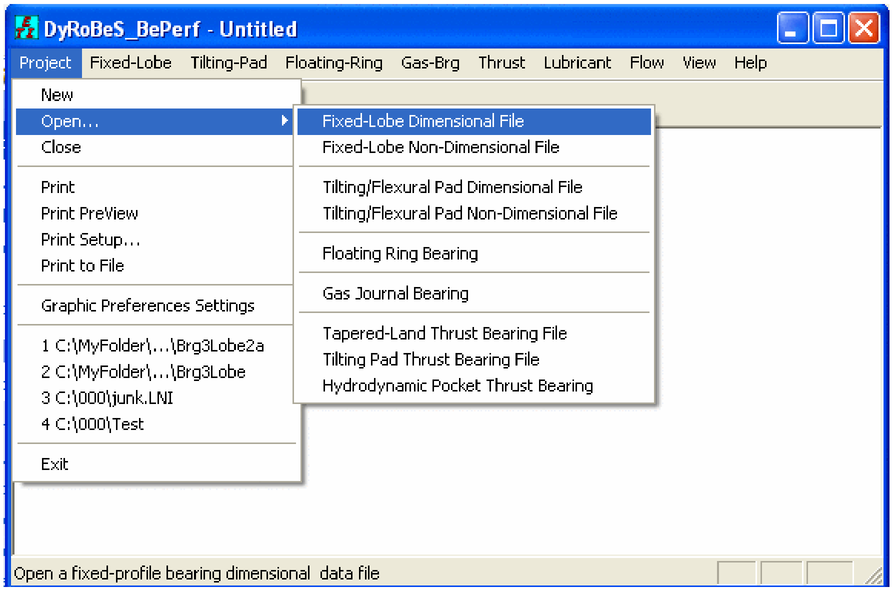
POC for pocket Thrust Bearing

HSJ for Hydrostatic Bearing



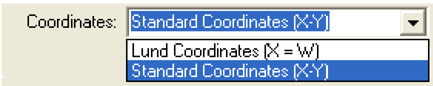
Graphic Preferences Settings allows you to set your own preferences settings for many graphic features. You can save these settings into a preference file, such as one for screen display, one for printer output. To change color for a specific setting, simply click the RGB color value to open the Color Dialog Box for selection, as illustrated in the following figure. The startup preferences file named MyPreferences.bpf will be automatically opened and applied when DyRoBeS-BePerf is activated. This will be your own default startup file. If MyPreferences.bpf file does not exist, the default settings by ETI will be applied. You can also restore the ETI defaults by clicking the Reset button.

You do not have to enter the file extension anywhere. The program takes care of this extension. You can open all the different bearing files for different analyses at the same time. The filename for the most recent one will be displayed in the frame title. If no file is open, then Untitled is displayed in the frame title as shown below:



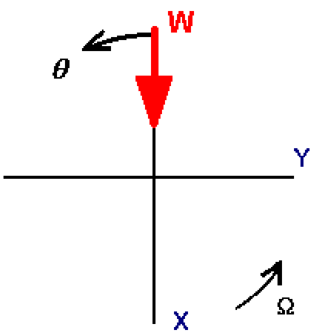
Coordinate Systems

There are two coordinate systems are commonly used by bearing analysts and rotordynamicists:

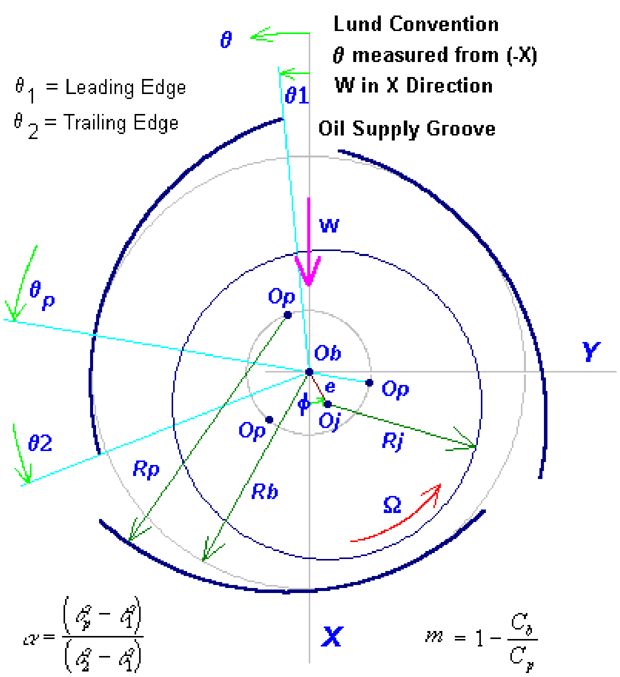


1. Lund Convention

The first Cartesian coordinate system (*X, Y, Z*) used to describe the bearing orientation and geometry is shown in the following figure. The coordinate system is commonly used by the bearing analysts to study the bearing performance. The *X*-axis is chosen to be collinear with the bearing load vector (*W*). Note that *X* axis does not have to be vertically down as shown in this sketch, it can be in any direction as long as *X* axis being aligned with the bearing load vector (*W*), i.e., the load vector can be in any direction. *Y*-axis is perpendicular with the *X*-axis in the direction of shaft rotation. θ is the circumferential angular coordinate measured from the negative load vector (negative *X* axis) in the direction of shaft rotation.



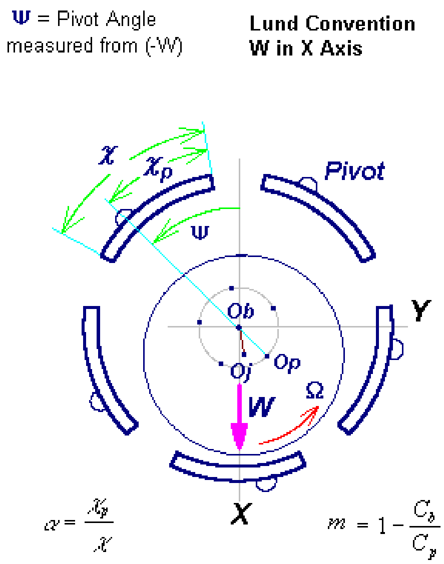
A typical 3 lobe bearing using this coordinate system is shown:



The lobe leading and trailing edges for a 20-degree oil supply groove are:

Lobe Number	Leading Edge	Trailing Edge
1	10	110
2	130	230
3	250	350

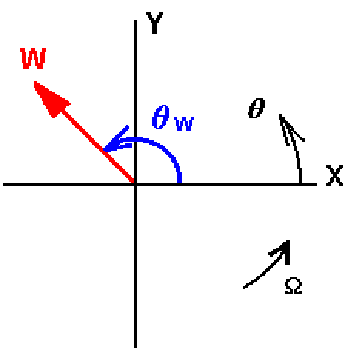
A typical 4-pads tilting pad bearing using this coordinate system is shown:



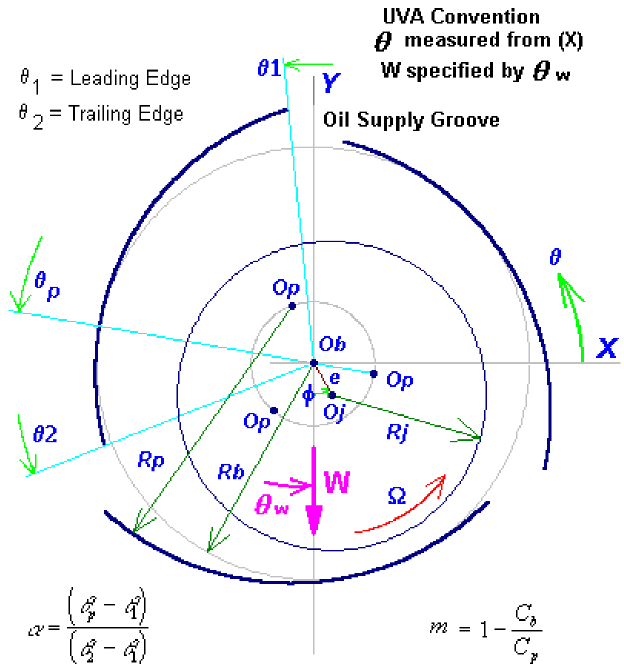
Note that the tilting pad pivot angle is measured from the Negative Load Vector in Lund's Coordinate System.

2. Standard Convention

The second Cartesian coordinate system (*X,Y,Z*) used to describe the bearing geometry, shown in the following figure, is a more conventional standard coordinate system and is commonly used by rotor dynamics analysts for the rotor dynamics study. X-axis is to the right and Y is to the top. The circumferential angular coordinate, θ, is measured from the positive *X*-axis in the direction of shaft rotation. The load vector (*W*) can be in any direction with respect to the *X*-axis by a specified angle.



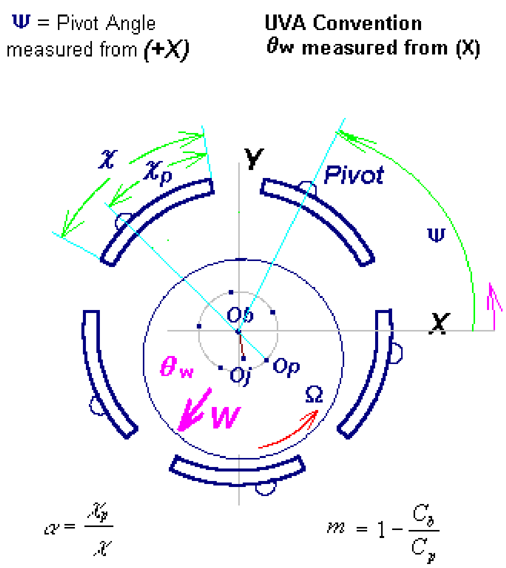
A typical 3 lobe bearing using this coordinate system is shown:



The lobe leading and trailing edges for a 20-degree oil supply groove now are:

Lobe Number	Leading Edge	Trailing Edge
1	100	200
2	220	320
3	340	440

A typical 4-pads tilting pad bearing using this coordinate system is shown:



Note that the tilting pad pivot angle is measured from the Positive X-axis in the Standard Coordinate System. The load vector is specified by an angle (θw) measured from the X-axis.

Each coordinate system has its own strength and weakness. The first coordinate system, commonly referred to be Lund's convention, describes the bearing geometry and load vector orientation by aligning the *X*-axis with the load vector. It is convenient in the bearing analysis. The disadvantage is that the bearing geometric data are dependent upon the loading direction. For a gear driven rotor, load vector can be in any direction due to the power level (loading condition) of the rotor. Then, for the same bearing analyzed with different loading direction, the bearing geometric data (leading and trailing edges of the lobe) must be re-entered. For the second coordinate system, the bearing geometric data are independent upon the load vector. Additional parameter is required to locate the load vector. The loading direction is specified by an angle. However, it is desirable to know the stiffness and damping coefficients in the loading direction and it’s perpendicular axis. Therefore, a coordinate transformation may be needed to transform the bearing coefficients to the loading direction.

Fixed Lobe Journal Bearing

This module performs the fixed lobe dimensional and non-dimensional analyses and displays results in text and graphic forms. The bearing stiffness and damping coefficients calculated from dimensional analysis can be output as a bearing file to be readily used by DyRoBeS©_Rotor. All the input and output data can be viewed from the Text Output option, while only the key output parameters are summarized in the Tabulated List and can be displayed in graphic forms.

Fixed Lobe Bearing Geometry

Parameters used to describe the bearing geometry are defined in this section.

Fixed Lobe Dimensional Analysis

The dimensional analysis includes Constant Viscosity analysis and Heat Balance analysis. For Constant Viscosity analysis, user must input a lubricant dynamic viscosity and no temperature rise will be calculated. For Heat Balance analysis, user must select a lubricant type and input the lubricant inlet temperature. The operating and maximum film temperatures will be calculated based on the heat balance method.

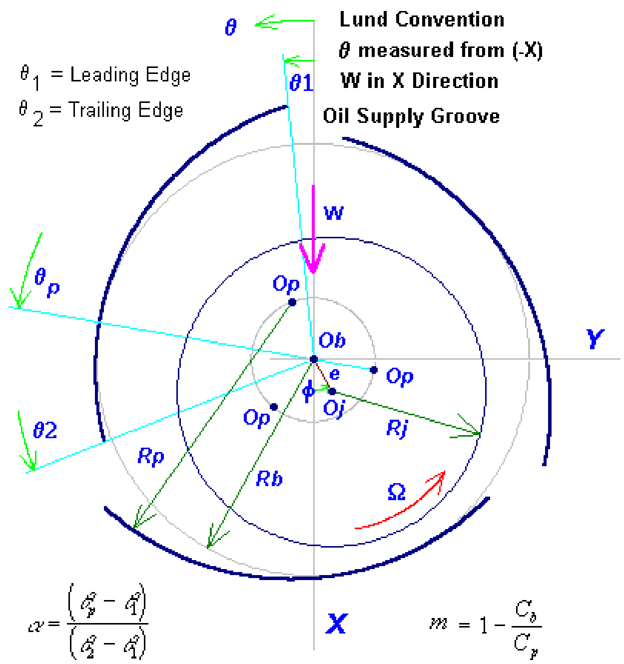
Fixed Lobe Non-Dimensional Analysis

The non-dimensional analysis is performed based on the given bearing eccentricity ratios.

See also Coordinate Systems, Tilting Pad Journal Bearing, Examples, and Nomenclature.

Fixed Lobe Bearing Geometry

The fixed lobe bearing is made up of a number of fixed circular arc segments called **lobes** or **pads**. The lobes are separated by axial lubricant supply grooves. A three-lobe bearing is sketched to illustrate the parameters used to describe the bearing geometry. Clearances are exaggerated in the figure for illustrative purposes.



Two coordinate systems can be used in *DyRoBeS©_BePerf* and they are described in the Coordinate Systems Section.

The journal static equilibrium position is defined by the journal eccentricity (e) and attitude angle (ϕ). Under dynamic conditions, the journal is oscillating with small amplitudes around this equilibrium position. However, the bearing dynamic coefficients (stiffness and damping coefficients) can be calculated in any coordinate system (x,y,z) by specifying a Coefficient Coordinate Angle in the bearing input data. The Coordinate Angle is measured from the X-axis (used to describe the bearing geometry and the load vector) to x-axis (used to describe the bearing coefficients). See Coefficients Coordinate Angle.

The bearing radius at minimum clearance (Rb) for a centered shaft can be described as the radius of the largest shaft that could be inserted into the bearing. A circle drawn based on Rb is referred to as a bearing base circle.

For a positive preloaded bearing, pad radius (Rp) is greater than bearing radius (Rb) and the circular pads are moved inward the bearing center. Thus, when the journal is centered in the bearing, the pads are loaded by geometry effect. The fraction of the distance between pad center of curvature and bearing center to pad radial clearance is called **Preload**:

$$m = \frac{\left(C_p - C_b\right)}{C_p} = 1 - \frac{C_b}{C_p}$$

when the preload is zero, the pad centers of curvature coincide with the bearing center and the bearing is cylindrical. When the preload has a value of 1, the shaft touches all the pads and the bearing minimum radial clearance is zero. Typical preload value for a fixed lobe bearing ranges from 0.4 to 0.75.

Another key parameter used to describe the preloaded bearing geometry is the fraction of converging pad length to the full arc length. This parameter is called **Offset** or **Tilt** and is given by the following expression:

$$\alpha = \frac{\left(\theta_p - \theta_1\right)}{\left(\theta_2 - \theta_1\right)} = \frac{\chi_p}{\chi}$$

The value of offset is meaningful only when the bearing is preloaded. At $\theta\, p$, the bearing has a minimum clearance for a centered shaft and the lobe arc intersects with bearing base circle.

A lobe which is symmetrically located with respect to the centered journal, i.e. offset = 0.5, is defined as having no **lobe tilt** and the clearance space has equal convergent and divergent arcs. An offset of 0.5 is commonly used to accommodate the reversal rotation of the shaft and also to avoid the problem of the bearing being installed backwards. An offset less than 0.5 increases the diverging film thickness and is not desirable. Typical offset ranges from 0.5 to 1.0. For an offset halves bearing, the offset could be larger than 1, depending on the position of pad center of curvature.

Several commonly used bearings are shown in the figures with clearance exaggerated for clarity. The capability of the program is not limited to these bearings.

Typical Bearing Types

Plain Cylindrical Journal Bearing

Partial Arc Bearing

Two Axial Grooves Bearing

Elliptical (Lemon Bore) Bearing

Offset Halves Bearing

Three Lobes Bearing

Four Lobes Bearing

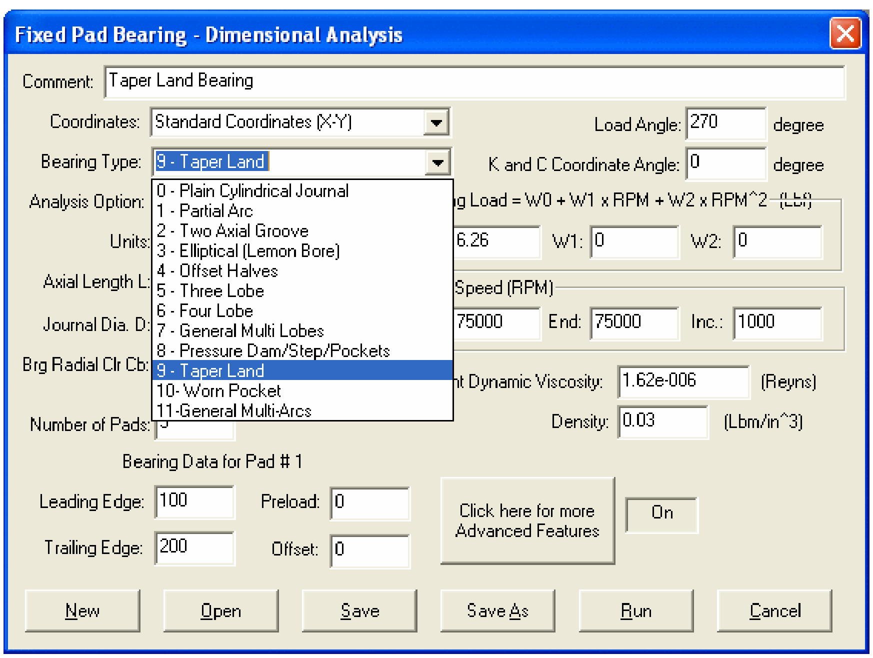
Pressure Dam Bearing

Multi-Pocket Bearing

Step Bearing

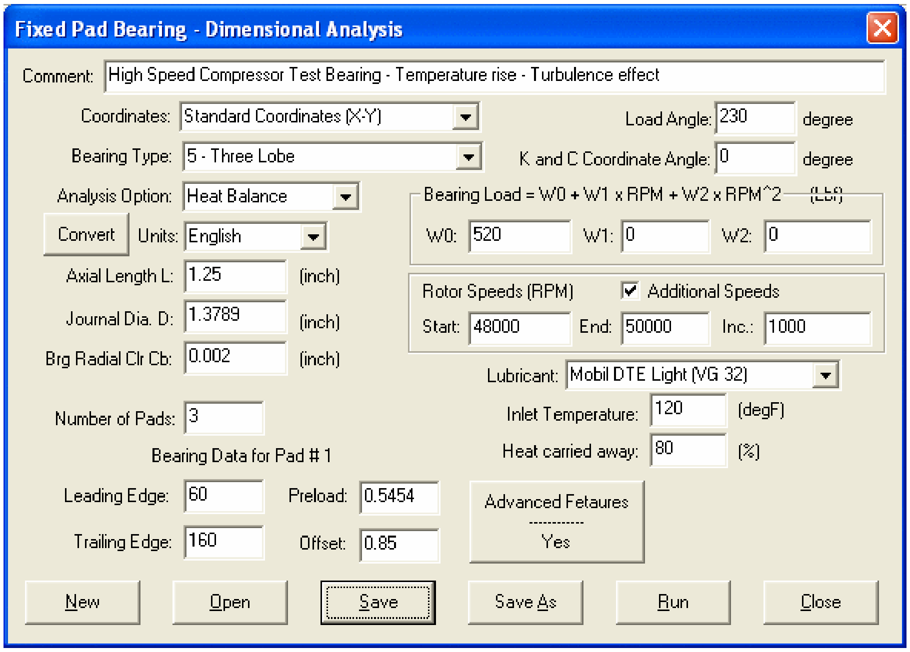
Taper Land Bearing

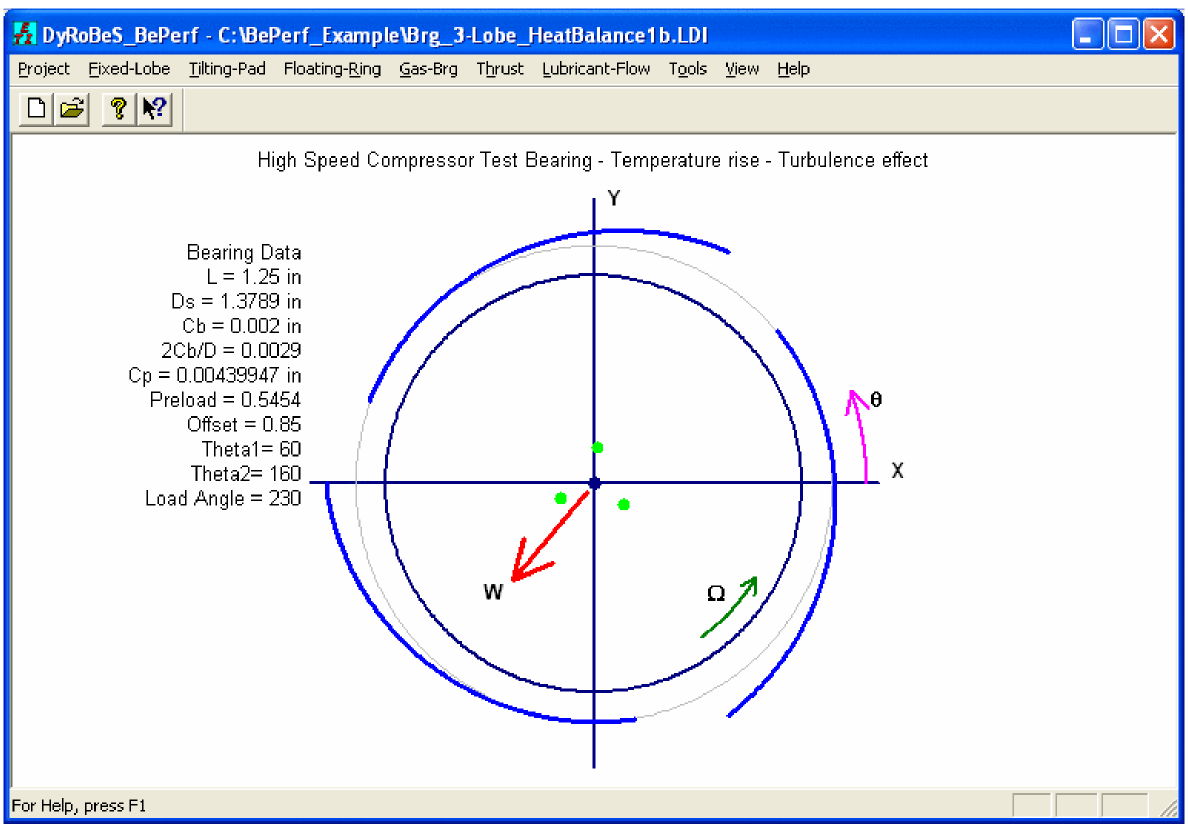
See also Coordinate Systems, Nomenclature, Fixed Lobe Dimensional Analysis, Fixed Lobe Non-Dimensional Analysis, Examples.



Fixed Lobe Bearing Dimensional Analysis

The input screen for the fixed lobe bearing dimensional analysis is shown below and the input parameters are also described below.



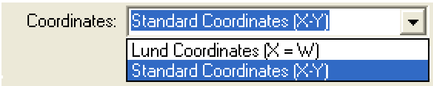


Comment

This is used to describe the bearing under study.

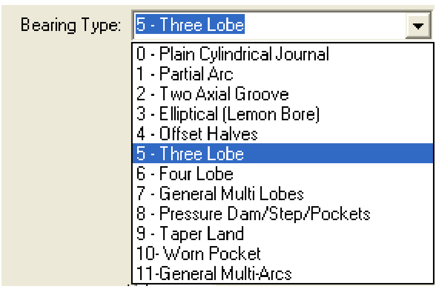
[Coordinates](#)

Two coordinate systems can be used to describe the bearing geometry. One is the Lund coordinate system where the load vector is collinear with the X-axis. One is the standard coordinate system where X-axis is to the right and Y-axis is to the top. The load vector direction is specified by an angle. Click **here** to see more description on coordinate systems.



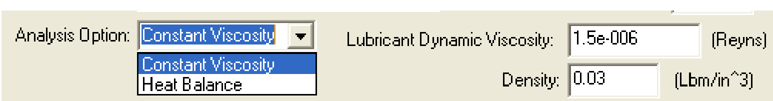
Bearing Type

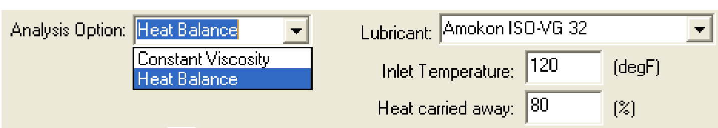
Several bearing types are provided in the list for selection. If the bearing under study is not in the list, select the General Fixed Profile type and input the bearing geometrical data. This selection has been made for the convenience of the user since it allows the program to supply the user with typical defaults in Number of Pads, Leading and Trailing Edges, Preload, and Offset. You are free to make your changes on these default data to suit for your need. Some special bearing types are also included, such as pressure dam bearings, step bearings, multi-pockets bearings, and taper land bearings, etc. These bearings have discontinuity in the bearing clearance and require additional inputs, which are under the Advanced Features button.



Analysis Option

The analysis can be performed in either Constant Viscosity or Heat Balance option. Depending upon the analysis type, the input dialog box changes accordingly. For Constant Viscosity analysis, a non-zero lubricant dynamic viscosity is required, and a lubricant density is needed if turbulence effect is considered. For Heat Balance option, user must select a lubricant from the list, input the oil inlet temperature, and estimate the percentage heat carried away by oil. The operating and maximum film temperatures will be calculated based on heat balance method.





Units

Two systems of units are provided, English or Metric units. See also Units.

Convert Button

The covert button allows you to convert the bearing input data from English to Metric or vice versa between two unit systems.

Axial Length (L)

Bearing (babbitt) axial length.

Journal Diameter (D)

Journal (shaft) diameter.

Bearing Radial Clearance (Cb)

Bearing assembled radial clearance. Cb = (Rb-Rs)

Number of Pads (Npad)

Number of lobes (pads) separated by oil supply grooves. If all the pads (lobes) are identical, only the first pad data are required. If there are not identical, or the **Advanced Features** are checked, then, each pad (lobe) data must be entered separately.

Pad #1 Leading Edge (θ_1) and Trailing Edge (θ_2)

The Leading Edge and Trailing Edge are the angles in degrees from the reference axis to the leading and trailing edges of the first pad. For the Lund Coordinate System, the reference axis is the negative Load vector (-W). For Standard Coordinate System, the reference axis is the positive X-axis (X).

Preload (*m*)

$$m = \frac{\left(C_p - C_b\right)}{C_p} = 1 - \frac{C_b}{C_p}$$

Typical Preload value for a fixed lobe bearing ranges from 0.4 to 0.75.

Offset

$$\alpha = \frac{\left(\theta_p - \theta_1\right)}{\left(\theta_2 - \theta_1\right)} = \frac{\chi_p}{\chi}$$

where θ_p, is the angle from the reference axis to the line connecting the bearing center and the pad center of curvature. At this point, the bearing has a minimum clearance for a centered shaft and the lobe arc intersects with bearing base circle. Typical Offset value for a fixed lobe bearing ranges from 0.5 to 1.0. Offset is meaningful only when preload is not zero.

Load Angle

The load angle is needed (and shown in the input screen) only when the Standard Coordinate system is selected. When Lund coordinate system is selected, the load vector is the same as the X-axis.

Coefficients Coordinate Angle

The coordinate system (*x,y,z*) used to describe the bearing dynamic coefficients (stiffness and damping coefficients) can be different from the (*X,Y,Z*) coordinate system used to define the bearing geometry. The Coefficients Coordinate Angle is the angle measured from the *X*-axis. For Lund Coordinate System, 0 degree (i.e., x axis is in the loading direction) and 90 degrees (i.e., negative y axis is in the loading direction) are commonly used.

Bearing Load (W)

The bearing load is expressed as a second order polynomial function of rotor speed (rpm). This provides an opportunity to approximate the variation in load with speed.

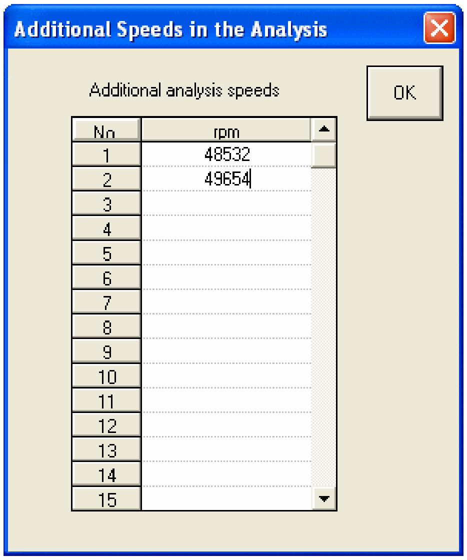
$$W = W_0 + W_1 \times \text{rpm} + W_2 \times \text{rpm}^2$$

Rotor Speed (rpm)

Start, End and Increment Speeds specify a list of speeds at which calculations are to be performed.

Additional Speeds

If the Additional Speeds is checked, additional speeds can be entered in additional to the speeds given by the Start, End and Increment Speeds.



Lubricant

This input is for **Heat Balance** analysis option only. If the lubricant used in the analysis is not in the list, you can enter it from the Edit Lubricant Library under the Lubricant menu.

Inlet Temperature

This input is for **Heat Balance** analysis option. The lubricant inlet (supply) temperature.

Percent Heat carried Away by Lubricant

This input is for **Heat Balance** analysis option. Default is 80 %. Typical value for fixed lobe bearings is between 80-90%. The heat generated in the bearing needs to be removed by lubricant and other means. Majority of the heat is removed by lubricant.

Lubricant Dynamic Viscosity

This input is for **Constant Viscosity** analysis option.

Lubricant Density

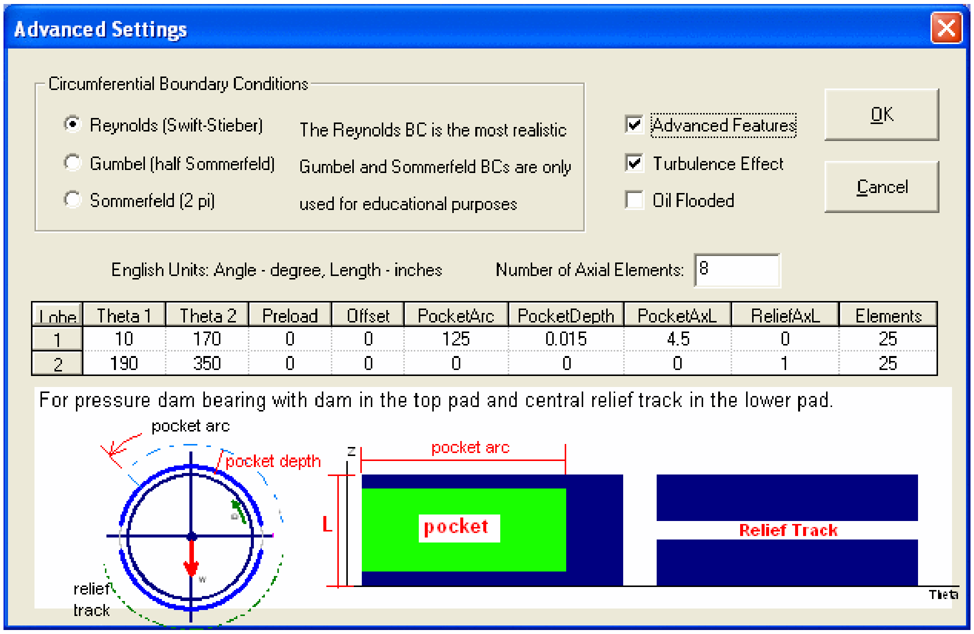
This input is for **Constant Viscosity** analysis option when the **Turbulence** effect is included. Turbulent effect is included in the Advanced Feature button.

Advanced Features

The advanced features allow you to include the turbulence effect, oil flooded, and types of boundary conditions in the circumferential direction. It also allows for the clearance discontinuity in the individual pad. The Advanced Feature must be checked (ON) for bearings with clearance discontinuity, such as Pressure Dam Bearing, Multi-Pocket Bearing, Step Bearing, and Taper Land Bearing. Also, for 3D pressure file plot, the Advanced Feature must be checked. Without Advanced Features, the pads are identical and no discontinuity in the bearing clearance for each pad. Therefore, only one (1) degree-of-freedom at each finite element node, that is, pressure is unknown at each finite element node without the Advanced Feature. However, with Advanced Features, the clearance can have sudden changes, such as pressure dam bearings and taper land bearings, therefore, three (3) degrees-of-freedom at each finite element node are assumed, that is, pressure, and pressure gradients in both axial and circumferential directions at each finite element node are unknown and are to be solved to accommodate the sudden changes in bearing clearance. With Advanced Features ON, the computational time will be greatly increased due to the increase of the degrees-of-freedom.

Although 3 types boundary conditions are provided, one should always use Reynolds boundary condition for design and practical purposes. Sommerfeld and half Sommerfeld (Gumbel) boundary conditions are only provided for educational and research purposes.

Pressure Dam Bearing



Advanced Settings

Circumferential Boundary Conditions

- Reynolds (Swift-Stieber)
- Gumbel (half Sommerfeld)
- Sommerfeld (2 pi)

The Reynolds BC is the most realistic
Gumbel and Sommerfeld BCs are only
used for educational purposes

- [x] Advanced Features
- [x] Turbulence Effect
- [ ] Oil Flooded

OK
Cancel

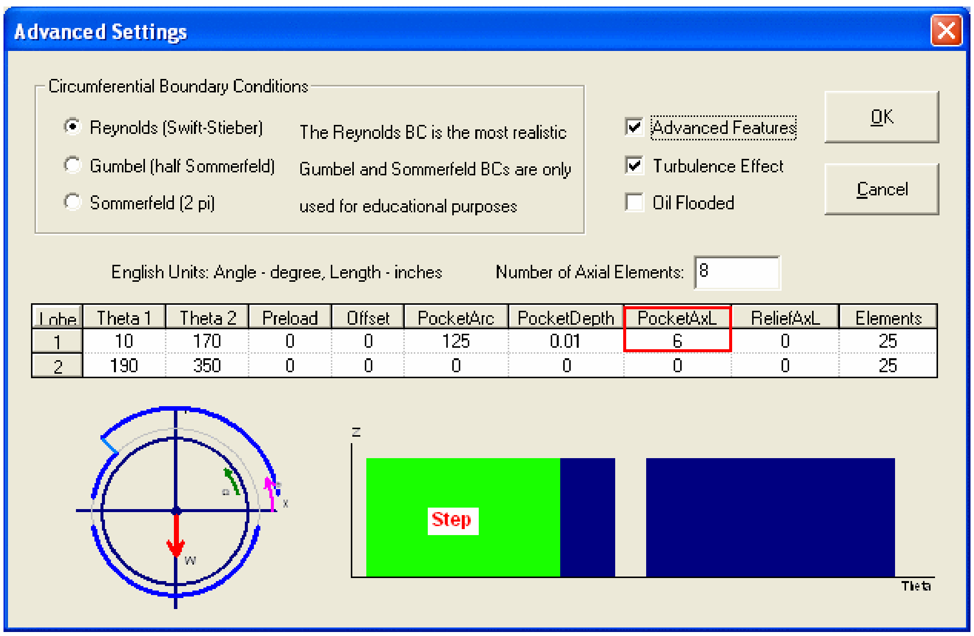
English Units: Angle - degree, Length - inches

Number of Axial Elements: 8

Lobe	Theta 1	Theta 2	Preload	Offset	PocketArc	PocketDepth	PocketAxL	ReliefAxL	Elements
1	10	170	0	0	125	0.015	4.5	0	25
2	190	350	0	0	0	0	0	1	25

For pressure dam bearing with dam in the top pad and central relief track in the lower pad.

When the PocketAxL = Bearing Axial Length, pressure dam becomes a step as shown below:



Advanced Settings

Circumferential Boundary Conditions

- Reynolds (Swift-Stieber)
- Gumbel (half Sommerfeld)
- Sommerfeld (2 pi)

The Reynolds BC is the most realistic
Gumbel and Sommerfeld BCs are only
used for educational purposes

- [x] Advanced Features
- [x] Turbulence Effect
- [ ] Oil Flooded

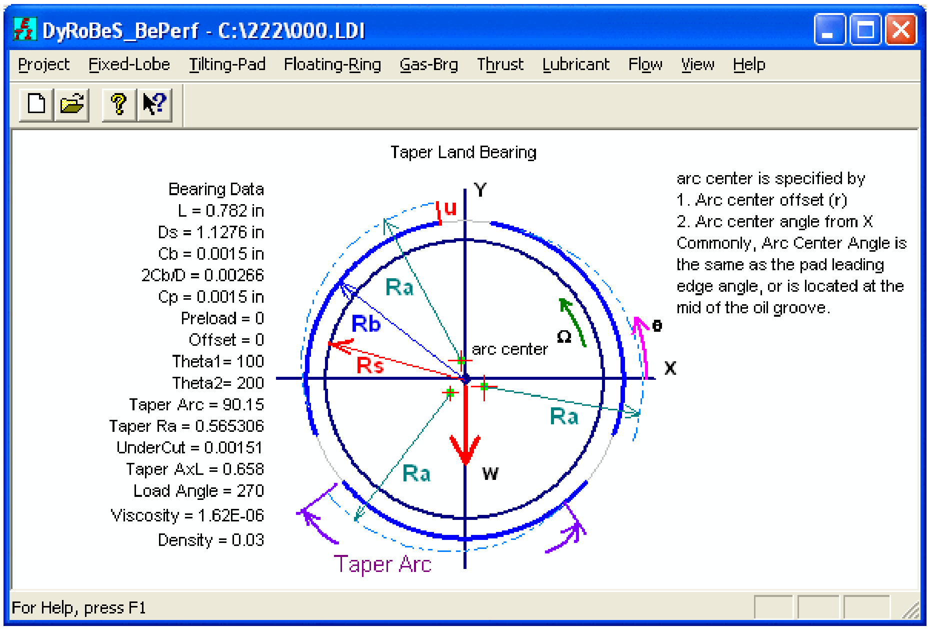
OK
Cancel

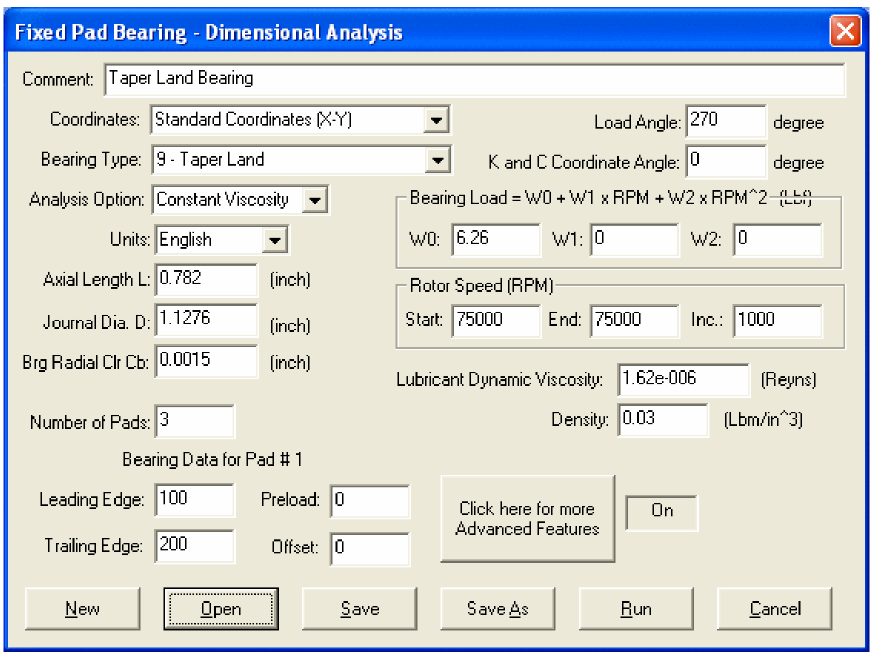
English Units: Angle - degree, Length - inches

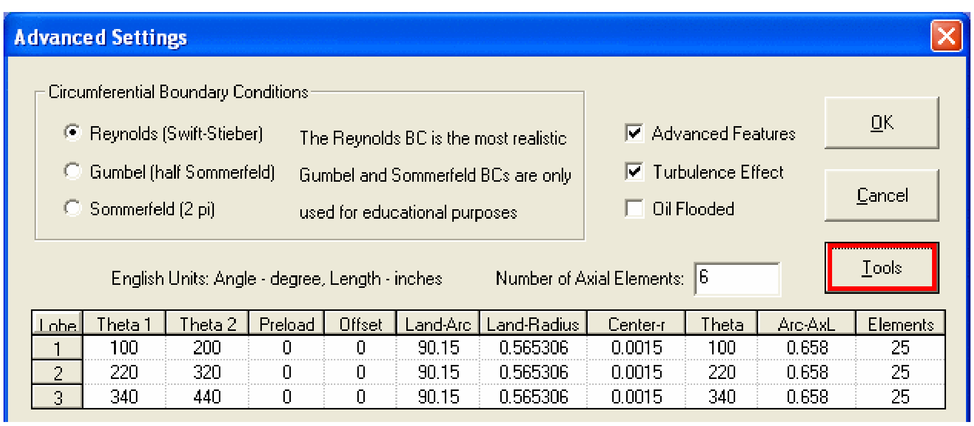
Number of Axial Elements: 8

Lobe	Theta 1	Theta 2	Preload	Offset	PocketArc	PocketDepth	PocketAxL	ReliefAxL	Elements
1	10	170	0	0	125	0.01	6	0	25
2	190	350	0	0	0	0	0	0	25

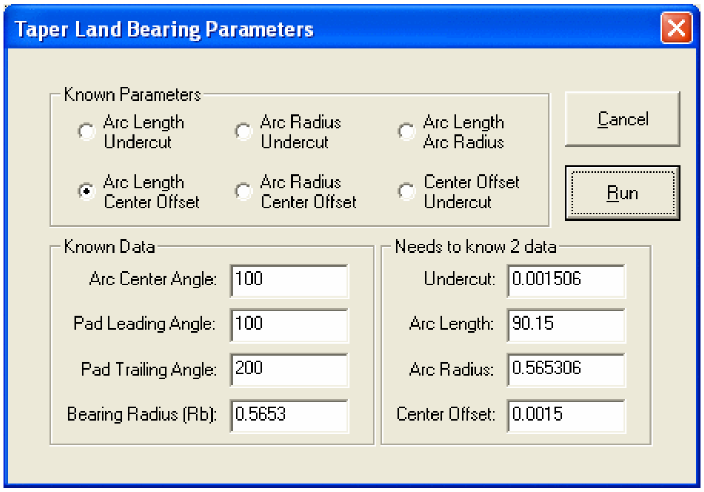
Taper Land Journal Bearing, click here for more descriptions on taper land bearings.



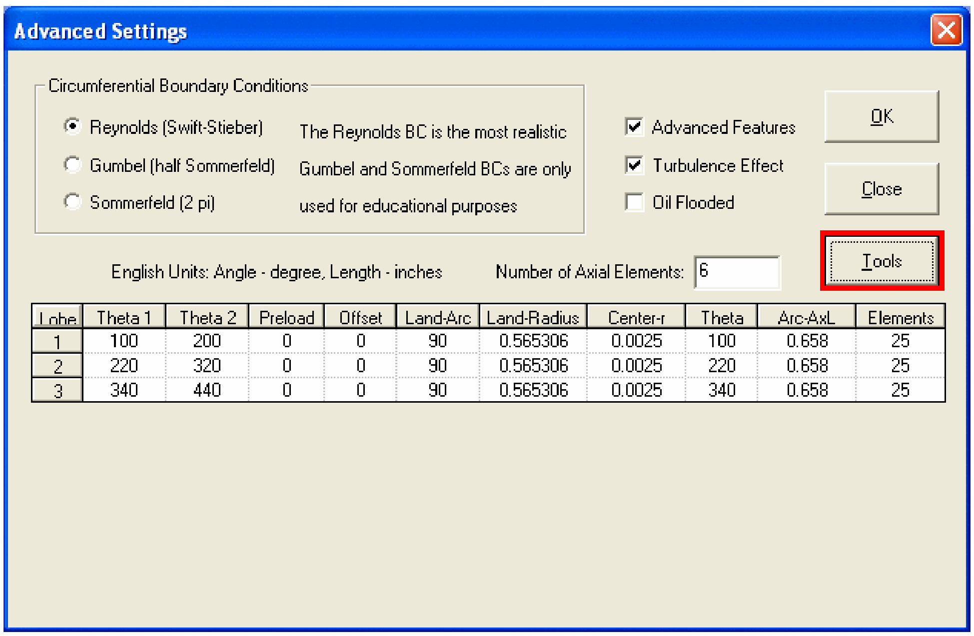


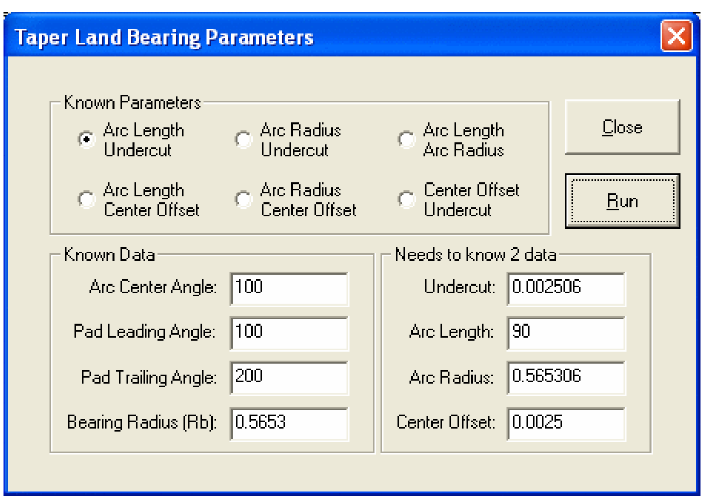


Lobe	Theta 1	Theta 2	Preload	Offset	Land-Arc	Land-Radius	Center-r	Theta	Arc-AxL	Elements
1	100	200	0	0	90.15	0.565306	0.0015	100	0.658	25
2	220	320	0	0	90.15	0.565306	0.0015	220	0.658	25
3	340	440	0	0	90.15	0.565306	0.0015	340	0.658	25



For Taper Land Bearing, the undercut and taper length are normally specified in the design process, however, the arc center and arc radius are typically specified in the manufacturing drawings. A Tools button is provided for this conversion.

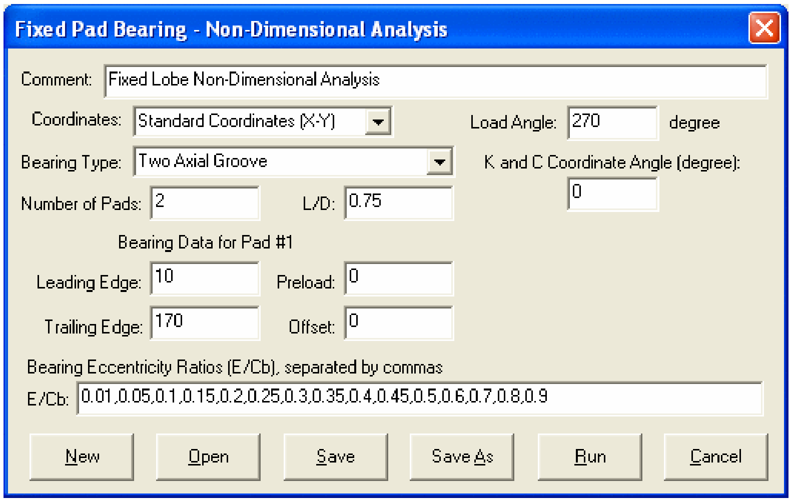




See also Coordinate Systems, Fixed Lobe Bearing Geometry, Fixed Lobe Non-Dimensional Analysis, Nomenclature, Examples, Units, Lubricant, Coefficients Coordinate Angle .

Fixed Lobe Bearing Non-Dimensional Analysis

The non-dimensional bearing analysis is performed based on the given bearing eccentricity ratios (*e*/*Cb*). The input eccentricity ratios are separated by a comma in the input string. For a given eccentricity ratio, an iterative procedure in determining the bearing attitude angle is repeated until the convergence criterion is satisfied. The input parameters are:



Bearing Type

Several bearing types are provided in the list for selection. If the bearing under study is not in the list, select the General Fixed Profile type and input the bearing geometrical data. This selection has been made for the convenience of the user since it allows the program to supply the user with typical defaults in Number of Pads, Leading and Trailing Edges, Preload, and Offset. You are free to make your changes on these default data to suit for your need.

Title

Length/Diameter Ratio (L/D)

Bearing Eccentricity Ratios (*e*/*Cb*) String

The eccentricity ratio is separated by a comma in the input string.

Number of Pads (Npad)

Coordinate Systems

Two coordinate systems can be used to describe the bearing geometry.

Pad #1 Leading Edge (θ_1) and Trailing Edge (θ_2)

The Leading Edge and Trailing Edge are the angles in degrees from the reference axis to the leading and trailing edges of the first pad. For the Lund Coordinate System, the reference axis is the negative Load vector (-W). For Standard Coordinate System, the reference axis is the positive X-axis (X).

Preload (m)

$$m = \frac{\left(C_p - C_b\right)}{C_p} = 1 - \frac{C_b}{C_p}$$

Typical Preload value for a fixed lobe bearing ranges from 0.4 to 0.75.

Offset (or Tilt)

$$\alpha = \frac{(\theta_p - \theta_1)}{(\theta_2 - \theta_1)} = \frac{\chi_p}{\chi}$$

where θ_p, is the angle from the reference axis to the line connecting the bearing center and the pad center of curvature. At this point, the bearing has a minimum clearance for a centered shaft and the lobe arc intersects with bearing base circle. Typical Offset value for a fixed lobe bearing ranges from 0.5 to 1.0.

Coefficients Coordinate Angle

The coordinate system (*x,y,z*) used to describe the bearing dynamic coefficients (stiffness and damping coefficients) can be different from the (*X,Y,Z*) coordinate system used to define the bearing geometry. The Coefficients Coordinate Angle is the angle measured from the *X*-axis. For Lund Coordinate System, 0 degree (i.e., x-axis is in the loading direction) and 90 degrees (i.e., negative y axis is in the loading direction) are commonly used.

See also Coordinate Systems, Fixed Lobe Bearing Geometry, Fixed Lobe Dimensional Analysis, Nomenclature, Non-Dimensional Parameters, Coefficients Coordinate Angle.

Tilting Pad Journal Bearing

For high speed and lightly loaded rotating machines, the bearings with fixed geometry are prone to self-excited vibration. Tilting pad (pivoted-pad) journal bearings are widely used in high-speed machinery because of their stability characteristics even though they are more expensive than fixed profile bearings. The bearing is made up of a number of pads (shoes) which are supported on pivots. The pads are free to tilt about the pivot points to accommodate the journal motion. Dynamic effects from each individual pad are assembled to obtain the full bearing performance.

Under Tilting-Pad menu, there are analysis and postprocessor for dimensional and non-dimensional analyses. The bearing stiffness and damping coefficients calculated from dimensional analysis can be saved as a bearing file to be readily used by DyRoBeS©_Rotor. All the input and output data can be viewed from the Text Output option, while only the key output parameters are summarized in the Tabulated List and can be displayed in the graphic forms.

Tilting Pad Bearing Geometry

Parameters used to describe the bearing geometry are defined in this section.

Tilting Pad Dimensional Analysis

The dimensional analysis includes Constant Viscosity analysis and Heat Balance analysis. For Constant Viscosity analysis, user must input a lubricant dynamic viscosity and no temperature rise will be calculated. For Heat Balance analysis, user must select a lubricant type and input the lubricant inlet temperature. Supplied oil flow rate can also be entered if it is known. Otherwise, the side leakage flow will be used in the heat balance calculation. The operating and maximum film temperatures will be calculated based on the heat balance method.

For heat balance calculation, the heat generated in the bearing is removed by the effective oil flow. The effective oil flow rate depends on many factors, such as the bearing construction, the specified oil flow rate, side leakage, total circumferential inlet flow, ways to supply the oil, and ways to drain the oil flow, etc. Several cases are considered:

1.When the supplied oil flow rate is NOT specified (i.e., Qsupplied = 0), the side leakage will be used as the effective oil flow. This is the default option and is commonly required in the bearing design process to determine the minimum required flow rate.

Qsupplied = 0, => Qeffective = Qside

2. When the specified oil flow rate is less than and equal to the side leakage (i.e., Qsupplied <= Qside), the specified flow rate will be used as the effective flow rate. Note, this starvation will result in overheated bearing and is not desirable.

Qsupplied <= Qside, => Qeffective = Qsupplied

1. When the specified oil flow rate is greater than the side leakage (i.e., Qsupplied > Qside), the effective flow rate is estimated using the empirical expression. Q Integration factor is a parameter used in the flow integration. Typical value for this Q integration factor from many test data shows that the value is between 0.2 and 0.4 with an average of 0.25 to 0.3. This parameter heavily depends on the bearing construction, pad shape and design, the orifice configuration, ways of supply oil, ways of drain oil, etc.

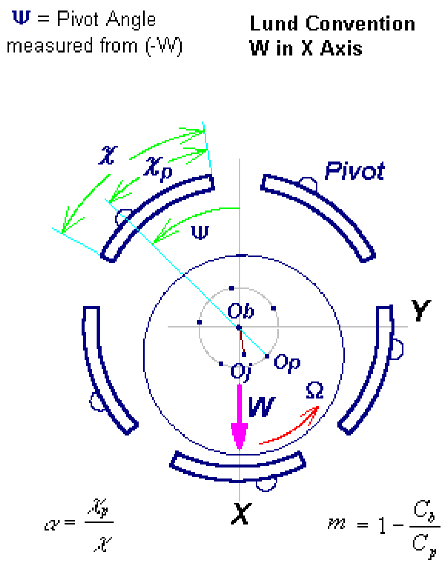
Tilting Pad Non-Dimensional Analysis

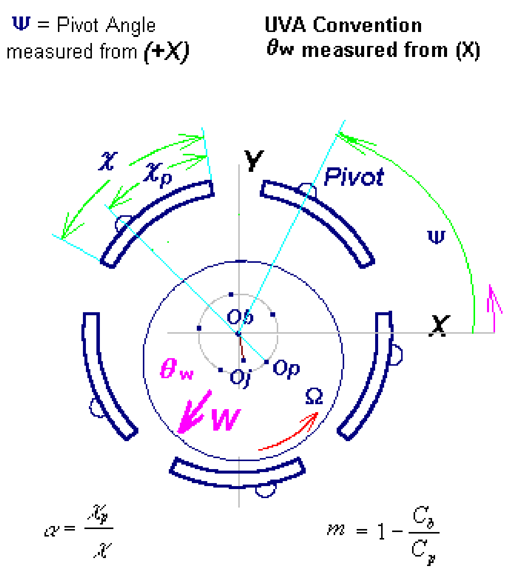
The non-dimensional analysis is performed based on the given bearing eccentricity ratios.

See also Coordinate Systems, Fixed Lobe Journal Bearing, PostProcessor, and Examples.

Tilting Pad Bearing Geometry

A 5-pad tilting pad journal bearing is shown schematically in the following figure. Clearances are exaggerated in the figure for illustrative purposes.





Two coordinate systems can be used in *DyRoBeS©_BePerf* and they are described in the Coordinate Systems Section.

The journal static equilibrium position is defined by the journal eccentricity (e) and attitude angle (ϕ). Under dynamic conditions, the journal is oscillating with small amplitudes around this equilibrium position. However, the bearing dynamic coefficients (stiffness and damping coefficients) can be calculated in any coordinate system (x,y,z) by specifying a Coefficient Coordinate Angle in the bearing input data. The Coordinate Angle is measured from the X-axis (used to describe the bearing geometry) to x-axis (used to describe the bearing coefficients). See Coefficients Coordinate Angle.

The same concept of preload described in the fixed lobe bearings applies to the tilting pad bearings**. Preload** is defined as the fraction of the distance between the pad center of curvature and bearing center to the pad radial clearance:

$$m = \frac{\left(C_p - C_b\right)}{C_p} = 1 - \frac{C_b}{C_p}$$

Typical preload value for a tilting pad bearing ranges from 0.15 to 0.75.

The **Offset**, also called **Pivot Ratio**, is the fraction of the distance between the leading edge and the pad pivot point to the complete pad arc length:

$$\alpha = \frac{\chi_p}{\chi}$$

The typical pivot offset ranges from 0.50 to 0.65, i.e. the pivot point can be anywhere from one-half the length of the pad to 65 % of the pad. A pivot ratio of 0.5 is also called **centrally pivoted** which is suitable for either direction of shaft rotation. For better load carrying capacity, the pivot point is usually placed further than the midpoint (say offset = 0.55). An offset factor less than 0.5 increases the diverging film thickness and is not desirable.

Since pad arc length and pivot offset are used in tilting pad bearings instead of leading and trailing edges of the lobe described in fixed lobe bearings, the **Pivot Angle** (ψ) must be specified in the tilting pad bearing to define the bearing orientation and load vector direction. Pivot Angle is the angle from the Negative Load Line for Lund's Coordinate System and from the positive X-axis for Standard Coordinate System to the first pad pivot point measured in the direction of shaft rotation. Most tilting pad bearings are designed such that the pivots are symmetrical with respect to the load vector, i.e. the load is directed onto a pad pivot or between two pivots. The Pivot Angles for **Load on Pivot** and **Load between Pivots** for the Lund's Coordinate System are listed below:

Npad	Load on Pivot	Load between Pivots
For even pads (2,4,6,8,....)	$\psi = 0$	$\psi = 180/\mathrm{Npad}$
For odd pads (3,5,7,9,....)	$\psi = 180/\mathrm{Npad}$	$\psi = 0$

For small bearings, the pad inertia and pivot flexibility are usually neglected. For large bearings, the pad inertia and pivot flexibility can reduce the bearing effective stiffness and damping significantly. Several types of pad and pivot flexibility effect are included in the program. They are:

Rigid pivot with inertia effect

Spherical pivot - point contact

Cylindrical pivot - line contact

General curvatures

Constant stiffness

The most commonly used tilting pad bearings are 4 pads and 5 pads bearings.

