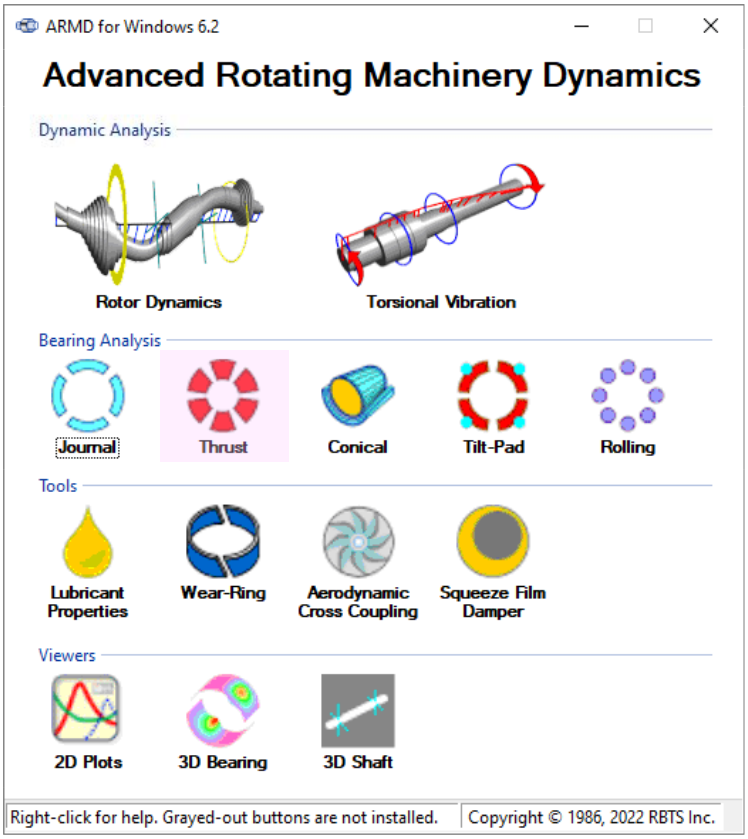
Advanced Rotating Machinery Dynamics

THRSBR Version 6.2

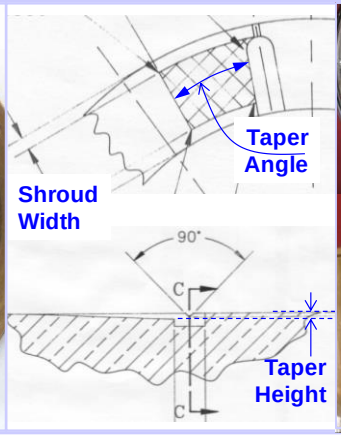
New Release

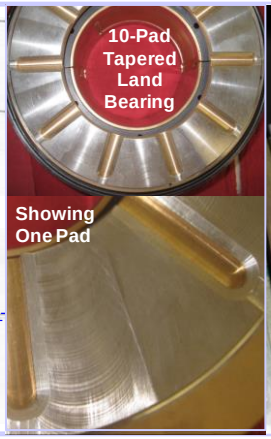


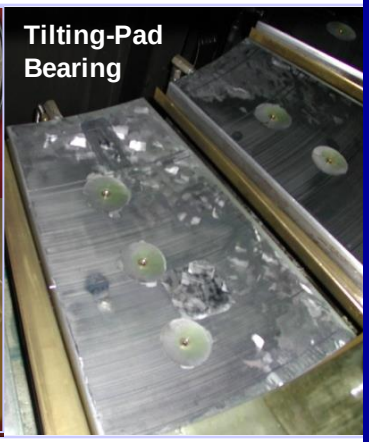
Fixed / Tilting-Pad Geometry Thrust Bearings
(THRSBR)

- **THRSBR Solver**
- **Post-Processor Single Case**
- **Post-Processor Multiple Case**