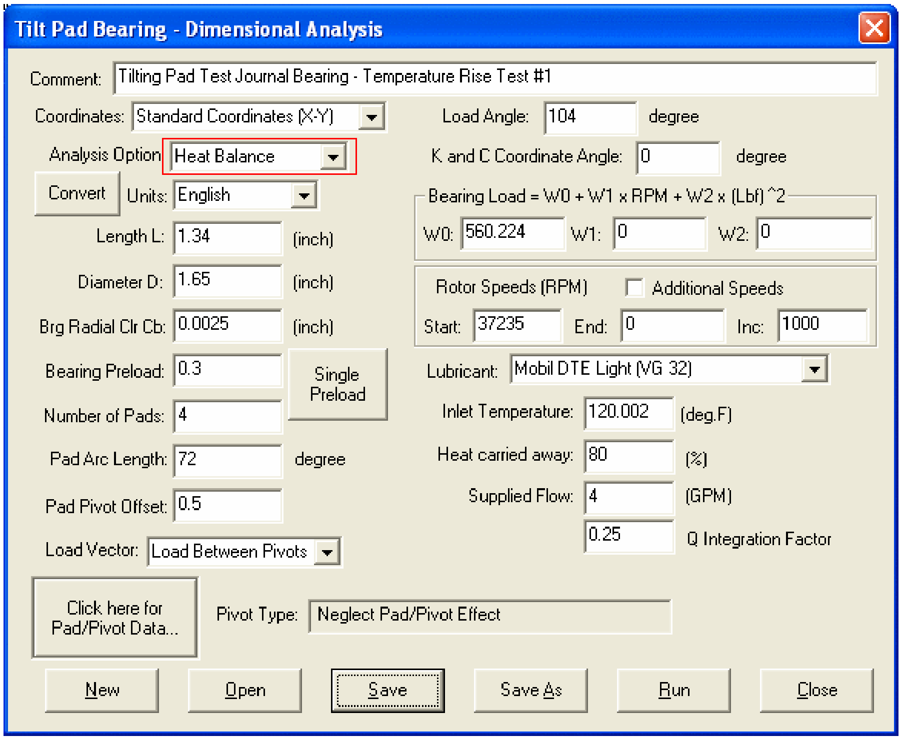
4 pads tilting pad bearing

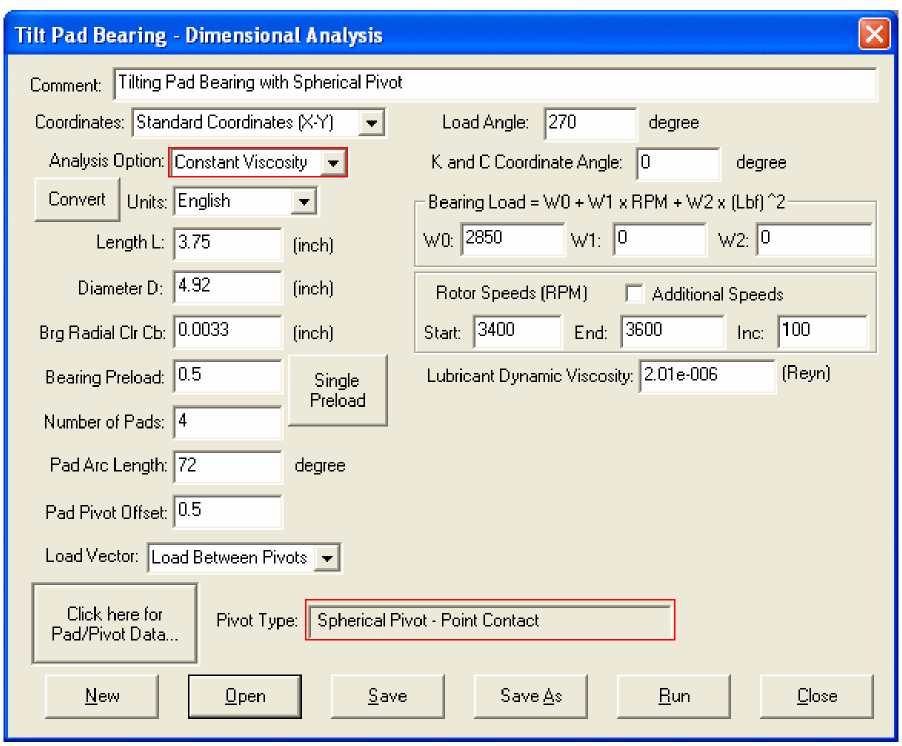
5 pads tilting pad bearing

See also Coordinate Systems, Nomenclature, Tilting Pad Dimensional Analysis, Tilting Pad Non-Dimensional Analysis, 4 pads tilting pad bearing, 5 pads tilting pad bearing, Fixed Lobe Bearing Geometry.

Tilting Pad Bearing Dimensional Analysis

The input parameters for tilting pad bearing dimensional analysis are:



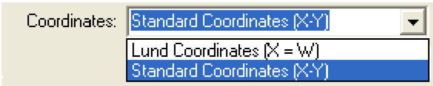


Comment

This is used to describe the bearing under study.

Coordinates

Two coordinate systems can be used to describe the bearing geometry. One is Lund coordinate system where the load vector is collinear with the X-axis. One is standard coordinate system where X-axis is to the right and Y-axis is to the top. The load vector direction is specified by an angle. Click **here** to see more description on coordinate systems.



Load Angle

The load angle is needed (and shown in the input screen) only when the Standard Coordinate system is selected. When Lund coordinate system is selected, the load vector is the same as the X-axis and it is not displayed on the screen.

Analysis Option

The analysis can be performed in either Constant Viscosity or Heat Balance option. Depending upon the analysis type, the input dialog box changes accordingly. For Heat Balance option, user must select a lubricant from the list, input the oil inlet temperature, and estimate the percentage heat carried away by oil. The operating and maximum film temperatures will be calculated based on heat balance method. In addition, the oil flow rate can be specified for heat balance calculation. If not specified, i.e. zero, then the side leakage will be used for the temperature rise calculation. For Constant Viscosity analysis, a lubricant dynamic viscosity is needed.

Units

Two unit systems are provided, English or Metric units.

See also Units.

Convert Button

The covert button allows you to convert the bearing input data from English to Metric or vice versa between two unit systems.

Length (L)

Bearing (babbitt) axial length.

Diameter (D)

Journal diameter.

Bearing Radial Clearance (Cb)

Bearing assembled radial clearance. Cb = Rb - Rs

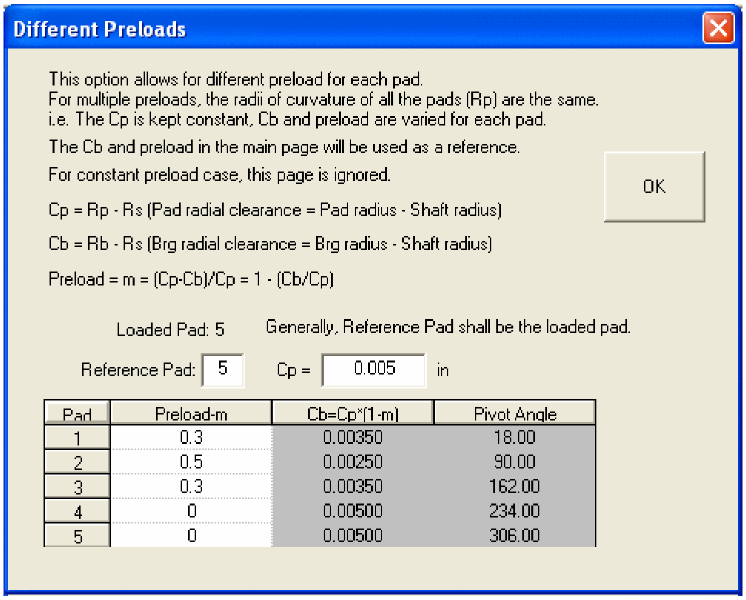
Preload (*m*)

$$m = \frac{\left(C_p - C_b\right)}{C_p} = 1 - \frac{C_b}{C_p}$$

Typical preload value ranges from 0.15 to 0.75 for tilting pad bearings.

Preload Button

Multiple preloads can be specified, i.e., different preload for different pad. Currently, the pad clearance is fixed, i.e., the pads are identical with the same pad radius. While assembling the bearing, different preloads can be obtained by adjusting the pad location to form different bearing clearance. This restriction will be eliminated in the next release and the user can select which clearance to be fixed.



Number of Pads (Npad)

Number of pads (lobes) supported by pivots.

Pad Arc Length (degrees)

$$\chi = \theta_2 - \theta_1$$

Typical values are 55-60 degrees for 5 pads bearings and 70-75 degrees for 4 pads bearings.

Pad Pivot Offset

$$\alpha = \frac{\chi_p}{\chi}$$

where χ_p is the angle from the leading edge of the pad to the pivot point in the direction of shaft rotation. Typical pivot offset value ranges from 0.5 to 0.65.

Load Vector and Pivot Angle (ψ)

The bearing can be orientated such that the load vector is directed onto the pivot, between the pivots, or at any arbitrarily specified pivot angle. Most tilting pad bearings are designed such that the pivots are symmetrical with respect to the load vector, i.e. the load is directed onto a pad pivot or between two pivots. When you select either Load on Pivot or Load between Pivots, then you do not need to input the Pivot Angle (it will not be shown in the screen either). The Pivot Angle will be calculated and updated automatically for you in these two cases.

Pivot angle is the angle in degrees measured from the Negative Load Line for Lund's Coordinate System, and measured from the positive X-axis for Standard Coordinate System to the first pad pivot point measured in the direction of shaft rotation. This angle determines the orientation of the bearing assembly. When you select **Specified Pivot Angle** in the **Load Vector** selection, then you need to input the Pivot Angle.

Coefficients Coordinate Angle

The coordinate system (x,y,z) used to describe the bearing dynamic coefficients (stiffness and damping coefficients) can be different from the (X,Y,Z) coordinate system used to define the bearing geometry. The Coefficients Coordinate Angle is the angle measured from the X-axis to the x-axis. Two most commonly used values for Lund Coordinate Systems are 0 (i.e., x axis is in the loading direction) and 90 degrees (i.e., negative y axis is in the loading direction).

Bearing Load (W)

The bearing load is expressed as a second order polynomial function of rotor speed (rpm). This provides an opportunity to approximate the variation in load with speed.

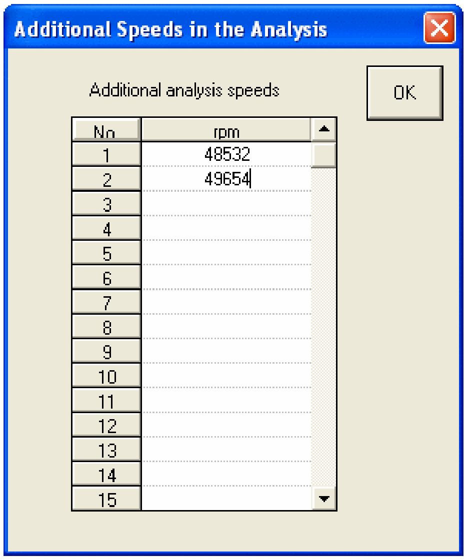
$$W = W_0 + W_1 \times \mathrm{rpm} + W_2 \times \mathrm{rpm}^2$$

Rotor Speed (rpm)

Start, End and Increment specify a list of speeds at which calculations are to be performed.

Additional Speeds

If the Additional Speeds is checked, additional speeds can be entered in additional to the speeds given by the Start, End and Increment Speeds.



Lubricant

This input is for Heat Balance analysis option. If the lubricant you want is not in the list, you can enter it from the Edit Lubricant Library under the Lubricant menu.

Inlet Temperature

This input is for Heat Balance analysis option.

Percent Heat carried Away by Lubricant

This input is for Heat Balance analysis option. Typical value is between 75-90%, default is 80%.

Lubricant Supply Flow

This input is for Heat Balance analysis option. If non-zero value is specified, the temperature rise will be calculated based on this flow rate. Otherwise, the side leakage will be used in the temperature rise calculation. In the tilting pad bearing design, end seals are commonly used to reduce the side leakage and the oil flow rate is controlled by either oil supply orifices or drain holes.

For heat balance calculation, the heat generated in the bearing is removed by the effective oil flow. The effective oil flow rate depends on many factors, such as the bearing construction, the specified oil flow rate, side leakage, total circumferential inlet flow, ways to supply the oil, and ways to drain the oil flow, etc. Several cases are considered:

1.When the supplied oil flow rate is NOT specified (i.e., Qsupplied = 0), the side leakage will be used as the effective oil flow. This is the default option and is commonly required in the bearing design process to determine the minimum required flow rate.

Qsupplied = 0, => Qeffective = Qside

2. When the specified oil flow rate is less than and equal to the side leakage (i.e., Qsupplied <= Qside), the specified flow rate will be used as the effective flow rate. Note, this starvation will result in overheated bearing and is not desirable.

Qsupplied <= Qside, => Qeffective = Qsupplied

1. When the specified oil flow rate is greater than the side leakage (i.e., Qsupplied > Qside), the effective flow rate is estimated using the empirical expression. Q Integration factor is a parameter used in the flow integration. Typical value for this Q integration factor from many test data shows that

the value is between 0.2 and 0.4 with an average of 0.25 to 0.3. This parameter heavily depends on the bearing construction, pad shape and design, the orifice configuration, ways of supply oil, ways of drain oil, etc.

Q Integration Factor

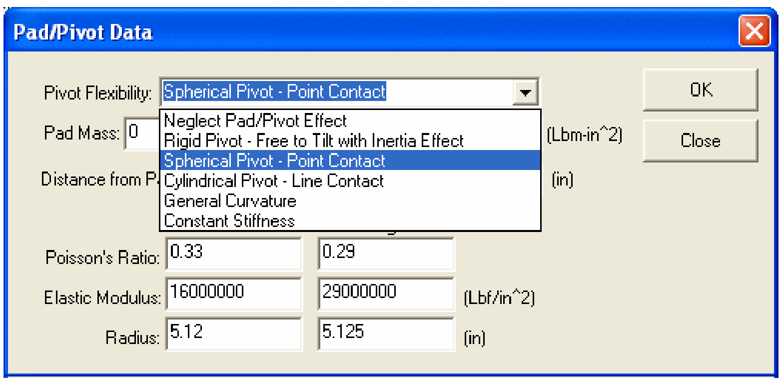
Typical value for this Q integration factor from many test data shows that the value is between 0.2 and 0.4 with an average of 0.25 to 0.3.

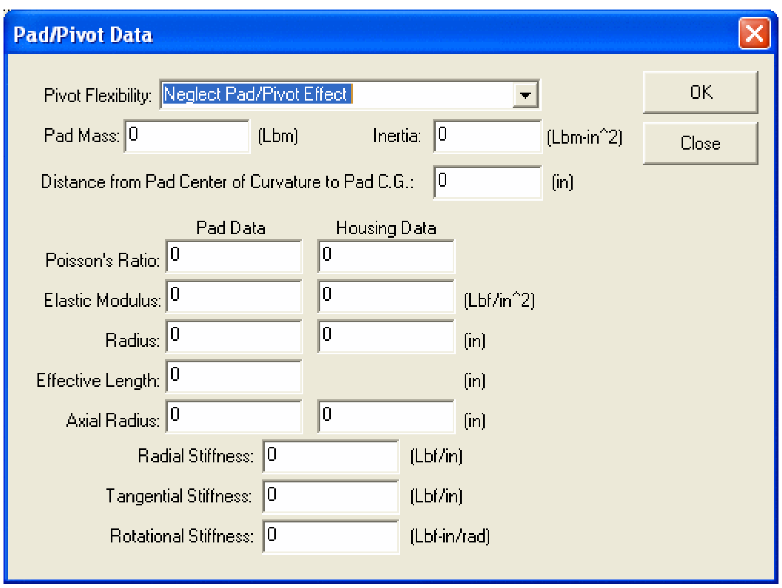
Lubricant Dynamic Viscosity

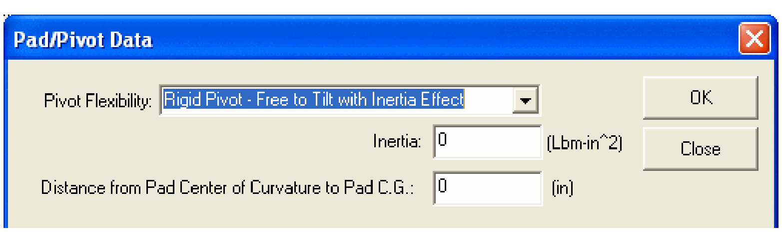
This input is for Constant Viscosity analysis option.

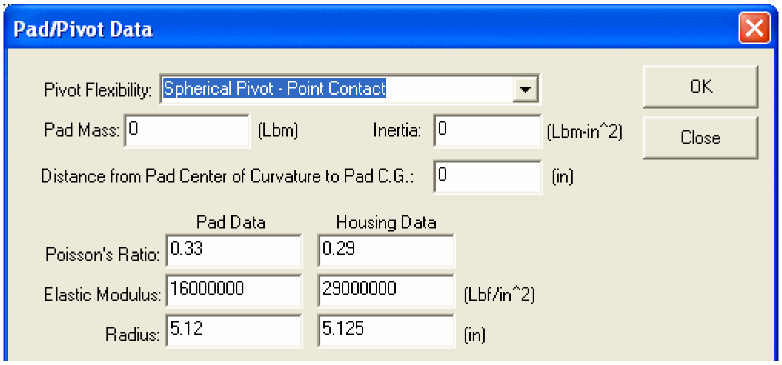
Pad/Pivot Data

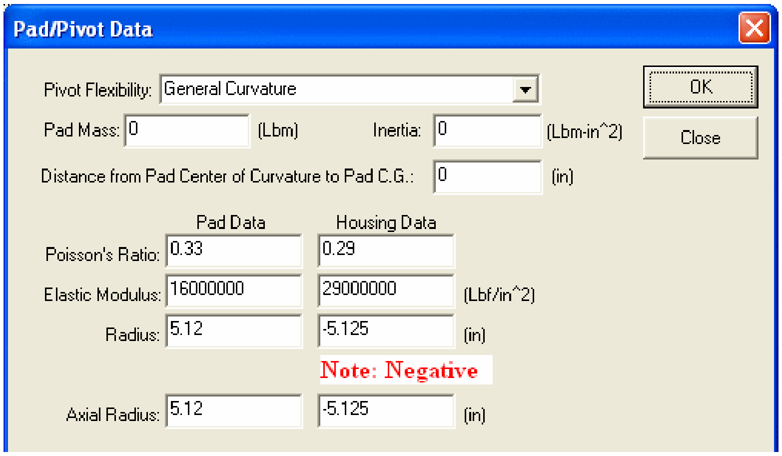
Several types of Pad/Pivot configurations are available in this program. When you click on Pad/Pivot Data Button, a new dialog box will pop-up as shown below. The input parameters are based on the type of Pivot Flexibility selection. The dialog box will change itself depending upon the selection. Only the parameters required will appear in the dialog box. For **Spherical Pivot** and **Cylindrical Pivot**, the radii are always positive. For **General Curvatures**, the radii are positive if the center of curvature lies within the given body, i.e., the surface is convex, otherwise, the radii are negative. The pivot stiffness is derived from the deflection equation (references, Young and Hamrock). Caution must be taken when input Rotational Stiffness for **Flexure Pad** Bearing. The pad assembly method for tilting pad bearing is based on the assumption that the pads are free to tilt about the pivot points.

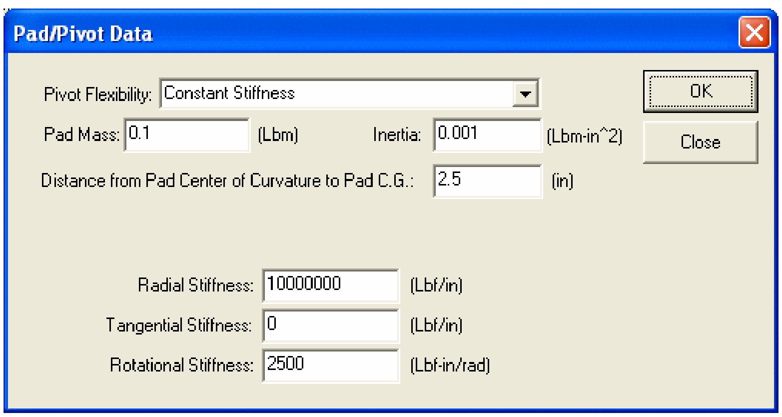












See also Coordinate Systems, Tilting Pad Bearing Geometry, Tilting Pad Non-Dimensional Analysis, Fixed Lobe Bearing Geometry, Nomenclature, Units, Lubricant, Examples, Coefficients Coordinate Angle .

Tilting Pad Bearing Non-Dimensional Analysis

In the non-dimensional tilting pad bearing analysis, the effects of pad inertia and pivot flexibility are neglected.

Number of Pads (Npad)

Coordinate Systems

Two coordinate systems can be used to describe the bearing geometry.

Pad Arc Length (degrees)

$$\chi = \theta_2 - \theta_1$$

Typical values are 57 degrees for 5 pads bearings and 72 degrees for 4 pads bearings.

Pad Pivot Offset

$$\alpha = \frac{\chi_p}{\chi}$$

where χ_p is the angle from the leading edge of the pad to the pivot point in the direction of shaft rotation. Typical pivot offset value ranges from 0.5 to 0.65.

Length/Diameter Ratio (L/D)

Bearing length / diameter ratio.

Preload (*m*)

$$m = \frac{\left(C_p - C_b\right)}{C_p} = 1 - \frac{C_b}{C_p}$$

Typical preload value ranges from 0.15 to 0.75 for tilting pad bearings. Multiple preloads are allowed with a constant Cp. The different preloads are separated by a comma in the input string. That is, one can enter a preload string, such as, 0.5,0.5,0.3,0.3 for a 4-pads bearing and 0.4,0.5,0.4,0.25,0.25 for a 5-pads bearing. If only one preload value is entered, then it is a constant preload bearing. For multiple preloads, the various Cb for each pad are calculated based on the pad preload value and the constant Cp.

$$C_b = \left(1 - m\right) \cdot C_p$$

In the data normalization, preload at the loaded pad will be used. That is the Cb at the loaded pad will be used as the reference.

Load Vector and Pivot Angle (ψ)

The bearing can be orientated such that the load vector is directed onto the pivot, between the pivots, or at any arbitrarily specified pivot angle. Most tilting pad bearings are designed such that the pivots are symmetrical with respect to the load vector, i.e. the load is directed onto a pad pivot or between two pivots. When you select either Load on Pivot or Load between Pivots, then you do not need to input the Pivot Angle. The Pivot Angle will be calculated and updated automatically for you in these two cases.

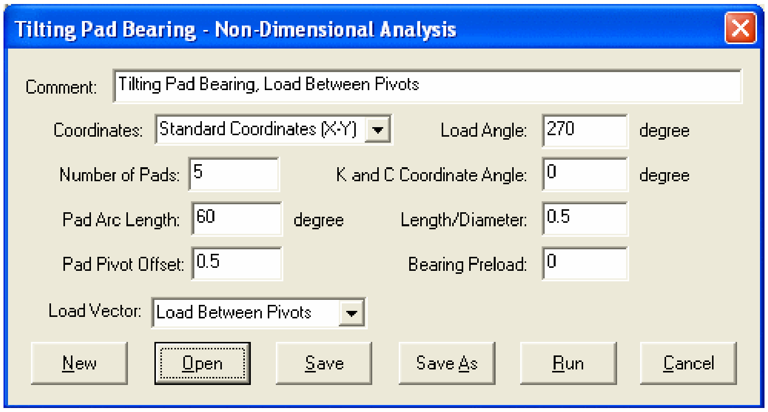
Pivot angle is the angle in degrees measured from the Negative Load Line for Lund's Coordinate System and measured from the positive X-axis for Standard Coordinate System to the first pad pivot point measured in the direction of shaft rotation. This angle determines the orientation of the bearing assembly. When you select **Specified Pivot Angle** in the **Load Vector** selection, then you need to input the Pivot Angle.

Coefficients Coordinate Angle

The coordinate system (*x,y,z*) used to describe the bearing dynamic coefficients (stiffness and damping coefficients) can be different from the (*X,Y,Z*) coordinate system used to define the bearing geometry. The Coefficients Coordinate Angle is the angle measured from the *X*-axis to the *x*-axis. Two most commonly used values for Lund Coordinate Systems are 0 (i.e., x axis is in the loading direction) and 90 degrees (i.e., negative y axis is in the loading direction).

Comments

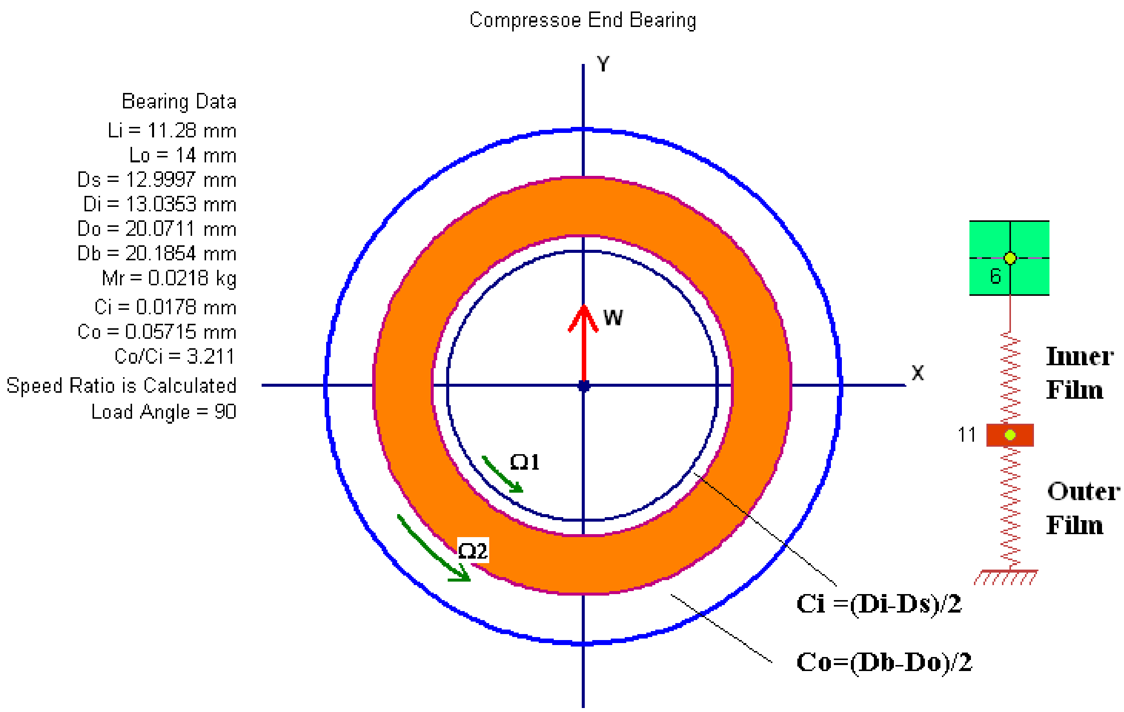
See also Coordinate Systems, Tilting Pad Bearing Geometry, Tilting Pad Dimensional Analysis, Nomenclature, Examples, Fixed Lobe Bearing Geometry, Non-Dimensional Parameters, Coefficients Coordinate Angle .



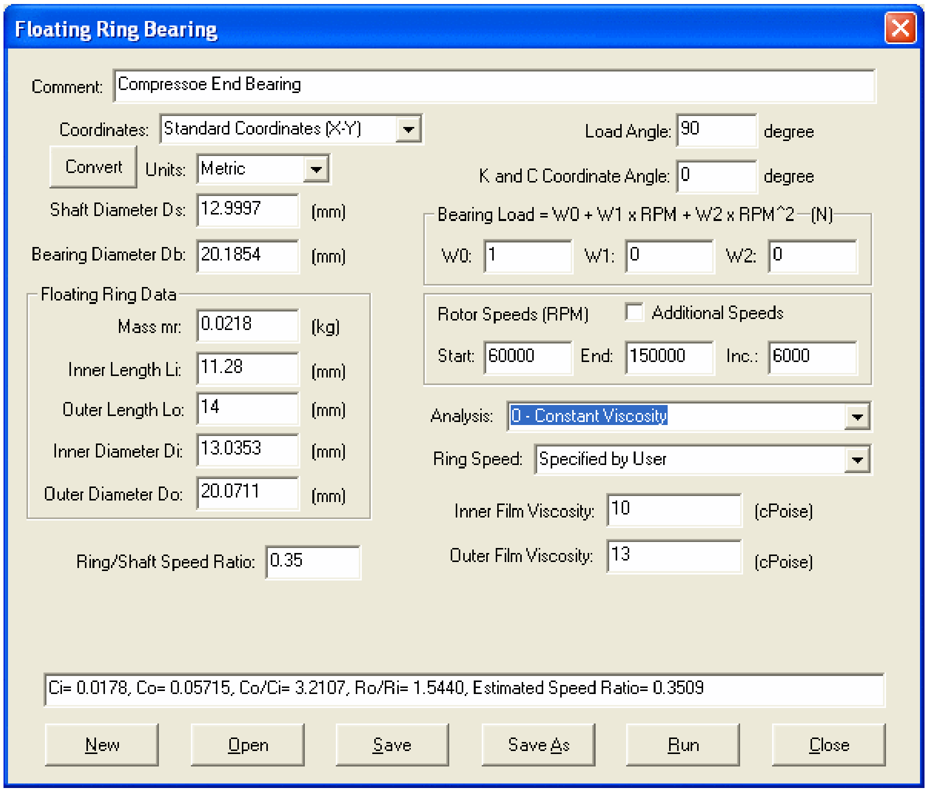
Floating Ring Bearing

The floating ring bearing can be treated as two fluid film bearings in series. The inner film bearing has two rotating surfaces (journal and ring), and the outer film bearing has one rotating surface (ring). The ring speed is calculated based on the torque balance of the ring due to inner film and outer film. However, the user can also specify the speed ratio in the input. There are 3 options for the analysis:

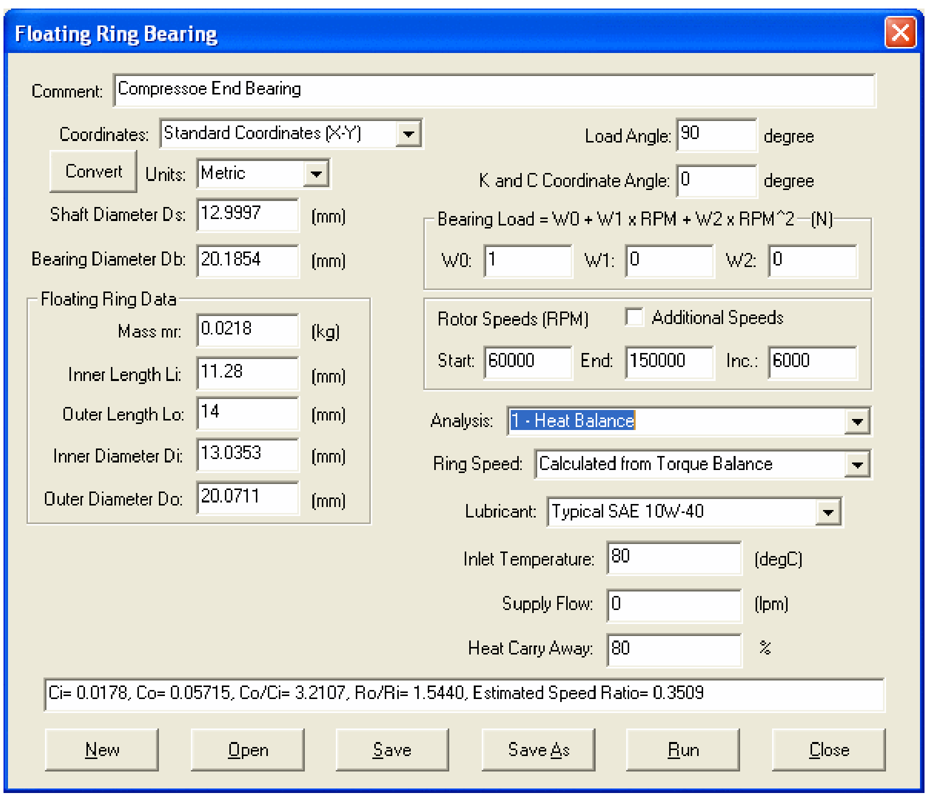
1. Constant viscosity – user specify the inner and outer film viscosities.
2. Heat Balance – user specify the lubricant type and inlet temperature. The program will calculate the effective viscosity based on the heat balance in the lubricant.
3. Speed Dependent Variables – User can specify the variables, such as viscosities, clearances, and speed ratios as a function of speed. This option is mainly used for the rotor time transient analysis without tedious bearing calcuation.



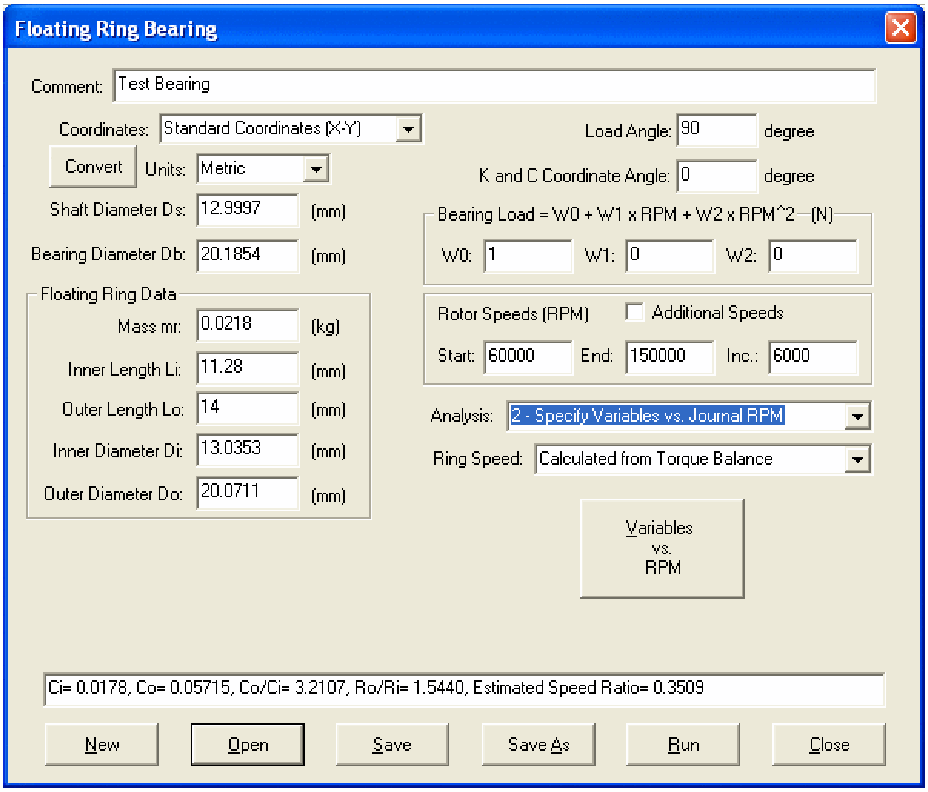
Constant Viscosities – specify the viscosities

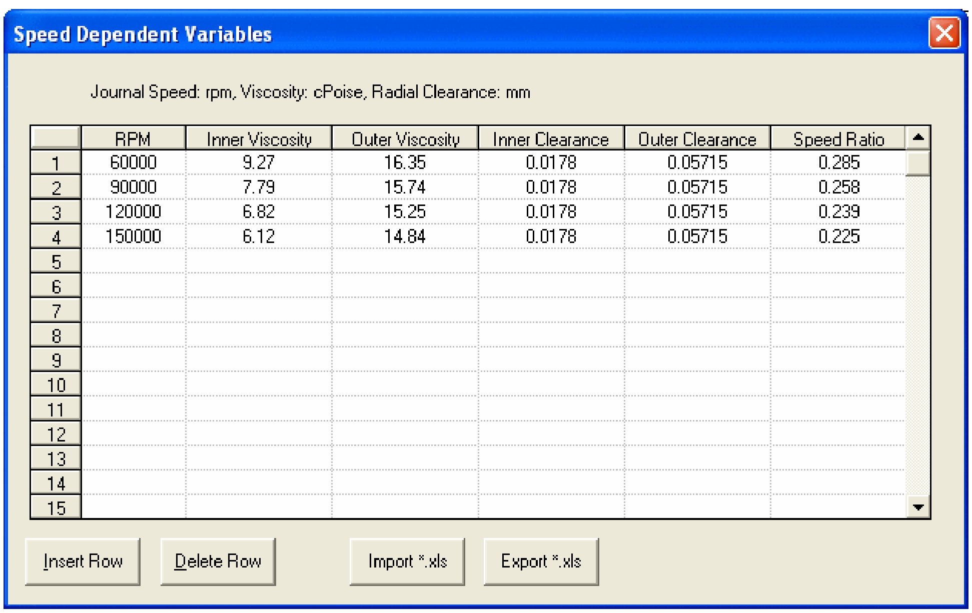


Heat Balance – specify the lubricant type, inlet temperature, supply flow, and percentage of heat carry away by lubricant. If the supply flow is not known, enter zero. A sufficient oil flow will be assumed to prevent starvation. In general, about 50-80% of the heat generated by the lubricant shear force is carry away by the lubricant.

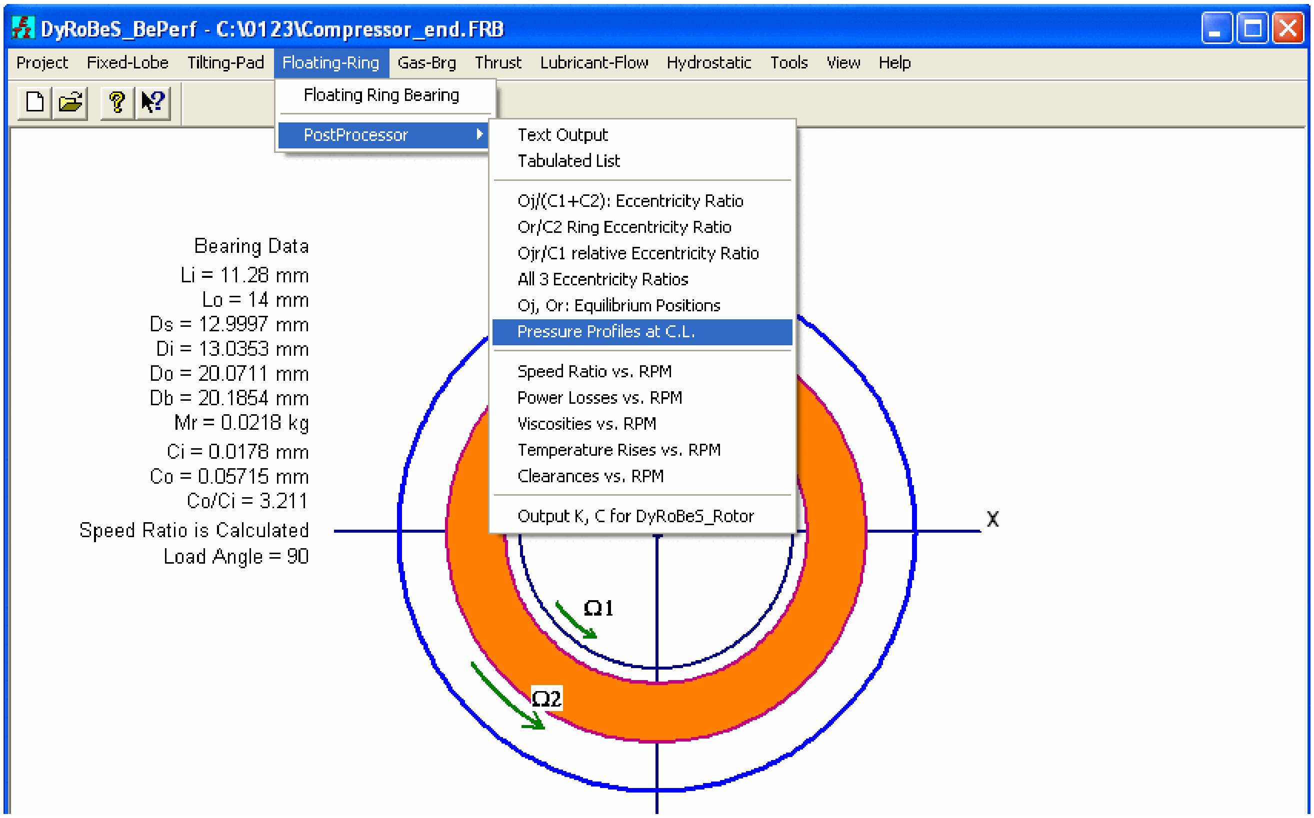


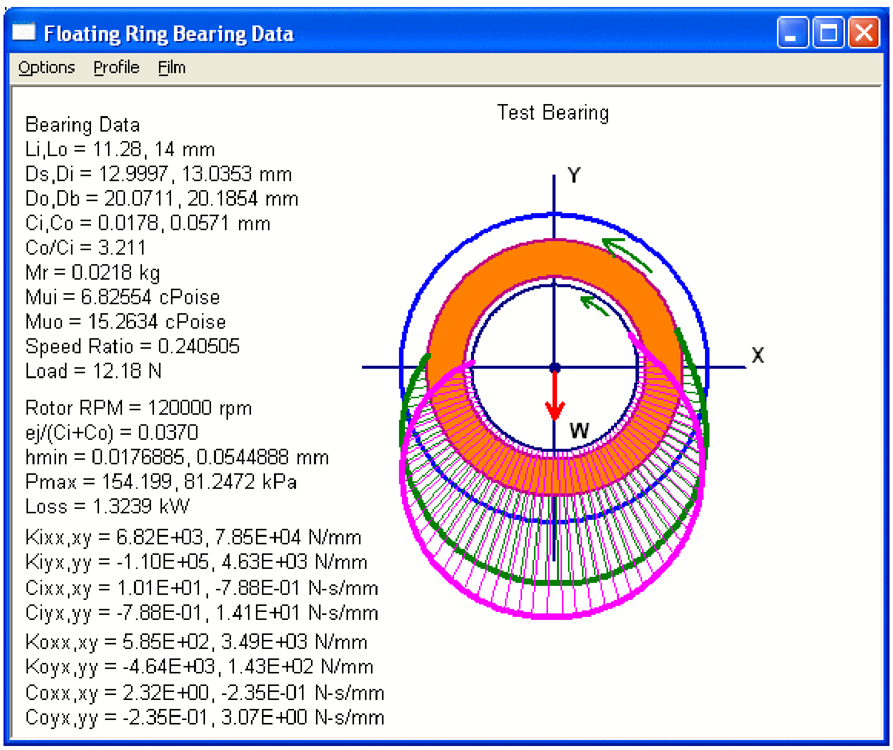
Speed Dependent Variables – specify the viscosities, clearances, and speed ratios vs. rpm if known.

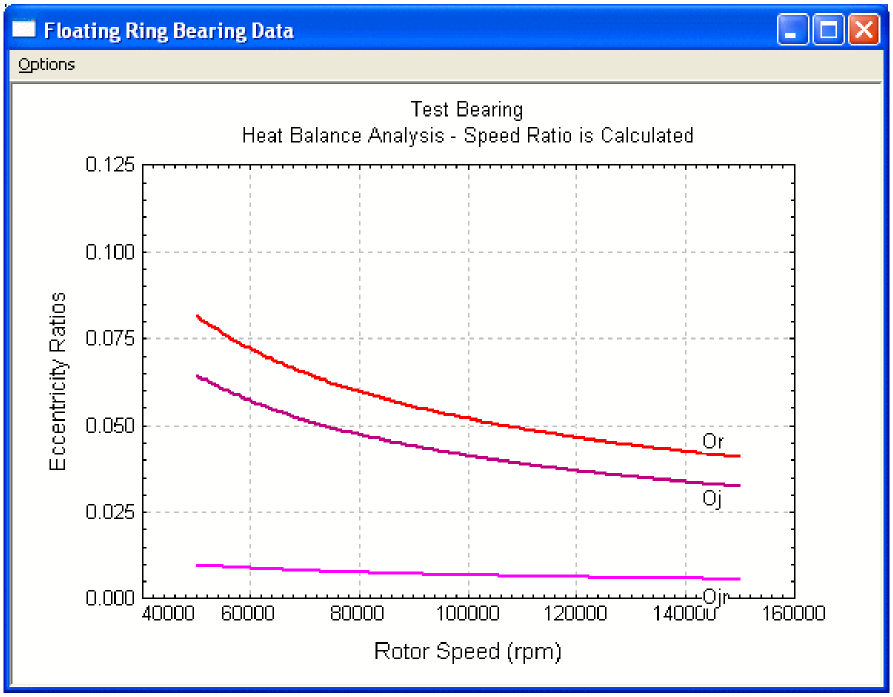


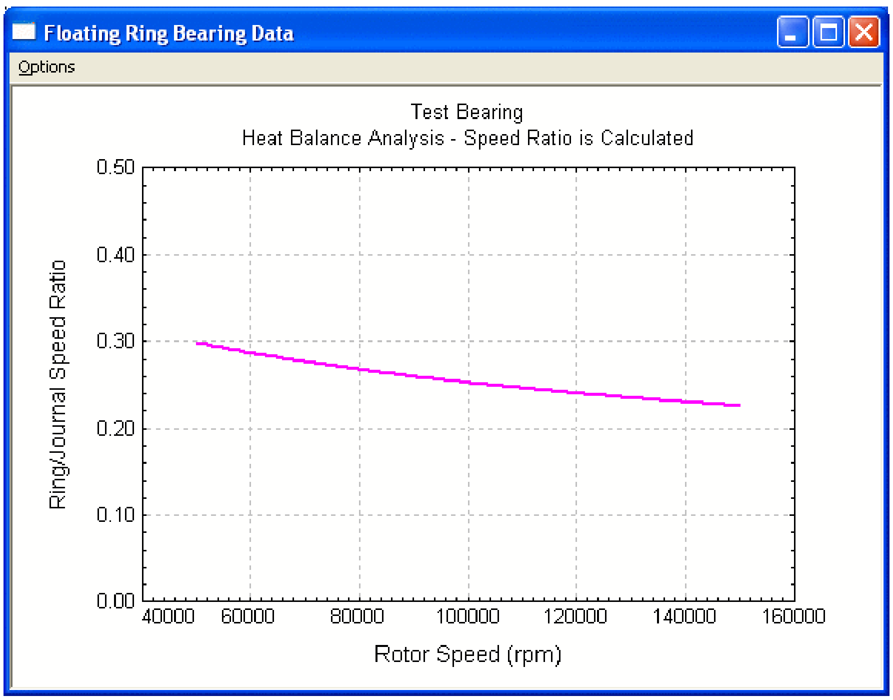


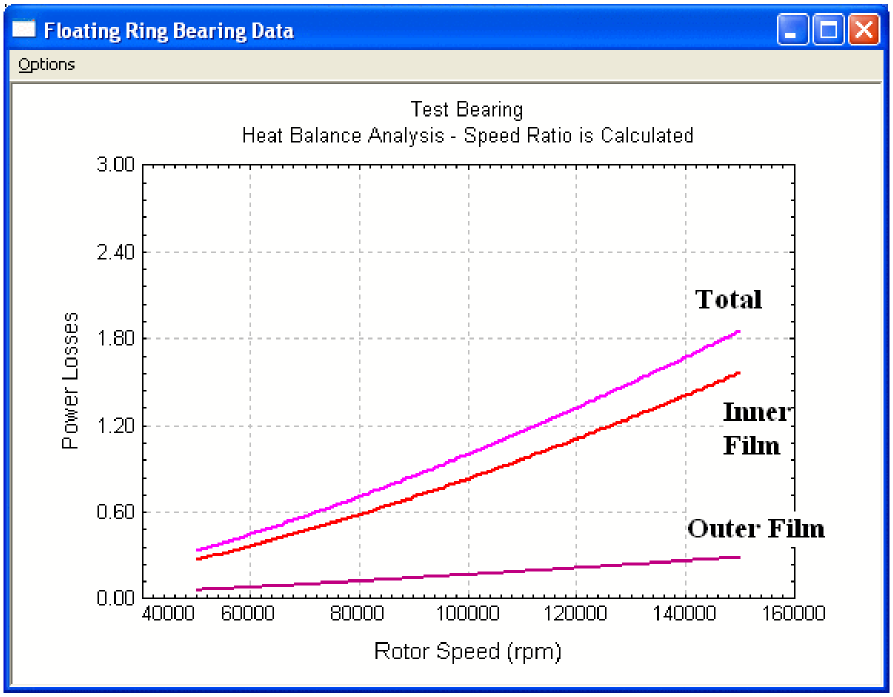
PostProcessor

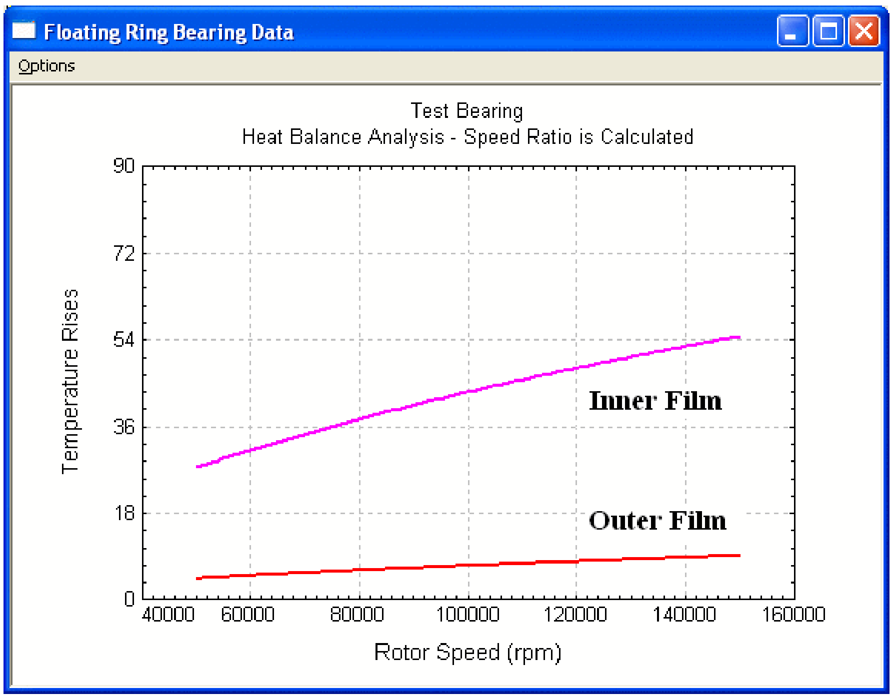

DyRoBeS_BePerf - C:\0123\Compressor_end.FRB
Project Fixed-Lobe Tilting-Pad Floating-Ring Gas-Brg Thrust Lubricant-Flow Hydrostatic Tools View Help
Floating Ring Bearing
PostProcessor
Text Output
Tabulated List
Oj/(C1+C2): Eccentricity Ratio
Or/C2 Ring Eccentricity Ratio
Ojr/C1 relative Eccentricity Ratio
All 3 Eccentricity Ratios
Oj, Or: Equilibrium Positions
Pressure Profiles at C.L.
Speed Ratio vs. RPM
Power Losses vs. RPM
Viscosities vs. RPM
Temperature Rises vs. RPM
Clearances vs. RPM
Output K, C for DyRoBeS_Rotor
Bearing Data
Li = 11.28 mm
Lo = 14 mm
Ds = 12.9997 mm
Di = 13.0353 mm
Do = 20.0711 mm
Db = 20.1854 mm
Mr = 0.0218 kg
Ci = 0.0178 mm
Co = 0.05715 mm
Co/Ci = 3.211
Speed Ratio is Calculated
Load Angle = 90
X
Ω1
Ω2


Floating Ring Bearing Data
Options Profile Film
Test Bearing
Bearing Data
Li,Lo = 11.28, 14 mm
Ds,Di = 12.9997, 13.0353 mm
Do,Db = 20.0711, 20.1854 mm
Ci,Co = 0.0178, 0.0571 mm
Co/Ci = 3.211
Mr = 0.0218 kg
Mui = 6.82554 cPoise
Muo = 15.2634 cPoise
Speed Ratio = 0.240505
Load = 12.18 N
Rotor RPM = 120000 rpm
ej/(Ci+Co) = 0.0370
hmin = 0.0176885, 0.0544888 mm
Pmax = 154.199, 81.2472 kPa
Loss = 1.3239 kW
Kixx,xy = 6.82E+03, 7.85E+04 N/mm
Kiyx,yy = -1.10E+05, 4.63E+03 N/mm
Cixx,xy = 1.01E+01, -7.88E-01 N-s/mm
Ciyx,yy = -7.88E-01, 1.41E+01 N-s/mm
Koxx,xy = 5.85E+02, 3.49E+03 N/mm
Koyx,yy = -4.64E+03, 1.43E+02 N/mm
Coxx,xy = 2.32E+00, -2.35E-01 N-s/mm
Coyx,yy = -2.35E-01, 3.07E+00 N-s/mm
Y
X
W


Floating Ring Bearing Data
Options
Test Bearing
Heat Balance Analysis - Speed Ratio is Calculated
Eccentricity Ratios
0.125
0.100
0.075
0.050
0.025
0.000
40000
60000
80000
100000
120000
140000
160000
Rotor Speed (rpm)
Or
Oj
Ojr


Floating Ring Bearing Data
Options
Test Bearing
Heat Balance Analysis - Speed Ratio is Calculated
Ring/Journal Speed Ratio
0.50
0.40
0.30
0.20
0.10
0.00
40000
60000
80000
100000
120000
140000
160000
Rotor Speed (rpm)



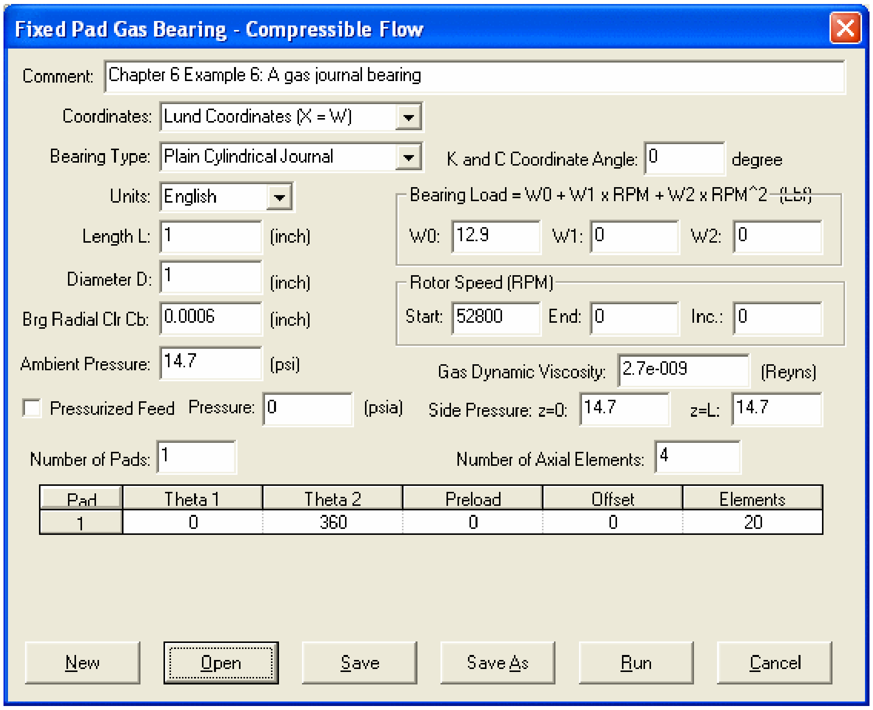


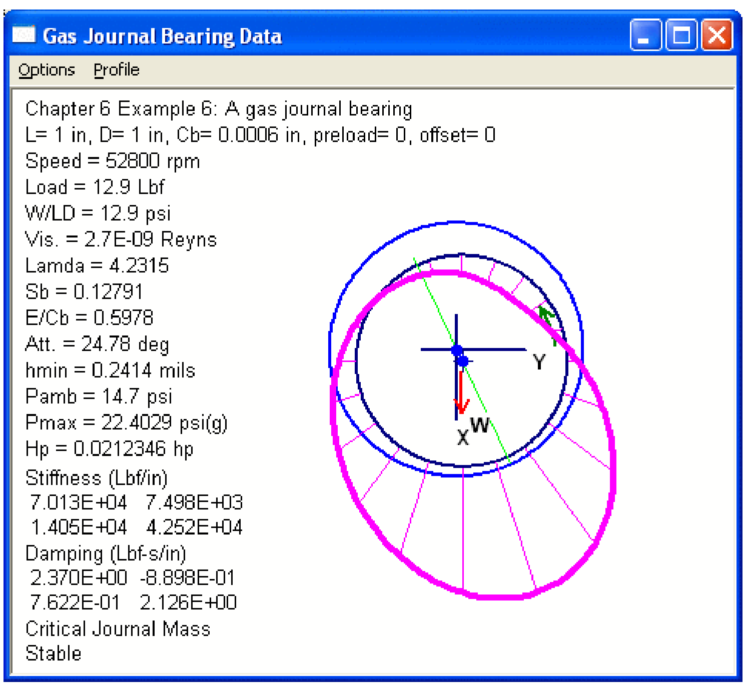
See also Examples.

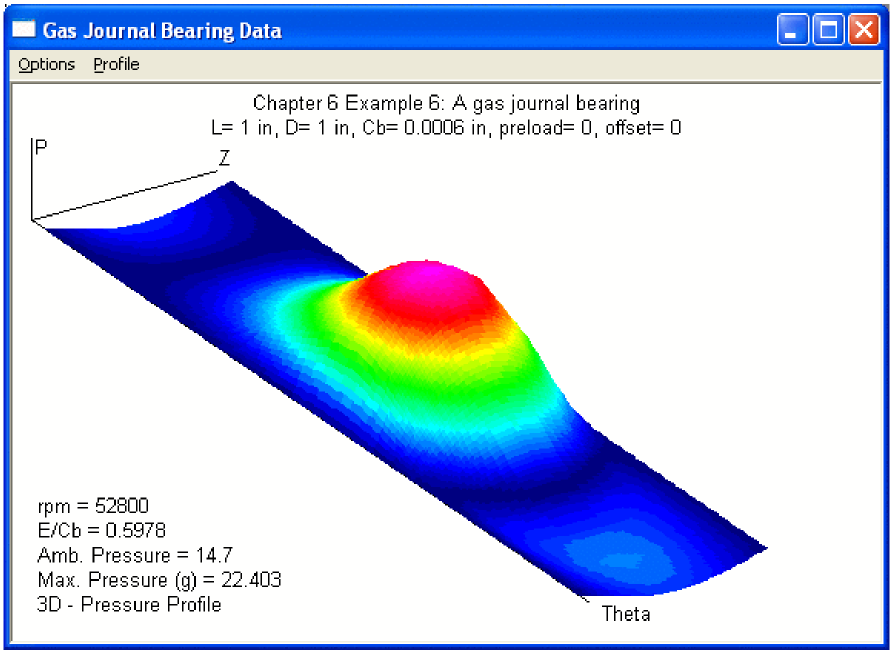
Gas Bearing - Fixed Lobe Bearing Dimensional Analysis

This option is for gas bearing application. The **compressible Reynolds equations** are solved to obtain the equilibrium position and bearing dynamic coefficients.

See also Coordinate Systems, Fixed Lobe Bearing Geometry.







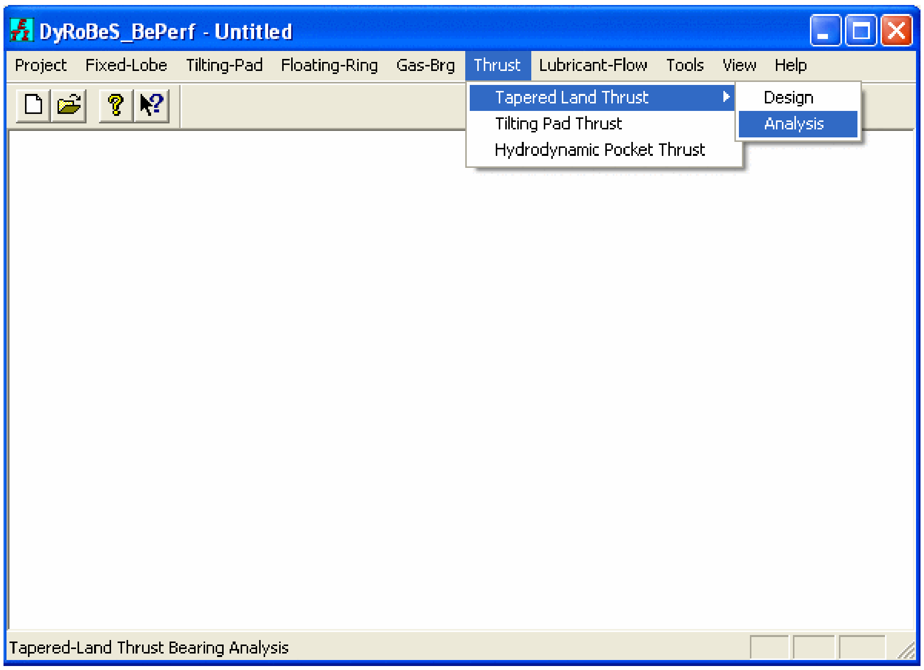
See also Examples.

Thrust Bearing Analysis

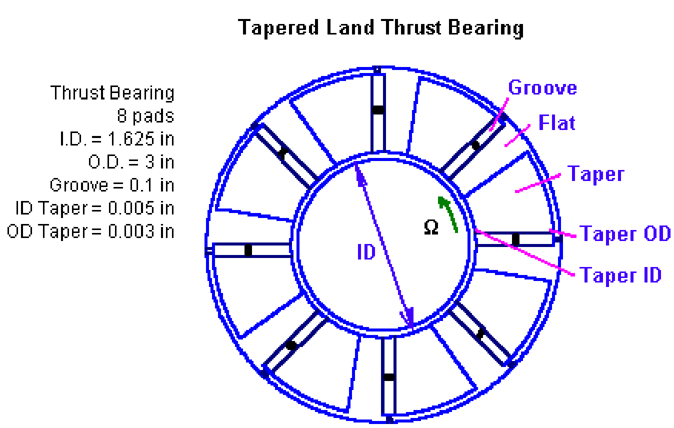
Three most commonly used thrust bearing types are included in this program. They are: tapered-land thrust bearing, tilting-pad thrust bearing, and hydrodynamic pocket thrust bearing. The analysis is based on the following references:

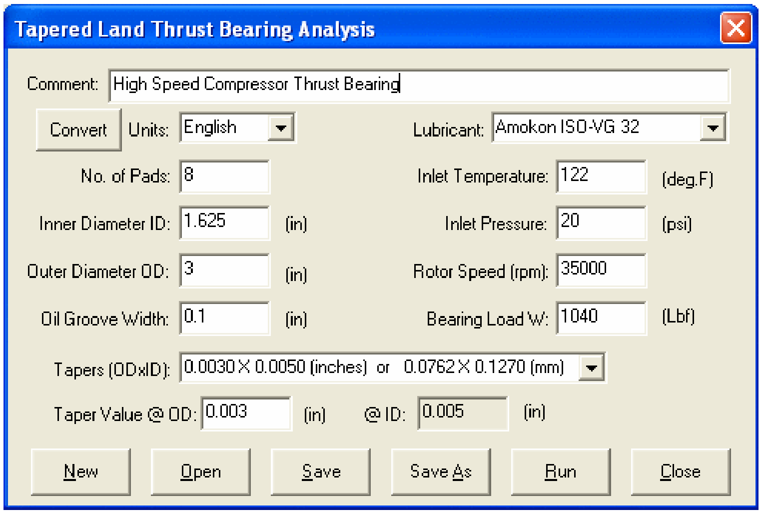
1. Machinery's Handbook by Eric Oberg, Franklin D. Jones and Holbrook L. Horton, Industrial Press Inc., New York, NY 10157
2. Bearing Design and Application, by Donald F. Wilcock and E. Richard Booser, McGraw-Hill Book Company, New York, NY, 1957.
3. The Hydrodynamic Pocket Thrust Bearing, by Donald F. Wilcock, ASME Trans. 1955, pp. 311-319.

A complete FEA thrust bearing analysis is also available (DyRoBeS-ThrustBrg) which analyzes various thrust bearings with the Reynolds equation coupled with the energy equation in uni- or bi-directional rotations. Both pressure and temperature distribution can be obtained in this FEA program. This is a separate program from BePerf..

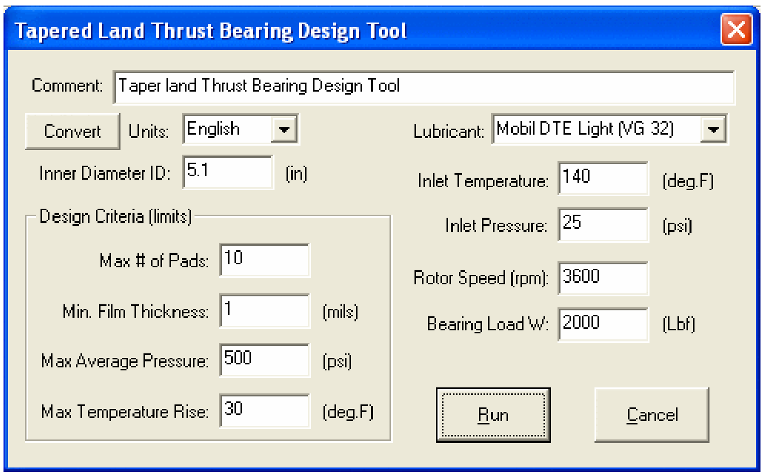


Taper Land Thrust Bearing

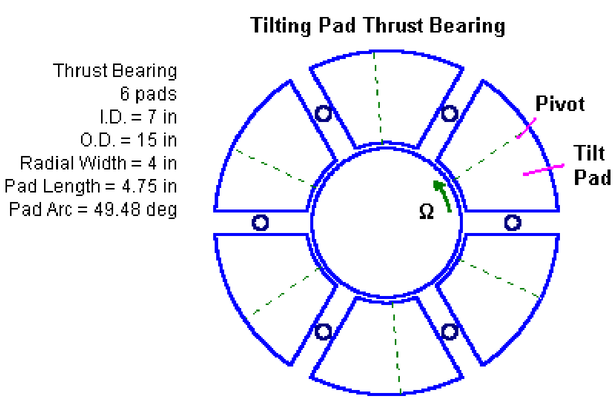


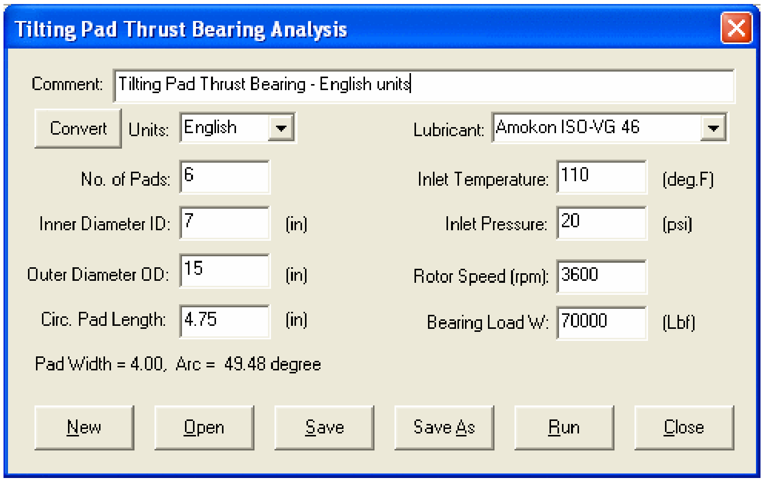


Taper Land Thrust Bearing Design Tool

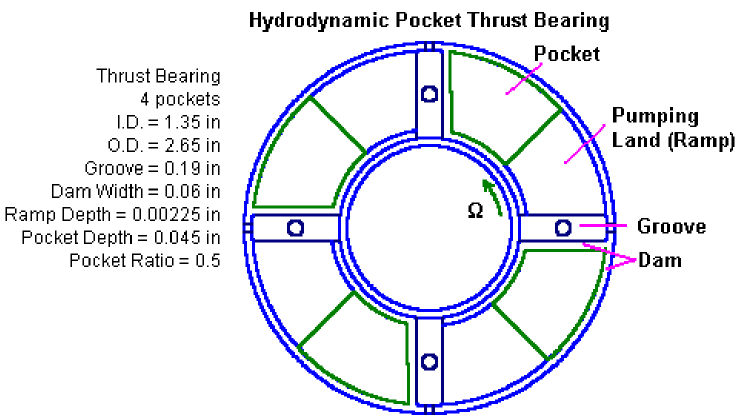


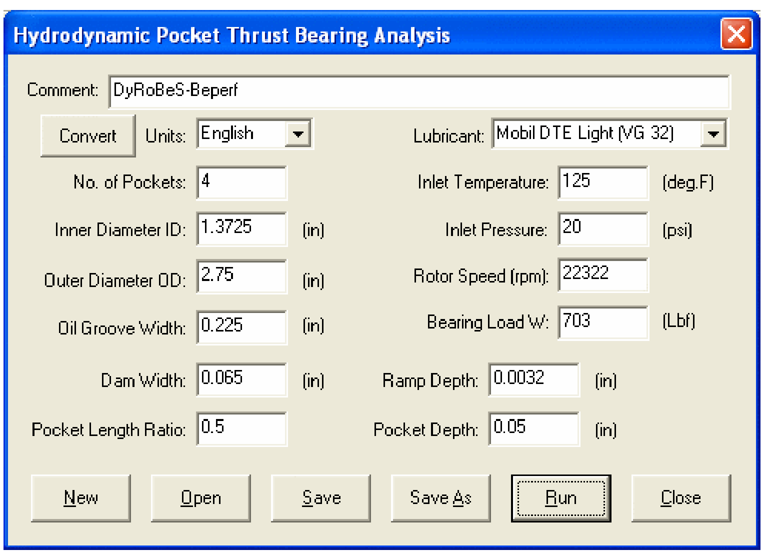
Tilting Pad Thrust Bearing



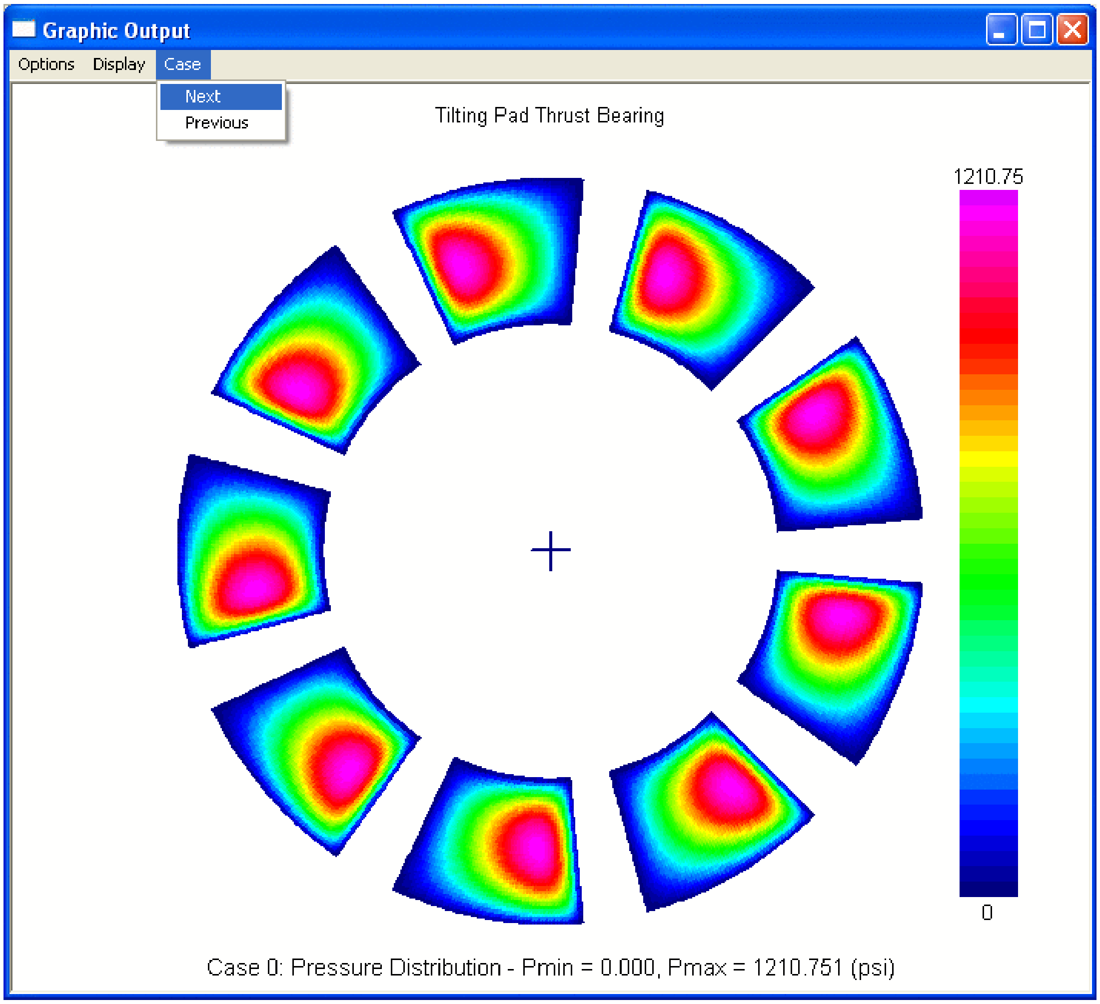


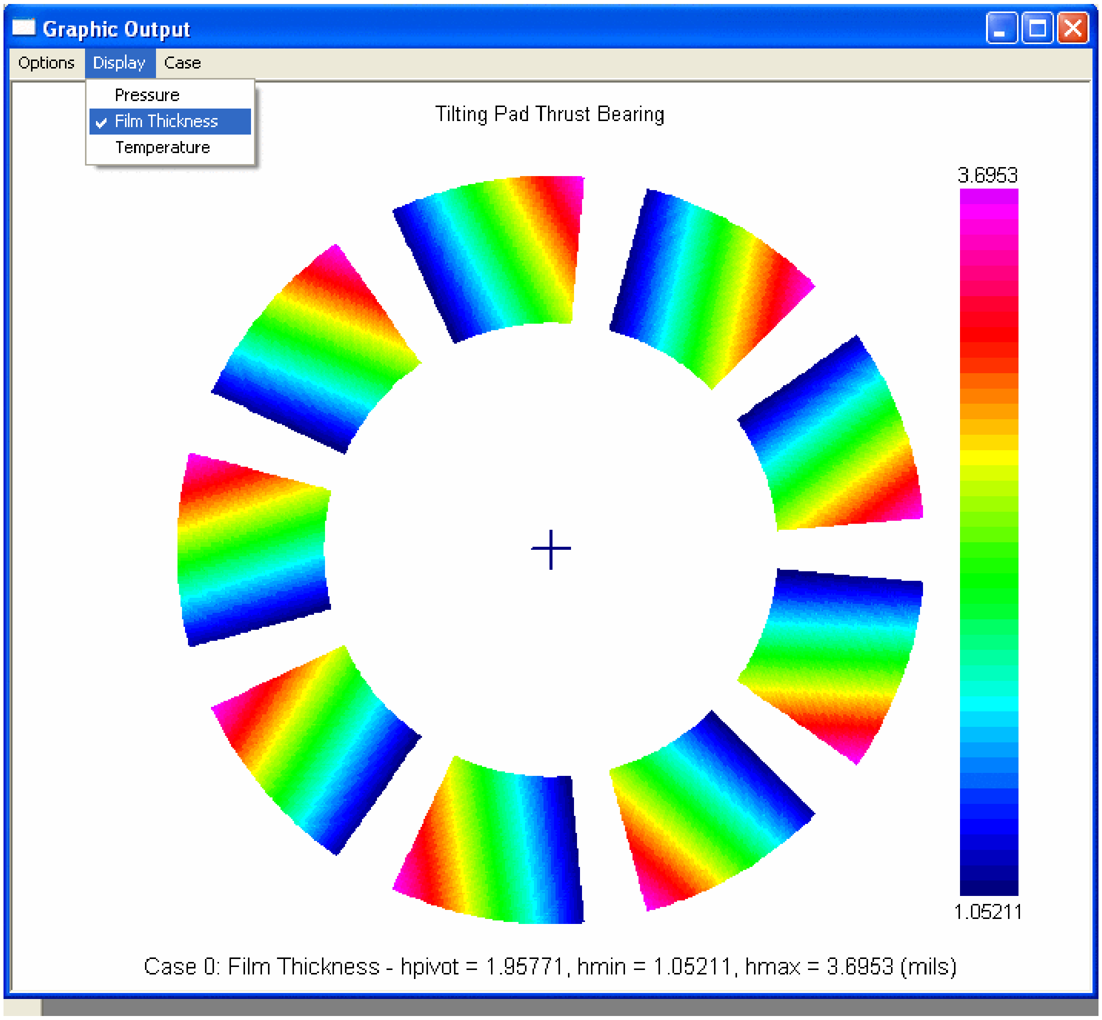
Pocket Thrust Bearing

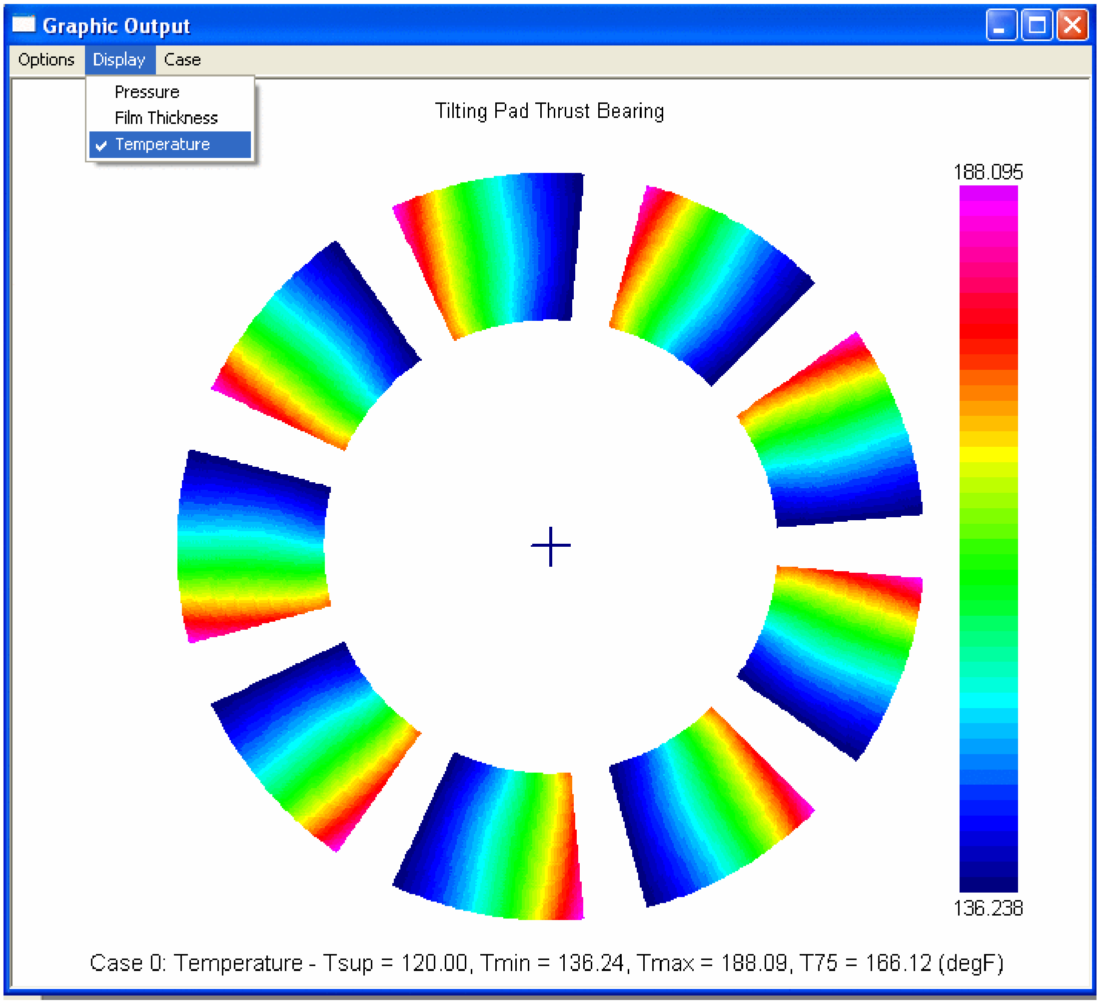




sample outputs from the program ThrustBrg


Graphic Output
Options
Display
Case
Next
Previous
Tilting Pad Thrust Bearing
1210.75
0
Case 0: Pressure Distribution - Pmin = 0.000, Pmax = 1210.751 (psi)


Graphic Output
Options
Display
Case
Pressure
Film Thickness
Temperature
Tilting Pad Thrust Bearing
3.6953
1.05211
Case 0: Film Thickness - hpivot = 1.95771, hmin = 1.05211, hmax = 3.6953 (mils)


Graphic Output
Options Display Case
Pressure
Film Thickness
Temperature
Tilting Pad Thrust Bearing
188.095
136.238
Case 0: Temperature - Tsup = 120.00, Tmin = 136.24, Tmax = 188.09, T75 = 166.12 (degF)

Hydrostatic - Hybrid Bearing Analysis

Hydrostatic journal bearing design is very different from the design of hydrodynamic bearings. Many design concepts are fundamentally different; such as increasing the load (or bearing eccentricity) will increase the bearing stiffness due to the higher hydrodynamic resistance for a hydrodynamic bearing. However, increasing the load (or bearing eccentricity) for a hydrostatic bearing may lower the bearing stiffness due to the higher pressure ratio, Pr/Ps (Recess pressure/supply pressure). For hydrostatic bearing, the bearing stiffness is mainly influenced by the Pr/Ps, however, the recess pressure is controlled by the flow through the land and the restrictor (capillary, orifice, etc.). For more information on the hydrostatic bearing design:

H.C. Rippel, "Design of Hydrostatic Bearings," Machine Design, Part 1-10, Aug. 1 to Dec 5, 1963.

J. P. O'Donoghue and W. B. Rowe, "Hydrostatic Bearing Design," Tribology, Vol. 2, Feb. 1969.

A. Cameron, "Basic Lubrication Theory," 1981.

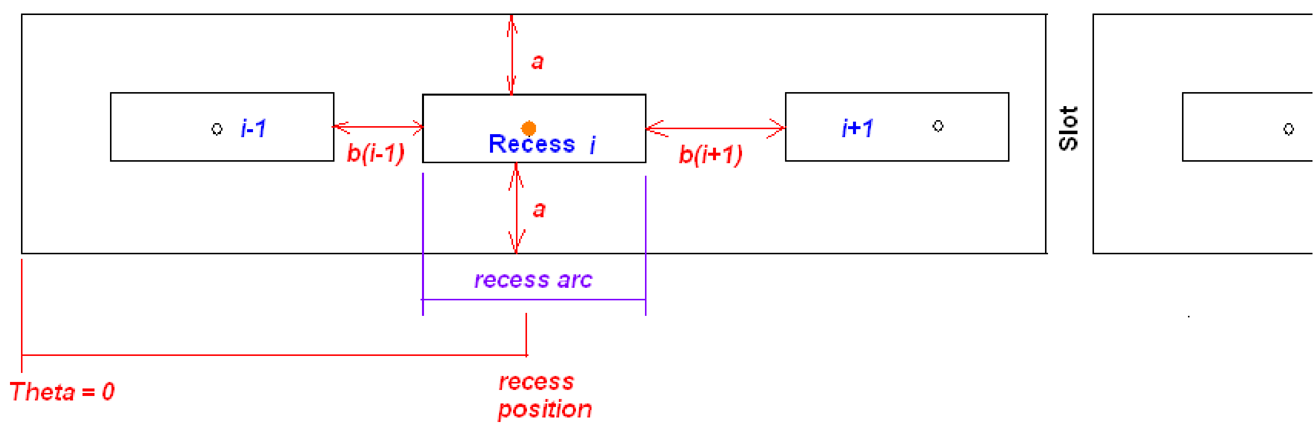
J. Frene, etc., "Hydrodynamic Lubrication: Bearings & Thrust Bearings," Editor: D. Dowson Elsevier, 1990.

W. B. Rowe, "Hydrostatic, Aerostatic, and Hybrid Bearing Design,", Elsevier, 2012

Since the design of the hydrostatic bearing is mainly in the restrictor design, therefore, a design tool is also provided in this program.

Hydrostatic-Hybrid Journal Analysis

All the inputs are self-explanatory, the recess data are described below:



For recess I, the recess position is measured from theta = 0 to the center of the recess. Note that the oil supply hole may not be at the center in many situations. But, that does not affect the recess pressure. Recess position is used to identify the recess location.

I-1 is the previous recess number, it can be 0 if I is connected to the slot, not another recess.

I+1 is the next recess number, it can be 0 if I is connected to the slot, not another recess.

Assuming N is the total recess numbers. For the first recess (I=1), I-1 will be either N (cyclic symmetric and not slot) or 0 (if slot exists). For the last recess (I=N), I+1 will be either 1 (cyclic symmetric and no slot) or 0 if slot exists.

b(I-1) is the inter-recess land between I and I-1.

b(I+1) is the inter-recess land between I and I+1.

a is the axial land width per side.

Pad number is needed only if bearing is preloaded and/or tilting pad bearing. Each pad is separately by the oil slot.

Three different restrictor types can be used in this program: They are: Capillary, Orifice, and constant flow. Many examples are provided for reference.

DyRoBeS_BePerf - C:\1610\Hybrid_RBTS.HSJ

Project Fixed-Lobe Tilting-Pad Floating-Ring Gas-Brg Thrust Lubricant-Flow Hydrostatic Tools View Help

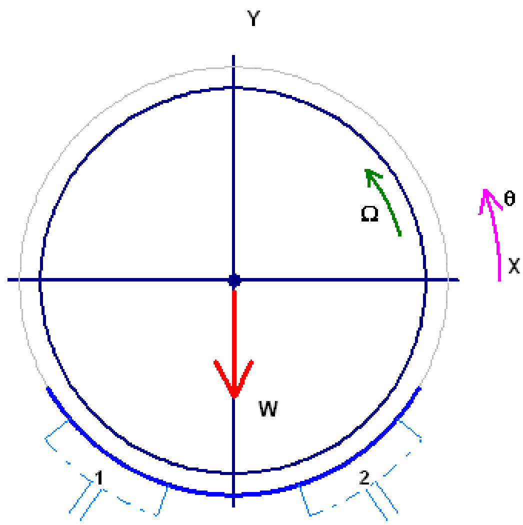
RBTS Example - Coal Pulverizer - Flow is specified per Recess

Bearing Data
L = 28 in
Ds = 90 in
Cb = 0.02 in
2Cb/D = 0.0004

Recess Ang = 236, 304
Recess Arc = 32, 32
b(i-1) = 10, 36
b(i+1) = 36, 10
2 Theta = 55, 55
slot = 240.00, 0.00
a = 9, 9 in
Depth = 0.1, 0.1 in

Ps = 100 psi
Restrictor = Qr

Viscosity = 2E-06 (Reyns)



For Help, press F1 NUM

Hydrostatic - Hybrid Journal Bearings

Comment: RBTS Example - Coal Pulverizer - Flow is specified per Recess

Coordinate System: Standard Coordinates (X-Y), theta from +X (pos X) Analysis: Isothermal

Convert Units: English in, Lbf, psi, degF, Reyns, Lbm/in^3, gpm, rpm

Journal Dia. D: 90

Axial Length L: 28 Viscosity: 2E-06 Density: 0 Pamb: 0

Brg Radial Clr Cb: 0.02

Note: Pad data required only when preload exists

No. of Recesses: 2 Recess Data No. of Pads: 0 Pad Data

No. of Pumps: 1 Pump Data No. of Loads: 3 Load Data

New Open Save Save As Run Cancel

Pump Data

Supply Pressure is the pressure before the Restrictor

Flow Capacity is used for reference only

Psupply = psi; Qsupply = gpm; Eff = 0-1

No	Psupply	Qsupply	Efficiency
1	100	0	0.75

Loading Data

Load = Lbf; Angle = degree

No	rpm	W Load	Angle
1	12	12800	270
2	12	15000	270
3	12	60000	270

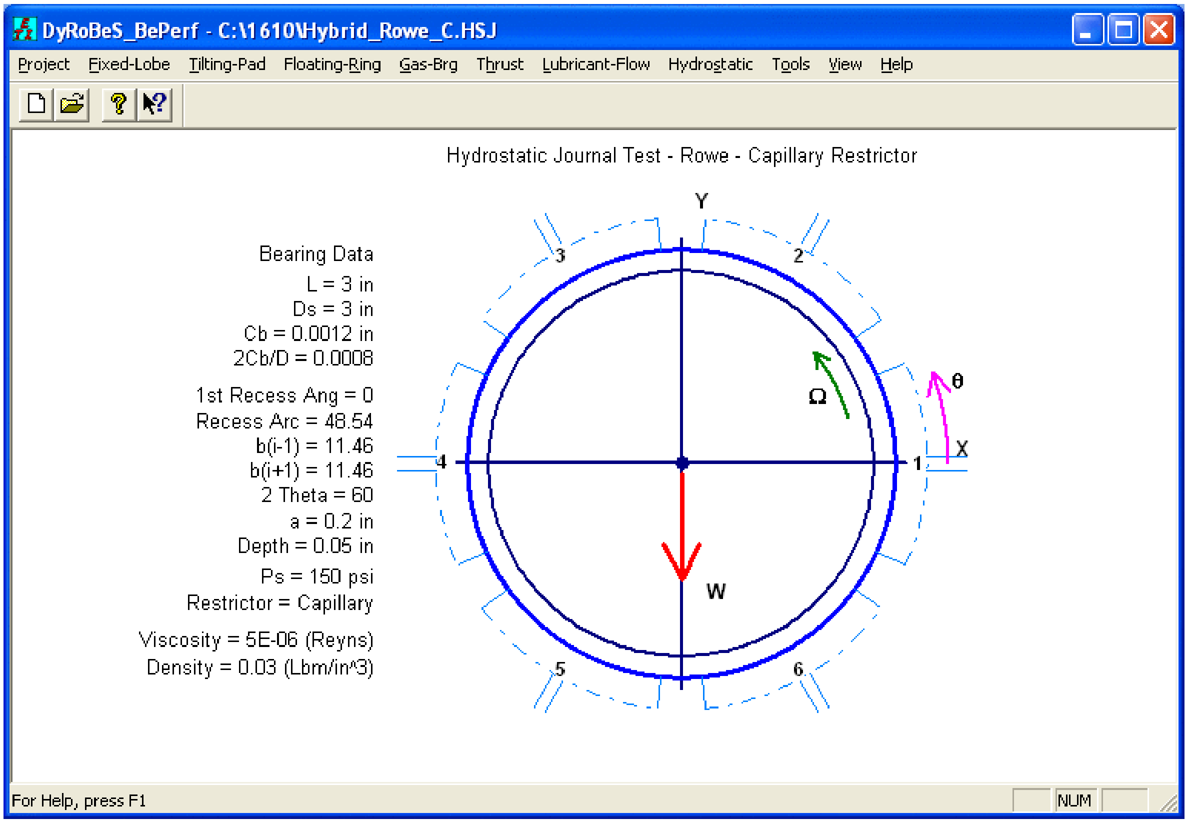
Recess (Pocket) Data

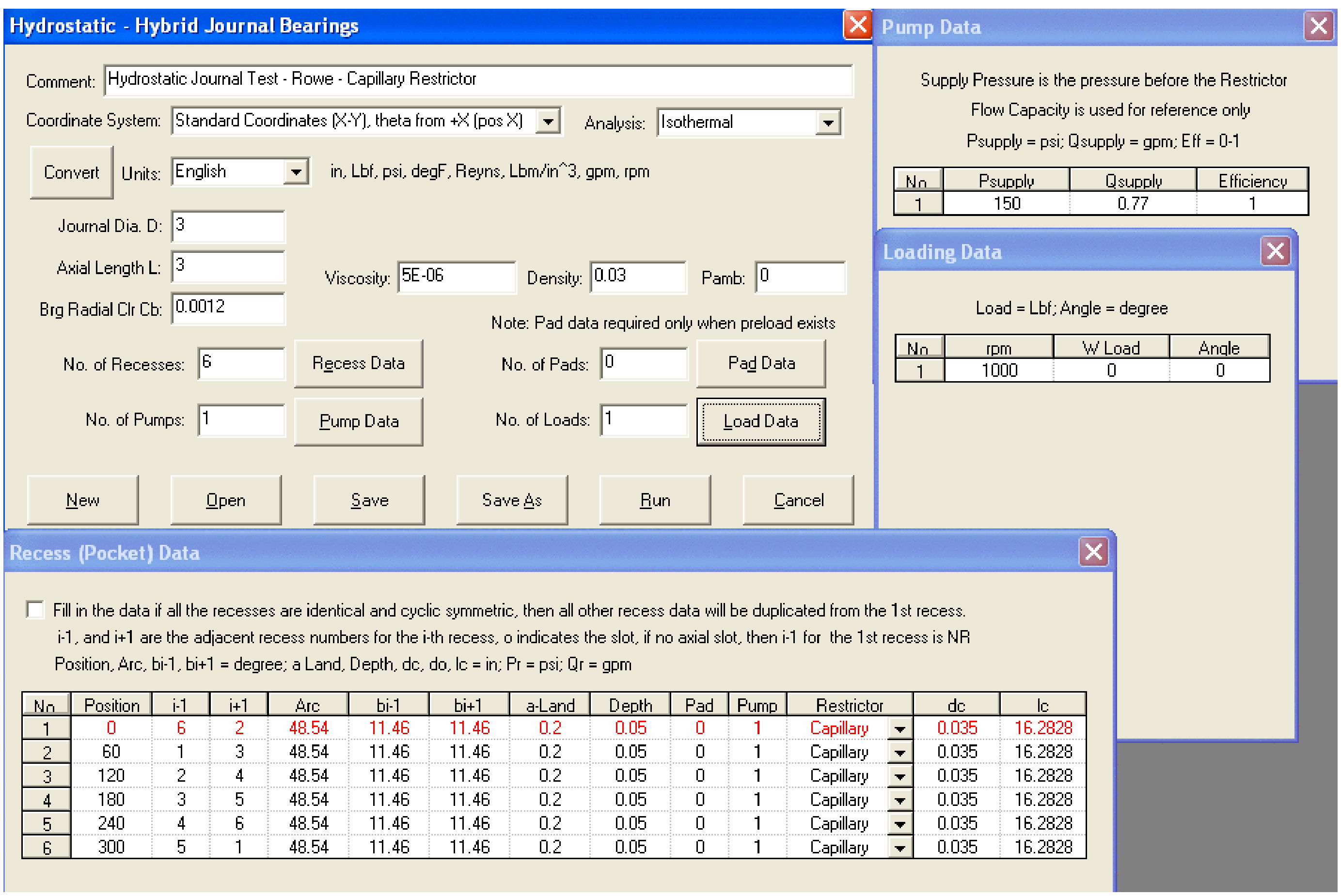
☐ Fill in the data if all the recesses are identical and cyclic symmetric, then all other recess data will be duplicated from the 1st recess.

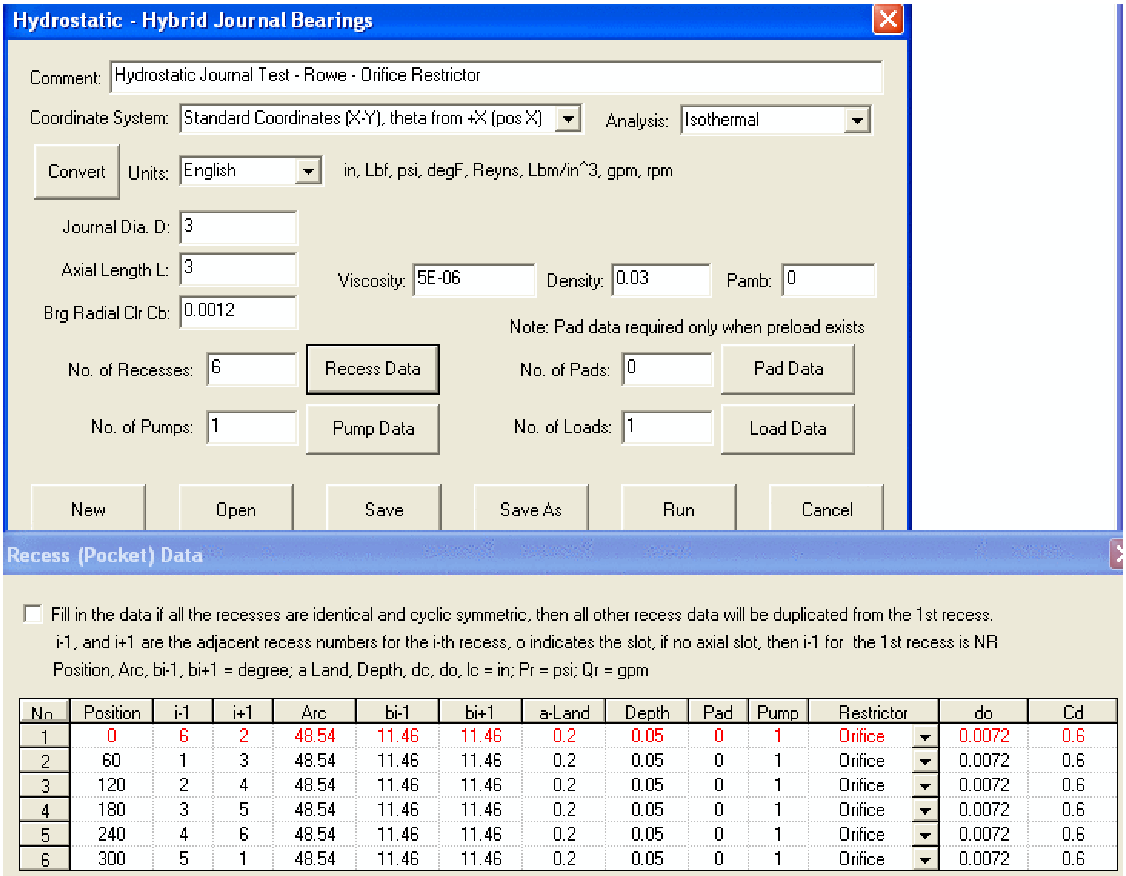
i-1, and i+1 are the adjacent recess numbers for the i-th recess, o indicates the slot, if no axial slot, then i-1 for the 1st recess is NR

Position, Arc, bi-1, bi+1 = degree; a Land, Depth, dc, do, lc = in; Pr = psi; Qr = gpm

No	Position	i-1	i+1	Arc	bi-1	bi+1	a-Land	Depth	Pad	Pump	Restrictor	Qr	
1	236	0	2	32	10	36	9	0.1	0	1	Qr Specified	10	0
2	304	1	0	32	36	10	9	0.1	0	1	Qr Specified	10	0


DyRoBeS_BePerf - C:\1610\Hybrid_Rowe_C.HSJ
Project Fixed-Lobe Tilting-Pad Floating-Ring Gas-Brg Thrust Lubricant-Flow Hydrostatic Tools View Help
Hydrostatic Journal Test - Rowe - Capillary Restrictor
Bearing Data
L = 3 in
Ds = 3 in
Cb = 0.0012 in
2Cb/D = 0.0008
1st Recess Ang = 0
Recess Arc = 48.54
b(i-1) = 11.46
b(i+1) = 11.46
2 Theta = 60
a = 0.2 in
Depth = 0.05 in
Ps = 150 psi
Restrictor = Capillary
Viscosity = 5E-06 (Reyns)
Density = 0.03 (Lbm/in^3)
Y
X
θ
Ω
W
1
2
3
4
5
6
For Help, press F1
NUM


Hydrostatic - Hybrid Journal Bearings
Comment: Hydrostatic Journal Test - Rowe - Capillary Restrictor
Coordinate System: Standard Coordinates (X-Y), theta from +X (pos X)
Analysis: Isothermal
Convert
Units: English
in, Lbf, psi, degF, Reyns, Lbm/in^3, gpm, rpm
Journal Dia. D: 3
Axial Length L: 3
Brg Radial Clr Cb: 0.0012
Viscosity: 5E-06
Density: 0.03
Pamb: 0
Note: Pad data required only when preload exists
No. of Recesses: 6
Recess Data
No. of Pads: 0
Pad Data
No. of Pumps: 1
Pump Data
No. of Loads: 1
Load Data
New
Open
Save
Save As
Run
Cancel
Pump Data
Supply Pressure is the pressure before the Restrictor
Flow Capacity is used for reference only
Psupply = psi; Qsupply = gpm; Eff = 0-1
No | Psupply | Qsupply | Efficiency
1 | 150 | 0.77 | 1
Loading Data
Load = Lbf; Angle = degree
No | rpm | W Load | Angle
1 | 1000 | 0 | 0
Recess (Pocket) Data
Fill in the data if all the recesses are identical and cyclic symmetric, then all other recess data will be duplicated from the 1st recess.
i-1, and i+1 are the adjacent recess numbers for the i-th recess, o indicates the slot, if no axial slot, then i-1 for the 1st recess is NR
Position, Arc, bi-1, bi+1 = degree; a Land, Depth, dc, do, lc = in; Pr = psi; Qr = gpm
No | Position | i-1 | i+1 | Arc | bi-1 | bi+1 | a-Land | Depth | Pad | Pump | Restrictor | dc | lc
1 | 0 | 6 | 2 | 48.54 | 11.46 | 11.46 | 0.2 | 0.05 | 0 | 1 | Capillary | 0.035 | 16.2828
2 | 60 | 1 | 3 | 48.54 | 11.46 | 11.46 | 0.2 | 0.05 | 0 | 1 | Capillary | 0.035 | 16.2828
3 | 120 | 2 | 4 | 48.54 | 11.46 | 11.46 | 0.2 | 0.05 | 0 | 1 | Capillary | 0.035 | 16.2828
4 | 180 | 3 | 5 | 48.54 | 11.46 | 11.46 | 0.2 | 0.05 | 0 | 1 | Capillary | 0.035 | 16.2828
5 | 240 | 4 | 6 | 48.54 | 11.46 | 11.46 | 0.2 | 0.05 | 0 | 1 | Capillary | 0.035 | 16.2828
6 | 300 | 5 | 1 | 48.54 | 11.46 | 11.46 | 0.2 | 0.05 | 0 | 1 | Capillary | 0.035 | 16.2828



Hydrostatic - Hybrid Journal Bearings

Comment: Hydrostatic Journal Test - Rowe - Orifice Restrictor

Coordinate System: Standard Coordinates (X-Y), theta from +X (pos X) Analysis: Isothermal

Convert Units: English in, Lbf, psi, degF, Reyns, Lbm/in^3, gpm, rpm

Journal Dia. D: 3

Axial Length L: 3 Viscosity: 5E-06 Density: 0.03 Pamb: 0

Brg Radial Clr Cb: 0.0012

Note: Pad data required only when preload exists

No. of Recesses: 6 Recess Data No. of Pads: 0 Pad Data

No. of Pumps: 1 Pump Data No. of Loads: 1 Load Data

New Open Save Save As Run Cancel

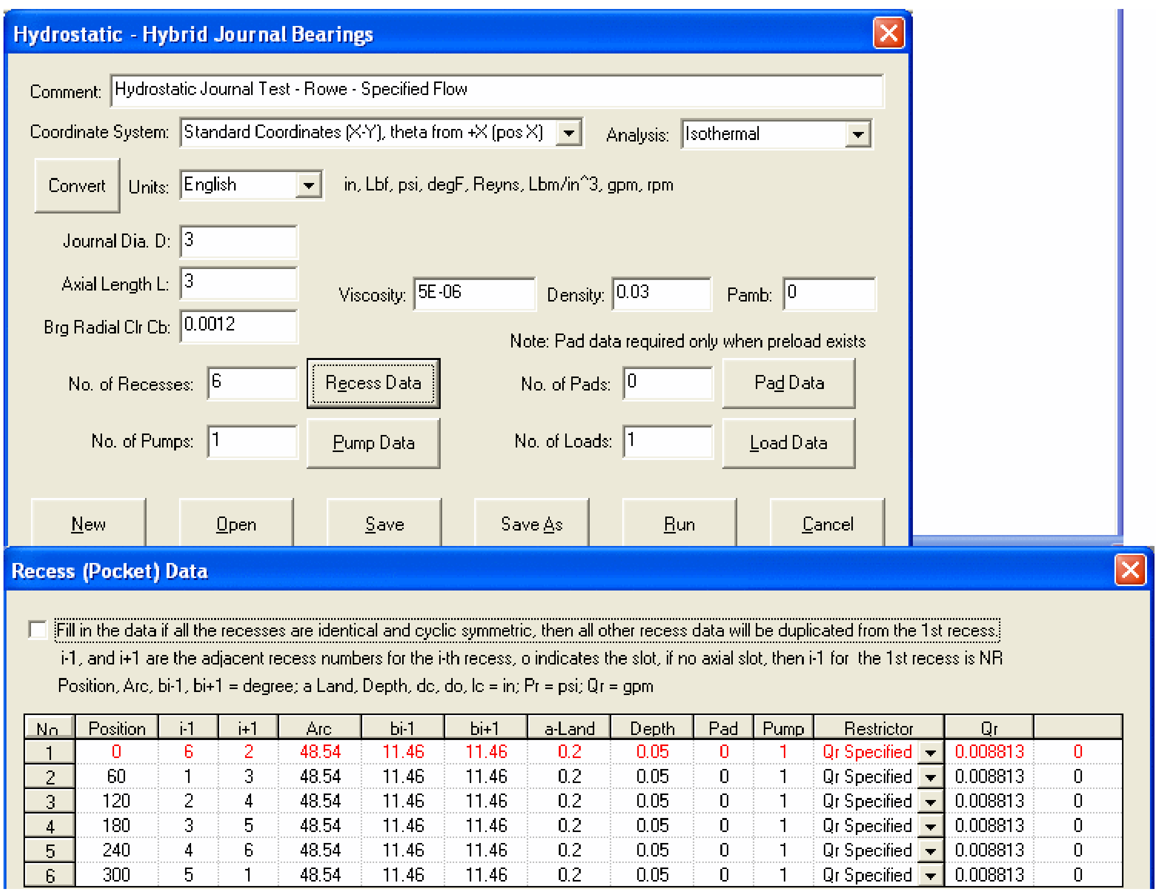
Recess (Pocket) Data

Fill in the data if all the recesses are identical and cyclic symmetric, then all other recess data will be duplicated from the 1st recess.

i-1, and i+1 are the adjacent recess numbers for the i-th recess, o indicates the slot, if no axial slot, then i-1 for the 1st recess is NR

Position, Arc, bi-1, bi+1 = degree; a Land, Depth, dc, do, lc = in; Pr = psi; Qr = gpm

No	Position	i-1	i+1	Arc	bi-1	bi+1	a-Land	Depth	Pad	Pump	Restrictor	do	Cd
1	0	6	2	48.54	11.46	11.46	0.2	0.05	0	1	Orifice	0.0072	0.6
2	60	1	3	48.54	11.46	11.46	0.2	0.05	0	1	Orifice	0.0072	0.6
3	120	2	4	48.54	11.46	11.46	0.2	0.05	0	1	Orifice	0.0072	0.6
4	180	3	5	48.54	11.46	11.46	0.2	0.05	0	1	Orifice	0.0072	0.6
5	240	4	6	48.54	11.46	11.46	0.2	0.05	0	1	Orifice	0.0072	0.6
6	300	5	1	48.54	11.46	11.46	0.2	0.05	0	1	Orifice	0.0072	0.6



Hydrostatic - Hybrid Journal Bearings

Comment: Hydrostatic Journal Test - Rowe - Specified Flow

Coordinate System: Standard Coordinates (X-Y), theta from +X (pos X) Analysis: Isothermal

Convert Units: English in, Lbf, psi, degF, Reyns, Lbm/in^3, gpm, rpm

Journal Dia. D: 3

Axial Length L: 3 Viscosity: 5E-06 Density: 0.03 Pamb: 0

Brg Radial Clr Cb: 0.0012

Note: Pad data required only when preload exists

No. of Recesses: 6 Recess Data No. of Pads: 0 Pad Data

No. of Pumps: 1 Pump Data No. of Loads: 1 Load Data

New Open Save Save As Run Cancel

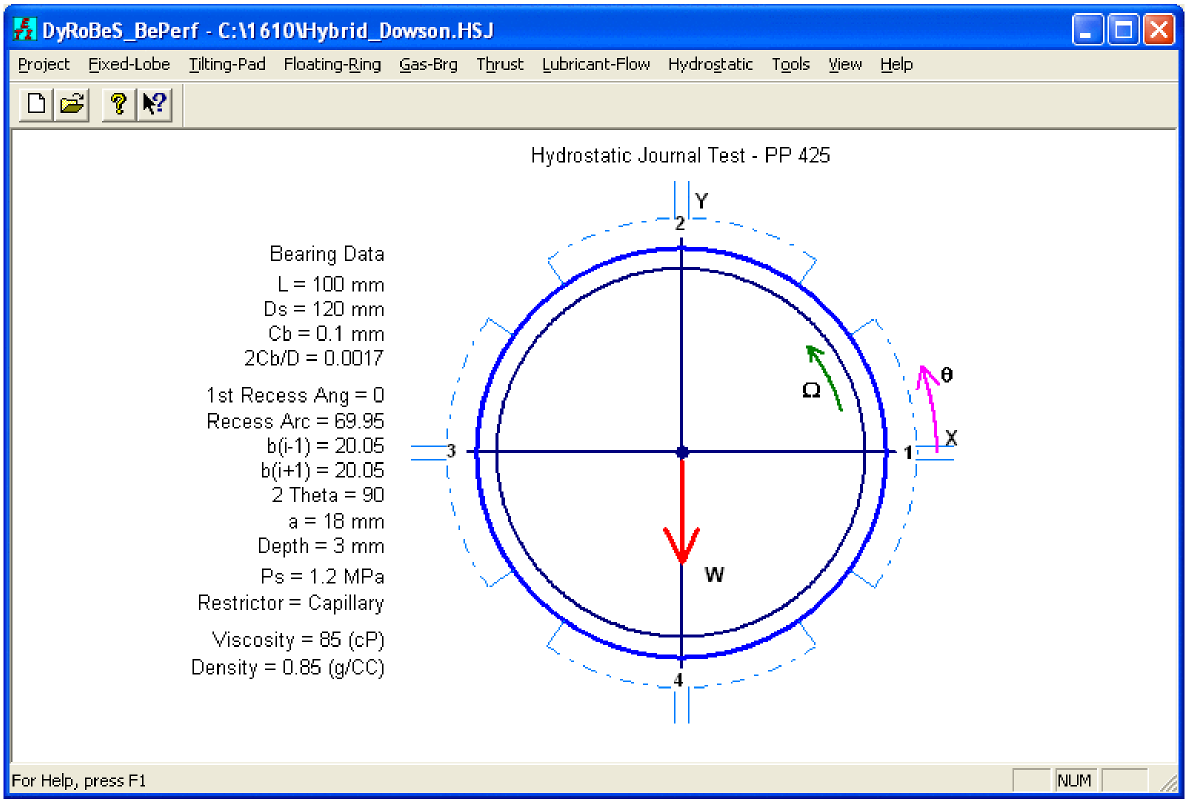
Recess (Pocket) Data

Fill in the data if all the recesses are identical and cyclic symmetric, then all other recess data will be duplicated from the 1st recess.

i-1, and i+1 are the adjacent recess numbers for the i-th recess, o indicates the slot, if no axial slot, then i-1 for the 1st recess is NR

Position, Arc, bi-1, bi+1 = degree; a Land, Depth, dc, do, lc = in; Pr = psi; Qr = gpm

No	Position	i-1	i+1	Arc	bi-1	bi+1	a-Land	Depth	Pad	Pump	Restrictor	Qr	
1	0	6	2	48.54	11.46	11.46	0.2	0.05	0	1	Qr Specified	0.008813	0
2	60	1	3	48.54	11.46	11.46	0.2	0.05	0	1	Qr Specified	0.008813	0
3	120	2	4	48.54	11.46	11.46	0.2	0.05	0	1	Qr Specified	0.008813	0
4	180	3	5	48.54	11.46	11.46	0.2	0.05	0	1	Qr Specified	0.008813	0
5	240	4	6	48.54	11.46	11.46	0.2	0.05	0	1	Qr Specified	0.008813	0
6	300	5	1	48.54	11.46	11.46	0.2	0.05	0	1	Qr Specified	0.008813	0



Hydrostatic - Hybrid Journal Bearings

Comment: Hydrostatic Journal Test - PP 425

Coordinate System: Standard Coordinates (X-Y), theta from +X (pos X) Analysis: Isothermal