Fixed & Tilting-Pad Fluid-Film Lubricated Thrust Bearings







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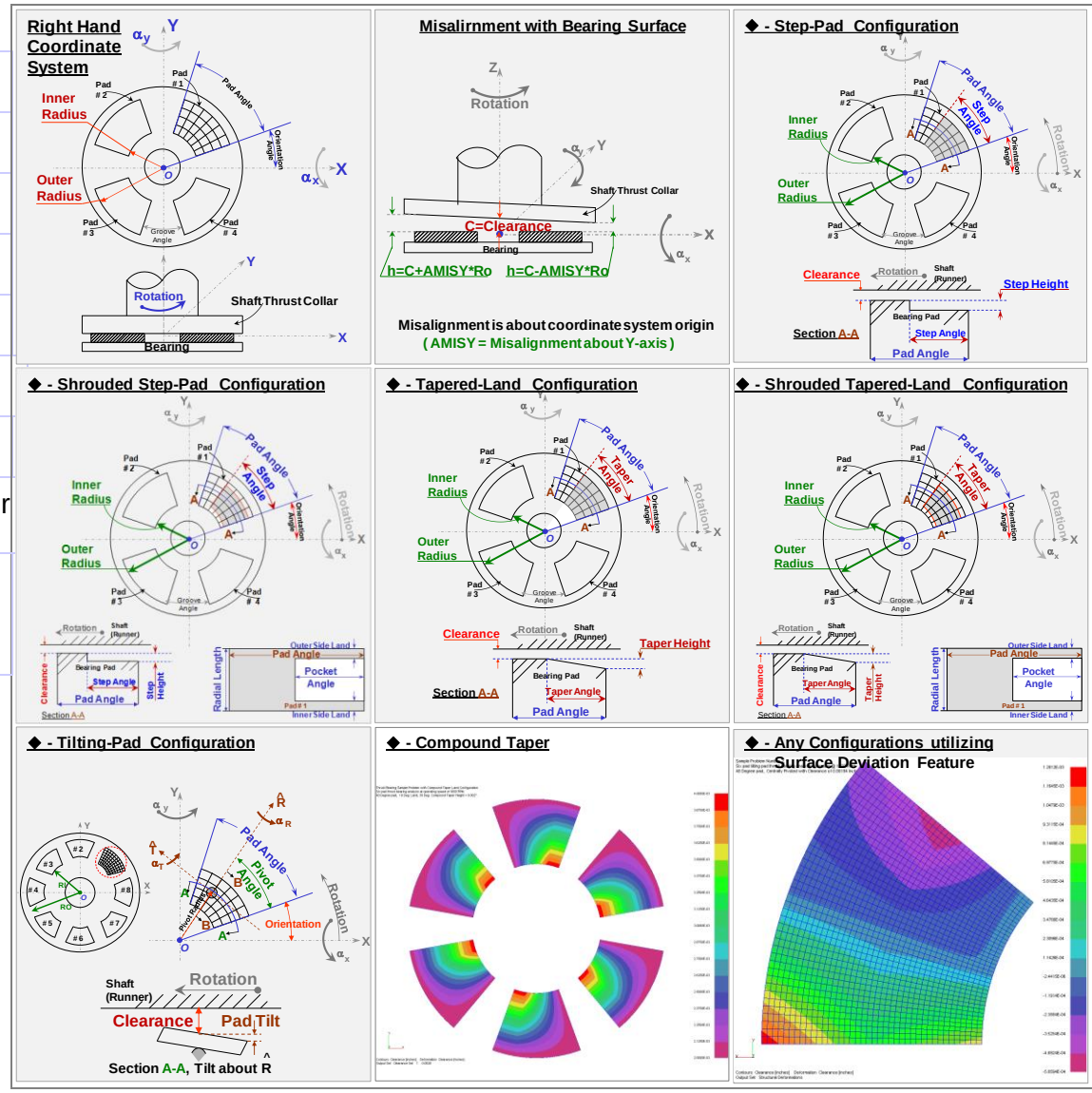
Rev:20230101

The fluid-film bearing module **THRSBR** provides a full-scale computerized analysis that incorporates state-of-the-art numerical and modeling features. It is an advanced program designed to handle complex bearing geometries of the fixed and tilting pad configuration. Complete performance predictions of **hydrodynamic**, **hydrostatic**, and **hybrid** lubricated thrust bearings operating in the laminar and/or turbulent regimes can be generated. Analysis starts with subdividing the bearing/pad surface area into grid pattern in two dimensions (circumferential & radial) and establishing the lubrication system of equations. Boundary conditions (pressurized boundaries, pockets, lines, recesses with specified pressures, surface deviation, etc.) are incorporated to the system of equations. An advanced variable-grid finite-difference numerical method is employed for obtaining a solution, thus eliminating any approximation typically associated with one dimensional analysis or look-up table methods.