Convert Units: Metric mm, Newton, MPa, degC, cPoise, gram/CC, lpm, rpm

Journal Dia. D: 120

Axial Length L: 100 Viscosity: 85 Density: 0.85 Pamb: 0

Brg Radial Clr Cb: 0.1

Note: Pad data required only when preload exists

No. of Recesses: 4 Recess Data No. of Pads: 0 Pad Data

No. of Pumps: 1 Pump Data No. of Loads: 2 Load Data

New Open Save Save As Run Cancel

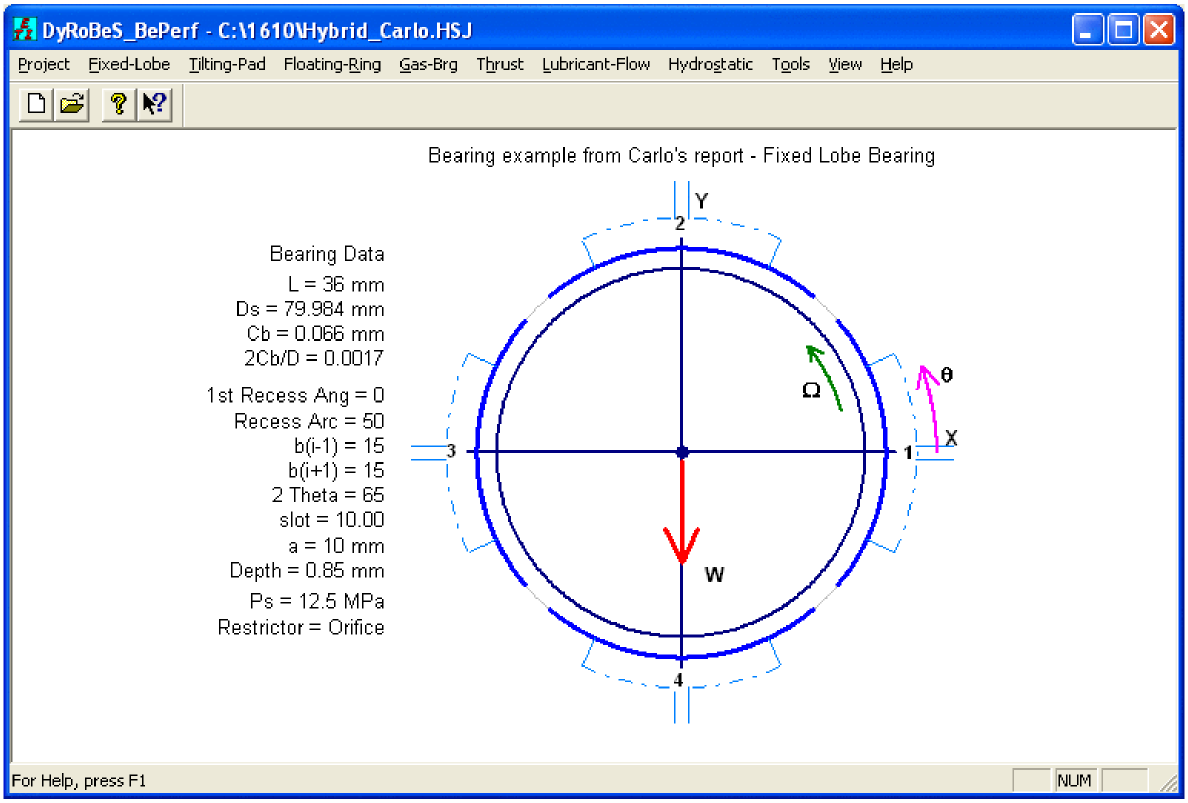
Recess (Pocket) Data

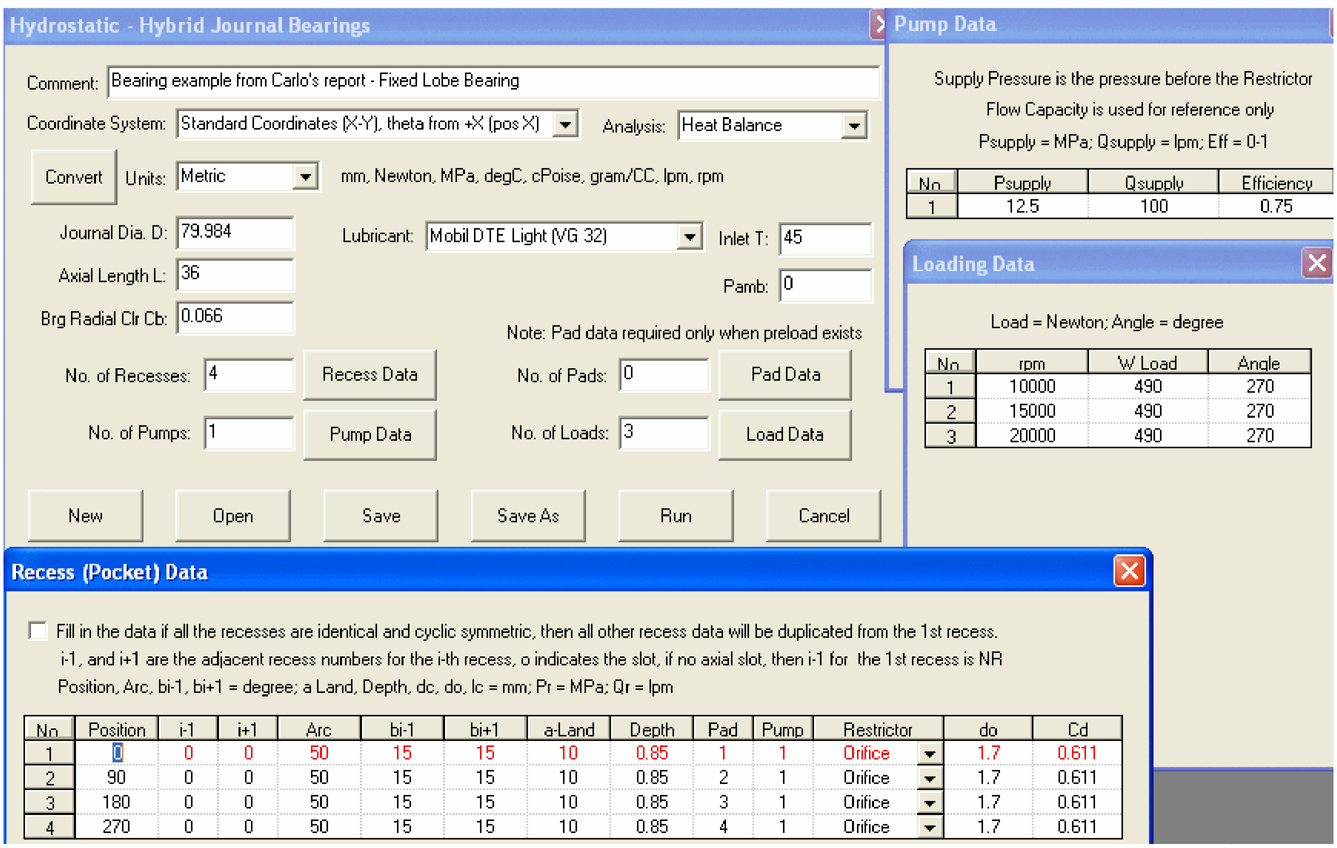
☐ Fill in the data if all the recesses are identical and cyclic symmetric, then all other recess data will be duplicated from the 1st recess.

i-1, and i+1 are the adjacent recess numbers for the i-th recess, o indicates the slot, if no axial slot, then i-1 for the 1st recess is NR

Position, Arc, bi-1, bi+1 = degree; a Land, Depth, dc, do, lc = mm; Pr = MPa; Qr = lpm

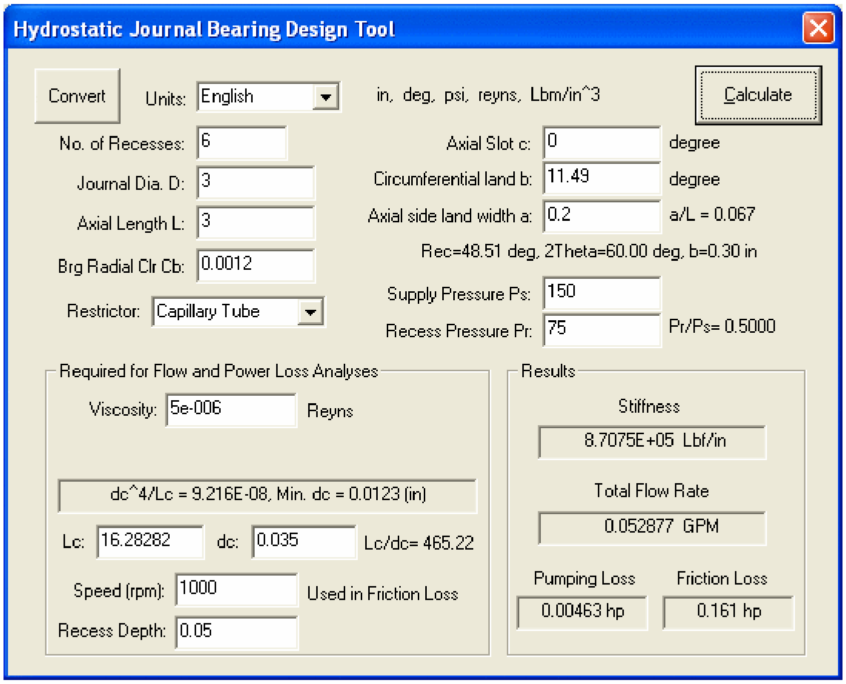
No	Position	i-1	i+1	Arc	bi-1	bi+1	a-Land	Depth	Pad	Pump	Restrictor	dc	lc
1	0	4	2	69.95	20.05	20.05	18	3	0	1	Capillary	1.2	58
2	90	1	3	69.95	20.05	20.05	18	3	0	1	Capillary	1.2	58
3	180	2	4	69.95	20.05	20.05	18	3	0	1	Capillary	1.2	58
4	270	3	1	69.95	20.05	20.05	18	3	0	1	Capillary	1.2	58

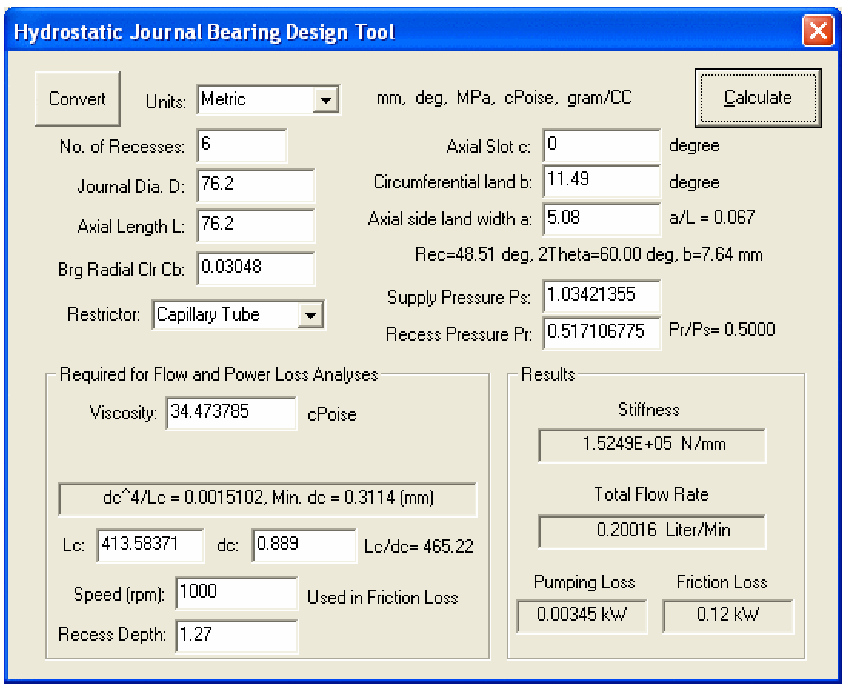


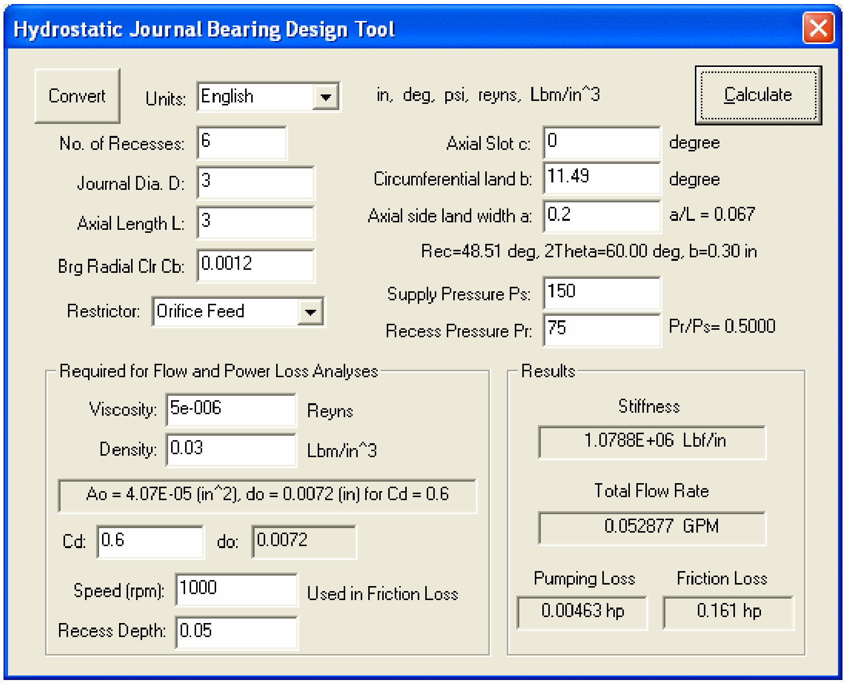


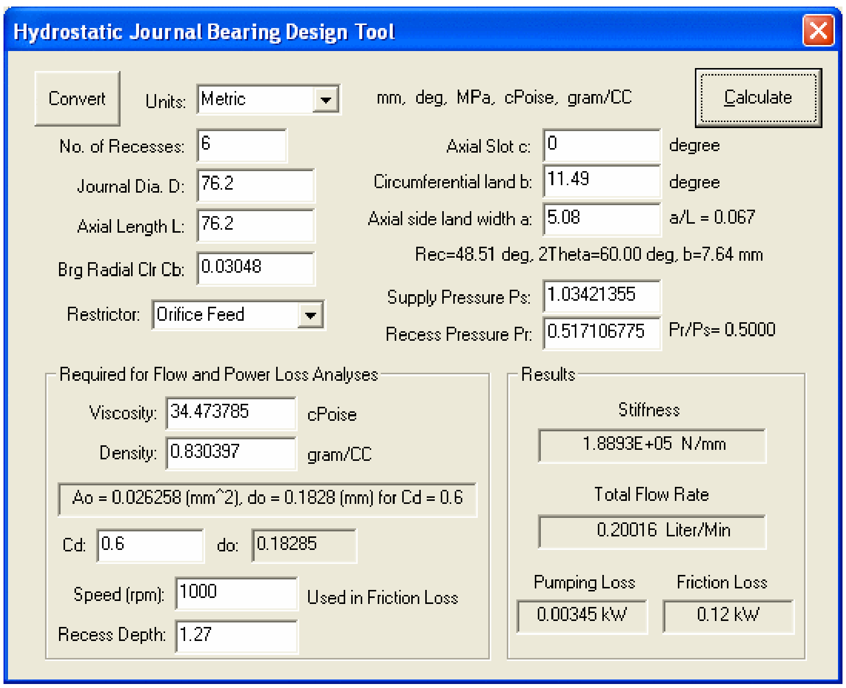
Hydrostatic Journal Analysis Design Tool

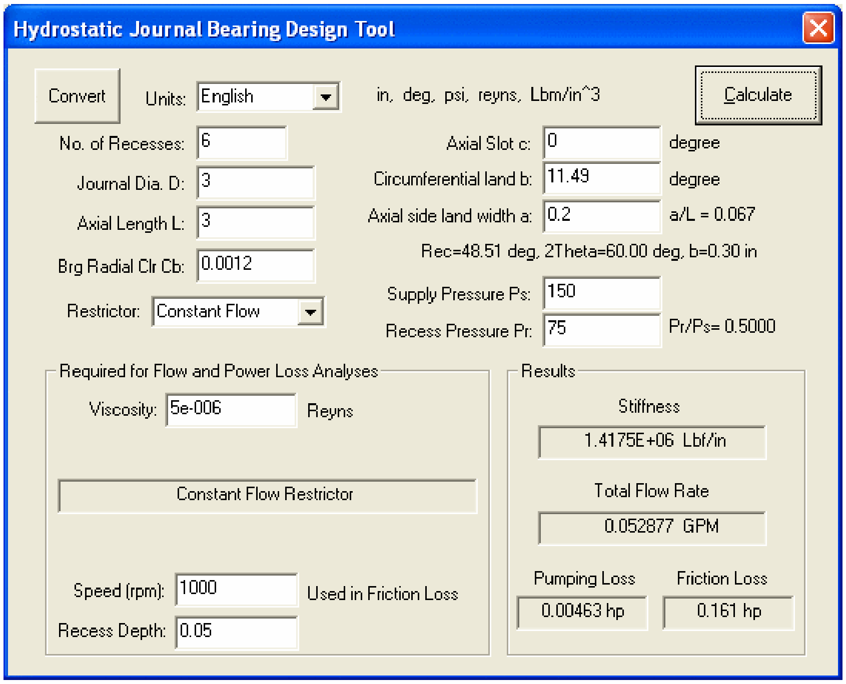
This tool is provided for the restrictor design.

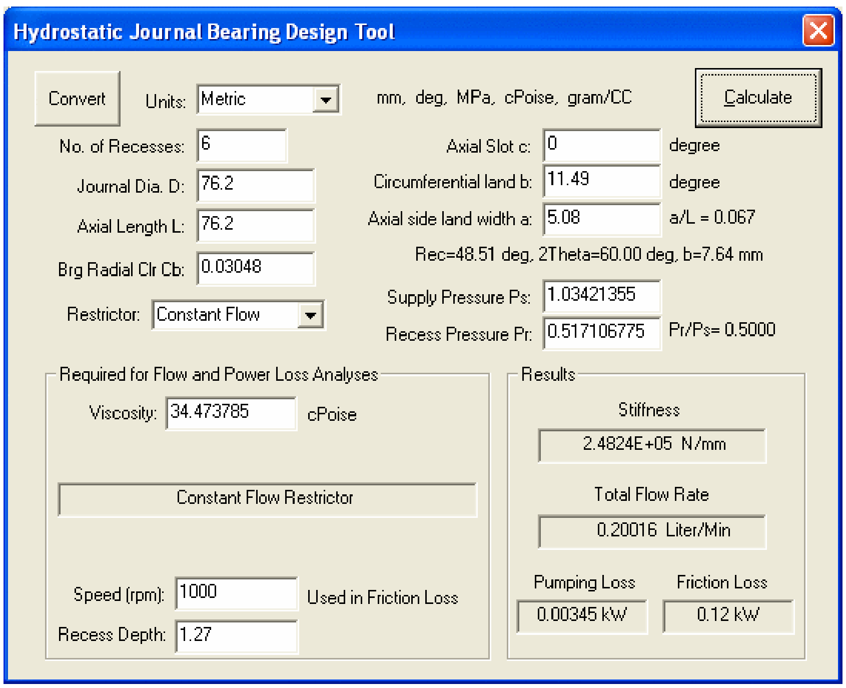

Hydrostatic Journal Bearing Design Tool
Convert
Units: English
in, deg, psi, reyns, Lbm/in^3
Calculate
No. of Recesses: 6
Journal Dia. D: 3
Axial Length L: 3
Brg Radial Clr Cb: 0.0012
Restrictor: Capillary Tube
Axial Slot c: 0 degree
Circumferential land b: 11.49 degree
Axial side land width a: 0.2 a/L = 0.067
Rec=48.51 deg, 2Theta=60.00 deg, b=0.30 in
Supply Pressure Ps: 150
Recess Pressure Pr: 75 Pr/Ps= 0.5000
Required for Flow and Power Loss Analyses
Viscosity: 5e-006 Reyns
dc^4/Lc = 9.216E-08, Min. dc = 0.0123 (in)
Lc: 16.28282 dc: 0.035 Lc/dc= 465.22
Speed (rpm): 1000 Used in Friction Loss
Recess Depth: 0.05
Results
Stiffness
8.7075E+05 Lbf/in
Total Flow Rate
0.052877 GPM
Pumping Loss
Friction Loss
0.00463 hp
0.161 hp

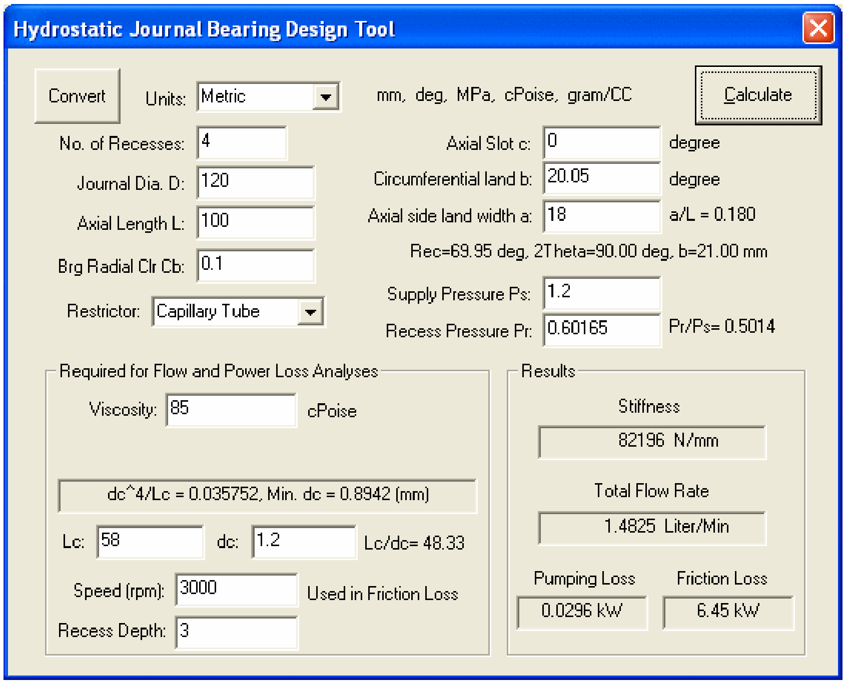

Hydrostatic Journal Bearing Design Tool
Convert
Units: Metric
mm, deg, MPa, cPoise, gram/CC
Calculate
No. of Recesses: 6
Journal Dia. D: 76.2
Axial Length L: 76.2
Brg Radial Clr Cb: 0.03048
Restrictor: Capillary Tube
Axial Slot c: 0 degree
Circumferential land b: 11.49 degree
Axial side land width a: 5.08 a/L = 0.067
Rec=48.51 deg, 2Theta=60.00 deg, b=7.64 mm
Supply Pressure Ps: 1.03421355
Recess Pressure Pr: 0.517106775 Pr/Ps= 0.5000
Required for Flow and Power Loss Analyses
Viscosity: 34.473785 cPoise
dc^4/Lc = 0.0015102, Min. dc = 0.3114 (mm)
Lc: 413.58371 dc: 0.889 Lc/dc= 465.22
Speed (rpm): 1000 Used in Friction Loss
Recess Depth: 1.27
Results
Stiffness
1.5249E+05 N/mm
Total Flow Rate
0.20016 Liter/Min
Pumping Loss
Friction Loss
0.00345 kW
0.12 kW


Hydrostatic Journal Bearing Design Tool
Convert
Units: English
in, deg, psi, reyns, Lbm/in^3
Calculate
No. of Recesses: 6
Journal Dia. D: 3
Axial Length L: 3
Brg Radial Clr Cb: 0.0012
Restrictor: Orifice Feed
Axial Slot c: 0 degree
Circumferential land b: 11.49 degree
Axial side land width a: 0.2 a/L = 0.067
Rec=48.51 deg, 2Theta=60.00 deg, b=0.30 in
Supply Pressure Ps: 150
Recess Pressure Pr: 75 Pr/Ps= 0.5000
Required for Flow and Power Loss Analyses
Viscosity: 5e-006 Reyns
Density: 0.03 Lbm/in^3
Ao = 4.07E-05 (in^2), do = 0.0072 (in) for Cd = 0.6
Cd: 0.6 do: 0.0072
Speed (rpm): 1000 Used in Friction Loss
Recess Depth: 0.05
Results
Stiffness
1.0788E+06 Lbf/in
Total Flow Rate
0.052877 GPM
Pumping Loss
Friction Loss
0.00463 hp
0.161 hp


Hydrostatic Journal Bearing Design Tool
Convert
Units: Metric
mm, deg, MPa, cPoise, gram/CC
Calculate
No. of Recesses: 6
Journal Dia. D: 76.2
Axial Length L: 76.2
Brg Radial Clr Cb: 0.03048
Restrictor: Orifice Feed
Axial Slot c: 0 degree
Circumferential land b: 11.49 degree
Axial side land width a: 5.08 a/L = 0.067
Rec=48.51 deg, 2Theta=60.00 deg, b=7.64 mm
Supply Pressure Ps: 1.03421355
Recess Pressure Pr: 0.517106775 Pr/Ps= 0.5000
Required for Flow and Power Loss Analyses
Viscosity: 34.473785 cPoise
Density: 0.830397 gram/CC
Ao = 0.026258 (mm^2), do = 0.1828 (mm) for Cd = 0.6
Cd: 0.6 do: 0.18285
Speed (rpm): 1000 Used in Friction Loss
Recess Depth: 1.27
Results
Stiffness
1.8893E+05 N/mm
Total Flow Rate
0.20016 Liter/Min
Pumping Loss
Friction Loss
0.00345 kW
0.12 kW

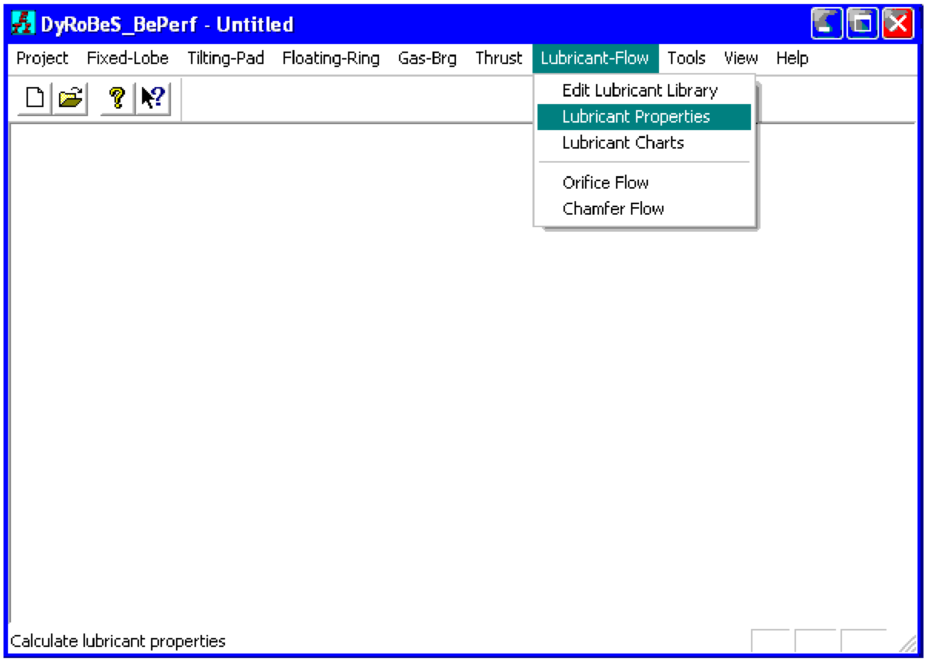

Hydrostatic Journal Bearing Design Tool
Convert
Units: English
in, deg, psi, reyns, Lbm/in^3
Calculate
No. of Recesses: 6
Journal Dia. D: 3
Axial Length L: 3
Brg Radial Clr Cb: 0.0012
Restrictor: Constant Flow
Axial Slot c: 0 degree
Circumferential land b: 11.49 degree
Axial side land width a: 0.2 a/L = 0.067
Rec=48.51 deg, 2Theta=60.00 deg, b=0.30 in
Supply Pressure Ps: 150
Recess Pressure Pr: 75 Pr/Ps= 0.5000
Required for Flow and Power Loss Analyses
Viscosity: 5e-006 Reyns
Constant Flow Restrictor
Speed (rpm): 1000 Used in Friction Loss
Recess Depth: 0.05
Results
Stiffness
1.4175E+06 Lbf/in
Total Flow Rate
0.052877 GPM
Pumping Loss
Friction Loss
0.00463 hp
0.161 hp


Hydrostatic Journal Bearing Design Tool
Convert
Units: Metric
mm, deg, MPa, cPoise, gram/CC
Calculate
No. of Recesses: 6
Journal Dia. D: 76.2
Axial Length L: 76.2
Brg Radial Clr Cb: 0.03048
Restrictor: Constant Flow
Axial Slot c: 0 degree
Circumferential land b: 11.49 degree
Axial side land width a: 5.08 a/L = 0.067
Rec=48.51 deg, 2Theta=60.00 deg, b=7.64 mm
Supply Pressure Ps: 1.03421355
Recess Pressure Pr: 0.517106775 Pr/Ps= 0.5000
Required for Flow and Power Loss Analyses
Viscosity: 34.473785 cPoise
Constant Flow Restrictor
Speed (rpm): 1000 Used in Friction Loss
Recess Depth: 1.27
Results
Stiffness
2.4824E+05 N/mm
Total Flow Rate
0.20016 Liter/Min
Pumping Loss
Friction Loss
0.00345 kW
0.12 kW


Hydrostatic Journal Bearing Design Tool
Convert
Units: Metric
mm, deg, MPa, cPoise, gram/CC
Calculate
No. of Recesses: 4
Journal Dia. D: 120
Axial Length L: 100
Brg Radial Clr Cb: 0.1
Restrictor: Capillary Tube
Axial Slot c: 0 degree
Circumferential land b: 20.05 degree
Axial side land width a: 18 a/L = 0.180
Rec=69.95 deg, 2Theta=90.00 deg, b=21.00 mm
Supply Pressure Ps: 1.2
Recess Pressure Pr: 0.60165 Pr/Ps= 0.5014
Required for Flow and Power Loss Analyses
Viscosity: 85 cPoise
dc^4/Lc = 0.035752, Min. dc = 0.8942 (mm)
Lc: 58 dc: 1.2 Lc/dc= 48.33
Speed (rpm): 3000 Used in Friction Loss
Recess Depth: 3
Results
Stiffness
82196 N/mm
Total Flow Rate
1.4825 Liter/Min
Pumping Loss
0.0296 kW
Friction Loss
6.45 kW

Lubricant

An accurate lubricant dynamic viscosity is essential to the calculation of bearing performance. The basic properties of a number of commonly used lubricants are collected and stored in a library. User can always add new lubricants into the library or edit the existing lubricants by selecting **Edit Lubricant Library**. The **Lubricant Properties** option tabulates the lubricant properties (viscosity, density, specific heat), for a range of temperatures specified in the dialog box. The **Lubricant Chart** option displays the lubricant properties for up to 3 different lubricants in a chart for comparison proposes.



Edit Lubricant Library

This function allows you to edit your own lubricants from the library and also to review the existing lubricants data in the library. Input parameters are:

Lubricant

Select the lubricant that you like to edit.

Title

This title will become the lubricant identification after the data is saved.

Specific gravity @ 60 ^oF (15.6 ^oC)

Very often ^{o}API is used to describe the specific gravity. The API gravity and the specific gravity at 60 ^oF are related by the following equation:

$$spgr_{60} = \frac{141.5}{(131.5 + \text{API})}$$

Viscosity (centiStoke) at two temperature points

The viscosities (cSt) at 100 ^oF and 210 ^oF (or at 40 ^oC and 100 ^oC) are commonly published by the lubricant suppliers. ASTM viscosity-temperature relationship is used to calculate the viscosity at any given temperature.

Pour and flash points

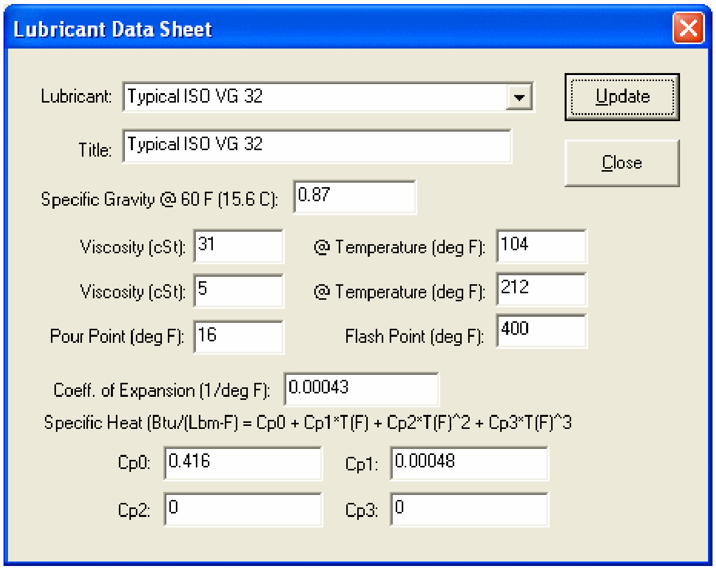
These data are entered for reference only.

Coefficient of expansion

If you do not know the coefficient of expansion, then enter zero in the input. The program will estimate it based on the specific gravity and data table provided in the Handbook of Lubrication.

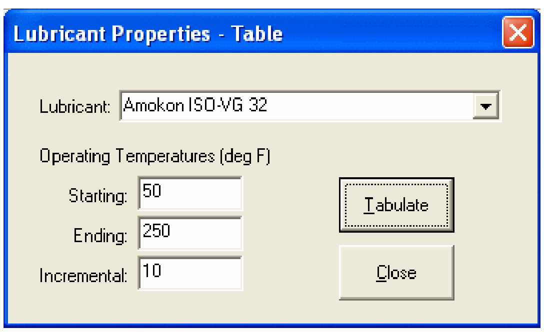
Coefficients for specific heat

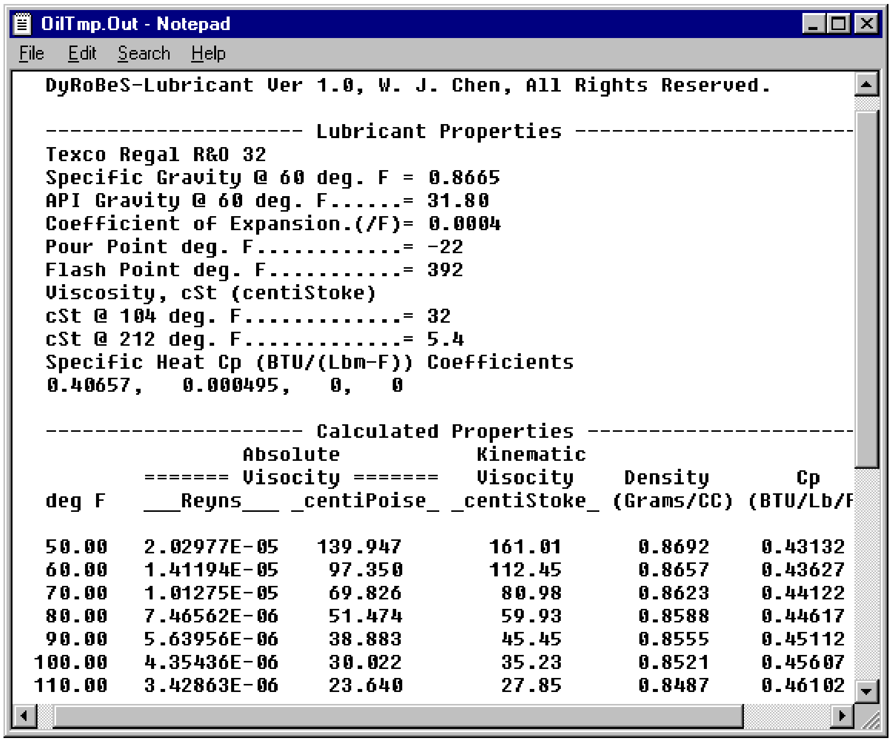
The specific heat is a function of temperature and specific gravity. If you do not know the coefficients for specific heat, then enter zeros. The program will estimate them based on the data provided in the Publication No. 97 from Bureau of Standards.



Lubricant Properties

This function tabulates the lubricant properties (viscosity, density, specific heat) for a range of temperatures specified in the dialog box. The results are displayed immediately on the screen. You can view, print, and save the file.

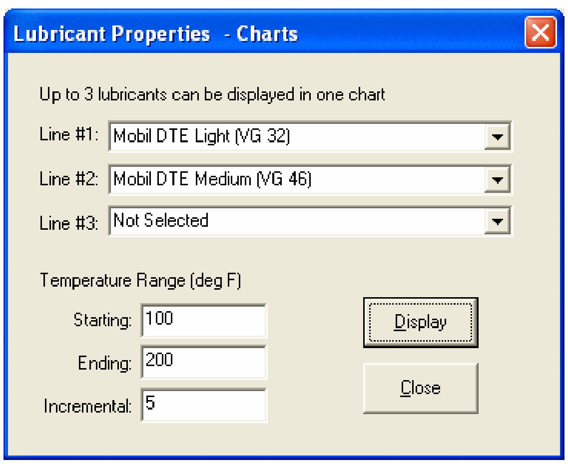


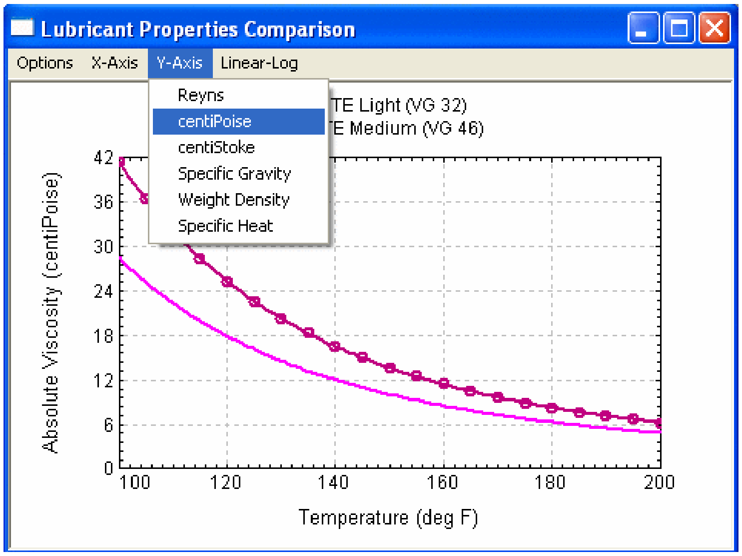


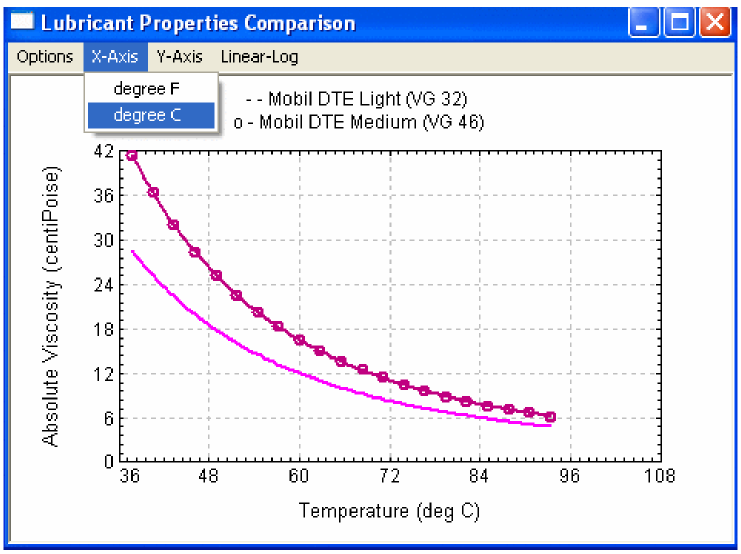

```
DyRoBeS-Lubricant Ver 1.0, W. J. Chen, All Rights Reserved.

--------------------- Lubricant Properties ----------------------
Texco Regal R&O 32
Specific Gravity @ 60 deg. F = 0.8665
API Gravity @ 60 deg. F......= 31.80
Coefficient of Expansion.(/F)= 0.0004
Pour Point deg. F............= -22
Flash Point deg. F...........= 392
Viscosity, cSt (centiStoke)
cSt @ 104 deg. F.............= 32
cSt @ 212 deg. F.............= 5.4
Specific Heat Cp (BTU/(Lbm-F)) Coefficients
0.40657,   0.000495,   0,   0

--------------------- Calculated Properties ---------------------
                Absolute             Kinematic
        ======= Viscocity =======    Viscocity    Density      Cp
deg F   ___Reyns___ _centiPoise_ _centiStoke_ (Grams/CC) (BTU/Lb/F

 50.00  2.02977E-05   139.947       161.01      0.8692    0.43132
 60.00  1.41194E-05    97.350       112.45      0.8657    0.43627
 70.00  1.01275E-05    69.826        80.98      0.8623    0.44122
 80.00  7.46562E-06    51.474        59.93      0.8588    0.44617
 90.00  5.63956E-06    38.883        45.45      0.8555    0.45112
100.00  4.35436E-06    30.022        35.23      0.8521    0.45607
110.00  3.42863E-06    23.640        27.85      0.8487    0.46102
```

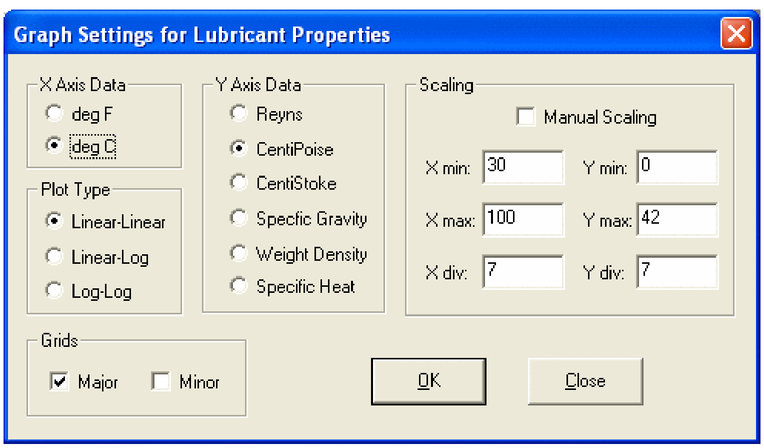
Lubricant Charts

This function allows you to compare the lubricant properties for up to 3 different lubricants. The graphic results are displayed immediately on the screen. The first default graph is the dynamic viscosity vs. temperature. You can choose **Settings** under the **Options** menu to select the desired graph data (Reyn, centiPoise, centiStoke, Specific Gravity, Weight Density, and Specific Heat), plot type (Linear-Linear, Linear-Log, Log-Log), and manual scaling the axes.



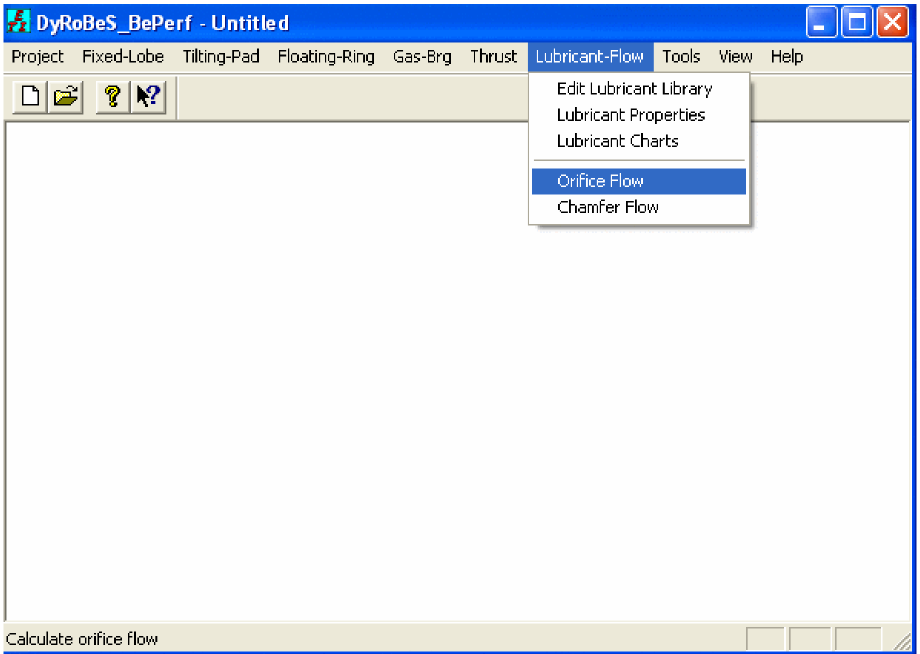

Lubricant Properties Comparison
Options
X-Axis
Y-Axis
Linear-Log
Reyns
centiPoise
centiStoke
Specific Gravity
Weight Density
Specific Heat
TE Light (VG 32)
E Medium (VG 46)
Absolute Viscosity (centiPoise)
Temperature (deg F)


Lubricant Properties Comparison
Options
X-Axis
Y-Axis
Linear-Log
degree F
degree C
- - Mobil DTE Light (VG 32)
o - Mobil DTE Medium (VG 46)
Absolute Viscosity (centiPoise)
Temperature (deg C)


Graph Settings for Lubricant Properties
X Axis Data
deg F
deg C
Y Axis Data
Reyns
CentiPoise
CentiStoke
Specfic Gravity
Weight Density
Specific Heat
Scaling
Manual Scaling
X min: 30
Y min: 0
X max: 100
Y max: 42
X div: 7
Y div: 7
Plot Type
Linear-Linear
Linear-Log
Log-Log
Grids
Major
Minor
OK
Close

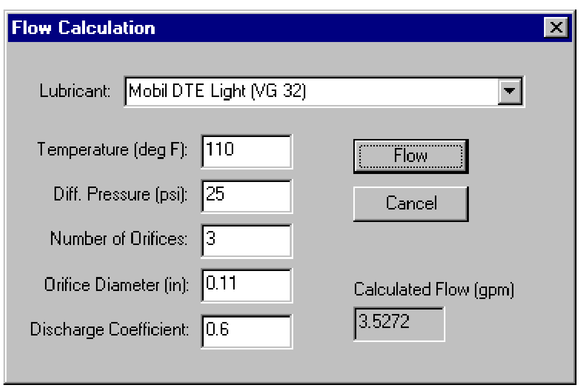
Flow Calculation

Two convenient tools for flow calculation are provided in this program. One is the for Orifice Flow calculation and the other is for the Chamfer Flow Calculation.



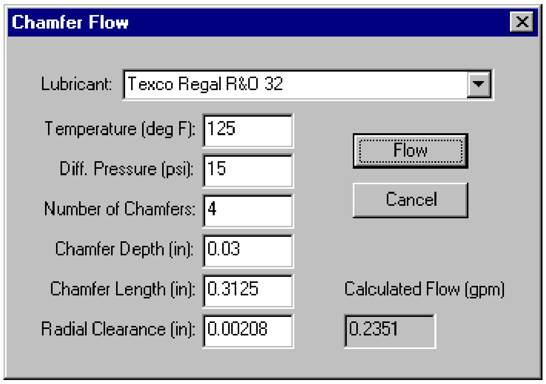
Orifice Flow

This dialog box calculates the oil flow through orifices.



Chamfer Flow

This dialog box calculates the oil flow through chamfers.


Chamfer Flow
Lubricant:
Texco Regal R&O 32
Temperature (deg F):
125
Diff. Pressure (psi):
15
Number of Chamfers:
4
Chamfer Depth (in):
0.03
Chamfer Length (in):
0.3125
Radial Clearance (in):
0.00208
Flow
Cancel
Calculated Flow (gpm)
0.2351

PostProcessor

The assessment of the analysis results constitutes an important aspect of the entire simulation process. The PostProcessor allows you to view the results in the ASCII (text) format and/or the graphics format. All the input and output data can be viewed by selecting the Text Output option. The results can also be tabulated in a compact format by selecting the Tabulated List option. If you decide to print the results from the Notepad, go to Page Setup under File menu and adjust (minimize) the page margins so that the results will fit into pages. In order to tabulate the results, abbreviations are used. See Nomenclature for their definitions. In the non-dimensional analysis, the results are normalized in two ways. The results normalized with respect to the pad radial clearance (*Cp*) are widely used in academy, however the bearing radial clearance (*Cb*) is commonly used in industry for the data normalization. See Non-Dimensional Parameters for their definitions. The non-dimensional results are displayed versus Sommerfeld Number and the dimensional results are displayed versus shaft speed. The units used in the dimensional results are discussed in Chapter Units.

DyRoBeS© also provides a large number of postprocessing tools for graphically displaying the results. You can open the Child Windows (PostProcessor graphics) as many as you like to help you to interpret and understand the analysis results. When you open a postprocessing Child Window, some default initial settings are used to display the results. To modify these settings, select the **Settings** under the **Options** to make necessary changes. The functions available in the PostProcessor are described below:

Redraw allows you to redraw the Child Window and refresh the picture.

Settings allows you to modify the default graphic settings to suit for your need.

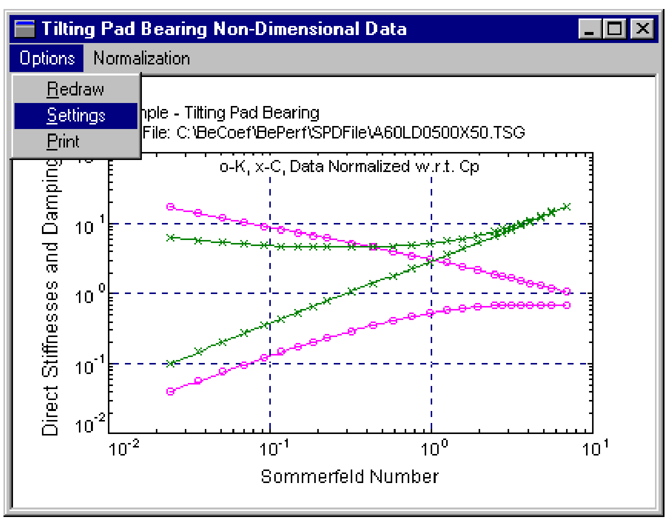
Print allows you to get a hard copy of the graph.

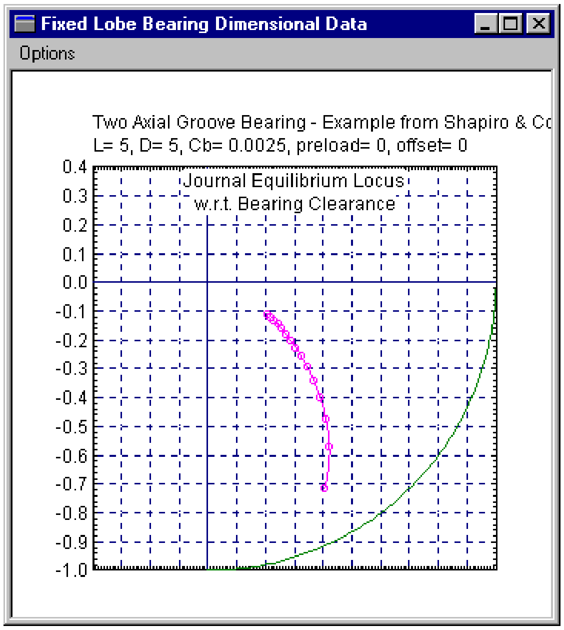
Normalization allows you to display the results normalized with respect to *Cp* or *Cb*.

Profile allows you to select the pressure profile at different shaft speed for dimensional analysis or eccentricity ratio for non-dimensional analysis.

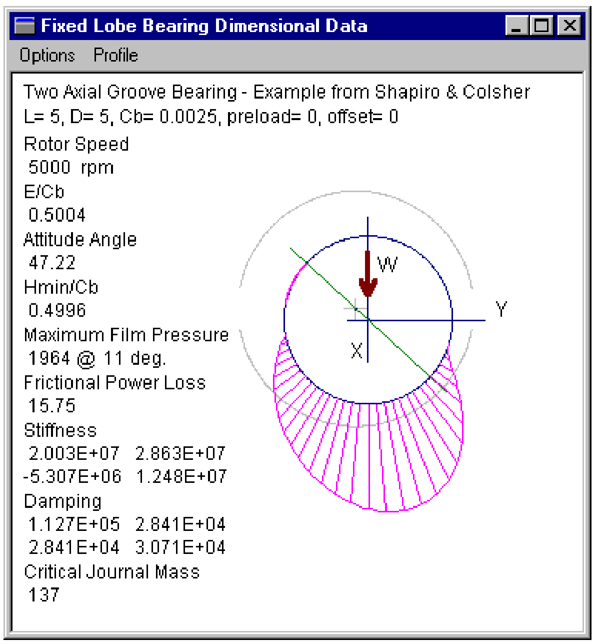
For 3D pressure profile plot, the **Advanced Features** must be checked (ON) in the input.

See also Fixed Lobe Dimensional Analysis, Fixed Lobe Non-Dimensional Analysis, Tilting Pad Dimensional Analysis, Tilting Pad Non-Dimensional Analysis, Non-Dimensional Parameters, Nomenclature, Examples.

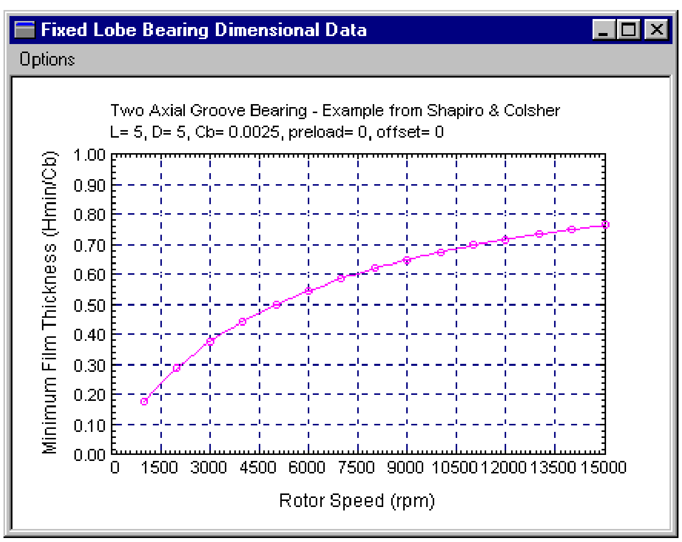




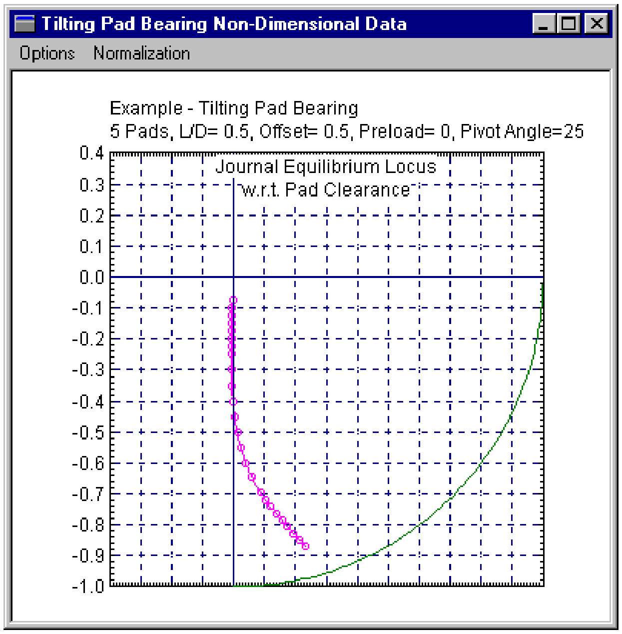
Fixed Lobe Bearing Dimensional Data
Options
Two Axial Groove Bearing - Example from Shapiro & Co
L= 5, D= 5, Cb= 0.0025, preload= 0, offset= 0
Journal Equilibrium Locus
w.r.t. Bearing Clearance
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0



Fixed Lobe Bearing Dimensional Data
Options Profile
Two Axial Groove Bearing - Example from Shapiro & Colsher
L= 5, D= 5, Cb= 0.0025, preload= 0, offset= 0
Rotor Speed
5000 rpm
E/Cb
0.5004
Attitude Angle
47.22
Hmin/Cb
0.4996
Maximum Film Pressure
1964 @ 11 deg.
Frictional Power Loss
15.75
Stiffness
2.003E+07 2.863E+07
-5.307E+06 1.248E+07
Damping
1.127E+05 2.841E+04
2.841E+04 3.071E+04
Critical Journal Mass
137
W
Y
X



Fixed Lobe Bearing Dimensional Data
Options
Two Axial Groove Bearing - Example from Shapiro & Colsher
L= 5, D= 5, Cb= 0.0025, preload= 0, offset= 0
Minimum Film Thickness (Hmin/Cb)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0 1500 3000 4500 6000 7500 9000 10500 12000 13500 15000
Rotor Speed (rpm)



Pressure Dam Bearing
L= 5, D= 5, Cb= 0.005, preload= 0, offset= 0

Rotor Speed
5000 rpm

E/Cb
0.3311

Attitude Angle
69.61

Hmin/Cb
0.6689

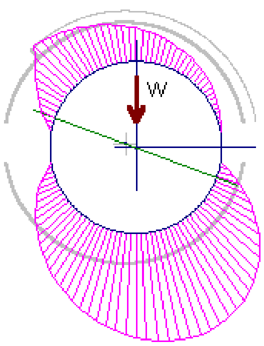
Maximum Film Pressure
254.4 @ 16 deg.

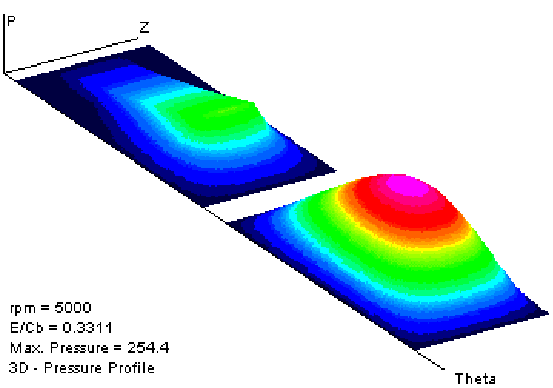
Frictional Power Loss
8.868

Stiffness
1.199E+06 2.747E+06
-5.396E+05 1.042E+06

Damping
9.572E+03 2.012E+03
2.014E+03 3.405E+03

Critical Journal Mass
13.04





Examples

There are many examples provided in the \example directory. Some examples are described below, but there are more examples in the DyRoBeS\Example directory. You are encouraged to go through all the examples.

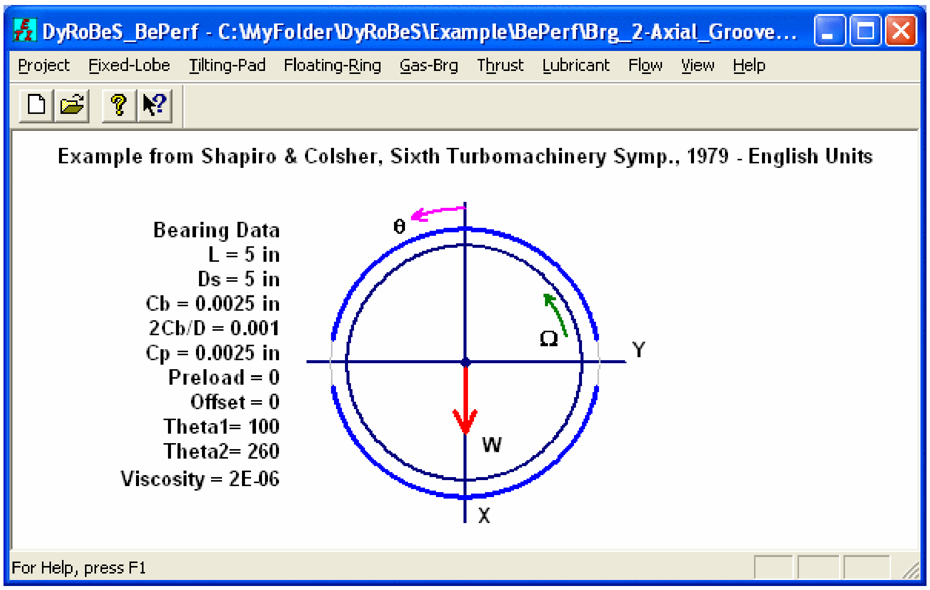
Example 1: 2-Axial Groove Bearing

File: Brg_2-Axial_Groove_Coor1.LDI – Lund Coordinate System

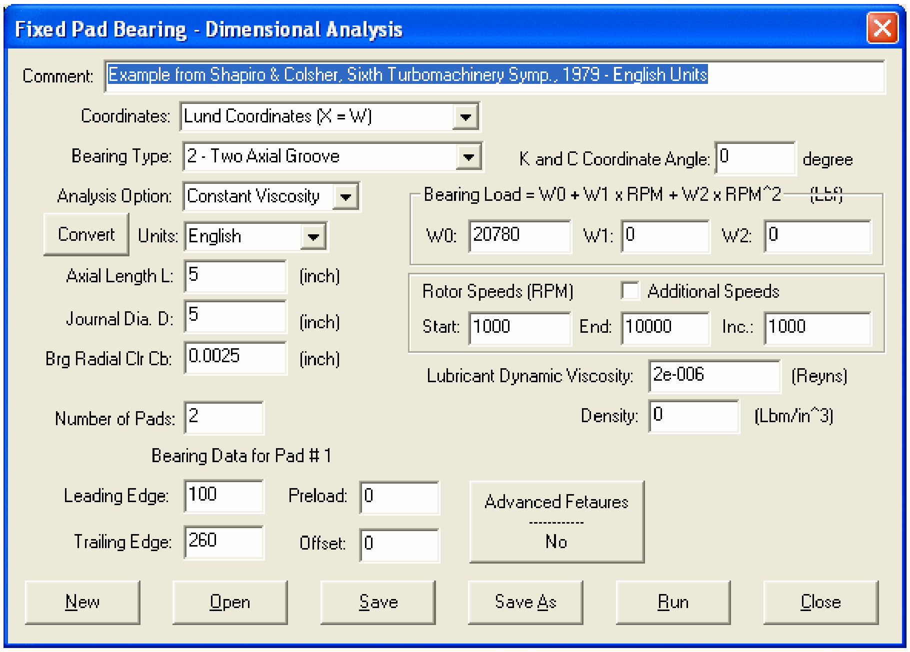
File: Brg_2-Axial_Groove_Coor2.LDI – Standard Coordinate System

File: Brg_2-Axial_Groove_Coor2.LDI – Metric Units

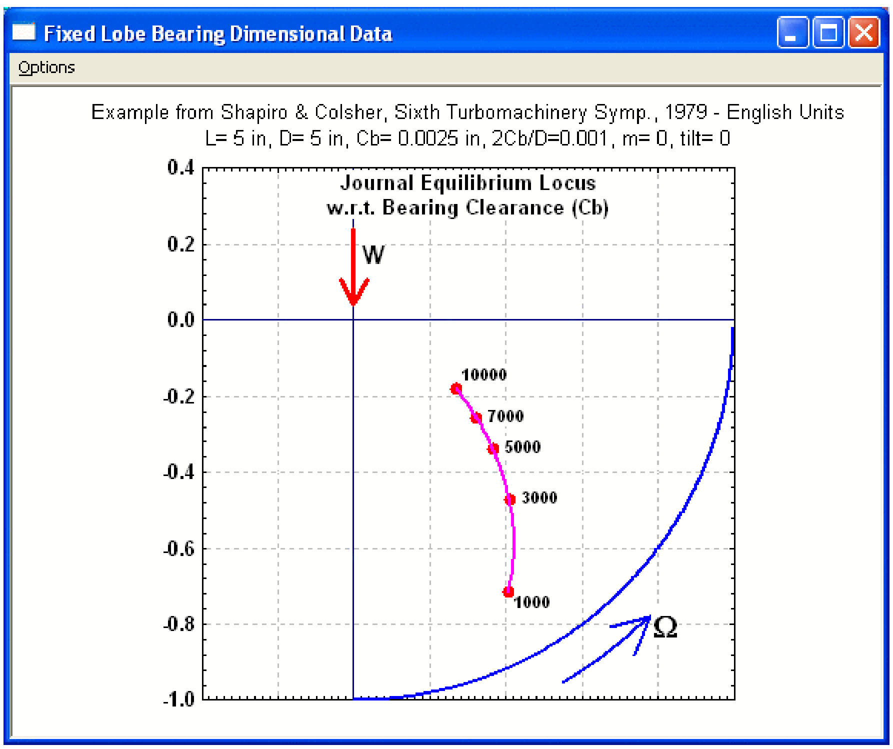
This example is taken from Shapiro & Colsher, Sixth Turbomachinery Symp., 1979. It is a 2-axial groove bearing as shown below:



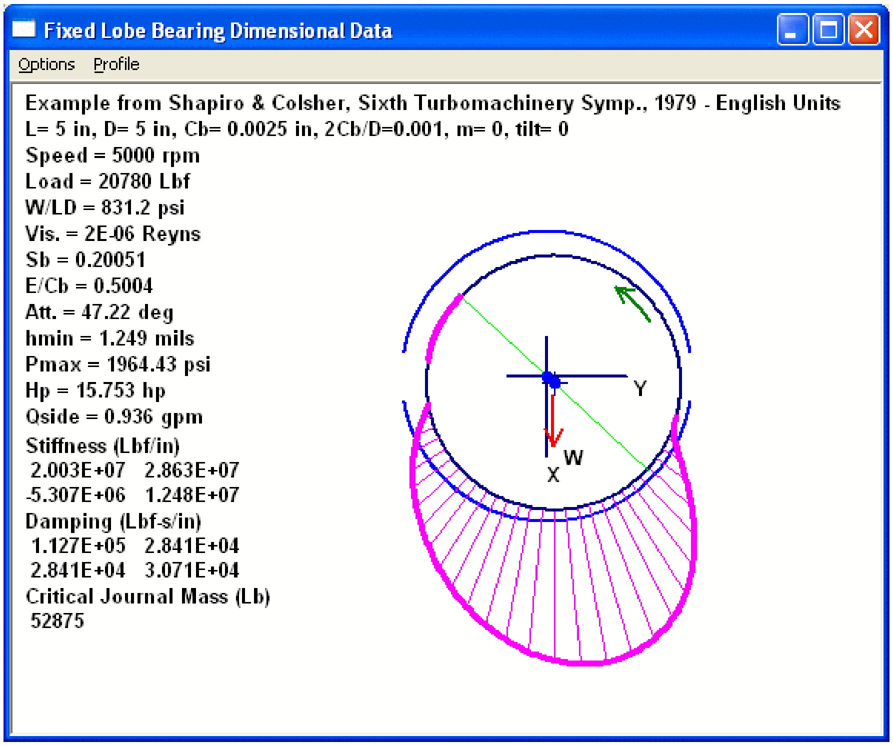
For comparison purposes with previous publications, the X-axis is aligned with the load vector (Lund coordinate system) and constant viscosity is used in File: Brg_2-Axial_Groove_Coor1.LDI. Since two lobes are identical, no discontinuity in the bearing clearance, and the turbulence effect is neglected, therefore, Advanced Feature is turned off (unchecked). The bearing parameters are listed below for reference.



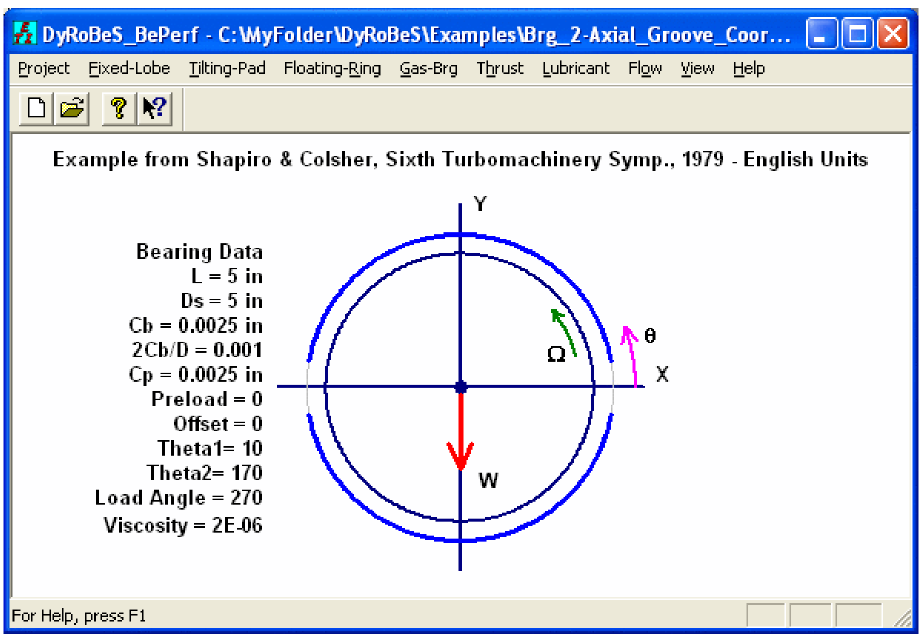
The journal equilibrium locus is shown below.

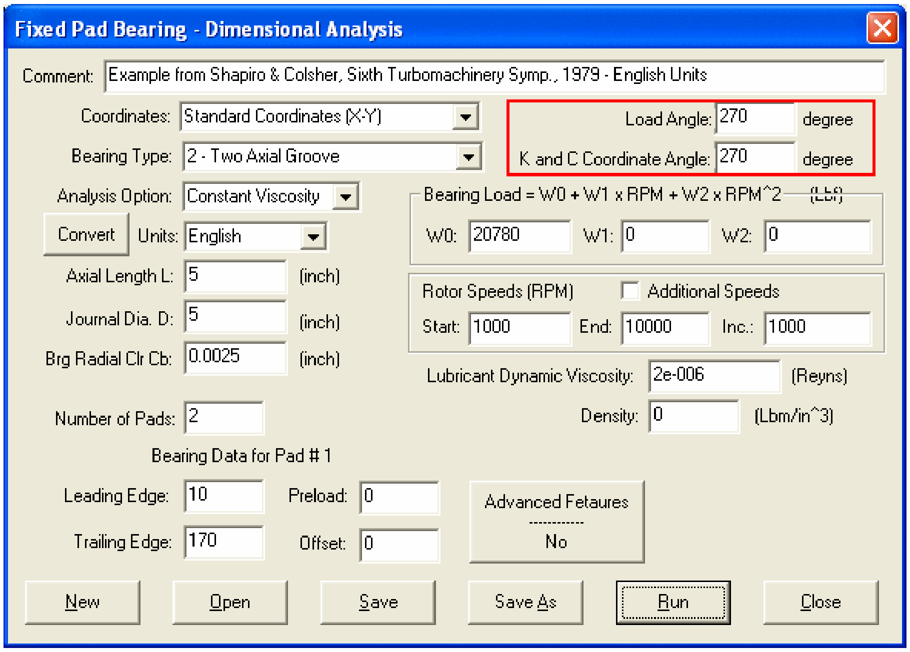


The bearing performance at 5000 rpm is shown and the results are in agreement with previous publications.

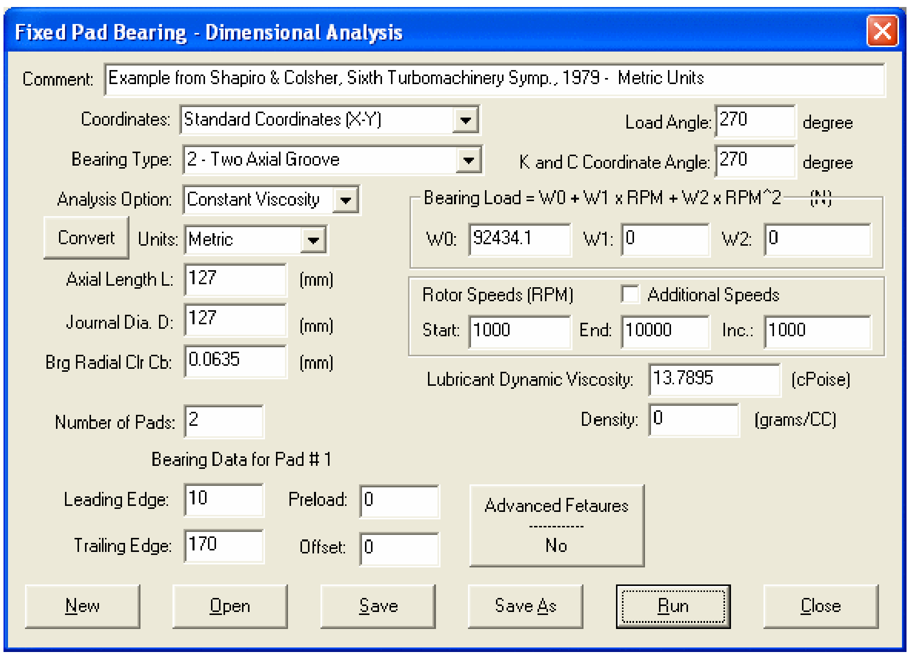


By selecting the Standard Coordinate System, an additional input for load vector, 270° in this case, is needed as demonstrated in File: Brg_2-Axial_Groove_Coor2.LDI. Again, for comparison purposes, the bearing coefficients are oriented such that the x-axis is collinear with the load vector as shown in the input. The results are identical with previous discussion.



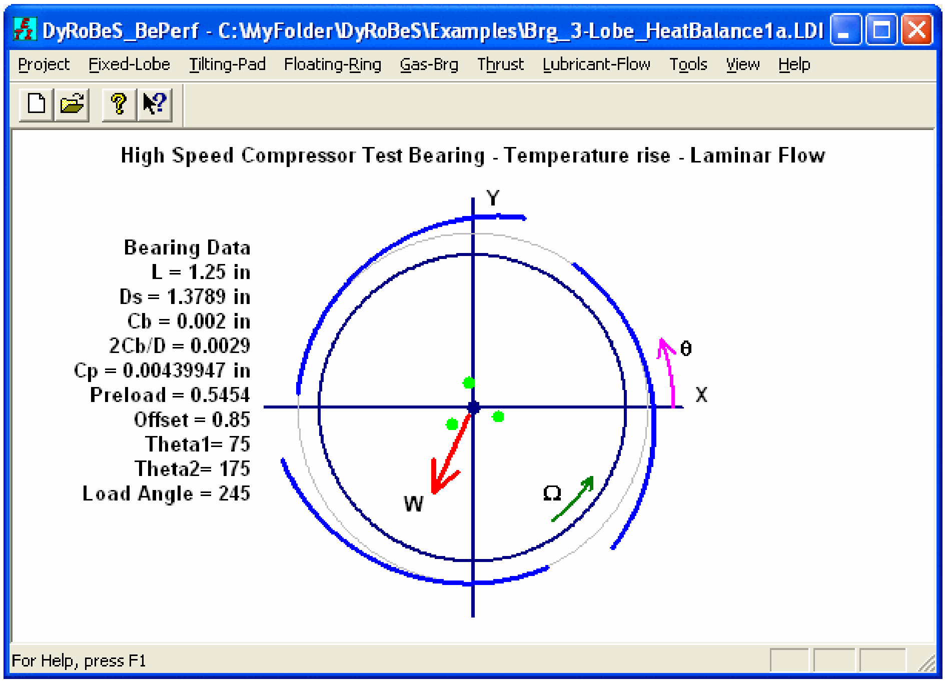


The input parameters can also be in metric units as demonstrated in File: Brg_2-Axial_Groove_Coor2_mm.LDI and shown below.

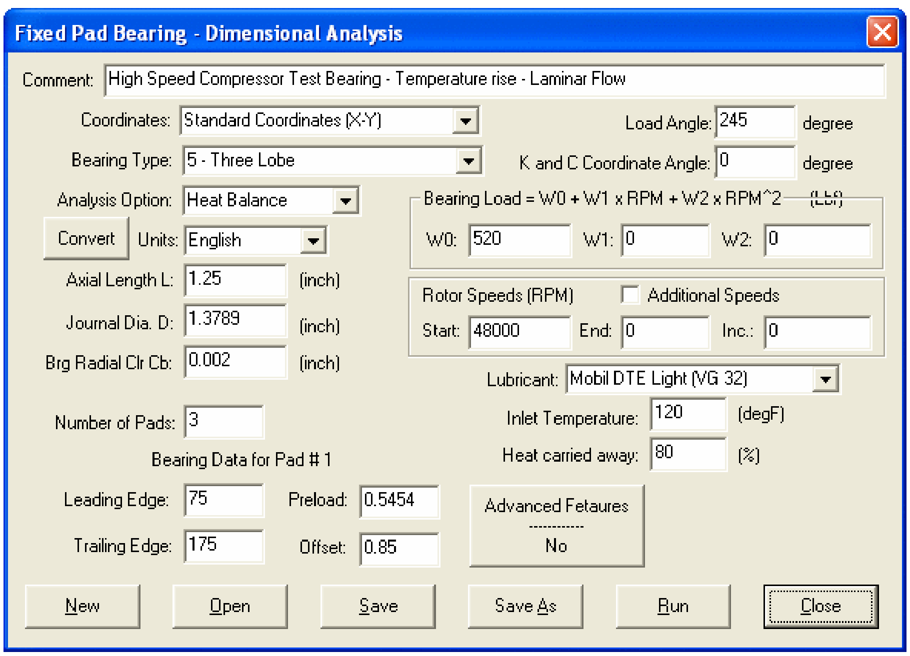


Example 2: 3 Lobe Bearing – Laminar and Turbulent Flow

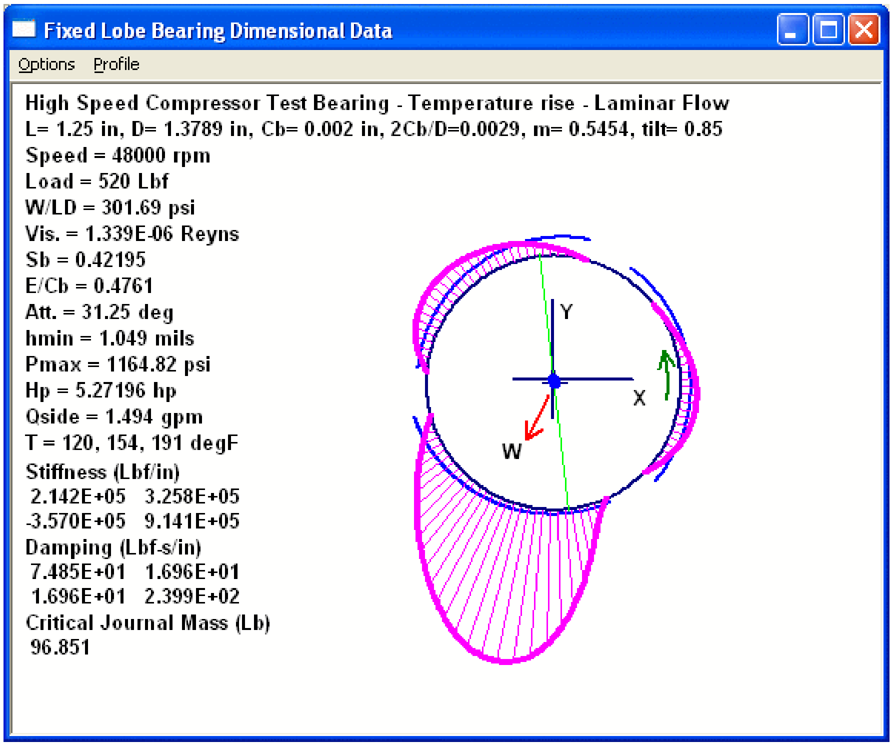
A 3 lobe bearing as shown below is used in a high-speed application. The load vector is directed in the middle of the lobe.



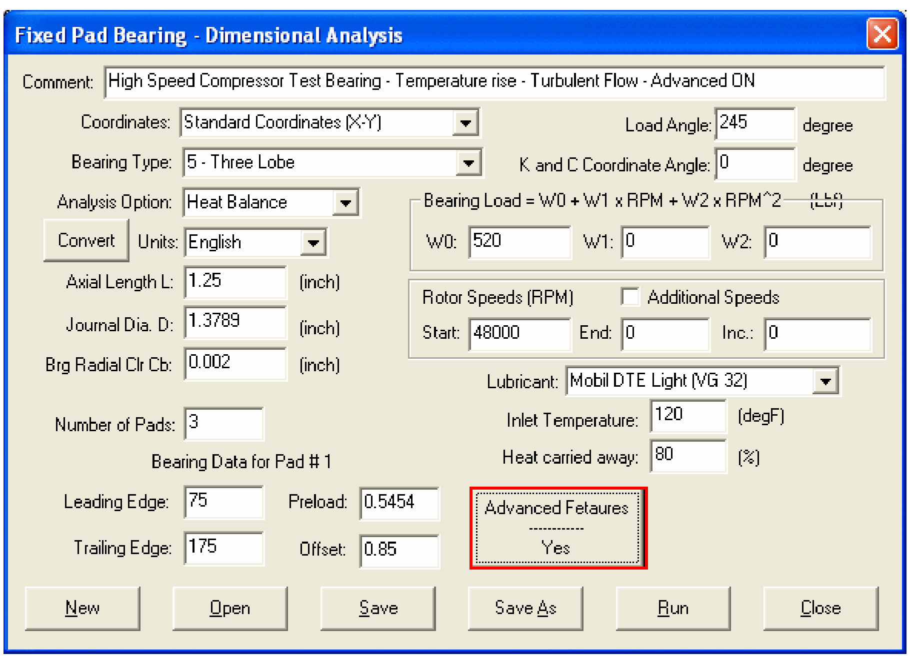
The bearing clearance for each lobe is continuous along the circumferential direction, although it is not a constant due to the preload. Each lobe is identical. Two cases are studied, one is laminar flow and second one is turbulent flow. With laminar flow assumption, the input parameters are shown below with Advanced Feature OFF:

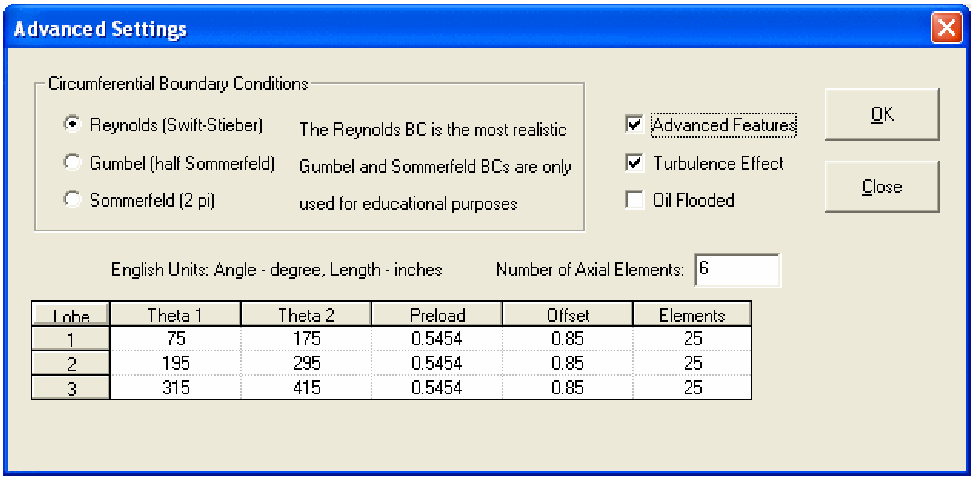


The bearing performance at 48,000 rpm is shown below. With 120° F oil inlet temperature, the operating and maximum bearing temperatures are 154° and 191° F with laminar flow assumption.

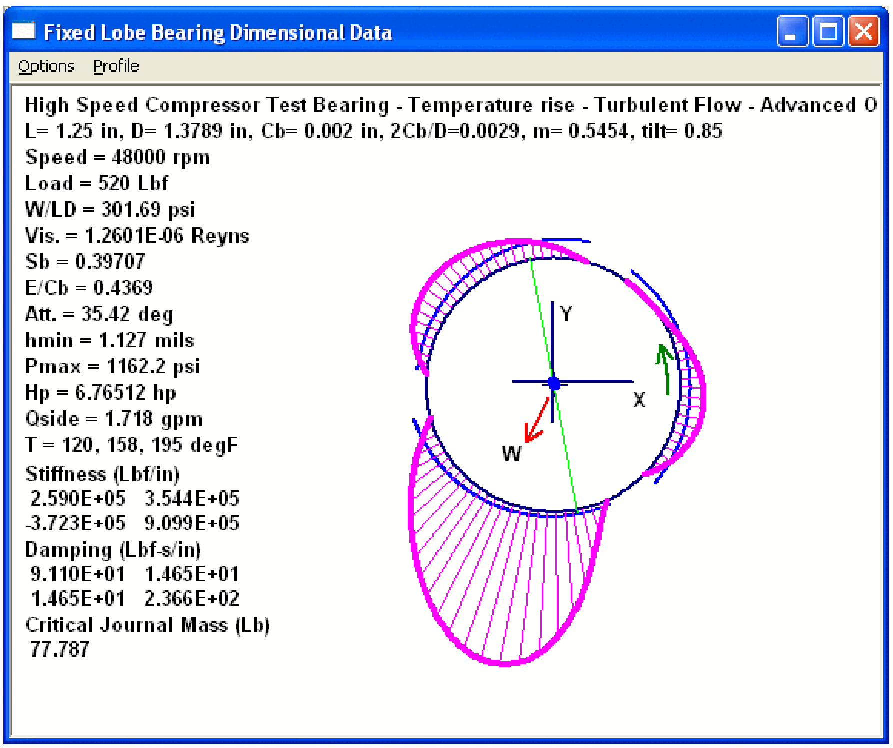


With the Advanced Feature OFF, the laminar flow is assumed. Also, without Advanced Feature, each finite element node has one (1) degree-of-freedom, i.e., pressure is the only unknown at each finite element node. With Advanced Feature ON, the turbulent effect can be included or neglected. Also, with Advanced Feature ON, each finite element node has three (3) degrees-of-freedom, i.e., pressure and pressure gradients in axial and circumferential directions are the unknowns at each finite element node. With turbulent flow assumption, the input parameters are shown below with Advanced Feature ON:

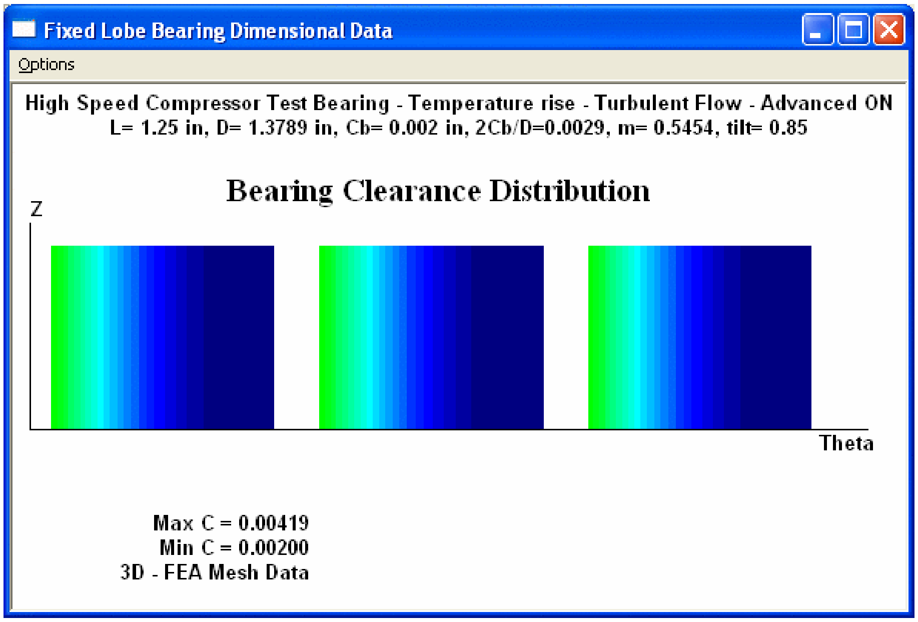


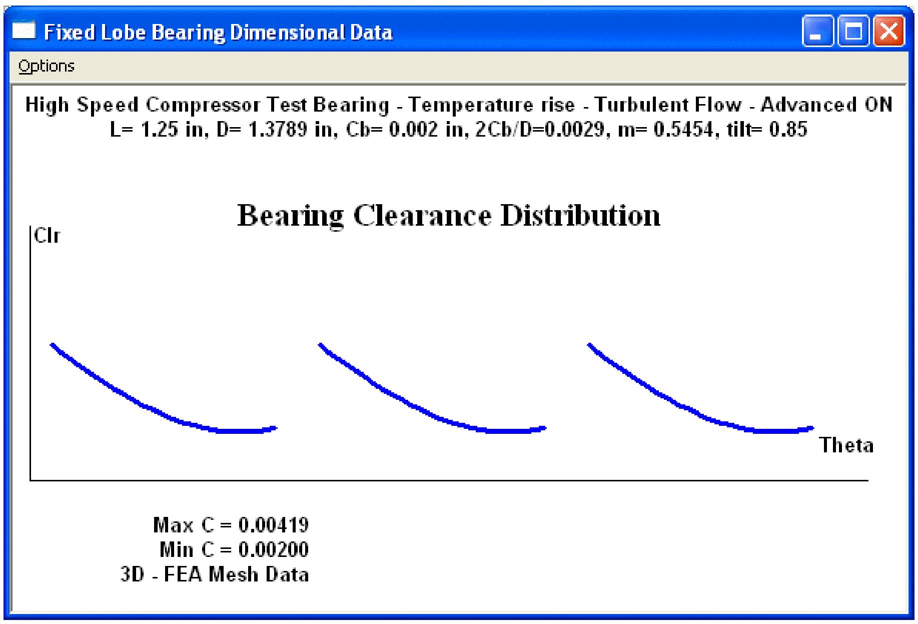


The bearing performance at 48,000 rpm is shown below with turbulence effect CHECKED, With 120° F oil inlet temperature, the operating and maximum bearing temperatures are 158° and 195° F.

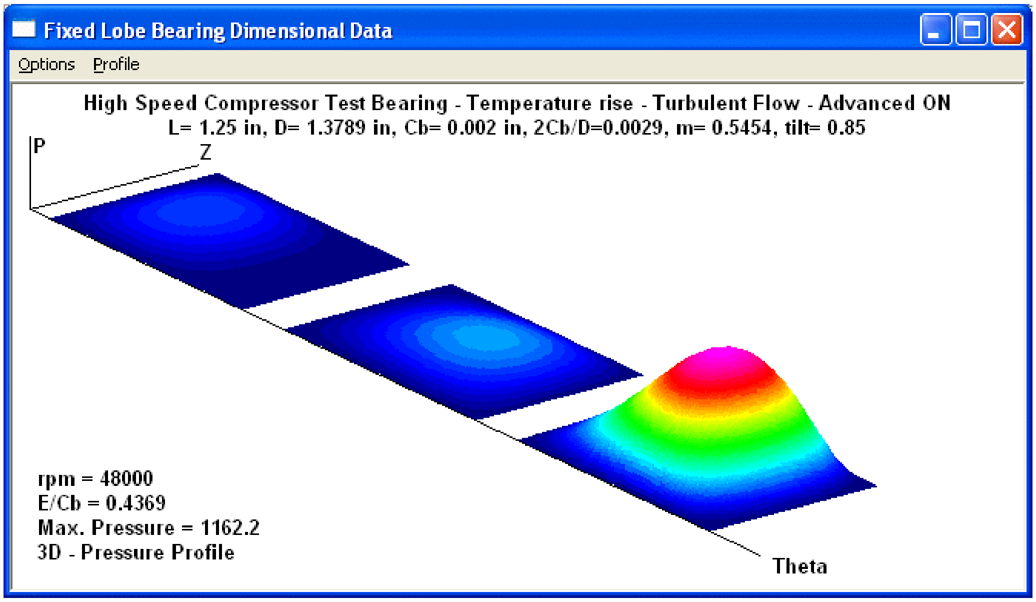


With Advanced Feature ON, the bearing clearance can be easily checked as shown below in top view and side view.



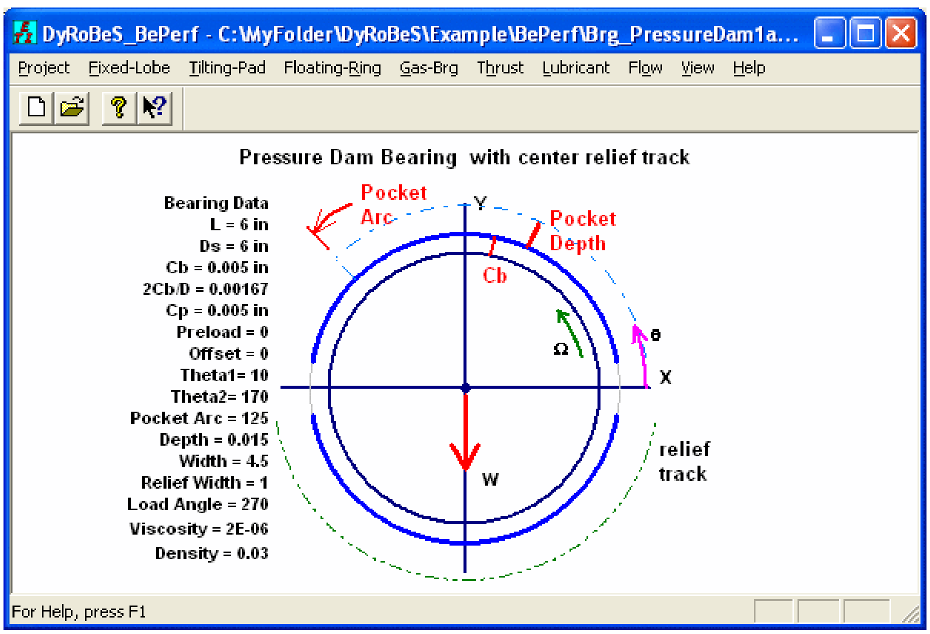


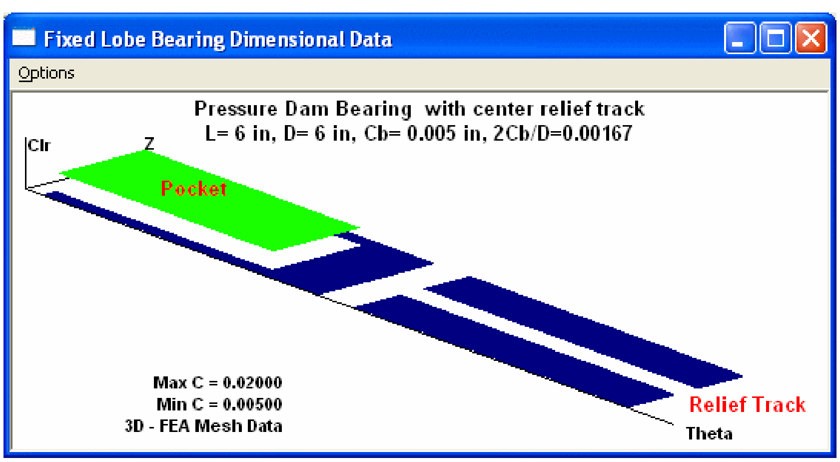
A 3 dimensional pressure profile can also be viewed.



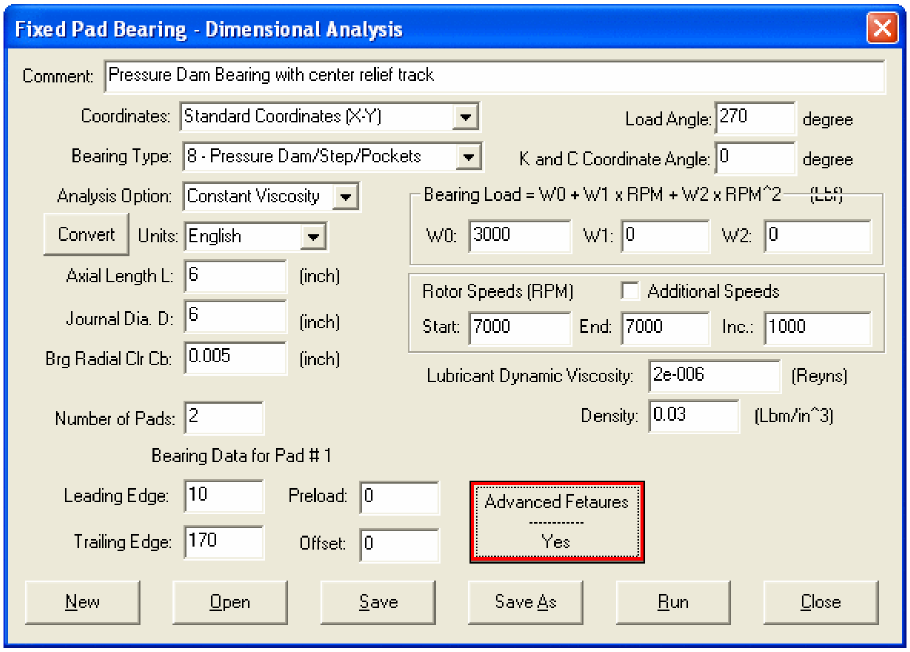
Example 3: Pressure Dam Bearings

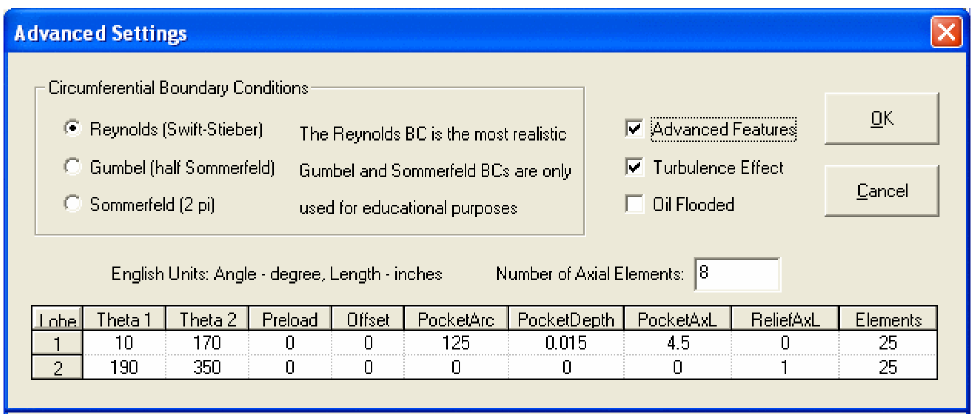
A conventional pressure dam bearing is demonstrated in this example. A pressure dam (pocket) with a constant depth is in the top lobe, and a central relief track with much larger depth is in the lower lobe where the load vector is located. The bearing geometry with exaggerated clearance and bearing clearance distribution are shown below:



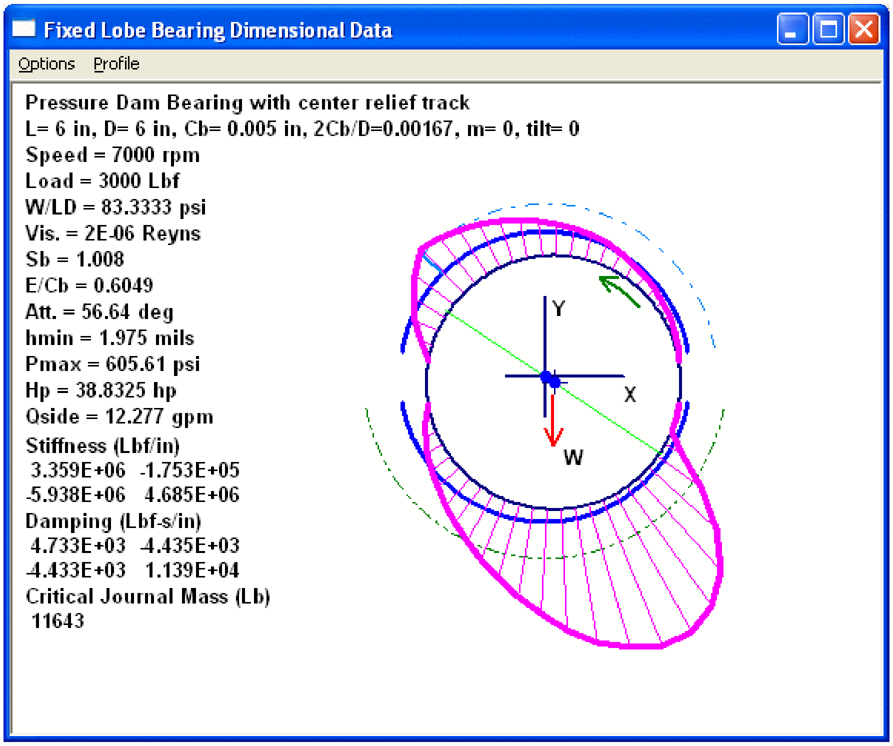


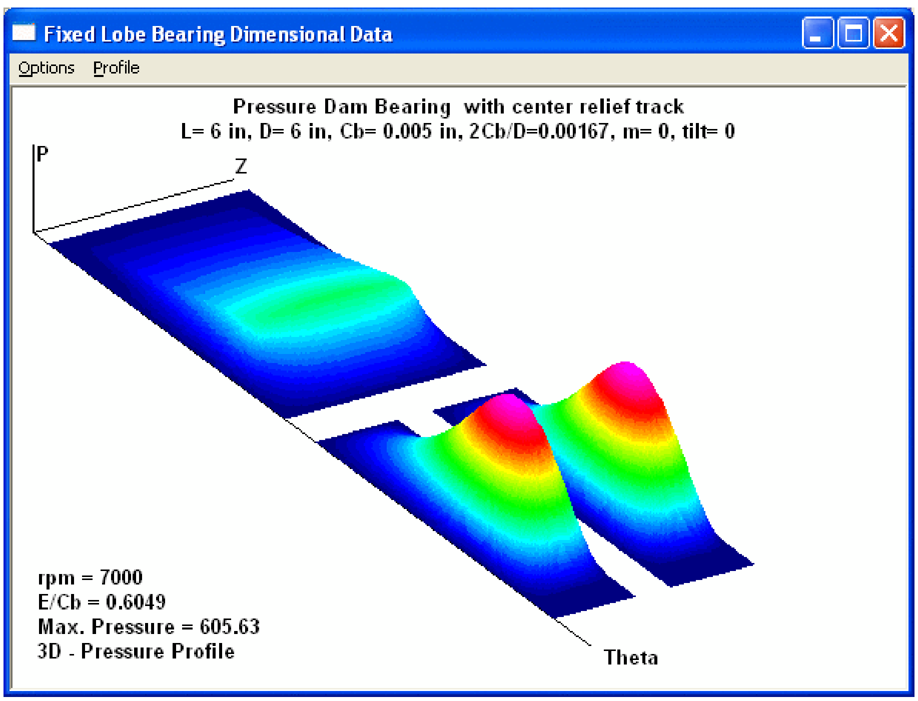
The pressure dam bearing has discontinuity in the bearing clearance. Therefore, the Advanced Feature must be turned ON. Additional data for the pocket and relief track are entered in the Advanced Feature dialog box. The computer program allows for the pocket and relief track in a preloaded lobe, although typically they are in a plain lobe without any preload. Note that the pocket axial length (PocketAxL) must be smaller than the bearing axial length in order to have a pocket with side dams. If PocketAxL equals to the bearing axial length, then it becomes a step bearing without side lands which is acceptable in this program. The pocket and relief track cannot co-exist.



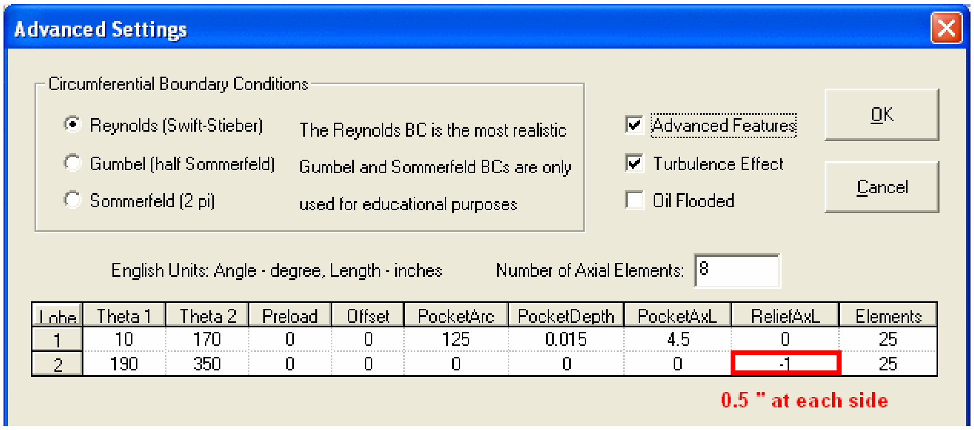


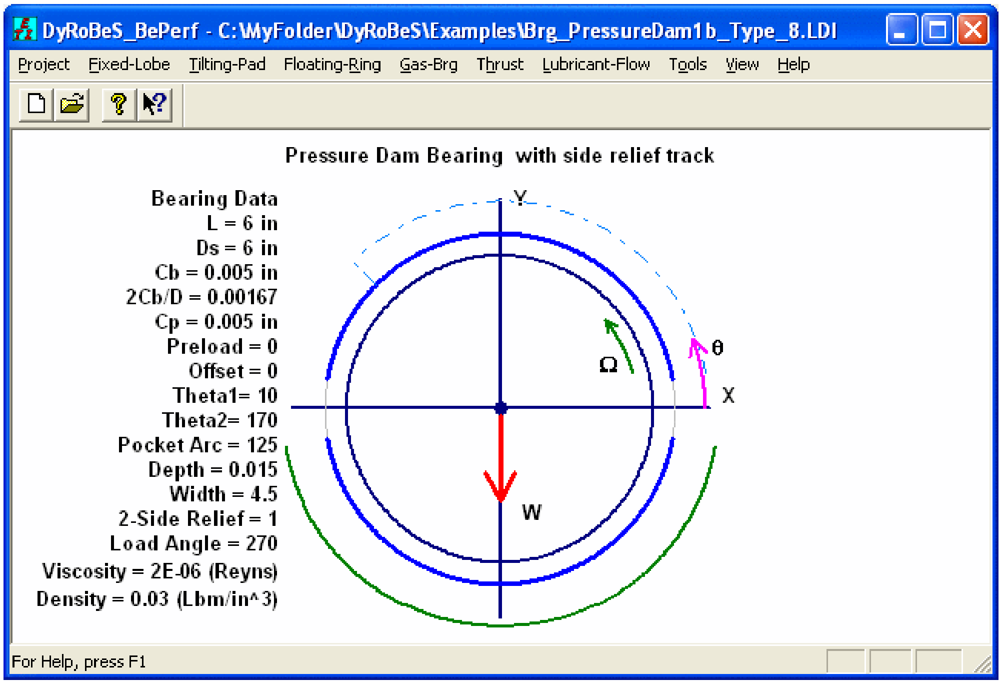
The bearing performance and pressure distribution are shown below.



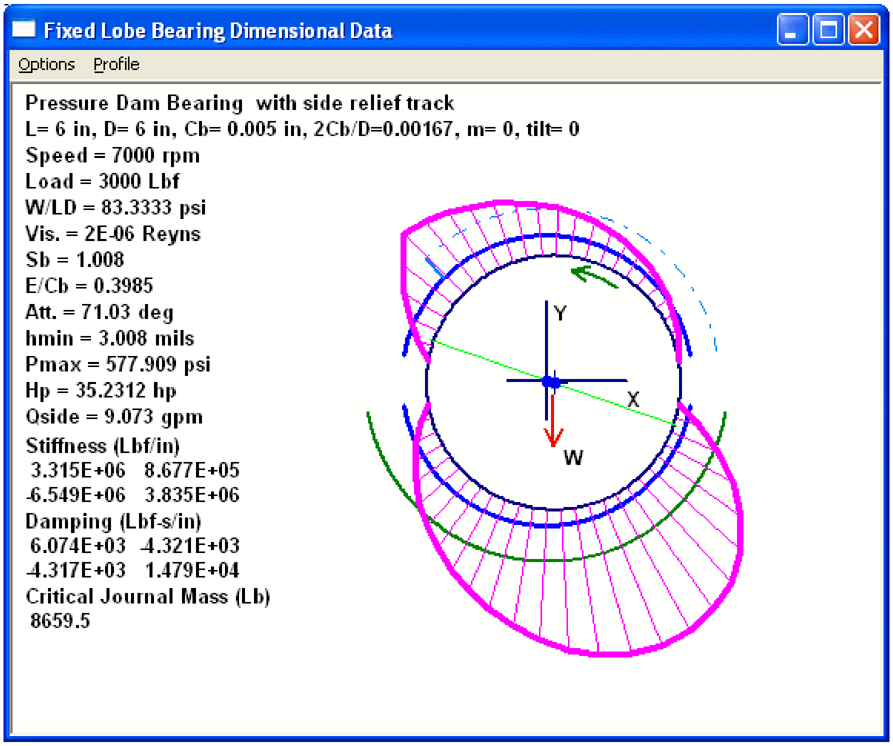


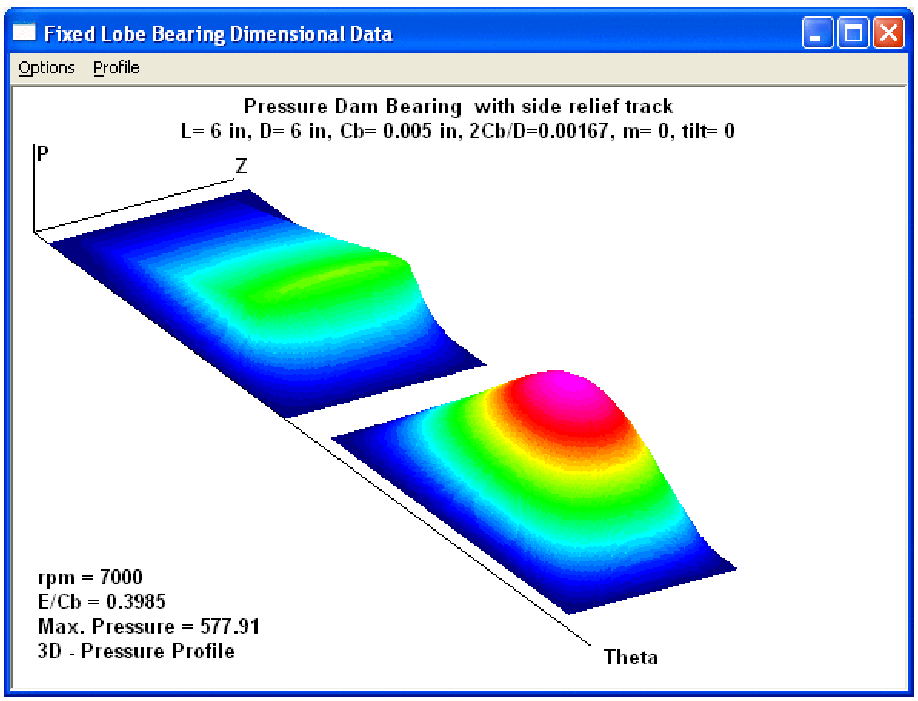
Note that, the central relief track can significantly lower the bearing load carrying capability. Therefore, caution must be taken when using the relief track. When the ReliefAxL is negative value, the relief track will be on both sides instead of at the center. The configuration with side relief track provides a better loading carrying capability than the central relief track. The same example with side relief track is illustrated below.



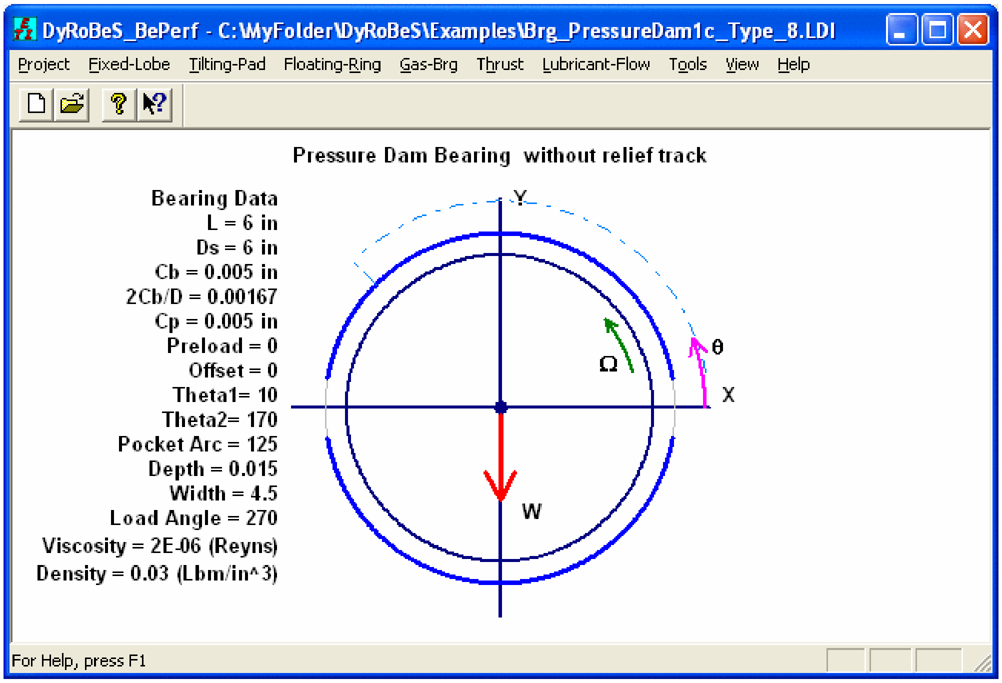


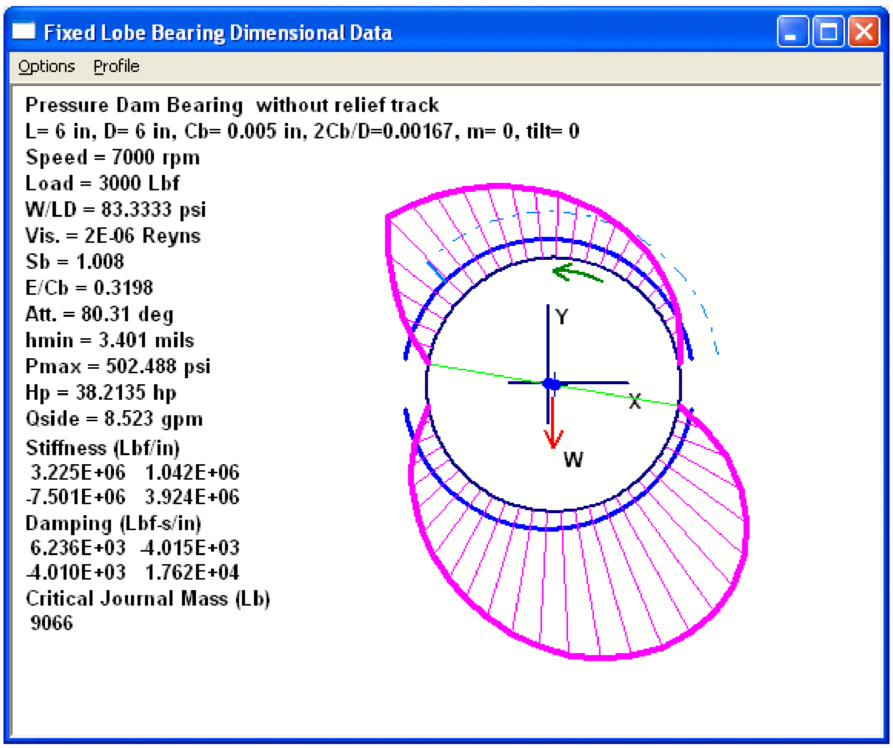
The bearing performance and pressure distribution are shown below.

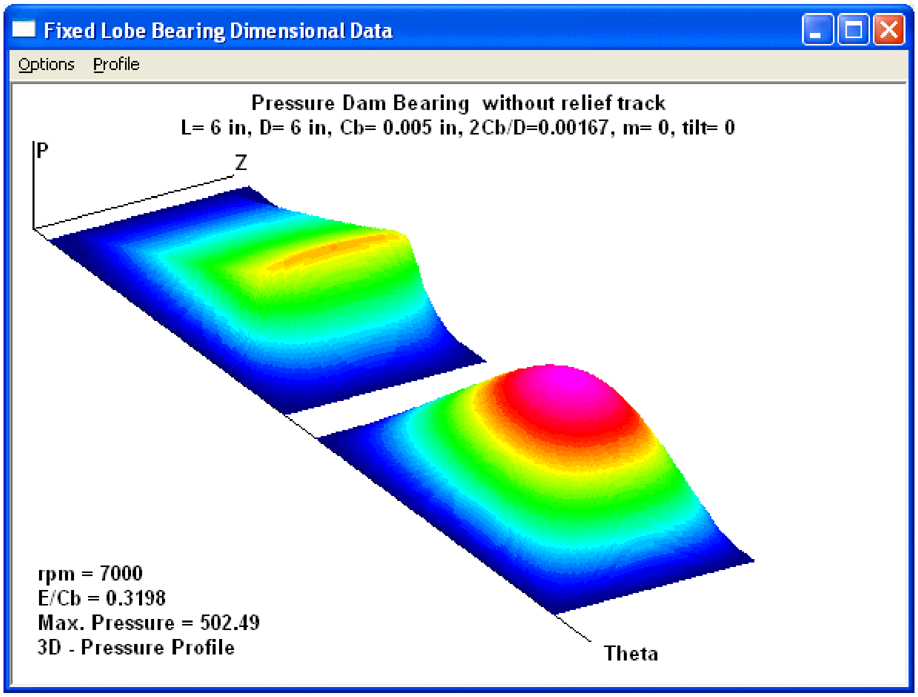




When ReliefAxL equals to zero, then no relief track is applied. The results are shown below.

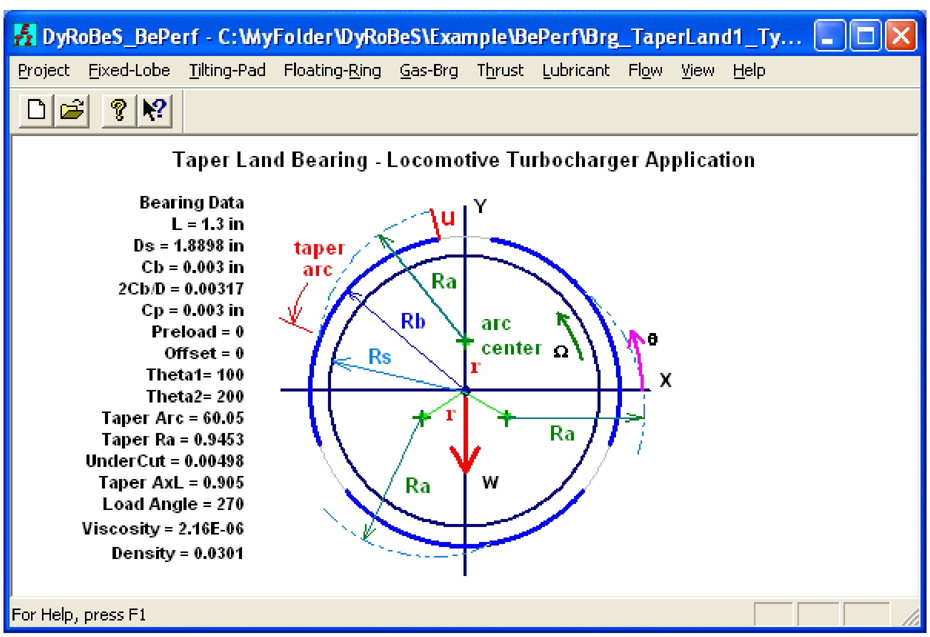

DyRoBeS_BePerf - C:\MyFolder\DyRoBeS\Examples\Brg_PressureDam1c_Type_8.LDI
Project Fixed-Lobe Tilting-Pad Floating-Ring Gas-Brg Thrust Lubricant-Flow Tools View Help
Pressure Dam Bearing without relief track
Bearing Data
L = 6 in
Ds = 6 in
Cb = 0.005 in
2Cb/D = 0.00167
Cp = 0.005 in
Preload = 0
Offset = 0
Theta1= 10
Theta2= 170
Pocket Arc = 125
Depth = 0.015
Width = 4.5
Load Angle = 270
Viscosity = 2E-06 (Reyns)
Density = 0.03 (Lbm/in^3)
Y
Ω
θ
X
W
For Help, press F1

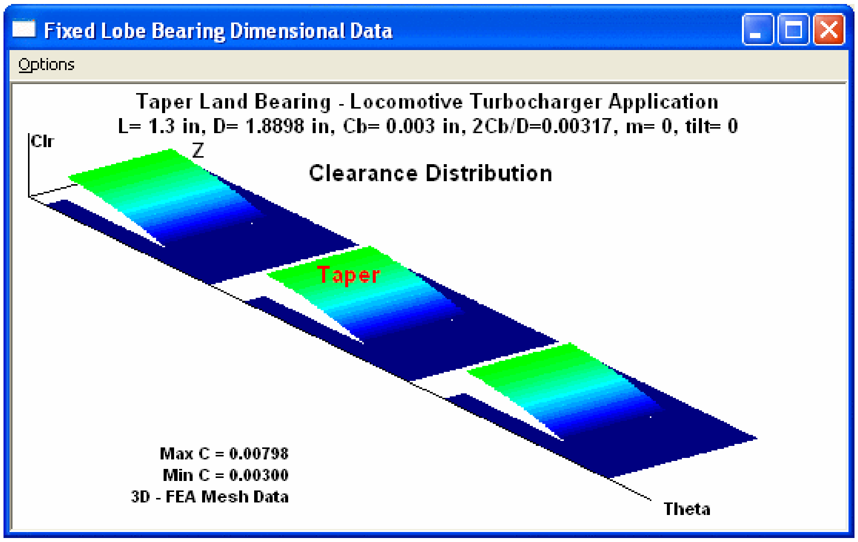

Fixed Lobe Bearing Dimensional Data
Options Profile
Pressure Dam Bearing without relief track
L= 6 in, D= 6 in, Cb= 0.005 in, 2Cb/D=0.00167, m= 0, tilt= 0
Speed = 7000 rpm
Load = 3000 Lbf
W/LD = 83.3333 psi
Vis. = 2E-06 Reyns
Sb = 1.008
E/Cb = 0.3198
Att. = 80.31 deg
hmin = 3.401 mils
Pmax = 502.488 psi
Hp = 38.2135 hp
Qside = 8.523 gpm
Stiffness (Lbf/in)
3.225E+06 1.042E+06
-7.501E+06 3.924E+06
Damping (Lbf-s/in)
6.236E+03 -4.015E+03
-4.010E+03 1.762E+04
Critical Journal Mass (Lb)
9066
Y
X
W



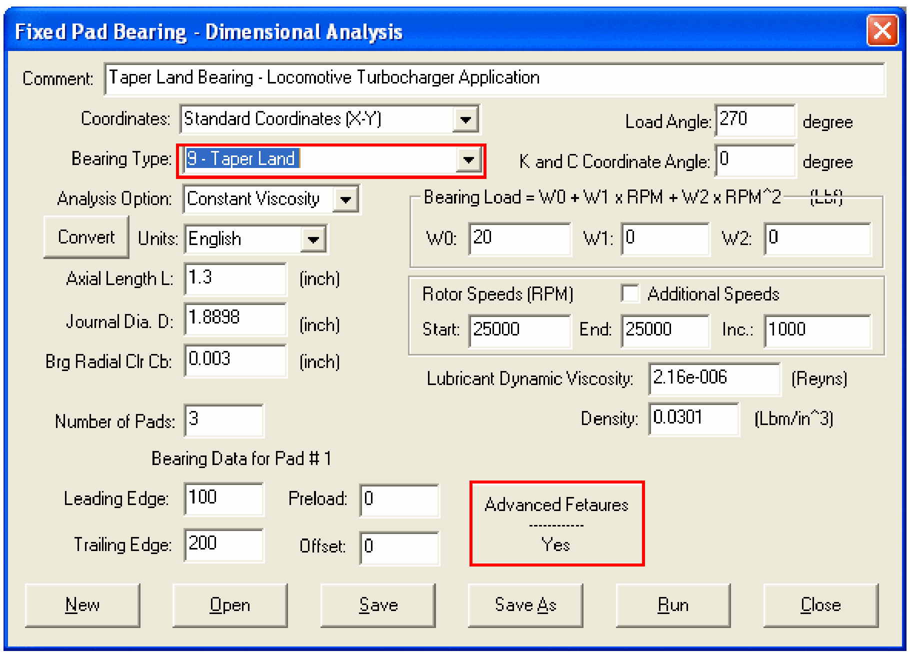
Example 4: Tapered Land Bearing

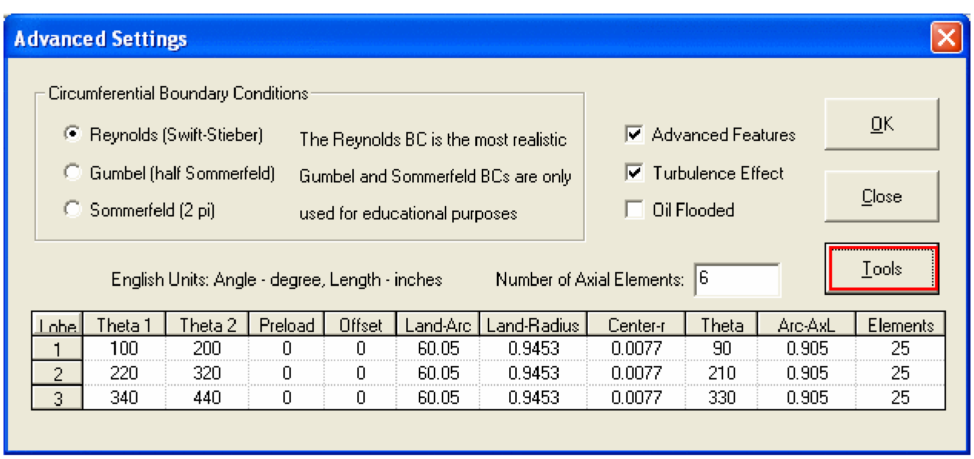
A locomotive turbocharger bearing is employed in this example. It is machined out of a standard 3-axial groove bearing as shown in figures below. Again, the clearances, arc center offset, and undercut are exaggerated for illustration purposes. Each lobe is machined with an arc to form the tapered land. The arc has a radius of Ra and the arc center is specified with a center offset of r and an angle Theta measured from the reference axis (X-axis). The arc center angle normally is either in the middle of the oil groove or the same as the leading edge of the lobe. Typically, there are side dams in the tapered land area similar to the pressure dam bearing. When taper arc axial equals to the bearing axial length, no side dam exists. The circumferential taper arc length is normally not specified for a tapered land bearing since it will be the end of the arc. However, this arc length can be specified to form a step in the tapered land area.

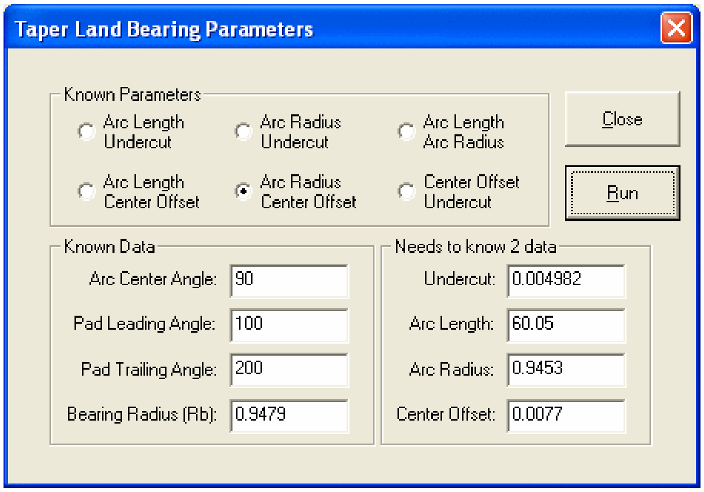




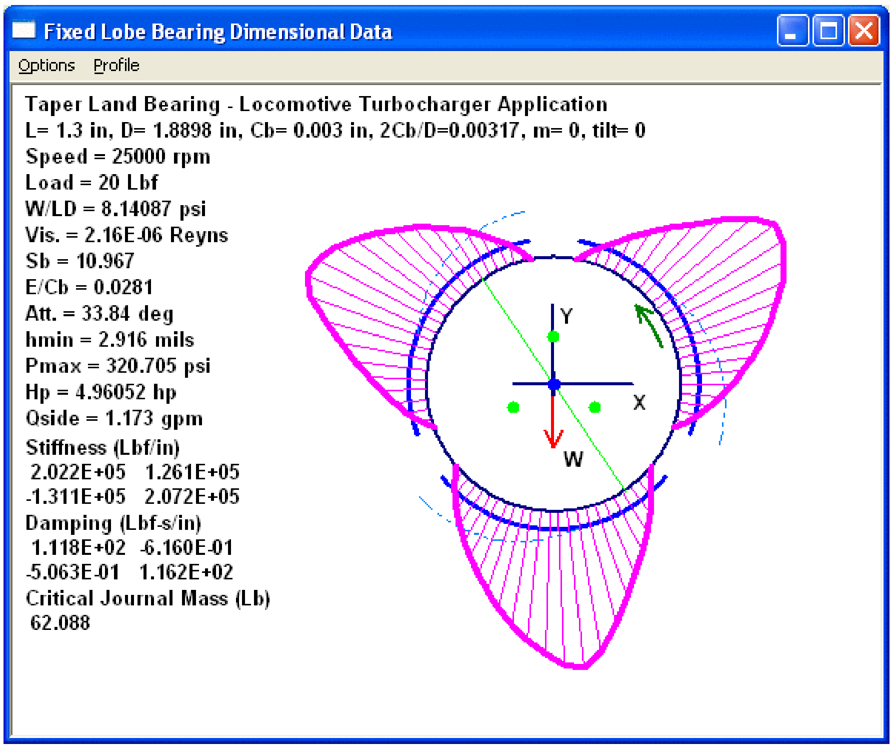
The input parameters for the tapered land bearing are shown below. Since the clearance is not continuous due to the side dams, Advanced Feature has to be ON. For the manufacturing drawing, the arc radius and arc center location (r, and theta) are normally specified. In the design process, the undercut and taper arc angle (length) are normally specified. For this purpose, a TOOLS button is provided in this dialog box. It allows the program users to specified any two parameters among the undercut (u), arc length (Arc theta), arc radius (Ra), and arc center offset (r) to calculate the other two unknowns.

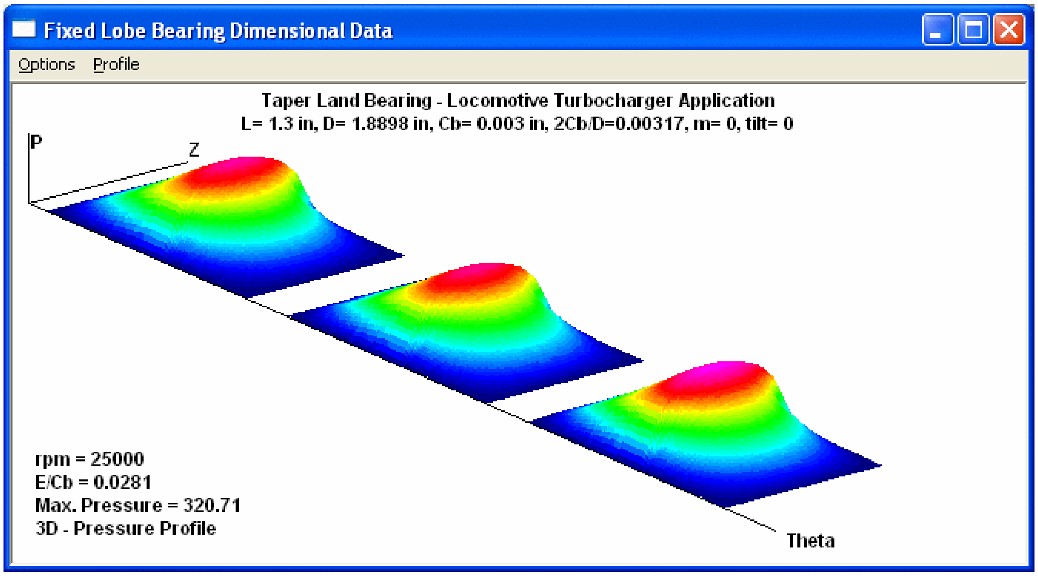


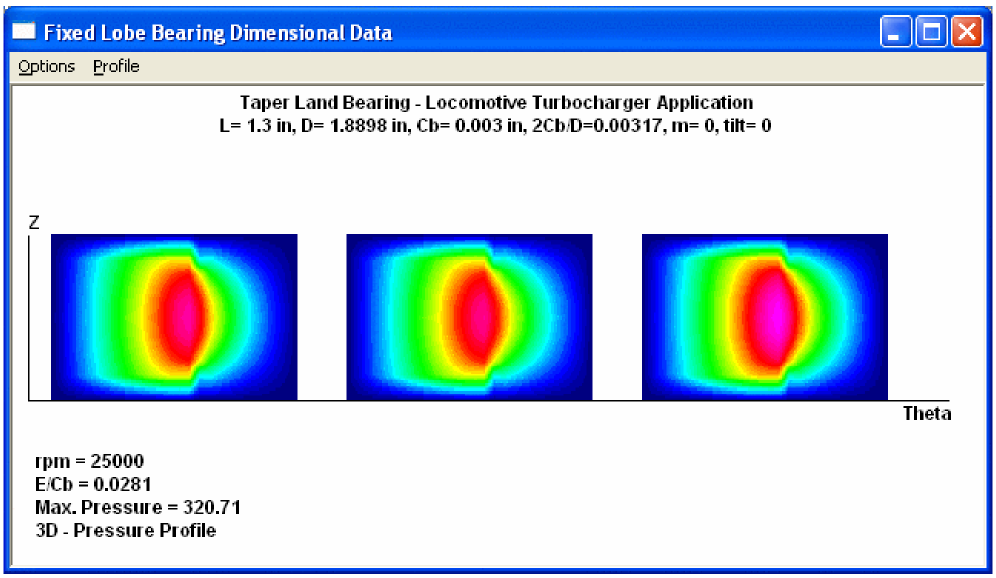




The results are present below.



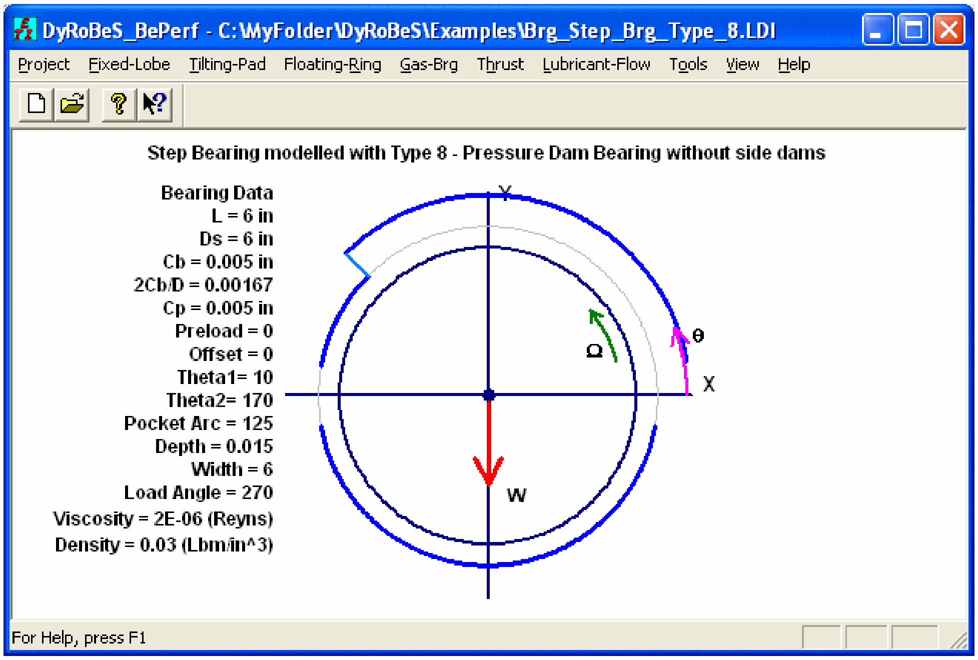


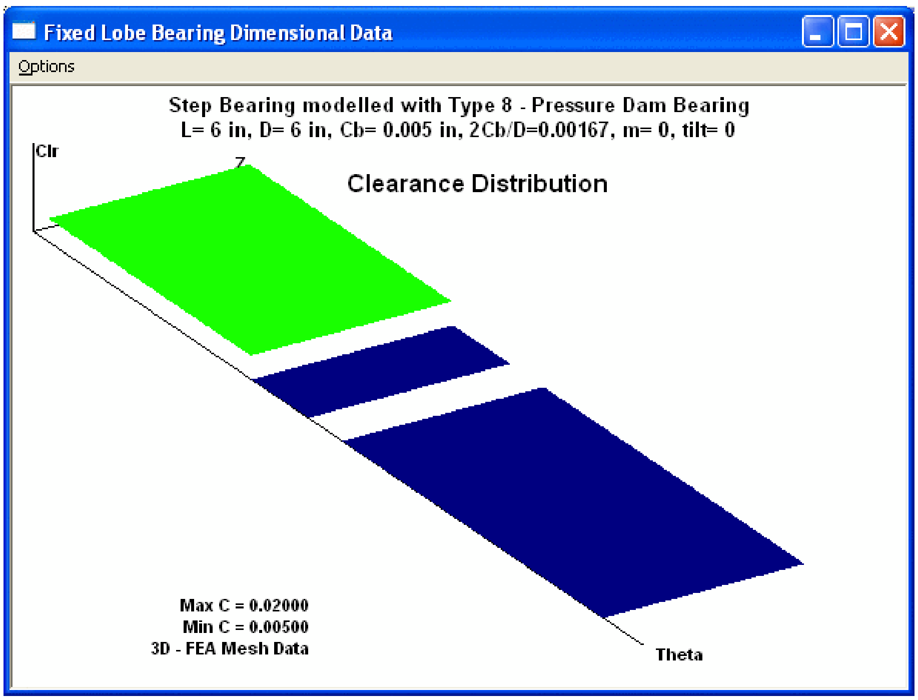


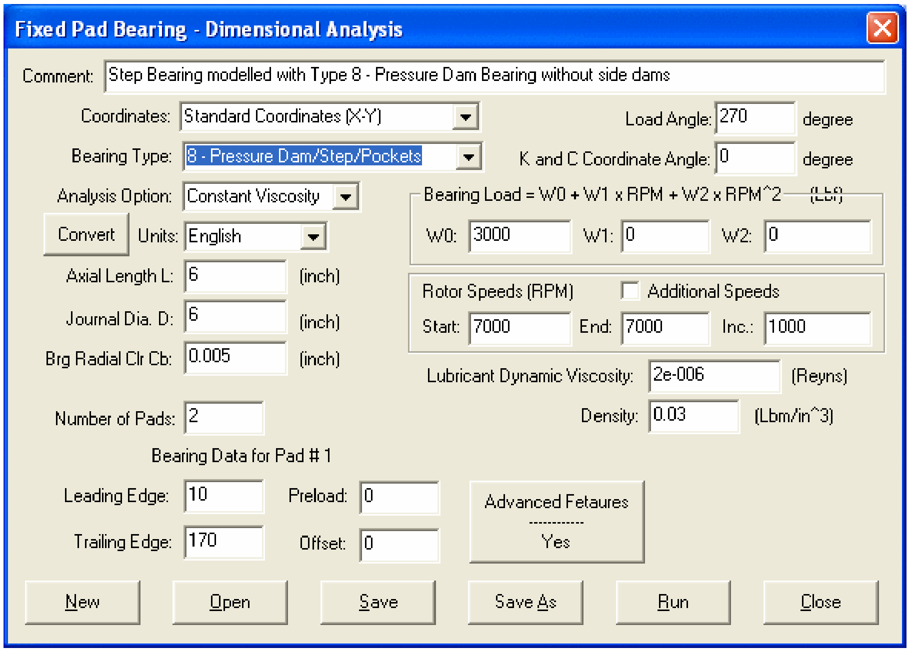
With this more general inputs, a pressure dam bearing without relief track can also be modeled with this bearing type.

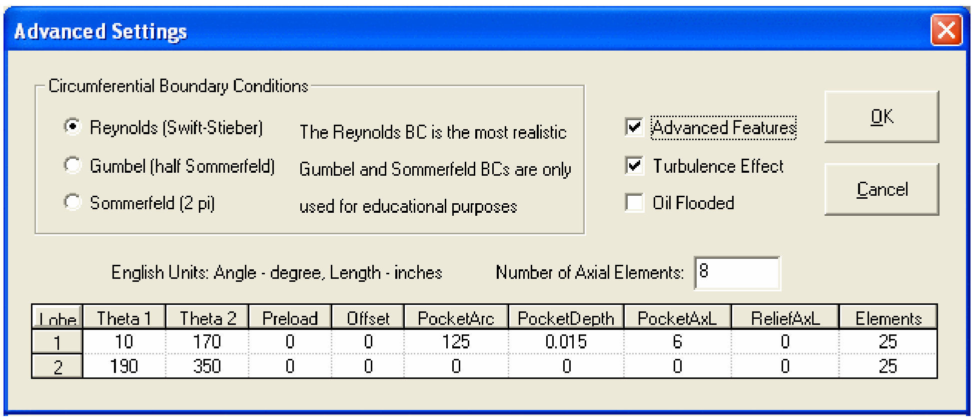
Example 5: Step Bearing

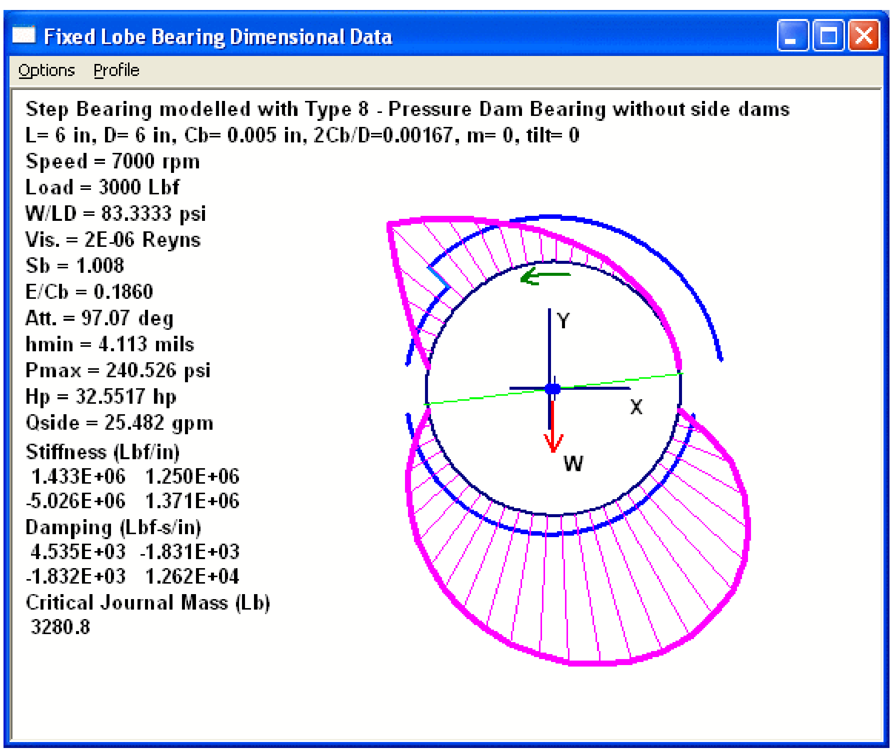
When the axial length of a pocket equals to the bearing axial length, it forms a step. A step bearing can be modeled using Type 8 – Pressure Dam Bearing with PocketAxL equals to the bearing axial length as demonstrated below.


DyRoBeS_BePerf - C:\MyFolder\DyRoBeS\Examples\Brg_Step_Brg_Type_8.LDI
Project Fixed-Lobe Tilting-Pad Floating-Ring Gas-Brg Thrust Lubricant-Flow Tools View Help
Step Bearing modelled with Type 8 - Pressure Dam Bearing without side dams
Bearing Data
L = 6 in
Ds = 6 in
Cb = 0.005 in
2Cb/D = 0.00167
Cp = 0.005 in
Preload = 0
Offset = 0
Theta1= 10
Theta2= 170
Pocket Arc = 125
Depth = 0.015
Width = 6
Load Angle = 270
Viscosity = 2E-06 (Reyns)
Density = 0.03 (Lbm/in^3)
Y
X
θ
Ω
W
For Help, press F1

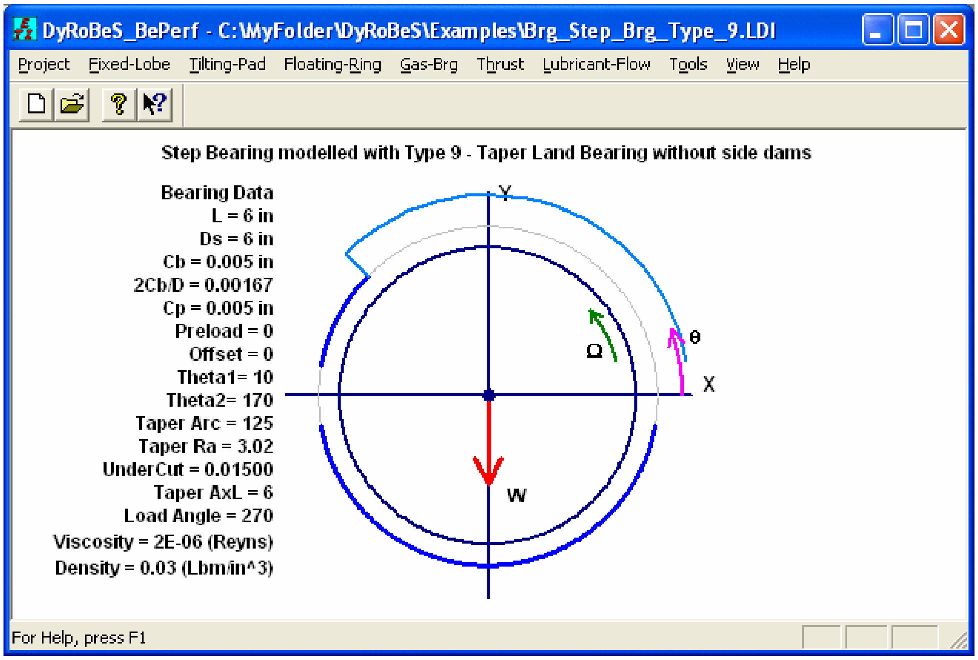

Fixed Lobe Bearing Dimensional Data
Options
Step Bearing modelled with Type 8 - Pressure Dam Bearing
L= 6 in, D= 6 in, Cb= 0.005 in, 2Cb/D=0.00167, m= 0, tilt= 0
Clr
Z
Clearance Distribution
Max C = 0.02000
Min C = 0.00500
3D - FEA Mesh Data
Theta

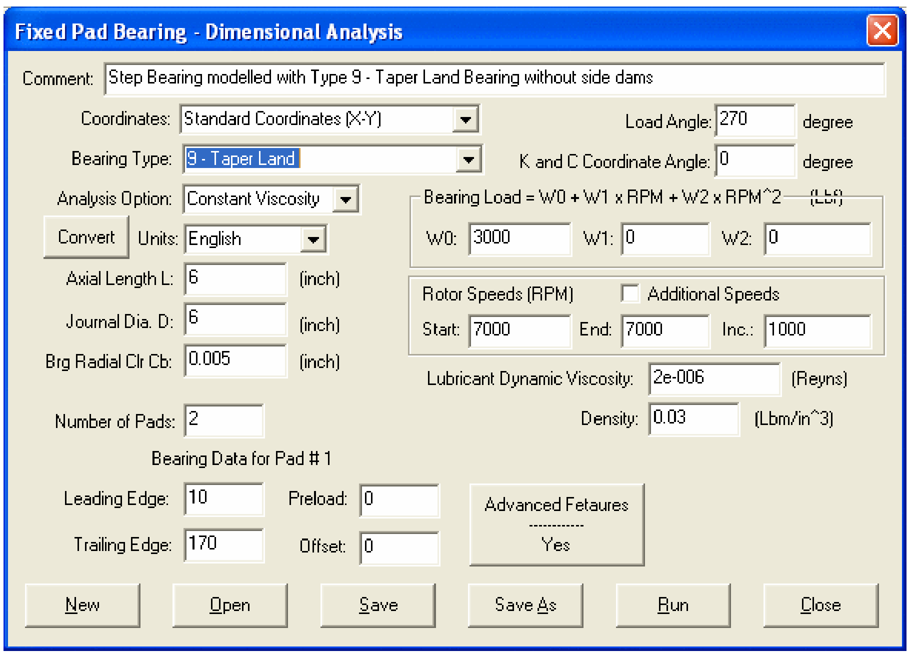

Fixed Pad Bearing - Dimensional Analysis
Comment: Step Bearing modelled with Type 8 - Pressure Dam Bearing without side dams
Coordinates: Standard Coordinates (X-Y)
Load Angle: 270 degree
Bearing Type: 8 - Pressure Dam/Step/Pockets
K and C Coordinate Angle: 0 degree
Analysis Option: Constant Viscosity
Bearing Load = W0 + W1 x RPM + W2 x RPM^2 (Lbf)
Convert
Units: English
W0: 3000 W1: 0 W2: 0
Axial Length L: 6 (inch)
Journal Dia. D: 6 (inch)
Brg Radial Clr Cb: 0.005 (inch)
Rotor Speeds (RPM)
Additional Speeds
Start: 7000 End: 7000 Inc.: 1000
Lubricant Dynamic Viscosity: 2e-006 (Reyns)
Number of Pads: 2
Density: 0.03 (Lbm/in^3)
Bearing Data for Pad # 1
Leading Edge: 10
Preload: 0
Advanced Fetaures
Yes
Trailing Edge: 170
Offset: 0
New
Open
Save
Save As
Run
Close

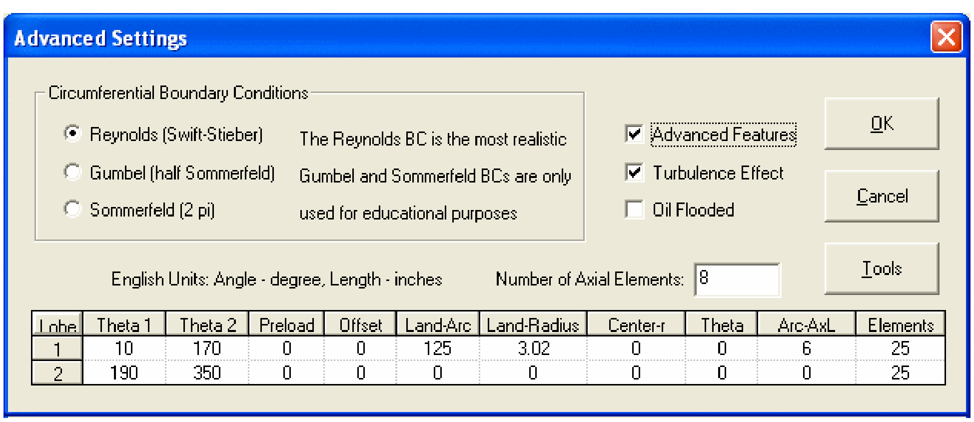

Advanced Settings
Circumferential Boundary Conditions
Reynolds (Swift-Stieber)
Gumbel (half Sommerfeld)
Sommerfeld (2 pi)
The Reynolds BC is the most realistic
Gumbel and Sommerfeld BCs are only
used for educational purposes
Advanced Features
Turbulence Effect
Oil Flooded
OK
Cancel
English Units: Angle - degree, Length - inches
Number of Axial Elements: 8
Lobe Theta 1 Theta 2 Preload Offset PocketArc PocketDepth PocketAxL ReliefAxL Elements
1 10 170 0 0 125 0.015 6 0 25
2 190 350 0 0 0 0 0 0 25


Fixed Lobe Bearing Dimensional Data
Options
Profile
Step Bearing modelled with Type 8 - Pressure Dam Bearing without side dams
L= 6 in, D= 6 in, Cb= 0.005 in, 2Cb/D=0.00167, m= 0, tilt= 0
Speed = 7000 rpm
Load = 3000 Lbf
W/LD = 83.3333 psi
Vis. = 2E-06 Reyns
Sb = 1.008
E/Cb = 0.1860
Att. = 97.07 deg
hmin = 4.113 mils
Pmax = 240.526 psi
Hp = 32.5517 hp
Qside = 25.482 gpm
Stiffness (Lbf/in)
1.433E+06 1.250E+06
-5.026E+06 1.371E+06
Damping (Lbf-s/in)
4.535E+03 -1.831E+03
-1.832E+03 1.262E+04
Critical Journal Mass (Lb)
3280.8
Y
X
W

It can also be modeled with Type 9 – Taper Land Bearing as illustrated below. The results are identical in two cases.



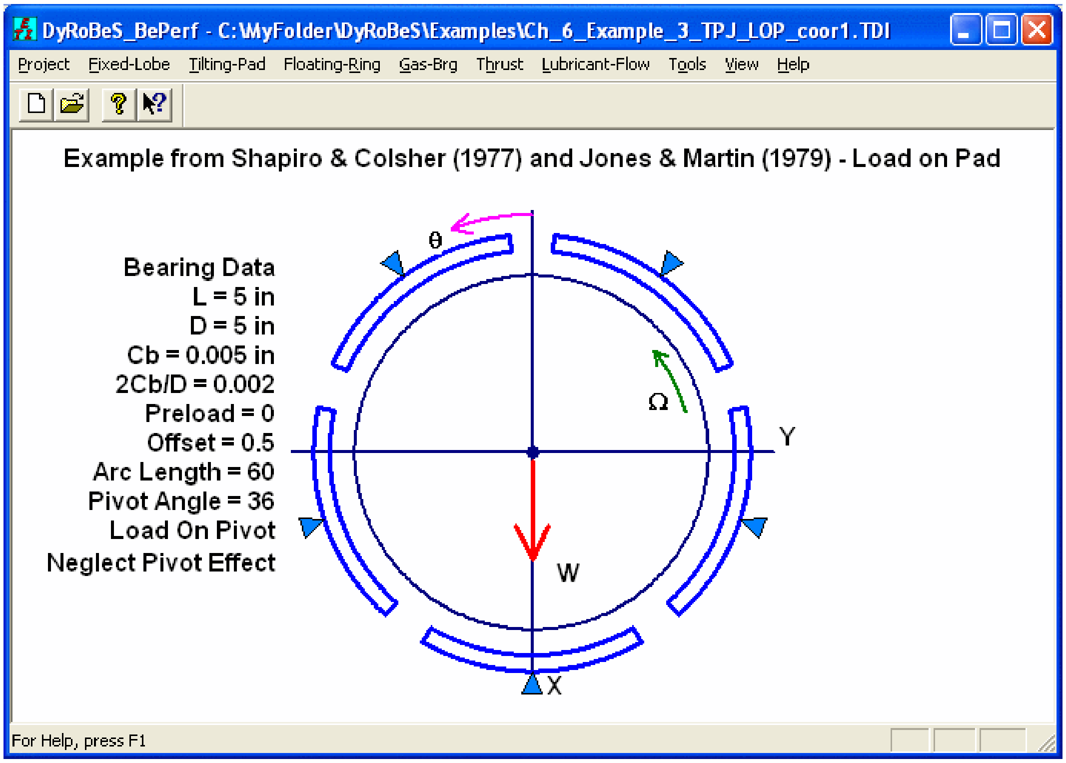


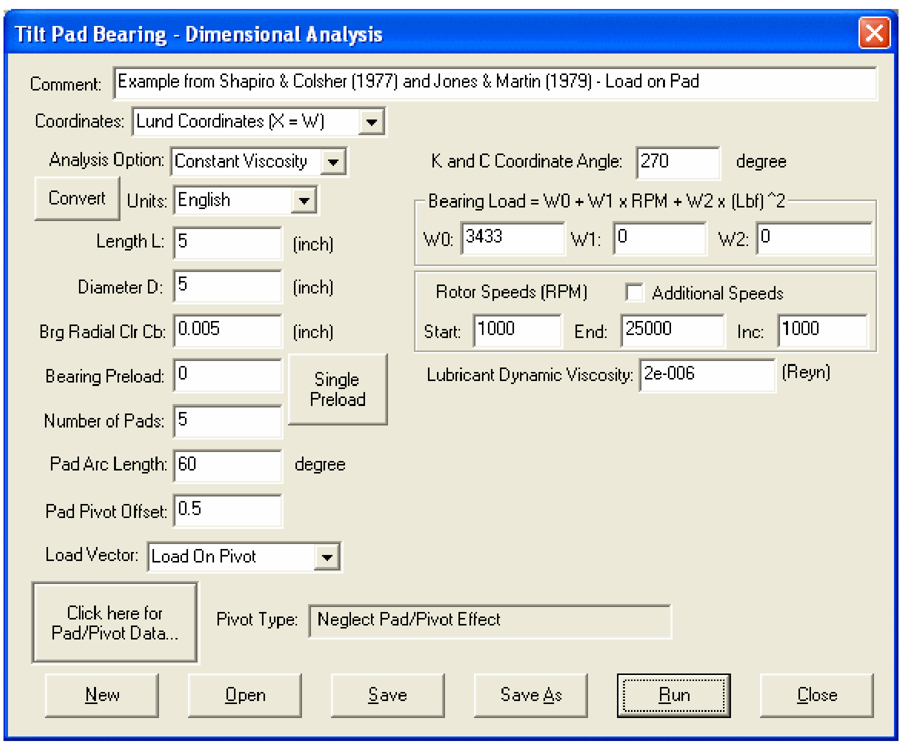


Again, with the general inputs of pressure dam bearing and taper land bearing, more other types bearing can be modeled using these two types bearings.

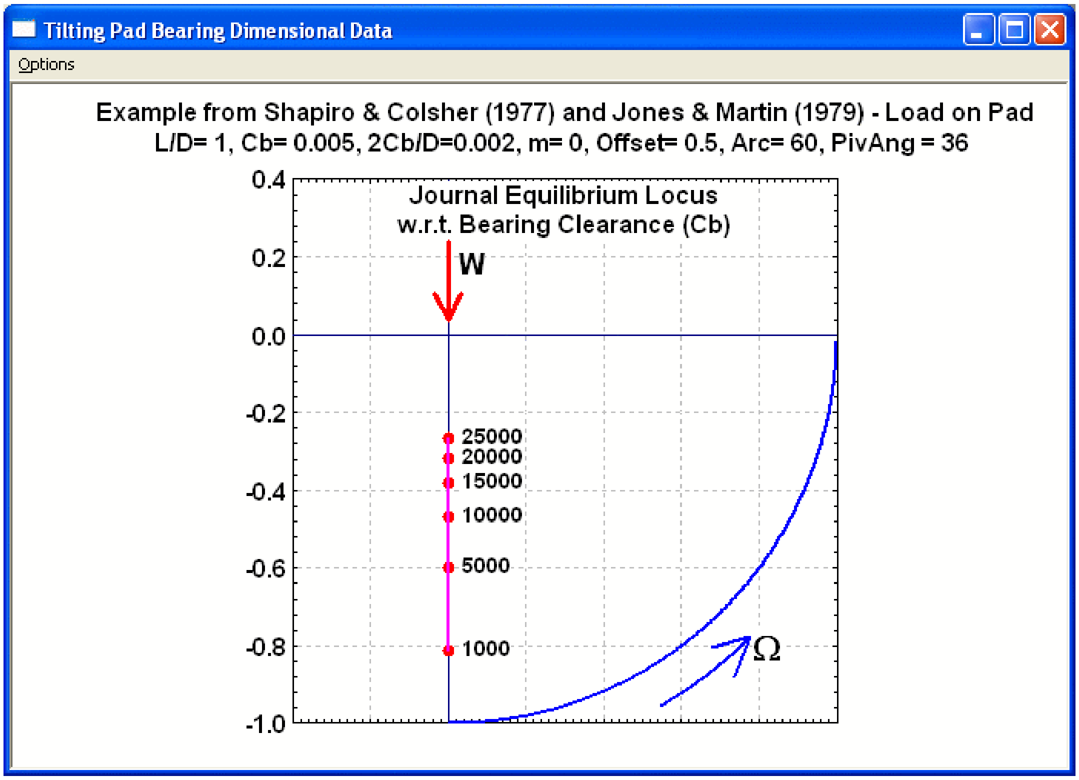
Example 6: 5-Pads Tilting Pad Bearing

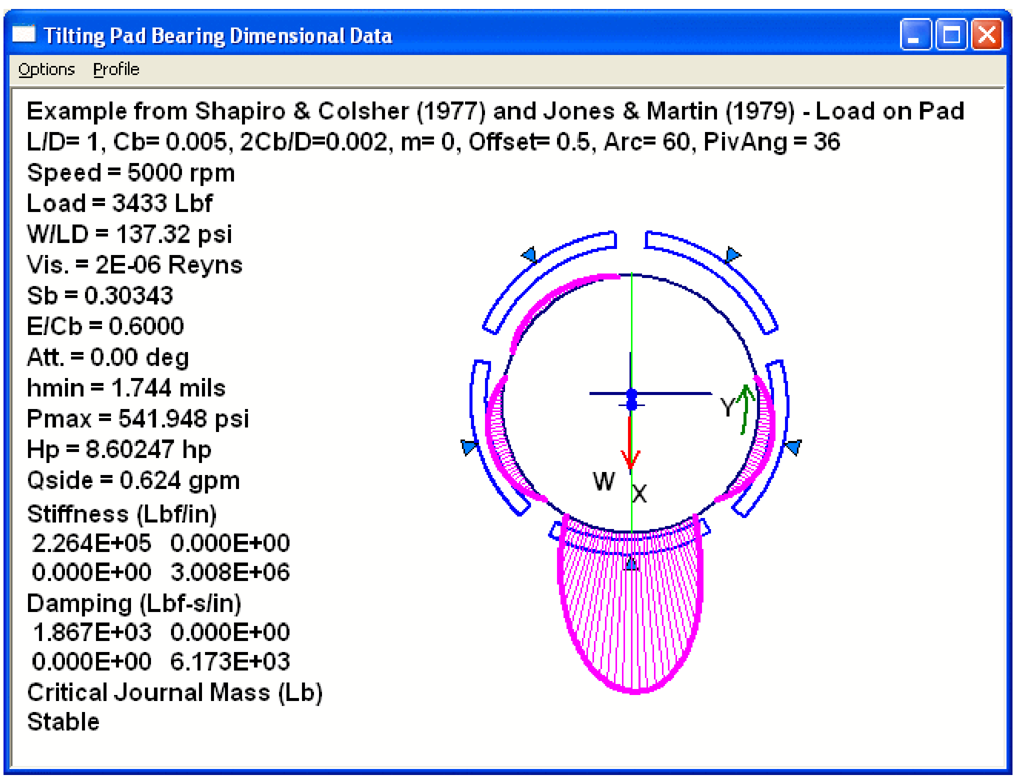
A 5-pads tilting pad bearing taken from Jones & Martin, ASLE Trans., 1979, is used in this example as shown below. For comparison purposes, Lund's coordinate system is used, that is, the load vector is aligned with the X-axis. Lubricant viscosity is assumed to be constant and pivot/pad flexibility is ignored. The input parameters are shown for reference. The first case considered is Load On Pivot.



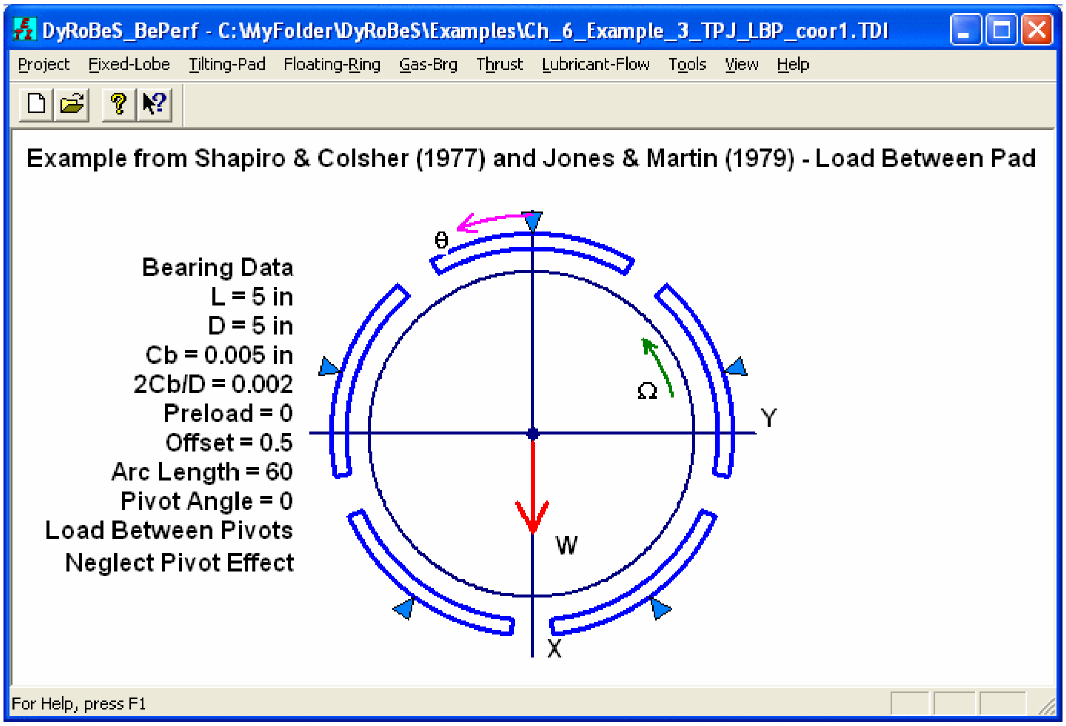


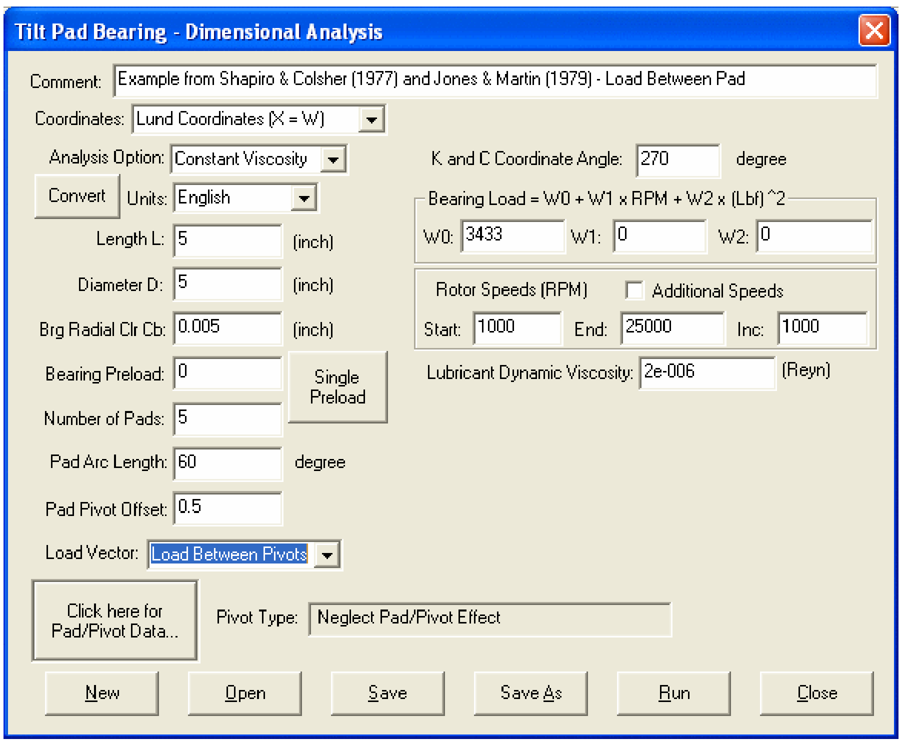
The results are presented below. Note that the bearing attitude angles are zero for the tilting pad bearings and the bearing cross-coupled stiffness coefficients are also zero. It indicates the inherently stable characteristics for the tilting pad bearings.

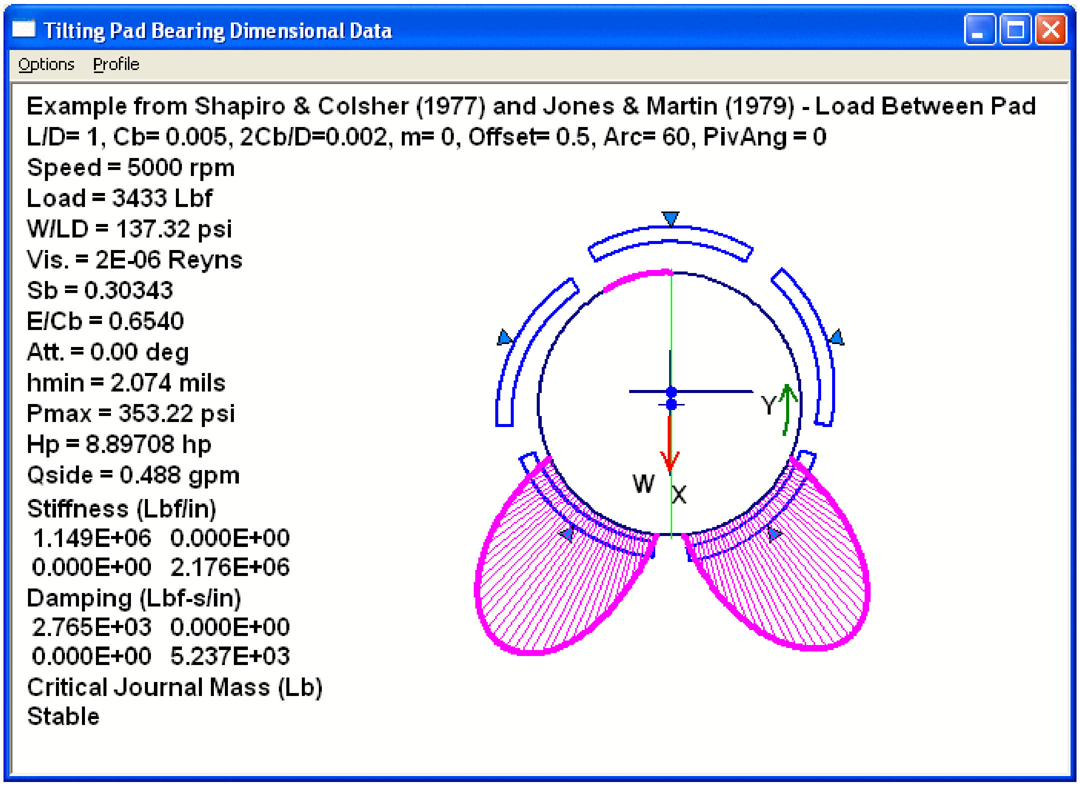




The second case considered is Load Between Pivots. The inputs and results are presented below.

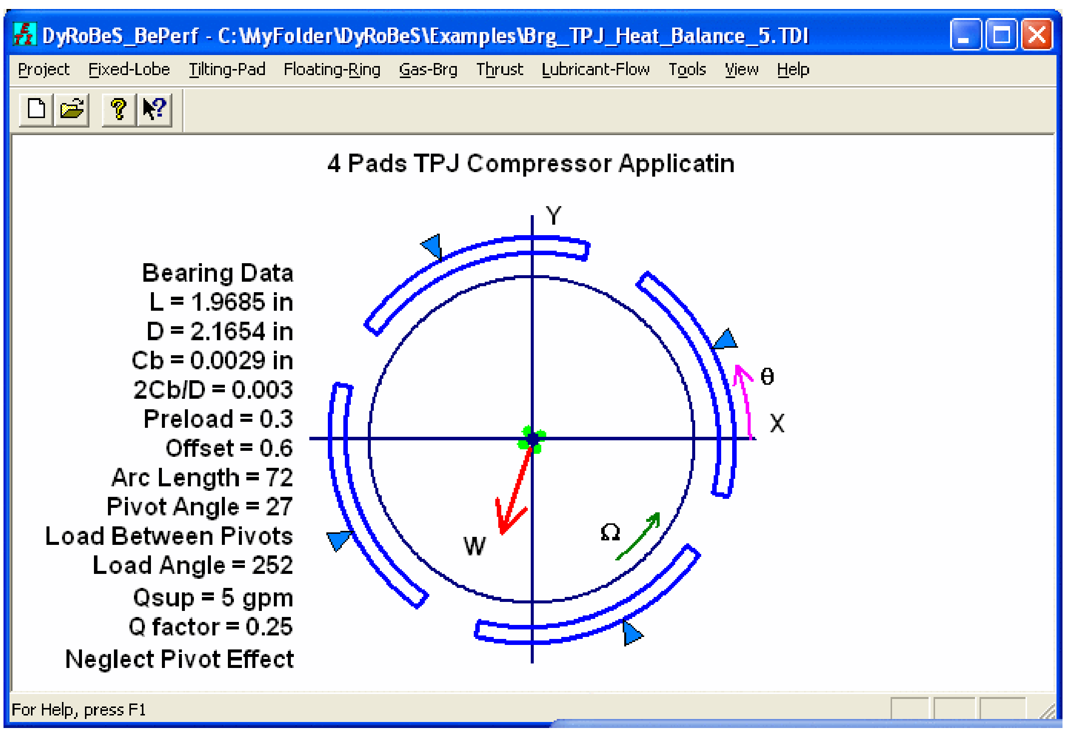

DyRoBeS_BePerf - C:\MyFolder\DyRoBeS\Examples\Ch_6_Example_3_TPJ_LBP_coor1.TDI
Project Fixed-Lobe Tilting-Pad Floating-Ring Gas-Brg Thrust Lubricant-Flow Tools View Help
Example from Shapiro & Colsher (1977) and Jones & Martin (1979) - Load Between Pad
Bearing Data
L = 5 in
D = 5 in
Cb = 0.005 in
2Cb/D = 0.002
Preload = 0
Offset = 0.5
Arc Length = 60
Pivot Angle = 0
Load Between Pivots
Neglect Pivot Effect
θ
Ω
Y
W
X
For Help, press F1

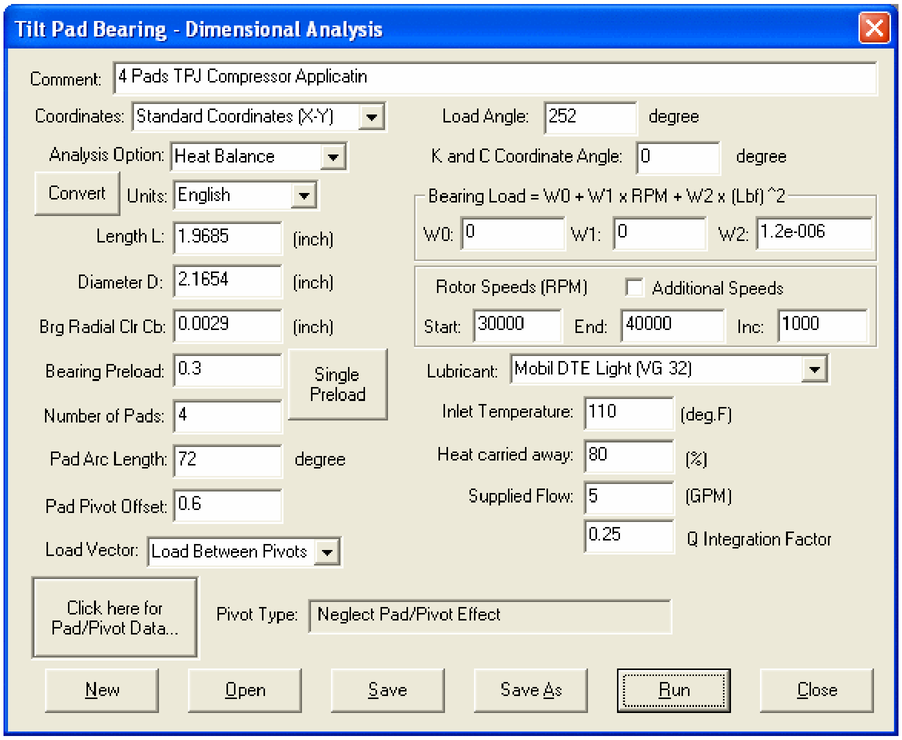

Tilt Pad Bearing - Dimensional Analysis
Comment: Example from Shapiro & Colsher (1977) and Jones & Martin (1979) - Load Between Pad
Coordinates: Lund Coordinates (X = W)
Analysis Option: Constant Viscosity
K and C Coordinate Angle: 270 degree
Convert
Units: English
Bearing Load = W0 + W1 x RPM + W2 x (Lbf)^2
W0: 3433
W1: 0
W2: 0
Length L: 5 (inch)
Diameter D: 5 (inch)
Rotor Speeds (RPM)
Additional Speeds
Start: 1000
End: 25000
Inc: 1000
Brg Radial Clr Cb: 0.005 (inch)
Bearing Preload: 0
Single Preload
Lubricant Dynamic Viscosity: 2e-006 (Reyn)
Number of Pads: 5
Pad Arc Length: 60 degree
Pad Pivot Offset: 0.5
Load Vector: Load Between Pivots
Click here for Pad/Pivot Data...
Pivot Type: Neglect Pad/Pivot Effect
New
Open
Save
Save As
Run
Close



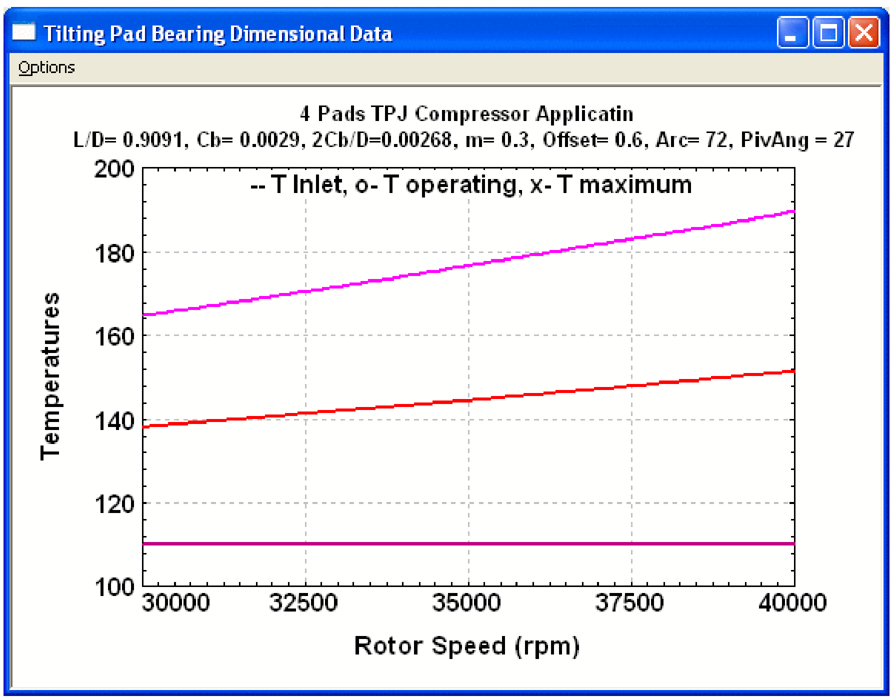
Example 7: 4-Pads Tilting Pad Bearing – compressor application

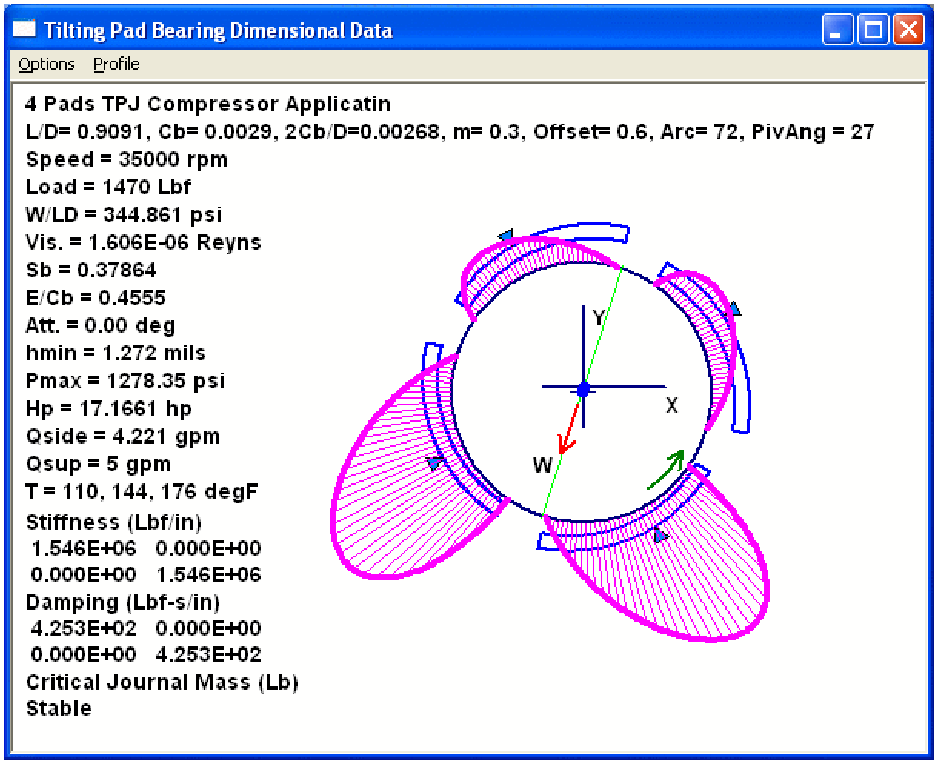
A 4-pads tilting pad bearing used in a gear driven centrifugal compressor is utilized in this example. The bearing load is mainly due to the gear force, which increases as the speed increases. For centrifugal compressor application, the gear load is a function of square of the rotor speed. Also, to lower the bearing maximum temperature, an pivot offset of 0.6 is used. The bearing is oriented such that the bearing load is directed between pivots. Note that the load vector is between pivots, not pads.





Some results are shown below:

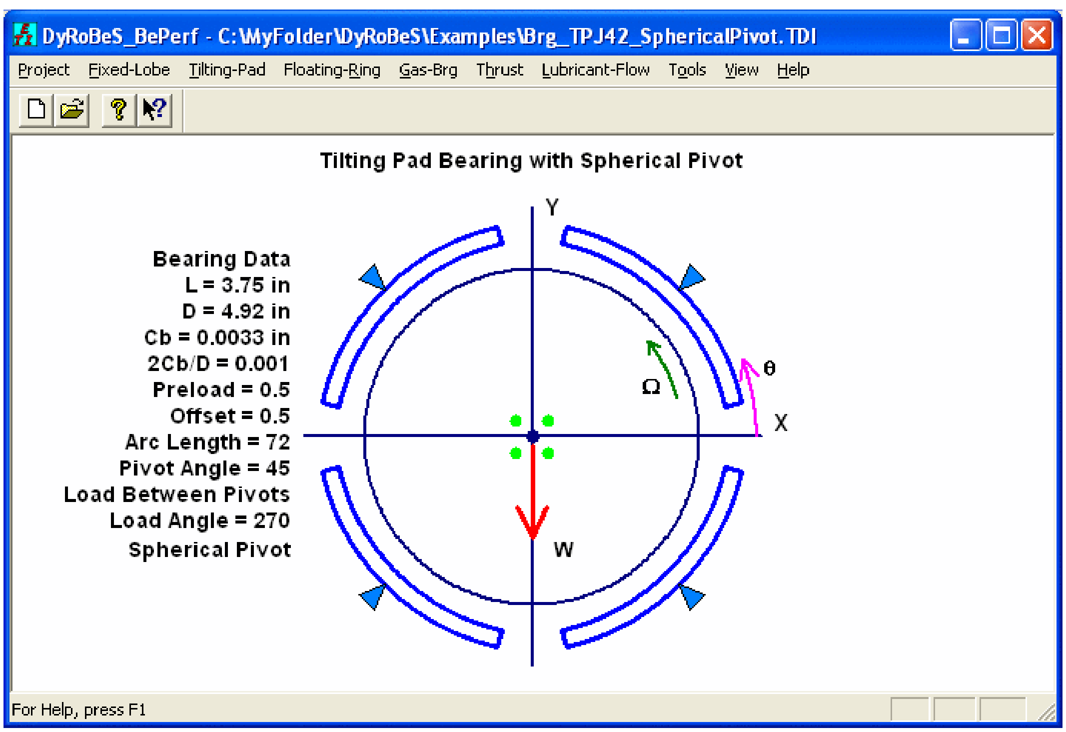


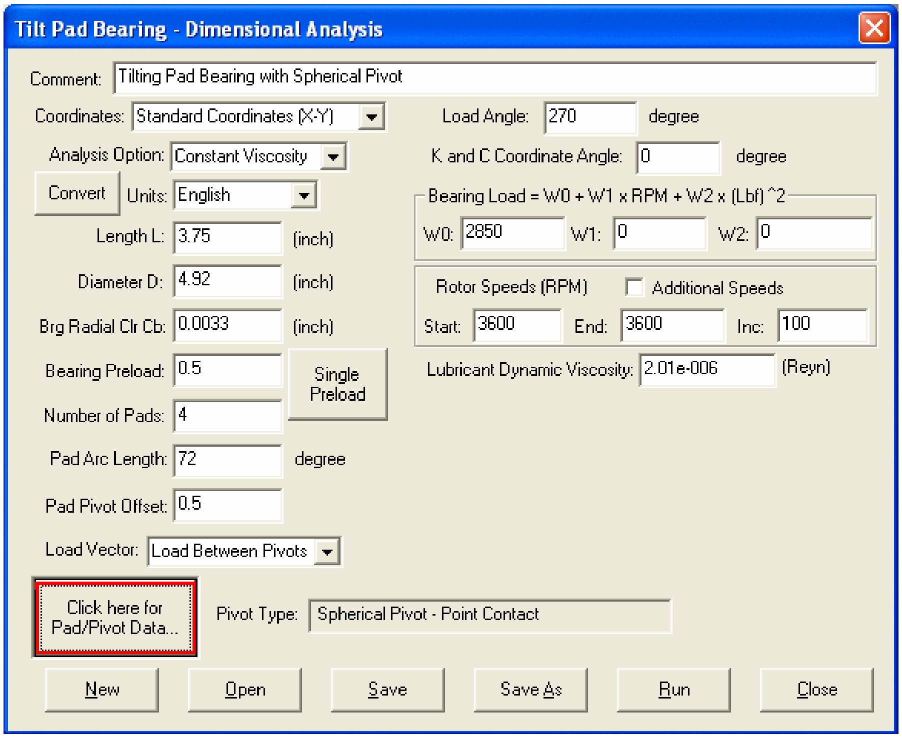


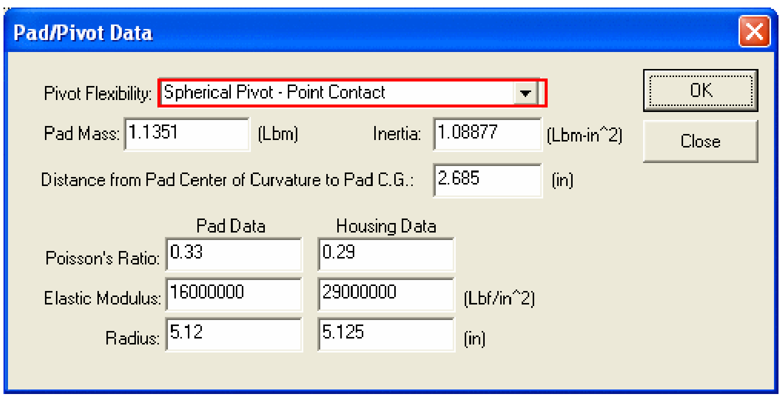
For 4-pads and load between pivots, the bearing stiffness and damping are identical in both X and Y directions. This implies that the bearing properties are isotropic.

Example 8: 4-Pads Tilting Pad Bearing with Pivot Flexibility

In this example, the pad/pivot flexibility is studied. For big bearings with larger pads, the pad effect may need to be included in the analysis. A tilting pad bearing used in the generator application is employed in this example. The bearing under study has spherical pivots. In this example, several different pad/pivot configurations are studied.



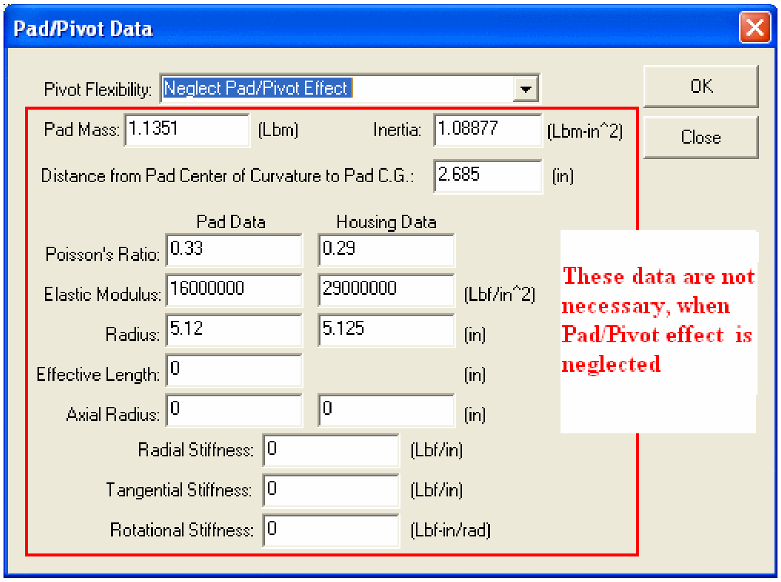


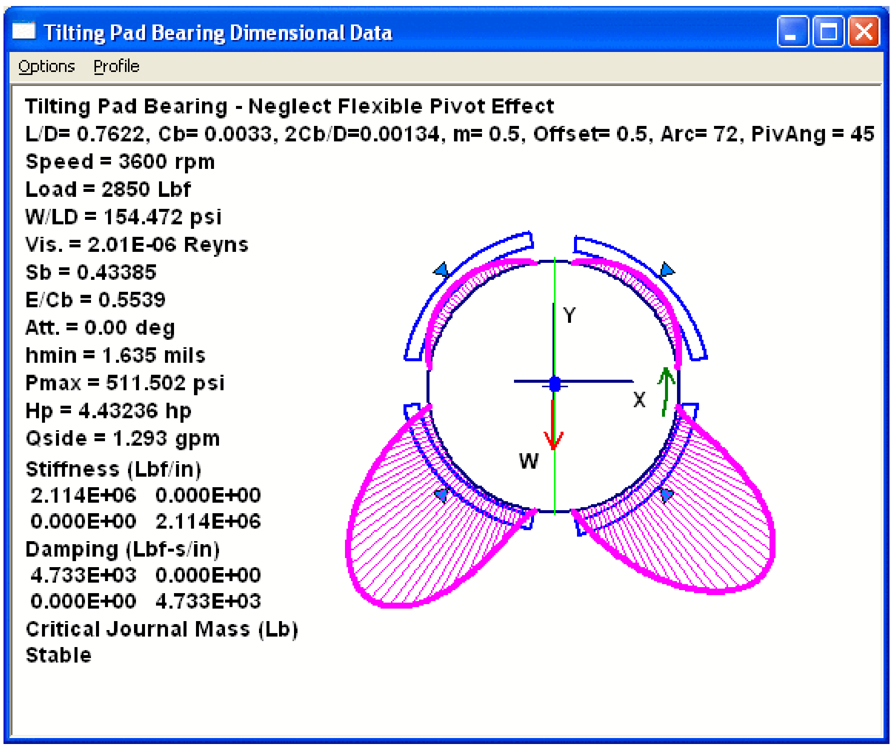


To select the pad/pivot configuration and enter the pad/pivot data, click the Pad/Pivot Data button as shown in the main input screen. They are several pivot configurations available in DyRoBeS.

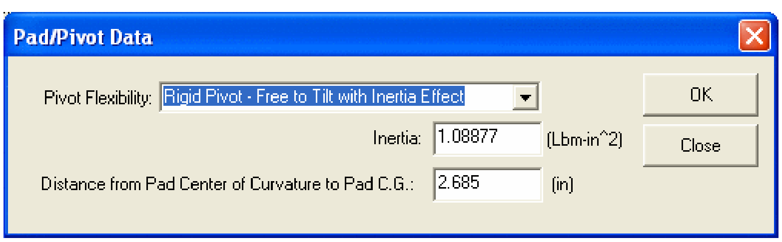
1. Neglect Pad/Pivot Effect. This is a conventional configuration, which neglects the pad/pivot effect. The pad is free to tilt without any restrictions.
2. Rigid Pivot which is free to tilt with inertia effect. In this configuration, the pad inertia is included in the pad rotational equation of motion.
3. Spherical Pivot, it implies the point contact.
4. Cylindrical Pivot, it implies the line contact.
5. General curvatures, it has curvatures in both directions.
6. Constant stiffness, this is used for flexural pad bearings.

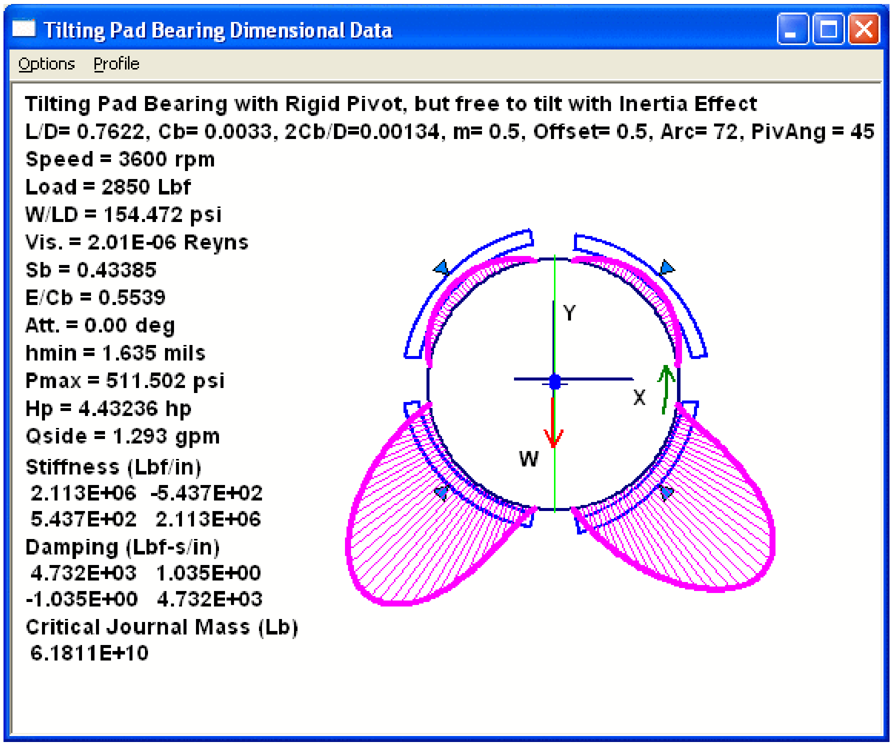
Case 1 – Neglect Pad/Pivot Effect



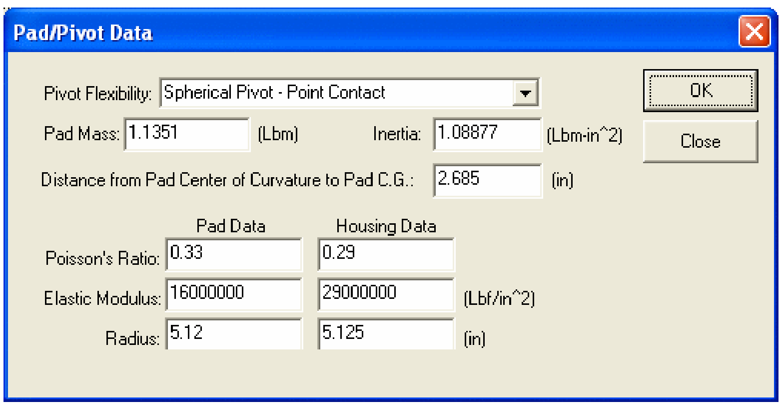


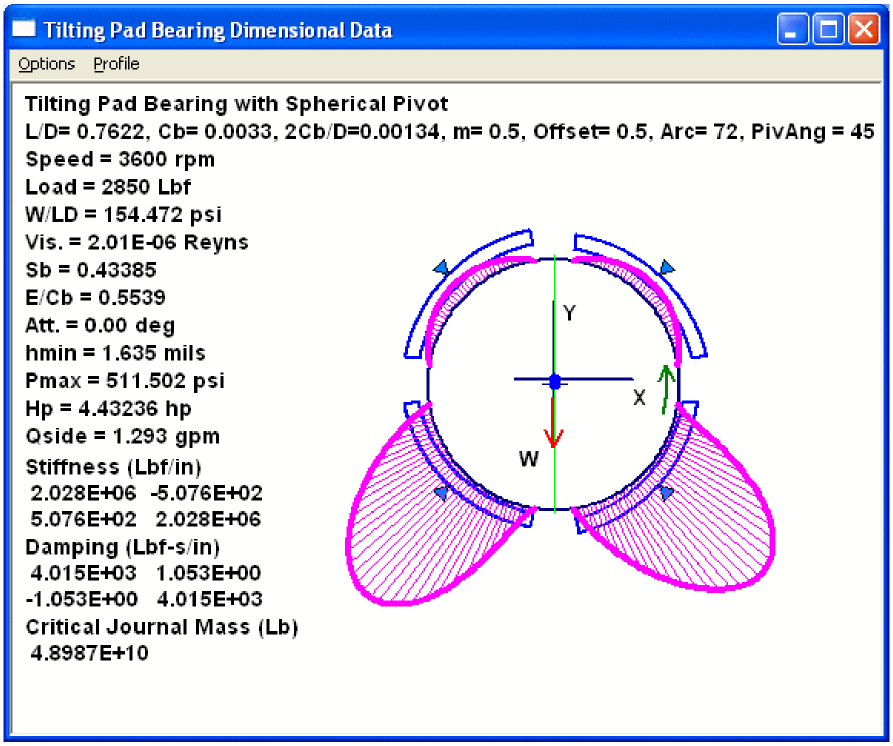
Case 2 – Rigid Pivot with inertia effect



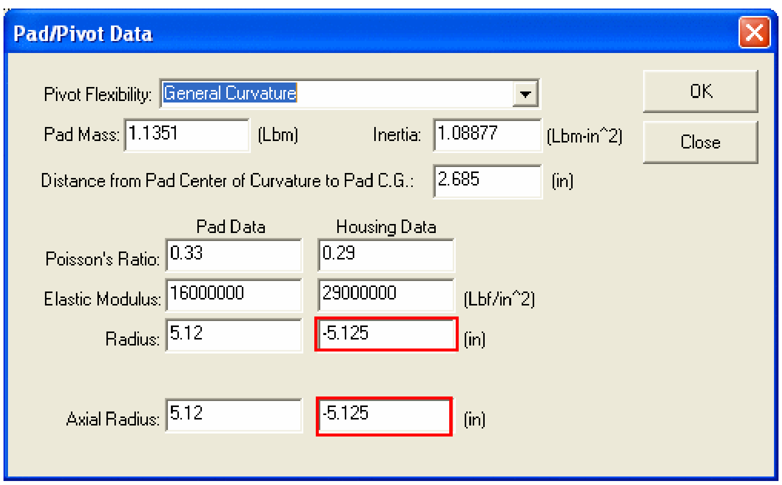


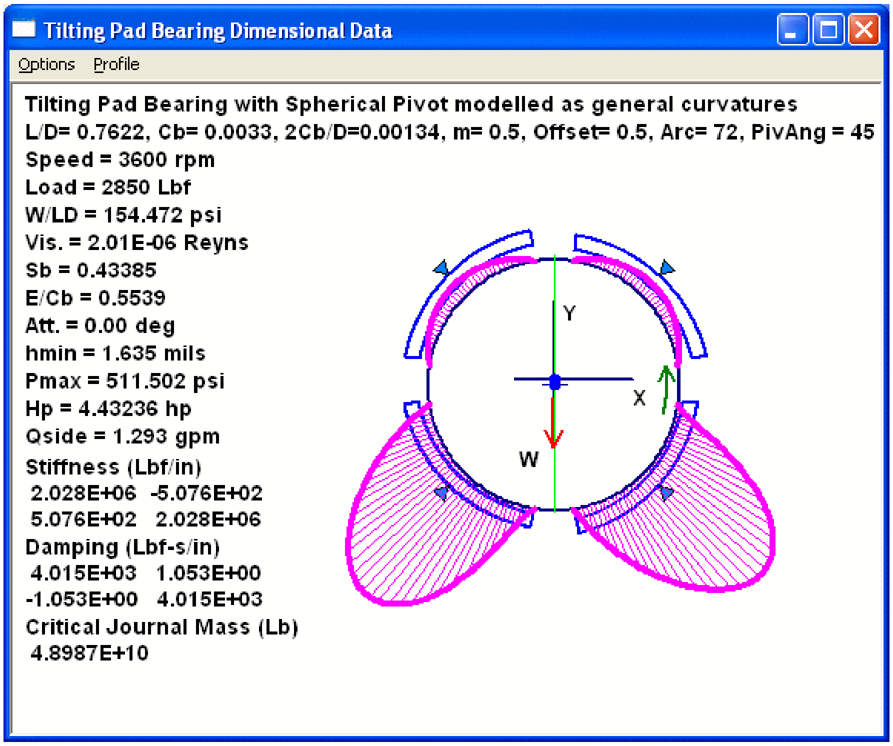
Case 3 – Spherical Pivot, this is the true configuration.





Case 4 – General Curvatures, The spherical pivot can be modeled using this more general input.

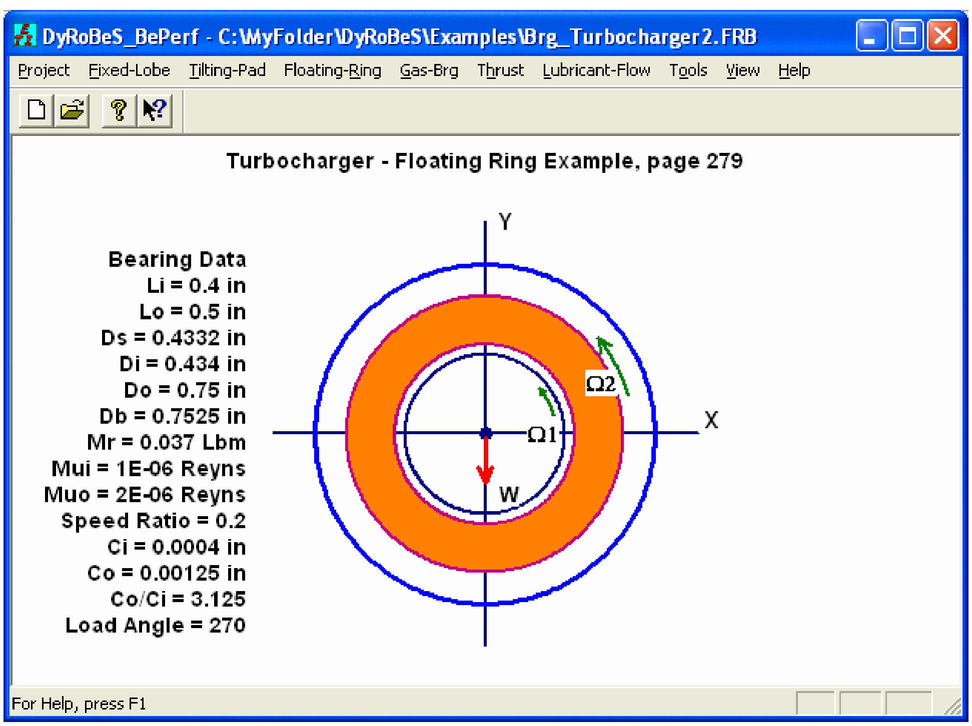


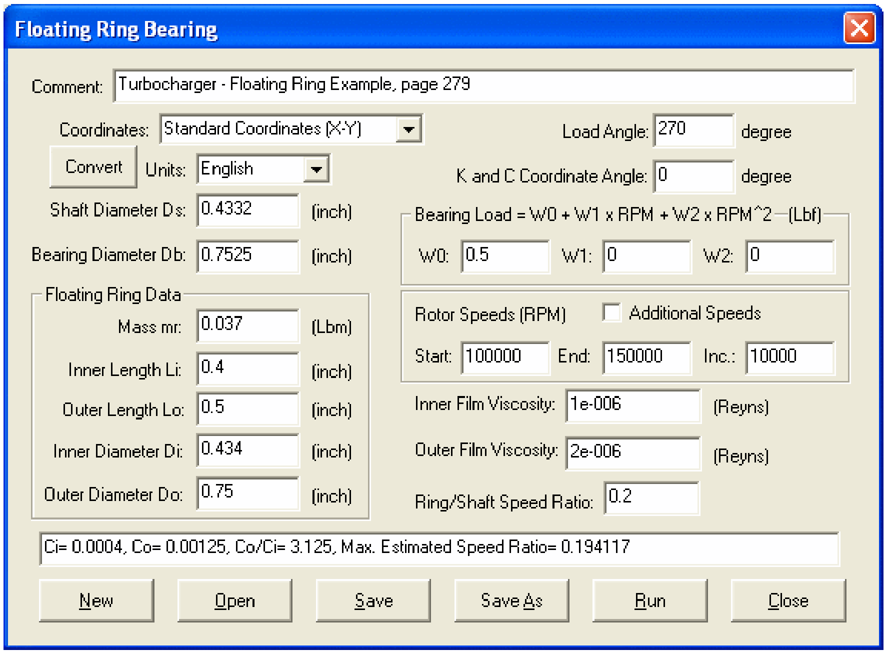


These results are identical to case 3. For **Spherical Pivot** and **Cylindrical Pivot**, the radii are always positive. For **General Curvatures**, the radii are positive if the center of curvature lies within the given body, i.e., the surface is convex, otherwise, the radii are negative.

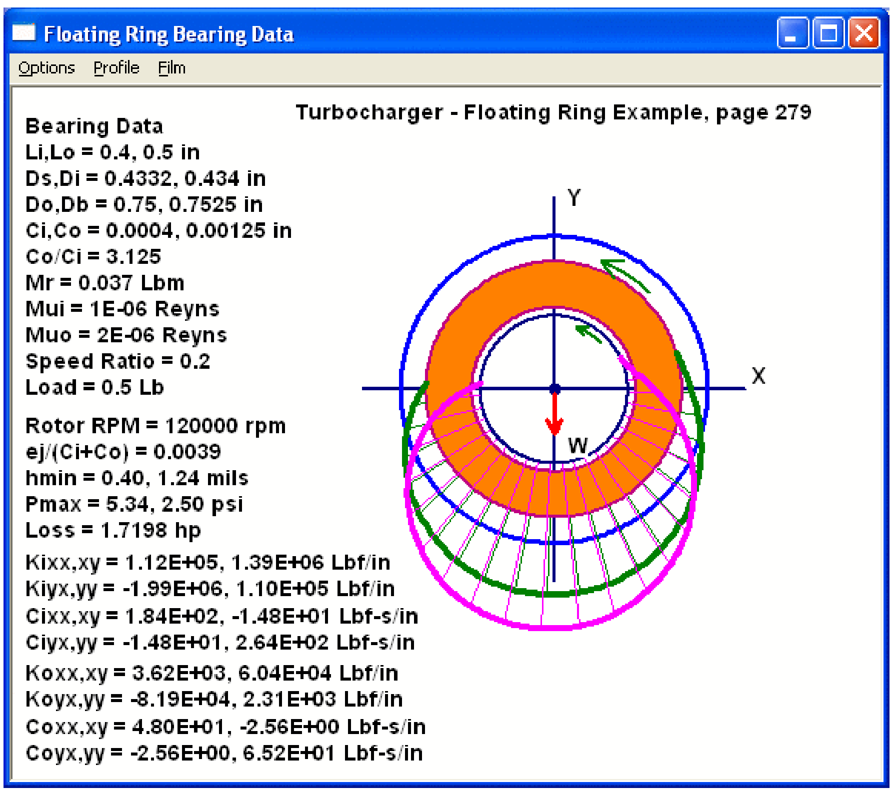
Example 9: Floating Ring Bearing

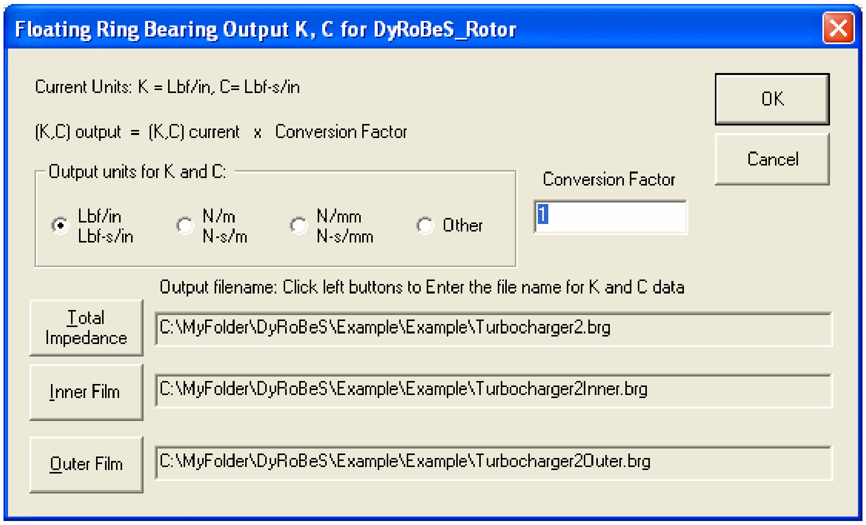
Floating ring bearing is commonly used in the automotive turbocharger application. There are two oil films separated by a floating ring. It is like two bearings in series. For a conventional floating ring bearing, the ring is free to rotate. Then, two bearings are conventional plain cylindrical journal bearings. Sometimes, anti-rotational pin is used to prevent the ring from rotating, then, the outer oil film becomes a squeeze film damper. The bearing type of outer film, either plain journal bearing or squeeze film damper, depends on the speed ratio specified in the input. In this example, the ring is free to rotate.





The temperature for the inner oil film is normally higher than that of the outer oil film, therefore, it has a smaller viscosity than that of outer film.

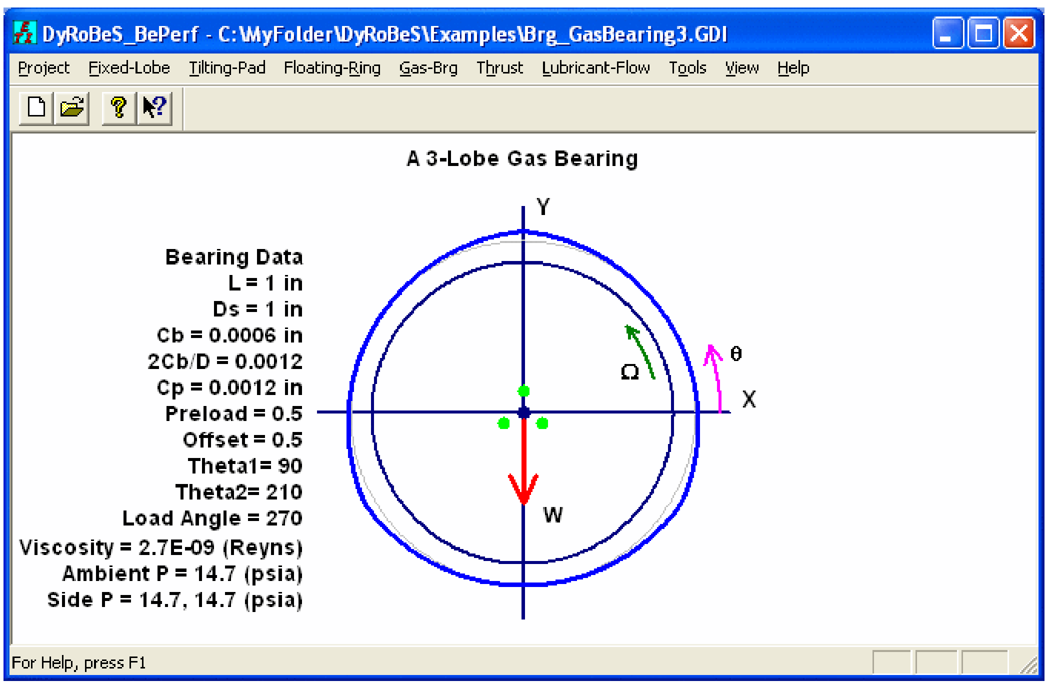


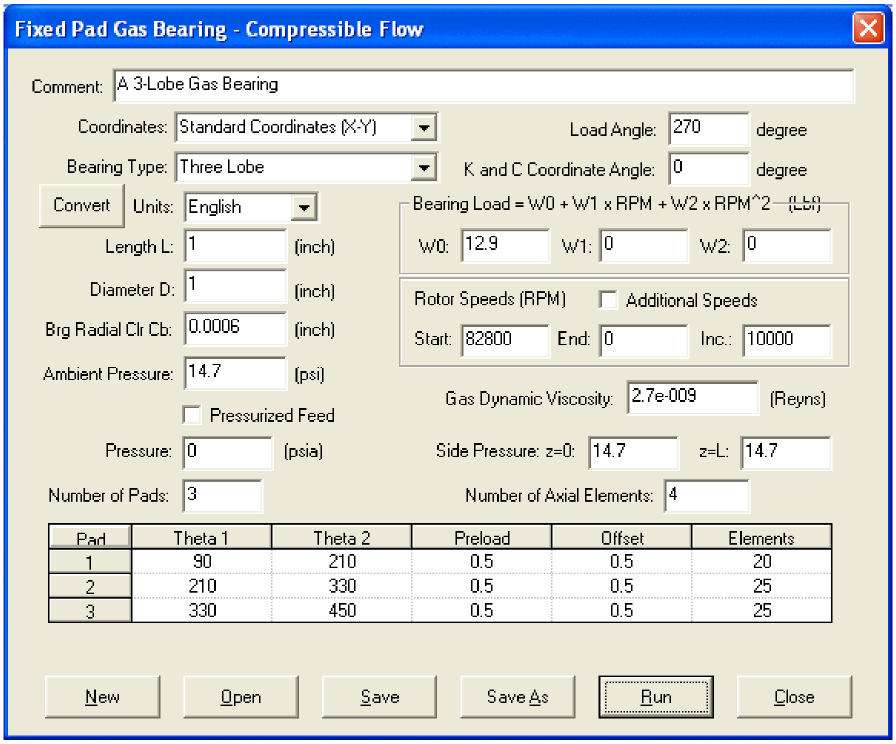


When outputs the bearing stiffness and damping coefficients, three files will be created. One is for the total impedance which synchronous excitation is assumed. The other two are the bearing stiffness and damping coefficients for the inner and outer films. It depends on how the rotor system is modeled. The users can make their decision on how to use these files.

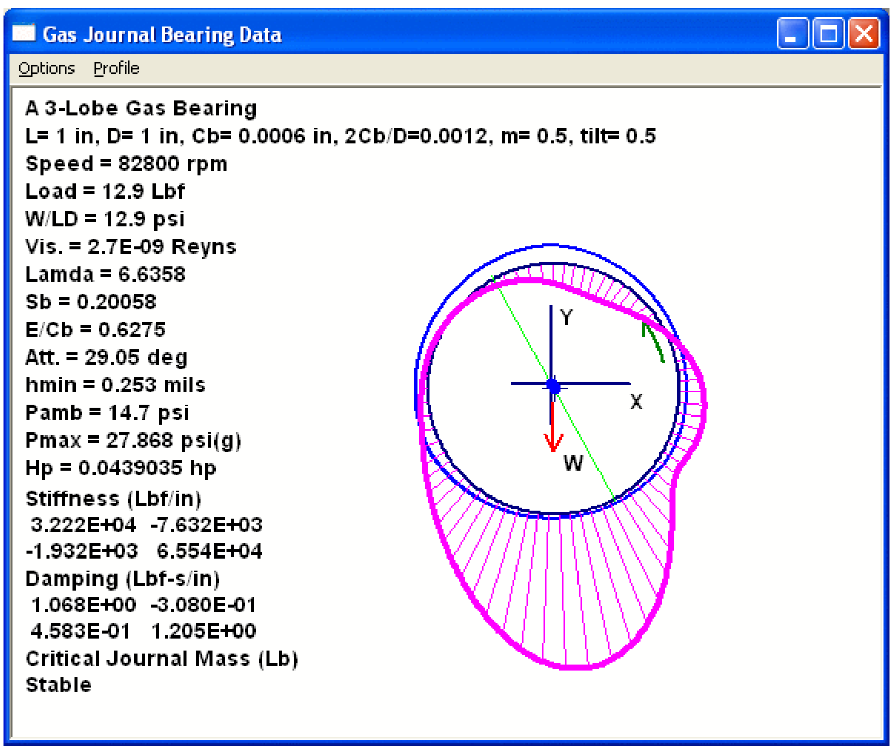
Example 10: A 3-Lobe Gas Bearing

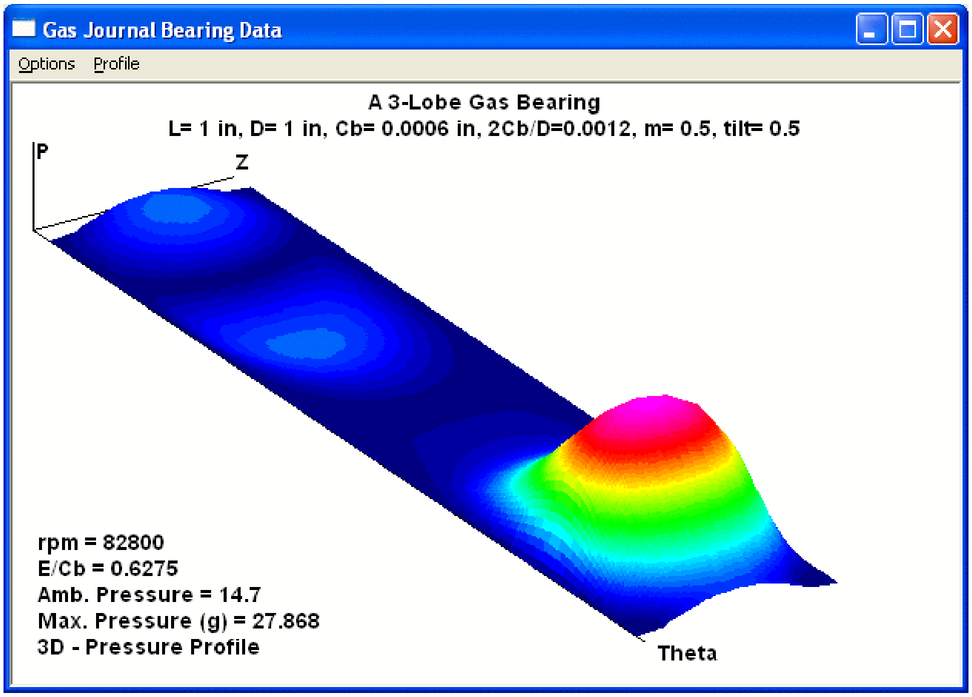
A 3-lobe gas bearing is used in this example. The input parameters are shown below.

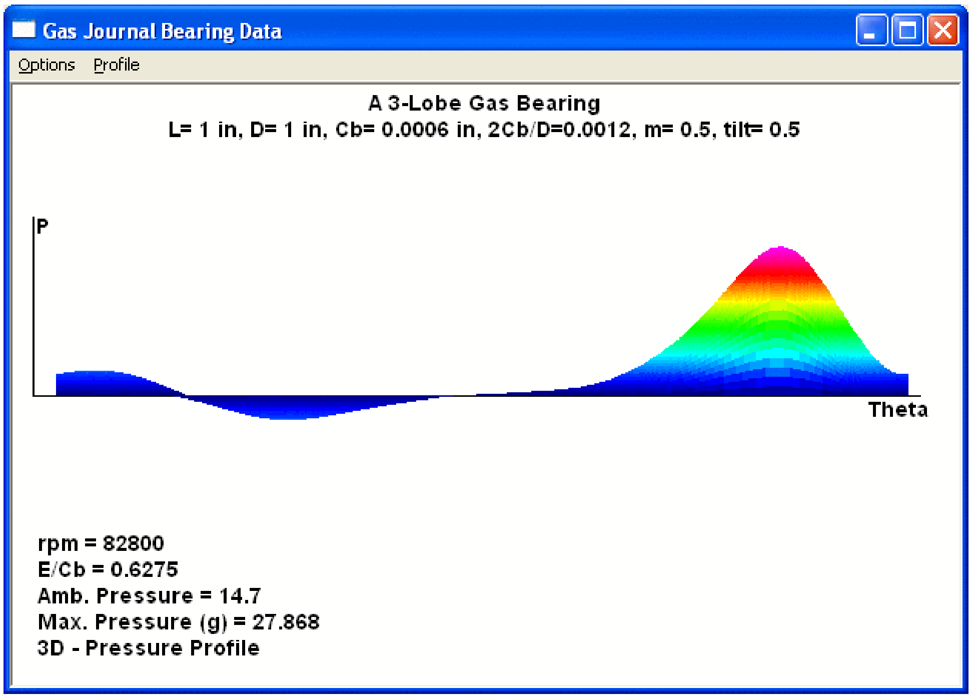




Some results are shown below.




Gas Journal Bearing Data
Options Profile
A 3-Lobe Gas Bearing
L= 1 in, D= 1 in, Cb= 0.0006 in, 2Cb/D=0.0012, m= 0.5, tilt= 0.5
P
Z
rpm = 82800
E/Cb = 0.6275
Amb. Pressure = 14.7
Max. Pressure (g) = 27.868
3D - Pressure Profile
Theta


Gas Journal Bearing Data
Options Profile
A 3-Lobe Gas Bearing
L= 1 in, D= 1 in, Cb= 0.0006 in, 2Cb/D=0.0012, m= 0.5, tilt= 0.5
P
Theta
rpm = 82800
E/Cb = 0.6275
Amb. Pressure = 14.7
Max. Pressure (g) = 27.868
3D - Pressure Profile

Nomenclature

Symbol	Description
Ob	Bearing center
Oj	Journal center
Op	Pad (lobe) center of curvature
Rb	Bearing assembled radius at minimum clearance
Rj	Journal shaft radius
Rp	Pad machined radius
e	Journal eccentricity, distance from bearing center to journal center
ϕ	Attitude angle, angle from X axis (load vector) to the line connecting bearing center and journal center
θ_1	Angle from the negative load vector (negative X axis) to leading edge of the first lobe
θ_2	Angle from the negative load vector (negative X axis) to trailing edge of the first lobe
θ_p	Angle from the negative load vector (negative X axis) to the line connecting the bearing center and the pad center of curvature
Npad	Number of pads (lobes)
L	Bearing (babbitt) axial length
D	Bearing diameter
Cb	Bearing minimum assembled radial clearance, *Cb* = *Rb* - *Rj*
Cp	Pad machined radial clearance, *Cp* = *Rp* - *Rj*
m	Preload, *m* = 1-(*Cb*/*Cp*)
χ	Lobe or Pad arc length, $\chi = \theta_2 - \theta_1$
χ_p	Angle from leading edge to the minimum clearance point for a centered shaft for fixed lobe bearings, or, Angle from leading edge to pad pivot point for tilting pad bearings, $\chi_p = \theta_p - \theta_1$
α	Offset, or Pivot Ratio, $\alpha = \chi_p / \chi$
W	Bearing load vector
Ω	Shaft rotational speed (rad/sec)
Ns	Shaft rotational speed (rps)
rpm	Shaft rotational speed (rpm)
μ	Lubricant dynamic viscosity
	The following parameters are used in the output
S	Sommerfeld Number
Cij	Damping coefficients (*Cxx*, *Cxy*, *Cyx*, *Cyy*)
Kij	Stiffness coefficients (*Kxx*, *Kxy*, *Kyx*, *Kyy*)
hmin	Minimum film thickness
hpiv	Film thickness at pivot point
Pmax	Maximum film pressure
Hp	Frictional power loss
Qs	Side leakage
Qin	Total inlet circumferential flow
T	Temperature
Tin	Inlet (supply) oil temperature
Top	Operating film temperature
Tmax	Maximum film temperature
dT	Temperature rise in loaded pad
Mcr	Critical journal mass
Whirl	Whirl/Spin ratio

See also Non-Dimensional Parameters.

Non-Dimensional Parameters

Description	Expression
Sommerfeld Number	$S = \frac{\mu N_s LD}{W}\left(\frac{R}{C}\right)^2$
Film Thickness	$\bar{h} = \frac{h}{C}$
Eccentricity Ratio	$\bar{e} = \frac{e}{C}$
Preload	$m = \frac{(C_p - C_b)}{C_p} = 1 - \frac{C_b}{C_p}$
Offset (or Pivot Ratio)	$\alpha = \frac{(\theta_p - \theta_1)}{(\theta_2 - \theta_1)} = \frac{\chi_p}{\chi}$
Damping Coefficients	$\overline{C}_{ij} = \left(\frac{\Omega C}{W}\right) C_{ij}$
Stiffness Coefficients	$\overline{K}_{ij} = \left(\frac{C}{W}\right) K_{ij}$
Film Pressure	$\overline{P} = \frac{1}{2\pi S}\ \frac{P}{W/LD}$
Frictional Power Loss	$\overline{Hp} = \left(\frac{C}{\pi^3 \mu N_s^2 LD^3}\right) Hp$
Flow	$\overline{Q} = \frac{Q}{\frac{1}{2}\pi N_s CLD}$
Critical Journal Mass	$\overline{M}_{CR} = \left(\frac{\Omega^2 C}{W}\right) M_{CR}$

where C can be the pad radial clearance or bearing radial clearance.

See also Nomenclature.

Units

Two systems of units are provided in this program. The unit conversion is listed below for reference.

Unit	English	Metric (SI)	Conversions (* = multiply)
Time	second (s)	second (s)	
Length	in	Meter (m)	m = 0.025400 * in
	in	mm	mm = 25.4 * in
Force	Lbf	Newton (N) 1N = 1kg * 1m/s^2	N = 4.448222 * Lbf N = 9.8066 * kgf
Moment	Lbf-in	N-m	N-m = 0.1129846 * Lbf-in
Mass	Lbf-s^2/in	kg = N-s^2/m	kg = 0.4535924 * Lbm kg = 175.1266 * Lbf-s^2/in Lbm = 386.088 * Lbf-s^2/in
Density	Lbf-s^2/in^4	kg/m^3	kg/m^3 = 2.767990E+04 * Lbm/in^3 kg/m^3 = 1.068688E+07 * Lbf-s^2/in^4
			g/cm^3 = 1 * g /cc g/cm^3 = 2.767990E+01 * Lbm/in^3 Lbm/in^3 = 0.0361273 * g/cm^3
Inertia	Lbf-s^2-in	kg-m^2	kg-m^2 = 0.1129846 * Lbf-s^2-in
Modulus	Lbf/in^2 (psi)	N/m^2 (Pa) kN/ m^2 (kPa)	Pa = 6.894757E+03 * psi kPa = 6.894757 * psi
Lateral Kt	Lbf/in	N/m	N/m = 175.1266 * Lbf/in N/mm = 0.1751266 * Lbf/in
Lateral Ct	Lbf-s/in	N-s/m	N-s/m = 175.1266 * Lbf-s/in N-s/mm = 0.1751266 * Lbf-s/in
Torsional K	Lbf-in/rad	N-m/rad	N-m/rad = 0.1129846 * Lbf-in/rad N-mm/rad = 112.9846 * Lbf-in/rad
Gravity - g	386.088 in/s^2	9.8066 m/s^2	
Temperature	°F	°C	°C = (°F-32) * 5/9
Viscosity	Reyn (Lbf-s/in^2)	centiPoise	cP = 6.894757E06 * Reyn cP = 1.0E03 * Pa-s cP = g/cc * cSt (mm^2/s)
Flow rate	gpm (gal/min)	m^3/hour	m^3/hour = 0.2271 * gpm
Power	hp	kWatt	kWatt = 0.7457 * hp
Unbalance			oz-in = 0.03527 * g-in g-in = 28.35 * oz-in

References

Bureau of Standards, Miscellaneous Publication of the Bureau of Standards No. 97, “Specific Heats of Lubricating Oils,”

Cameron,A., 1966, The Principles of Lubrication, Wiley, New York,

Chen, W. J., and Gunter, W. J, 2005, Introduction to Dynamics of Rotor-Bearing Systems, Trafford Publishing.

Chen, W. J., 1995, “Bearing Dynamic Coefficients of Flexible-Pad Journal Bearings,”STLE Tribology Transactionn, Vol. 38, pp.253-260.

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Nicholas,J.C., Gunter,E.J. ,and Allaire,P.E., 1979, "Stiffness and Damping Coefficients for the Five-Pad Tilting-Pad Bearing," ASLE Trans., Vol.22, No. 2

Orcutt, F.K., 1967, "The Steady-State and Dynamic Characteristics of Tilting-Pad Journal Bearing in Laminar and Turbulent Flow Regimes," Journal of Lubrication Technology.

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Shang L. and Dien, I. K., 1989, “A Matrix Method for Computing the Stiffness and damping Coefficients of Multi-Arc Journal bearings,” STLE Tribology Transactions.

Wilcock, D, F. and Booser, E. R., 1957, Bearing Design and Application, McGraw-Hill, New York.

Young, W.C, 1989, Roark’s Formulas for Stress & Strain, Sixth Edition, McGraw-Hill Book Company, pp.650-652.

DyRoBeS©_Rotor

DyRoBeS©_Rotor is a powerful rotor dynamics program based on Finite Element Analysis (FEA). This program has been developed for the analysis of free and forced vibrations (Lateral, Torsional, and Axial) of multi-shaft and multi-branch flexible rotor-bearing-support systems.

The lateral vibration of the discretized rotor system is described by two translational (*x*, *y*) and two rotational (θ_x, θ_y) coordinates at each finite element station, i.e. 4 degrees-of-freedom at each shaft station. The motion of a flexible support is described by two additional translational displacements (*x*, *y*). For flexible disks, two additional rotational displacements are introduced. That is, for a flexible disk, a total of six (6) degrees-of-freedom is required to describe the motion of the disk. The analyses for lateral vibration contain:

Static Deflection & Bearing/Constraint Reactions

Critical Speed Analysis

Critical Speed Map Analysis

Whirl Speed & Stability Analysis

Steady State Synchronous Response Analysis

Steady State Harmonic Excitations

Time Transient Analysis

Steady Maneuver Load Analysis

For torsional vibration, the motion of each finite element station is described by a rotational displacement (θ_z). The systems can be continuous, discrete, or the combination of continuous and discrete model. The analyses for the torsional vibration are:

Undamped and Damped Natural Frequencies Calculation

Steady State Forced Response Analysis

Transient Startup Analysis with speed dependent excitation

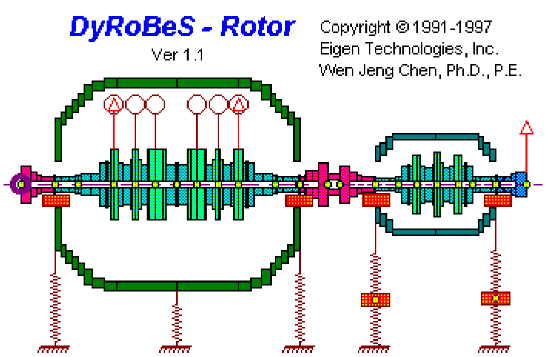
Transient Analysis with time dependent excitation

For axial vibration, the motion of each finite element station is described by a translational displacement (*z*). The systems can be continuous, discrete, or the combination of continuous and discrete model. The analyses for the axial vibrations are:

Undamped and Damped Natural Frequencies Calculation

Steady State Forced Response Analysis

The Lateral, Torsional, and Axial motions can be coupled through a gear mesh and thrust collar for a geared system.



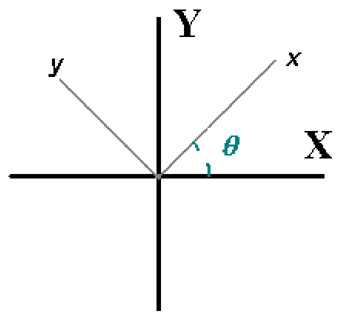
Coefficients Coordinate Angle

A Cartesian coordinate system (*X,Y,Z*) is used to describe the bearing geometry and load vector. However, the bearing dynamic coefficients (stiffness and damping coefficients) can be calculated in any coordinate system (*x,y,z*) by specifying a Coefficient Coordinate Angle in the bearing input data. The Coordinate Angle is measured from the *X*-axis (used to describe the bearing geometry) to *x*-axis (used to describe the bearing coefficients).

If the Lund's convention is used to be the coordinate system, two most commonly used Coefficient Coordinate Angle are:

1. θ = 0 , i.e., x axis is the loading direction

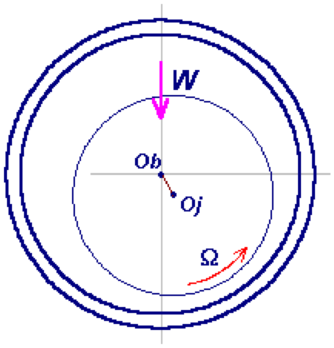
2. θ = 90 , i.e., negative y axis is the loading direction



Plain Cylindrical Journal Bearing

Typical data for Lund Coordinate System: $\theta_1 = 0$, $\theta_2 = 360$, $m = 0$, $\alpha = 0$

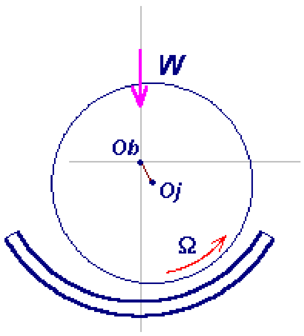
See also Coordinate Systems, Fixed Lobe Bearing Geometry.



Partial Arc Journal Bearing

Typical data for Lund Coordinate System: $\theta_1 = 120$, $\theta_2 = 240$ for 120 degree arc, and $\theta_1 = 105$, $\theta_2 = 255$ for 150 degree arc, $m = 0$, $\alpha = 0$

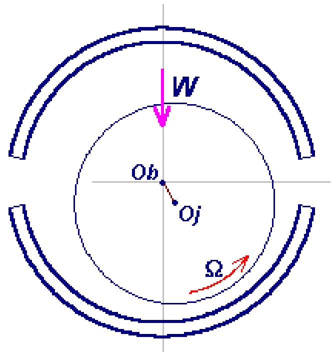
See also Coordinate Systems, Fixed Lobe Bearing Geometry.



Two Axial Grooves Journal Bearing

Typical data for Lund Coordinate System: $\theta_1 = 100$, $\theta_2 = 260$, $m = 0$, $\alpha = 0$

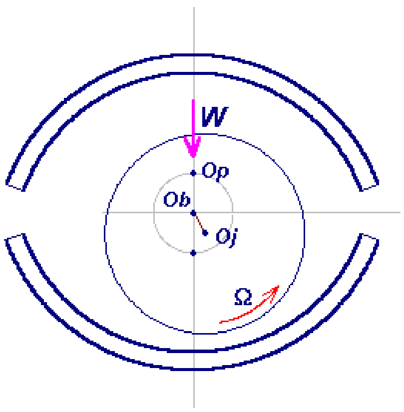
See also Coordinate Systems, Fixed Lobe Bearing Geometry.



Elliptical (Lemon Bore) Journal Bearing

Typical data for Lund Coordinate System: $\theta_1 = 100$, $\theta_2 = 260$, $m = 0.5$, $\alpha = 0.5$

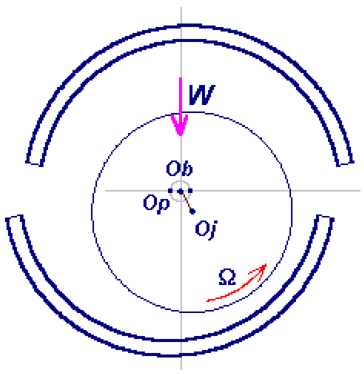
See also Coordinate Systems, Fixed Lobe Bearing Geometry.



Offset Halves Journal Bearing

Typical data for Lund Coordinate System: $\theta_1 = 105$, $\theta_2 = 255$, $m = 0.5$, $\alpha = 1.1$

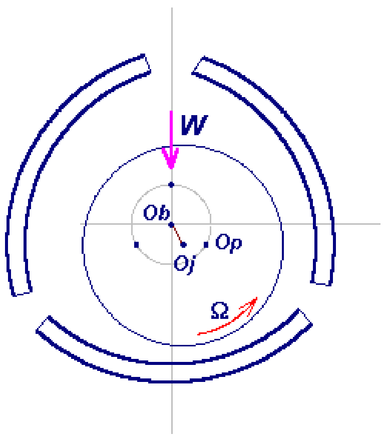
See also Coordinate Systems, Fixed Lobe Bearing Geometry.



Three Lobes Journal Bearing

Typical data for Lund Coordinate System: $\theta_1 = 10$, $\theta_2 = 110$, $m = 0.5$, $\alpha = 0.5$ or 1.0

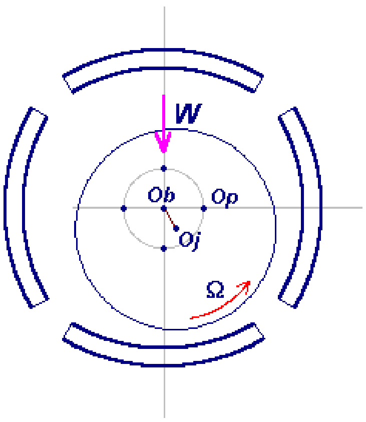
See also Coordinate Systems, Fixed Lobe Bearing Geometry.



Four Lobes Journal Bearing

Typical data for Lund Coordinate System: $\theta_1 = 52.5$, $\theta_2 = 127.5$, $m = 0.5$, $\alpha = 0.5$ or 1.0

See also Coordinate Systems, Fixed Lobe Bearing Geometry.

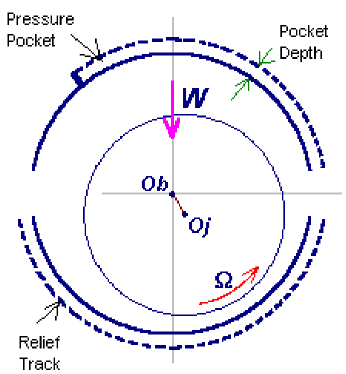


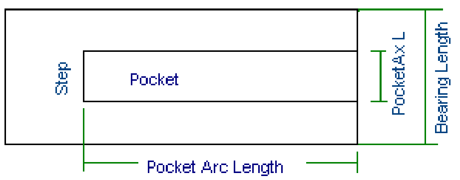
Pressure Dam Bearing, Multi-Pocket Bearing, or Step Bearings

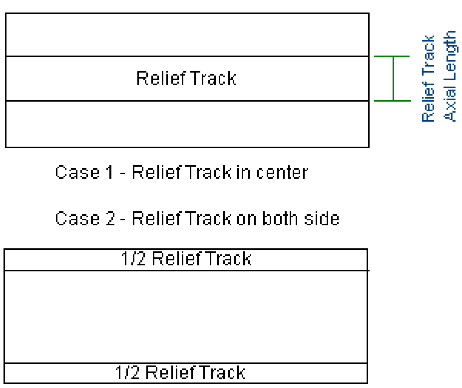
In addition to the standard lobed bearings with preload and offset, pressure dam (pocket) and relief track are introduced in these types of bearings. The following figures are shown for a typical 2 lobes pressure dam bearing. However, this option allows you to have as many lobes as you like and each lobe can have preload, offset, pressure pocket or relief track. The following design rules for the pressure dam bearings have been suggested by Dr. John Nicholas, a leading researcher in pressure dam bearings.

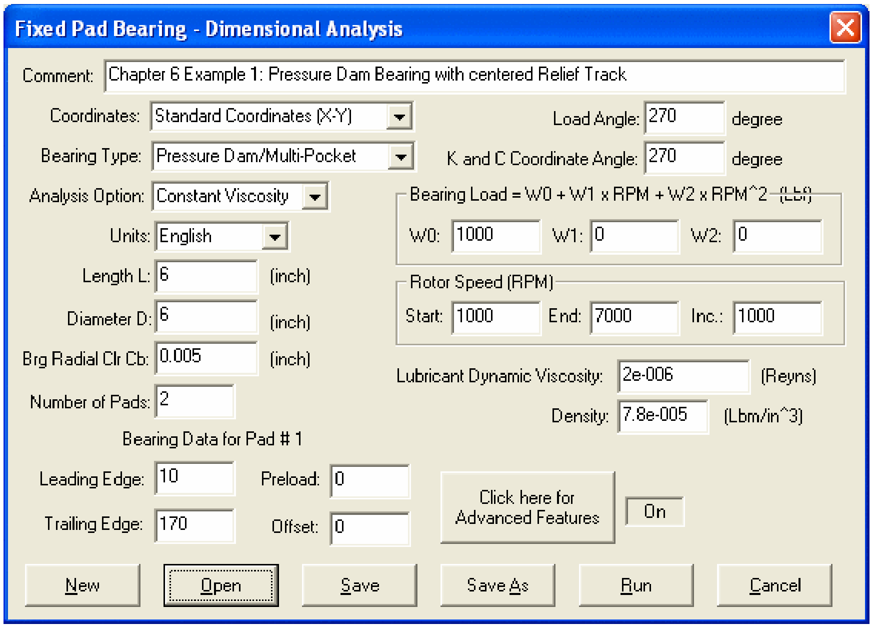
1. The optimum Sommerfeld number range for designing a pressure dam bearing to increase stability is S >= 2.0
2. The optimum Clearance Ratio is around 3.0. A slightly larger clearance ratio (3.0-6.0) is recommended to avoid the sudden drop in load capacity for clearance ratios below 3.0.
3. Steps should be located at about 75% of the total arc length of the pad. The optimum step location for stability is between 125 and 160 degrees for 2 lobes bearings depending upon the Sommerfeld number. A reasonable compromise value is 140 degrees.
4. Relief track in the loaded pad should be avoided due to the high operating eccentricity ratio.
5. Pocket axial length should be 65% to 70% of the total axial bearing length.

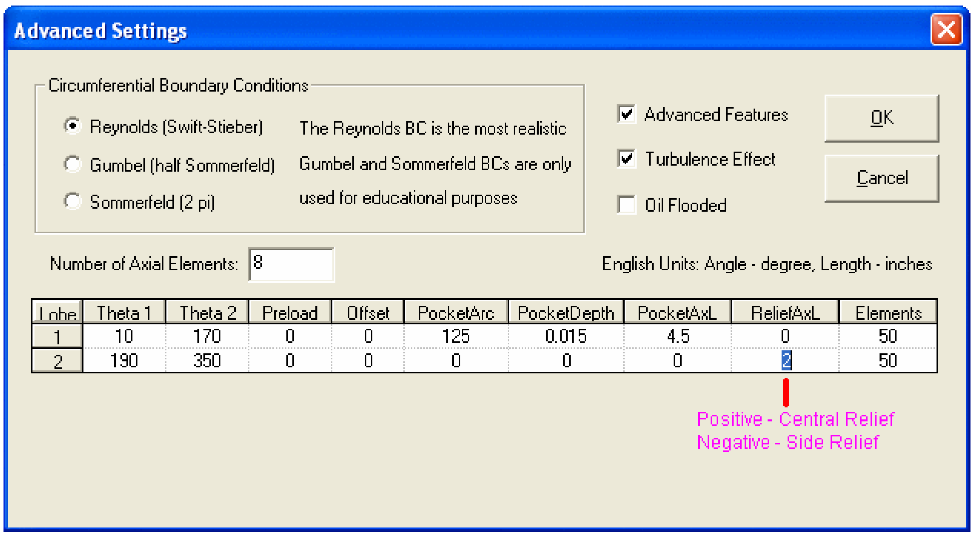
To use these types of bearings, the Advanced Features must be checked in the input. The positive relief track axial length indicates that the relief track is in the center and the negative relief track axial length indicates that the relief track is on both sides as shown below.

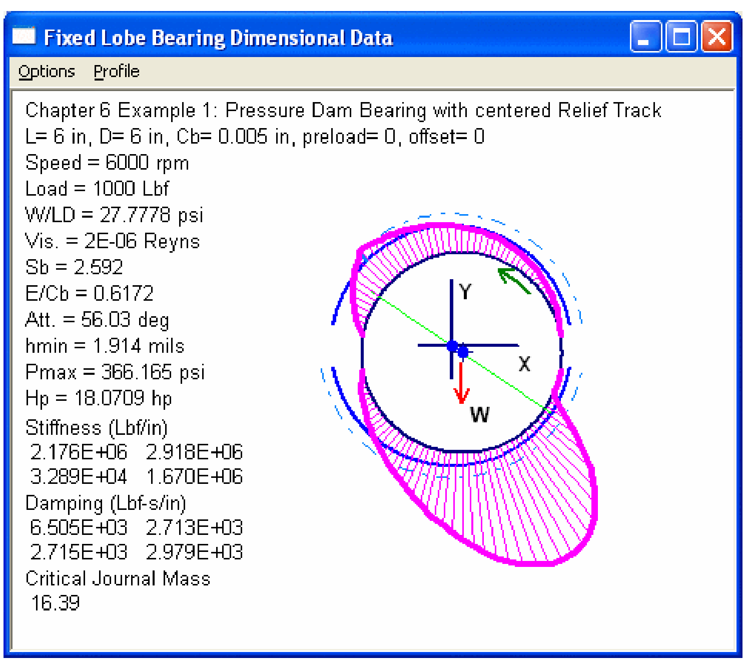


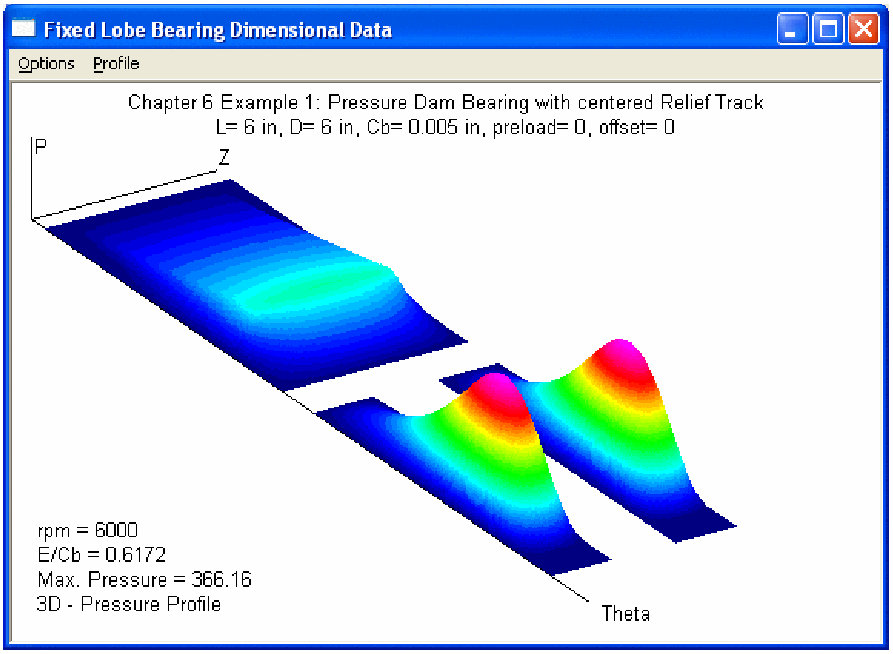


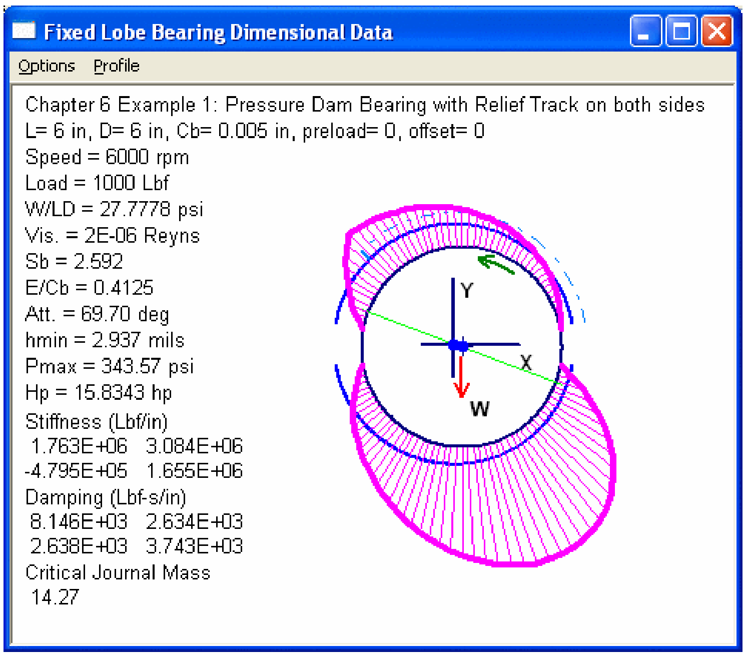


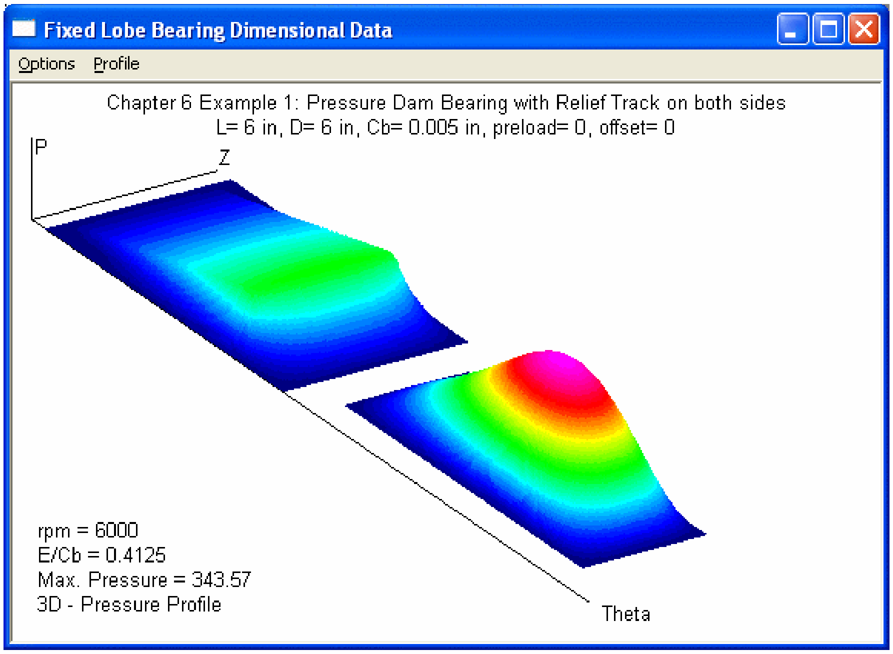

Fixed Pad Bearing - Dimensional Analysis
Comment: Chapter 6 Example 1: Pressure Dam Bearing with centered Relief Track
Coordinates: Standard Coordinates (X-Y)
Load Angle: 270 degree
Bearing Type: Pressure Dam/Multi-Pocket
K and C Coordinate Angle: 270 degree
Analysis Option: Constant Viscosity
Bearing Load = W0 + W1 x RPM + W2 x RPM^2 (Lbf)
W0: 1000 W1: 0 W2: 0
Units: English
Length L: 6 (inch)
Rotor Speed (RPM)
Start: 1000 End: 7000 Inc.: 1000
Diameter D: 6 (inch)
Brg Radial Clr Cb: 0.005 (inch)
Lubricant Dynamic Viscosity: 2e-006 (Reyns)
Number of Pads: 2
Density: 7.8e-005 (Lbm/in^3)
Bearing Data for Pad # 1
Leading Edge: 10
Preload: 0
Click here for Advanced Features
On
Trailing Edge: 170
Offset: 0
New
Open
Save
Save As
Run
Cancel


Advanced Settings
Circumferential Boundary Conditions
Reynolds (Swift-Stieber)
Gumbel (half Sommerfeld)
Sommerfeld (2 pi)
The Reynolds BC is the most realistic
Gumbel and Sommerfeld BCs are only
used for educational purposes
Advanced Features
Turbulence Effect
Oil Flooded
OK
Cancel
Number of Axial Elements: 8
English Units: Angle - degree, Length - inches
Lobe Theta 1 Theta 2 Preload Offset PocketArc PocketDepth PocketAxL ReliefAxL Elements
1 10 170 0 0 125 0.015 4.5 0 50
2 190 350 0 0 0 0 0 2 50
Positive - Central Relief
Negative - Side Relief

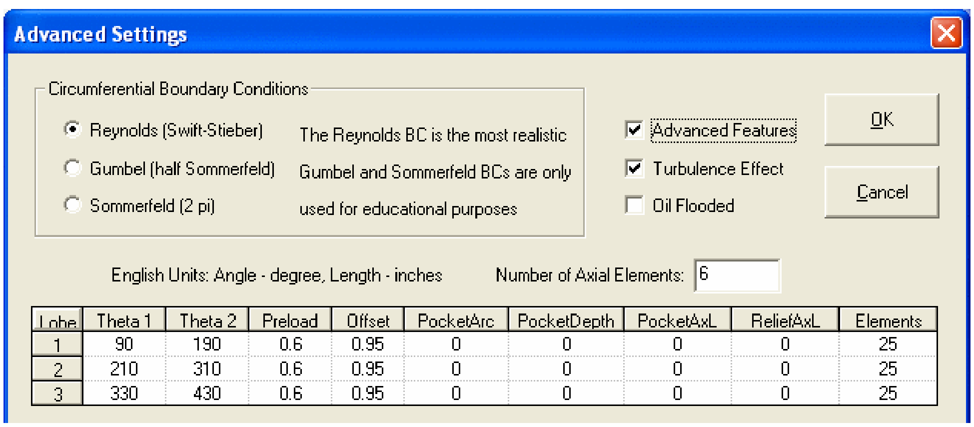

Fixed Lobe Bearing Dimensional Data
Options Profile
Chapter 6 Example 1: Pressure Dam Bearing with centered Relief Track
L= 6 in, D= 6 in, Cb= 0.005 in, preload= 0, offset= 0
Speed = 6000 rpm
Load = 1000 Lbf
W/LD = 27.7778 psi
Vis. = 2E-06 Reyns
Sb = 2.592
E/Cb = 0.6172
Att. = 56.03 deg
hmin = 1.914 mils
Pmax = 366.165 psi
Hp = 18.0709 hp
Stiffness (Lbf/in)
2.176E+06 2.918E+06
3.289E+04 1.670E+06
Damping (Lbf-s/in)
6.505E+03 2.713E+03
2.715E+03 2.979E+03
Critical Journal Mass
16.39
Y
X
W

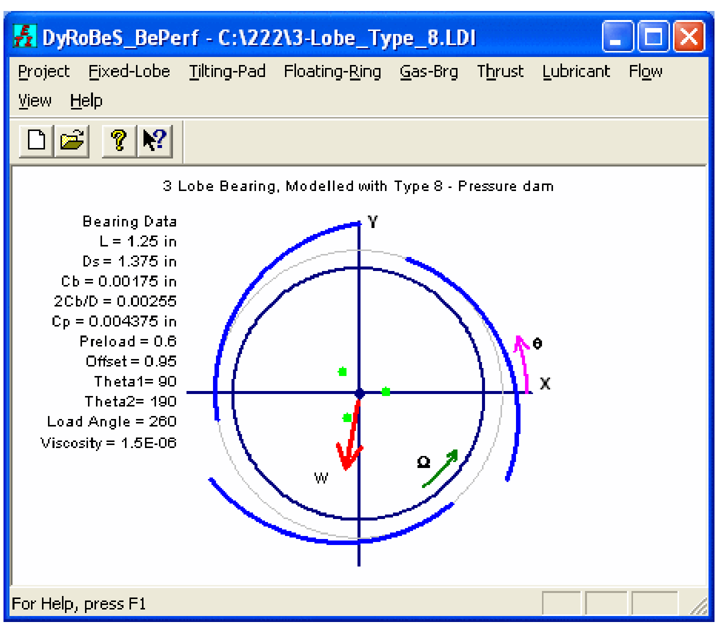

Fixed Lobe Bearing Dimensional Data
Options Profile
Chapter 6 Example 1: Pressure Dam Bearing with centered Relief Track
L= 6 in, D= 6 in, Cb= 0.005 in, preload= 0, offset= 0
P
Z
rpm = 6000
E/Cb = 0.6172
Max. Pressure = 366.16
3D - Pressure Profile
Theta


Fixed Lobe Bearing Dimensional Data
Options Profile
Chapter 6 Example 1: Pressure Dam Bearing with Relief Track on both sides
L= 6 in, D= 6 in, Cb= 0.005 in, preload= 0, offset= 0
Speed = 6000 rpm
Load = 1000 Lbf
W/LD = 27.7778 psi
Vis. = 2E-06 Reyns
Sb = 2.592
E/Cb = 0.4125
Att. = 69.70 deg
hmin = 2.937 mils
Pmax = 343.57 psi
Hp = 15.8343 hp
Stiffness (Lbf/in)
1.763E+06 3.084E+06
-4.795E+05 1.655E+06
Damping (Lbf-s/in)
8.146E+03 2.634E+03
2.638E+03 3.743E+03
Critical Journal Mass
14.27
Y
X
W

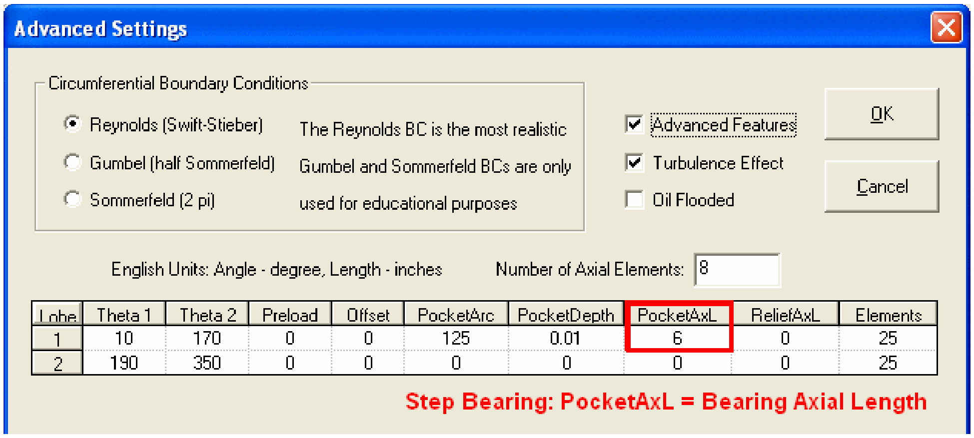


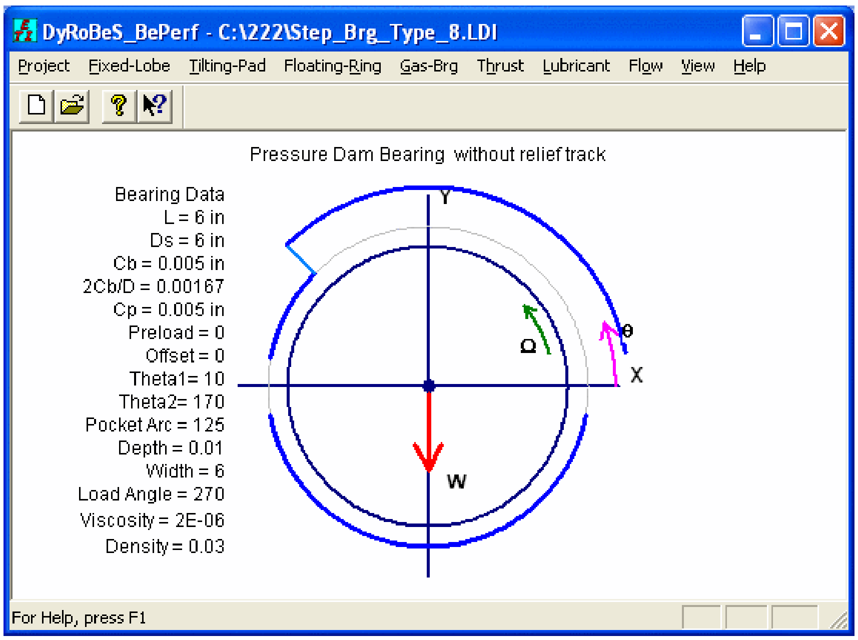
Note that this bearing type can be de-generated into a standard multi-lobe bearing, if PocketArc, PocketDepth, PocketAxL, and ReliefAxL are zero, as shown below:





Also, if PocketAxL = Bearing Axial Length, then, the pocket has open ends and it becomes a step bearing as shown below:

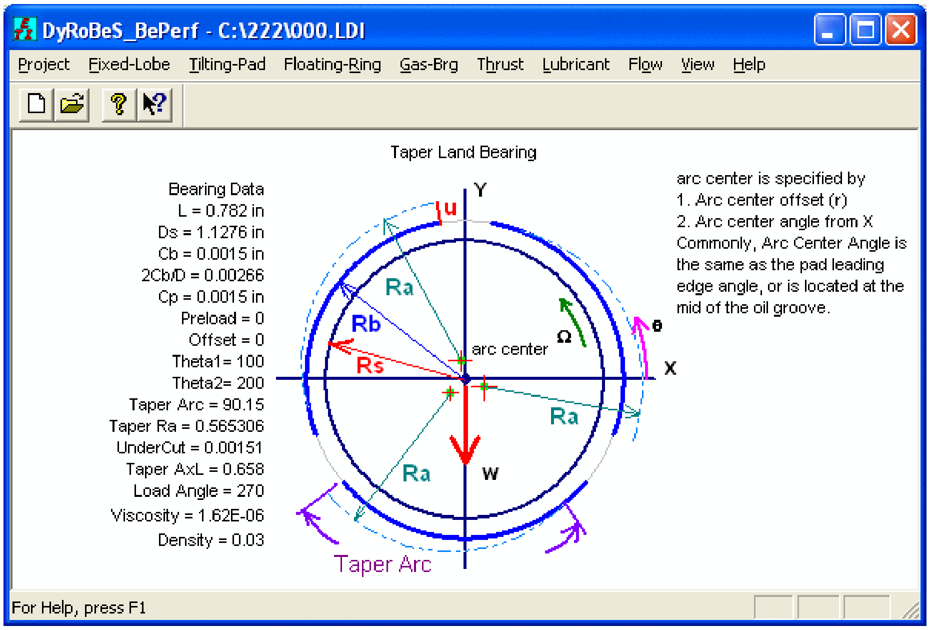


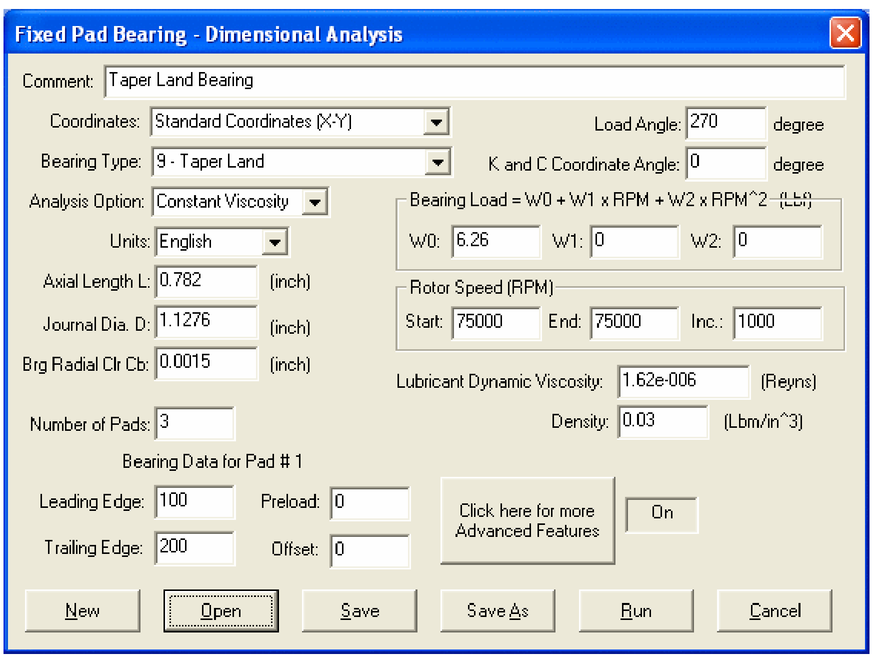


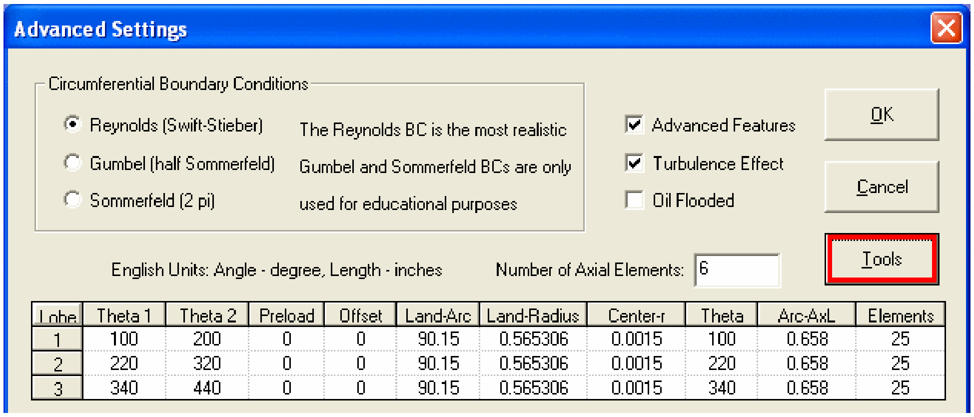
See also Coordinate Systems, Fixed Lobe Bearing Geometry, and Examples.

Taper Land Bearings

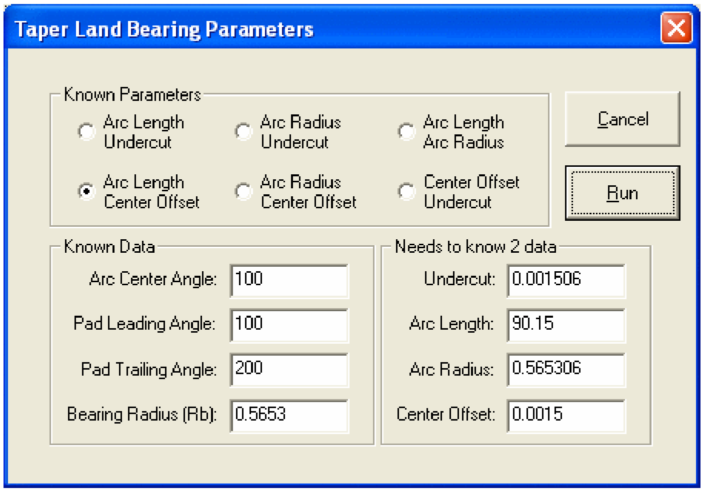
To use the Taper Land Bearing, the [Advanced Features](#) must be checked in the input. The taper land journal bearing is commonly used in locomotive turbocharger application. The leading convergent area of the lobe is cut by a taper arc to increase the convergent area. Normally, there are dams at both sides of the taper. There are some redundant inputs in the data sheet, however, these are entered as reference. For undercut, arc length, arc radius, and arc center offset, there are only two variables are needed. Click TOOLS to get other variables when only two variables are known.

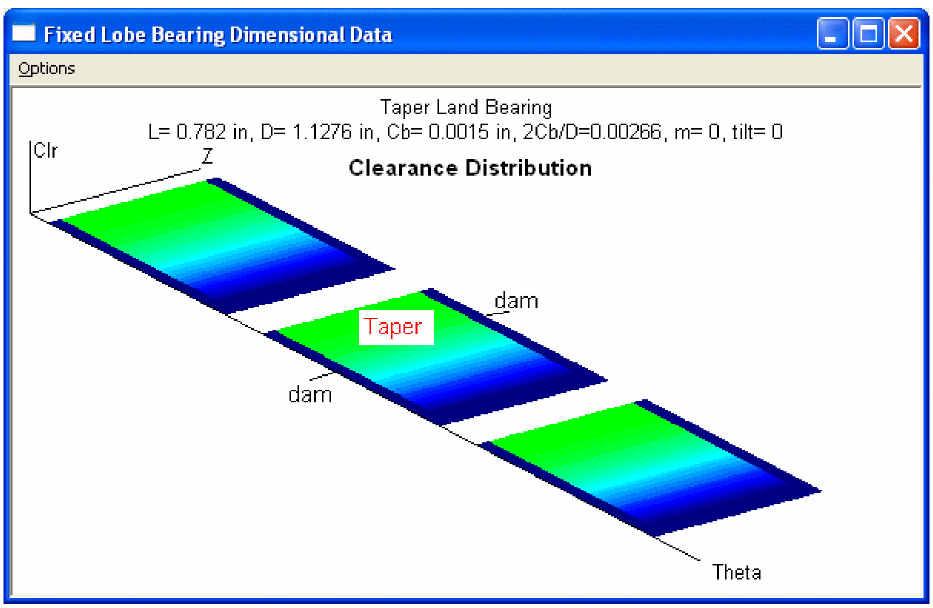


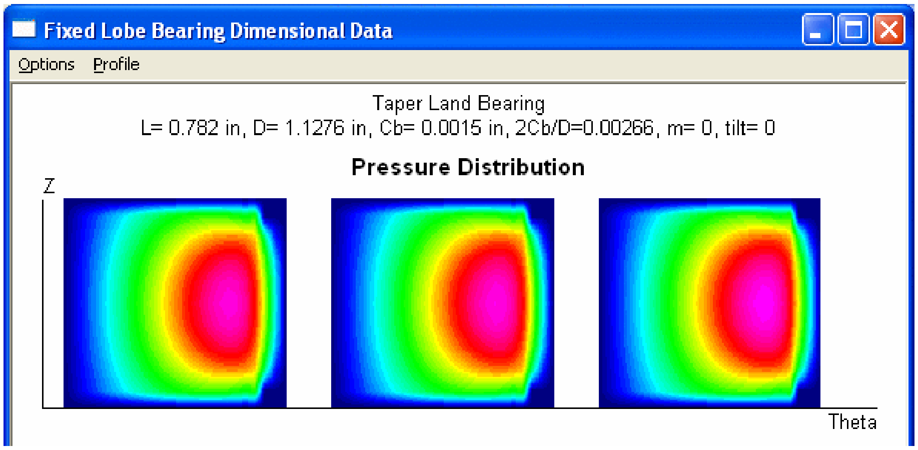


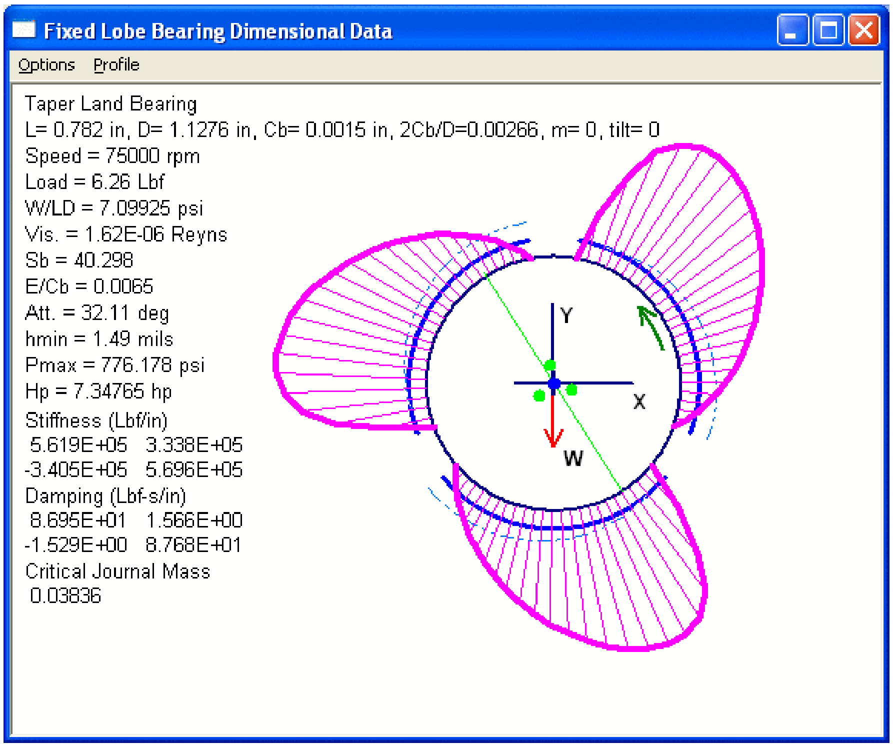

Advanced Settings
Circumferential Boundary Conditions
Reynolds (Swift-Stieber)
Gumbel (half Sommerfeld)
Sommerfeld (2 pi)
The Reynolds BC is the most realistic
Gumbel and Sommerfeld BCs are only
used for educational purposes
Advanced Features
Turbulence Effect
Oil Flooded
OK
Cancel
Tools
English Units: Angle - degree, Length - inches
Number of Axial Elements: 6

Lobe	Theta 1	Theta 2	Preload	Offset	Land-Arc	Land-Radius	Center-r	Theta	Arc-AxL	Elements
1	100	200	0	0	90.15	0.565306	0.0015	100	0.658	25
2	220	320	0	0	90.15	0.565306	0.0015	220	0.658	25
3	340	440	0	0	90.15	0.565306	0.0015	340	0.658	25


Taper Land Bearing Parameters
Known Parameters
Arc Length Undercut
Arc Radius Undercut
Arc Length Arc Radius
Arc Length Center Offset
Arc Radius Center Offset
Center Offset Undercut
Cancel
Run
Known Data
Arc Center Angle: 100
Pad Leading Angle: 100
Pad Trailing Angle: 200
Bearing Radius (Rb): 0.5653
Needs to know 2 data
Undercut: 0.001506
Arc Length: 90.15
Arc Radius: 0.565306
Center Offset: 0.0015


Fixed Lobe Bearing Dimensional Data
Options
Taper Land Bearing
L= 0.782 in, D= 1.1276 in, Cb= 0.0015 in, 2Cb/D=0.00266, m= 0, tilt= 0
Clearance Distribution
Clr
Z
dam
Taper
dam
Theta





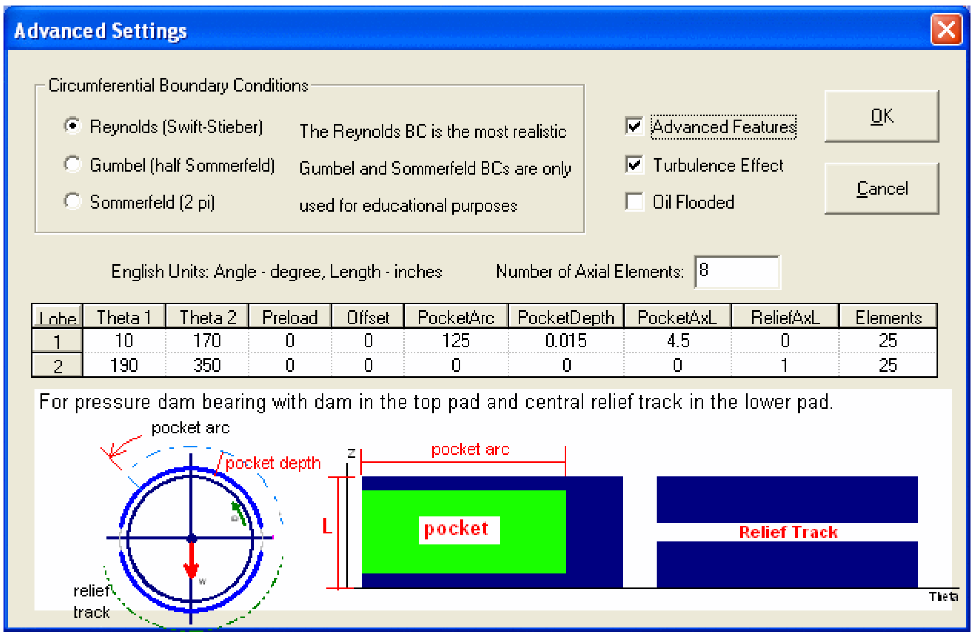
See also Coordinate Systems, Fixed Lobe Bearing Geometry, and Examples.

Advanced Features

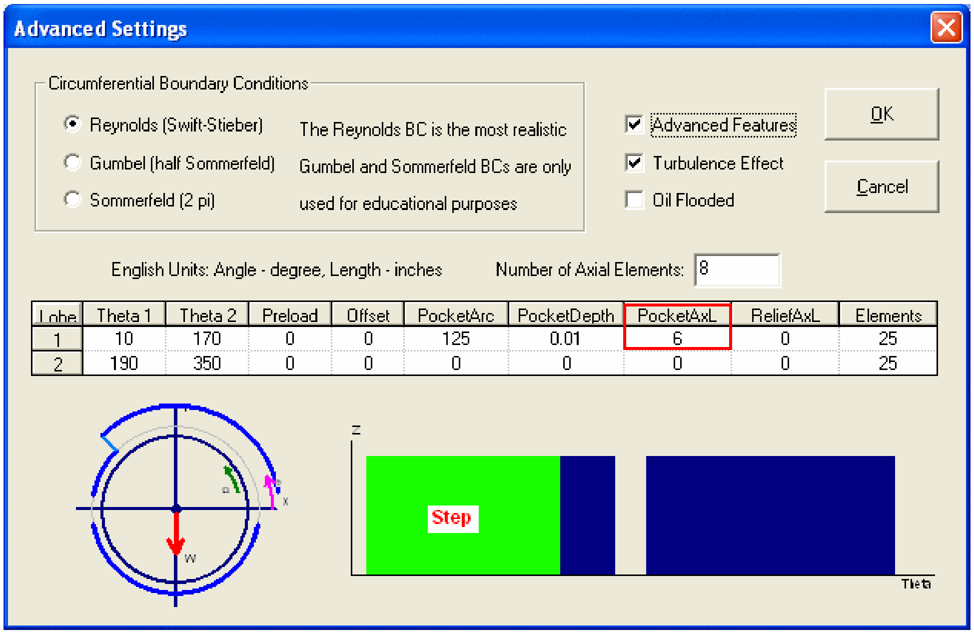
The advanced features allow you to include the turbulence effect, oil flooded, and types of boundary conditions in the circumferential direction. It also allows for the clearance discontinuity in the individual pad. The Advanced Feature must be checked (ON) for bearings with clearance discontinuity, such as Pressure Dam Bearing, Multi-Pocket Bearing, Step Bearing, and Taper Land Bearing. Also, for 3D pressure file plot, the Advanced Feature must be checked. Without Advanced Features, the pads are identical and no discontinuity in the bearing clearance for each pad. Therefore, only one (1) degree-of-freedom at each finite element node, that is, pressure is unknown at each finite element node without the Advanced Feature. However, with Advanced Features, the clearance can have sudden changes, such as pressure dam bearings and taper land bearings, therefore, three (3) degrees-of-freedom at each finite element node are assumed, that is, pressure, and pressure gradients in both axial and circumferential directions at each finite element node are unknown and are to be solved to accommodate the sudden changes in bearing clearance. With Advanced Features ON, the computational time will be greatly increased due to the increase of the degrees-of-freedom.

Although 3 types boundary conditions are provided, one should always use Reynolds boundary condition for design and practical purposes. Sommerfeld and half Sommerfeld (Gumbel) boundary conditions are only provided for educational and research purposes.

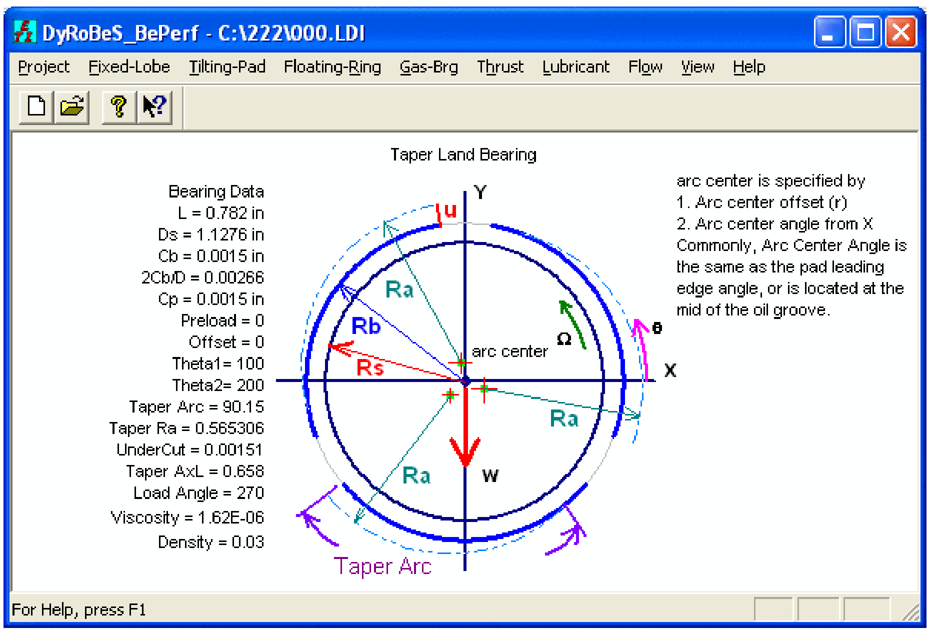
Pressure Dam Bearing

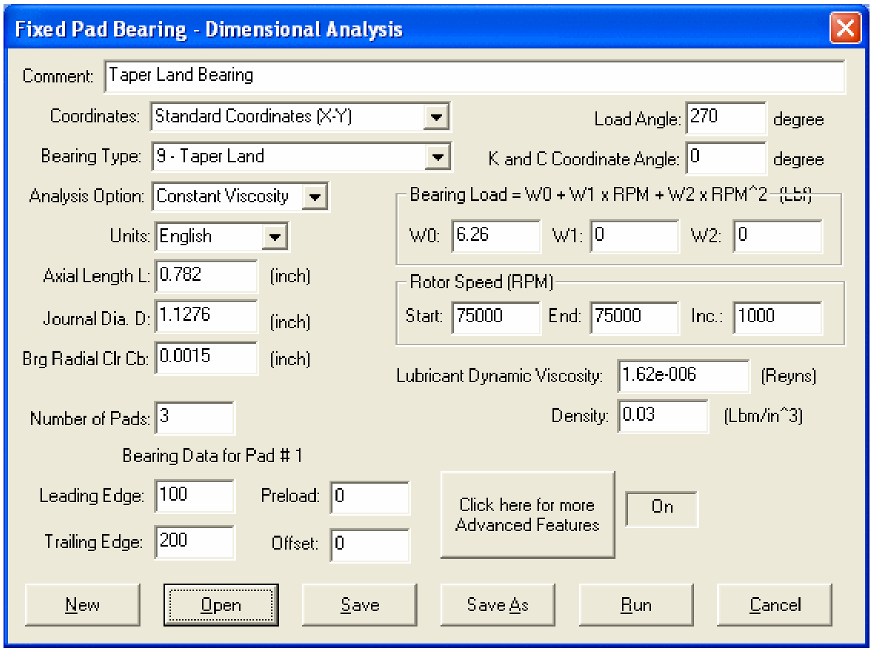


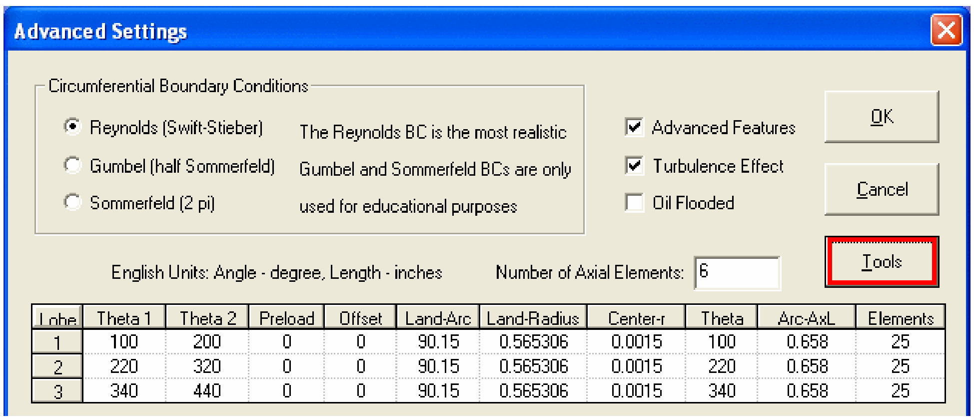
When the PocketAxL = Bearing Axial Length, pressure dam becomes a step as shown below:

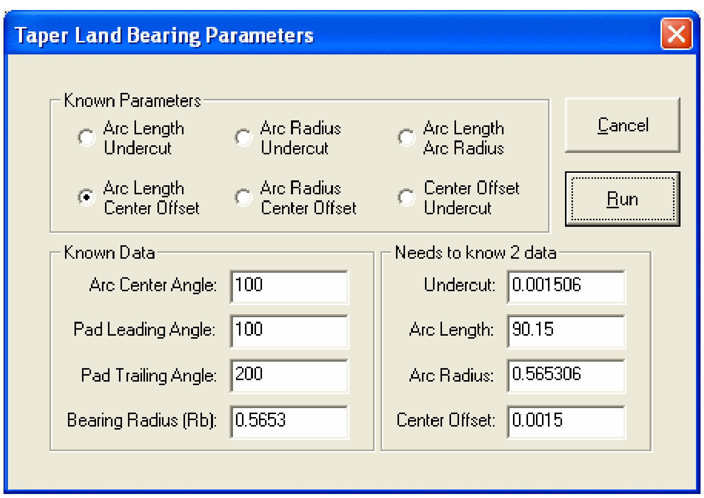


Taper Land Journal Bearing, click here for more descriptions on taper land bearings.

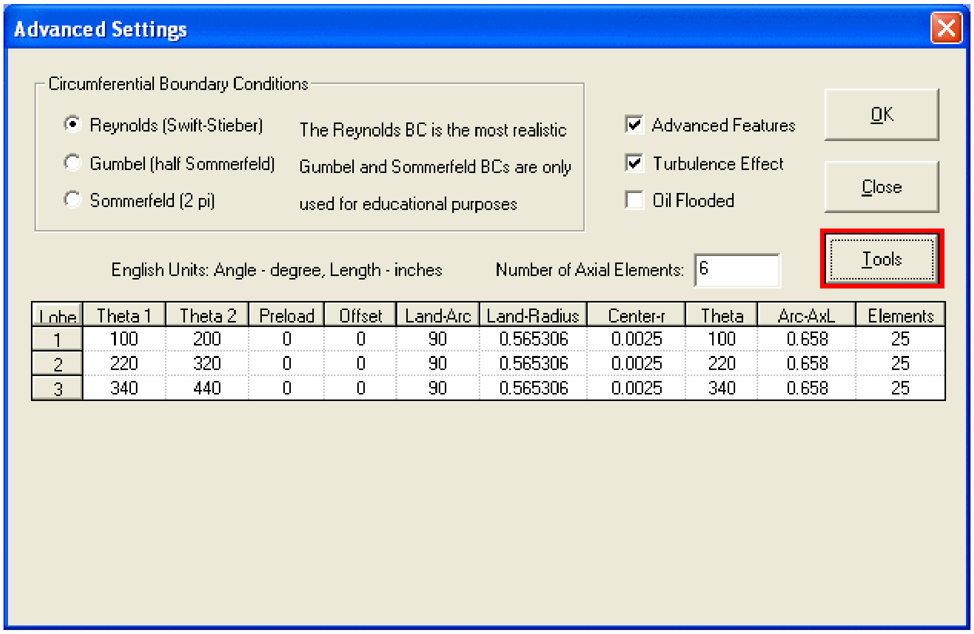


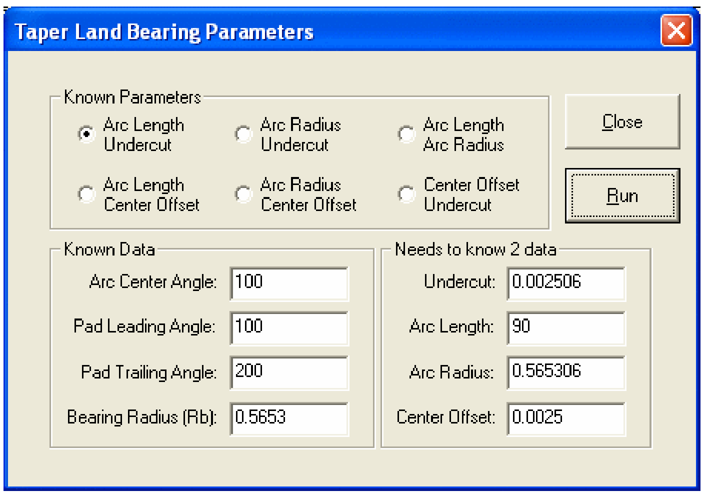






For Taper Land Bearing, the undercut and taper length are normally specified in the design process, however, the arc center and arc radius are typically specified in the manufacturing drawings. A Tools button is provided for this conversion.

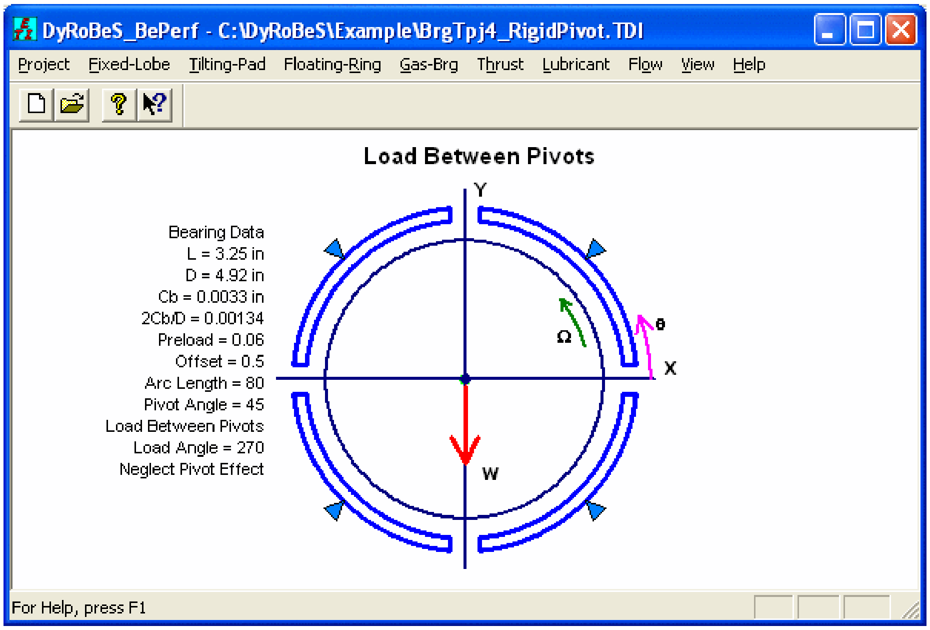


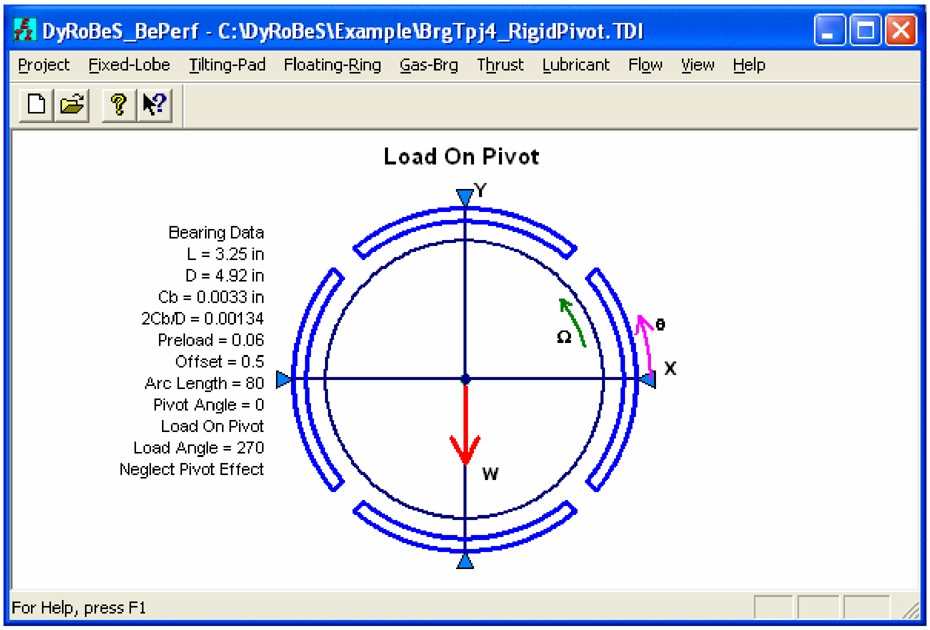


See also Coordinate Systems, Fixed Lobe Bearing Geometry, Fixed Lobe Non-Dimensional Analysis, Nomenclature, Examples, Units, Lubricant, Coefficients Coordinate Angle .

Typical 4 pads tilting pad bearing

See also Tilting Pad Bearing Geometry, Nomenclature.





Typical 5 pads tilting pad bearing

See also Tilting Pad Bearing Geometry, Nomenclature.