A wide variety of fixed and tilting pad geometries thrust bearings that can be analyzed include but not limited to:

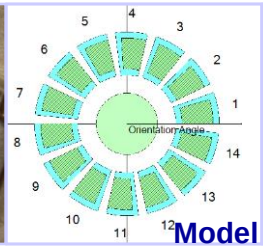
a. Plain surface
b. Multi-groove
c. Step pad
d. Step pocket
e. Tapered land
f. Tapered pocket
g. Tilting pad
h. Compound taper
i. Any configurable pad surfaces

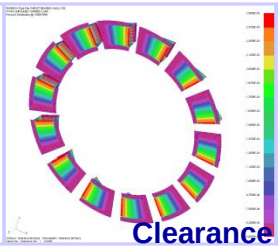


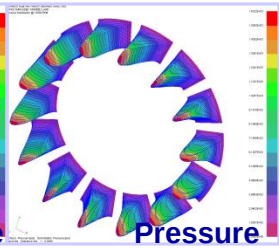
ARMD™ V6.2 – THRSBR Module

Simulation capabilities with **THRSBR** include such effects as misalignment, pressurized boundaries or grooves, structural deformation/surface deviation, lubricant feed circuitry with specified pressures and feed orifices/nozzles, groove geometry and chamfers to mention a few. Performance results include the following.

- **Load capacity**
- **Runner position**
- **Viscous power loss**
- **Righting moments**
- **Flow requirements**
- **Stiffness and damping (dynamic) coefficients**
- **Clearance and pressure distribution**
- **Heat balance and temperature rises**







TaperedLandShrouded14PadThrust...

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"GEARBOX Fluid-Film THRUST BEARING ANALYSIS."
"14 PAD SHROUDED TAPERED LAND."
"Bearing Performance Including Pressure Distributio
```

Case No.	Film-Temp (Deg-C)	Applied Load-NEWTON	Projected Pressure (Pascal)	Speed (rpm)
1	50.947	6.535E+02	2.098E+05	1.000E+03
2	52.234	1.246E+03	3.999E+05	2.000E+03
3	55.485	2.215E+03	7.109E+05	4.000E+03
4	59.212	2.920E+03	9.373E+05	6.000E+03
5	63.102	3.425E+03	1.099E+06	8.000E+03
6	66.999	3.787E+03	1.216E+06	1.000E+04
7	70.844	4.050E+03	1.300E+06	1.200E+04
8	74.601	4.242E+03	1.362E+06	1.400E+04
9	76.446	4.318E+03	1.386E+06	1.500E+04

TaperedLandShrouded14PadThrust...

Case No.	Supply Flow-Rate (Liter/m)	Side Leakage (Liter/m)	ID Side Leakage (Liter/m)	OD Side Leakage (Liter/m)
1	5.000E+00	1.768E-01	6.923E-02	1.076E-01
2	5.000E+00	3.537E-01	1.385E-01	2.152E-01
3	5.000E+00	7.074E-01	2.769E-01	4.305E-01
4	5.000E+00	1.061E+00	4.154E-01	6.457E-01
5	5.000E+00	1.415E+00	5.538E-01	8.610E-01
6	5.000E+00	1.768E+00	6.923E-01	1.076E+00
7	5.000E+00	2.122E+00	8.307E-01	1.291E+00
8	5.000E+00	2.476E+00	9.692E-01	1.507E+00
9	5.000E+00	2.653E+00	1.038E+00	1.614E+00

TaperedLandShrouded14PadThrust...

Case No.	Film-Temp (Deg-C)	Viscosity (Pascal-S)	Heat Content (J/m^3/K)	Groove Temp (Deg-C)
1	50.947	1.754E-02	1.750E+06	5.023E+01
2	52.234	1.672E-02	1.753E+06	5.087E+01
3	55.485	1.486E-02	1.761E+06	5.308E+01
4	59.212	1.306E-02	1.770E+06	5.605E+01
5	63.102	1.149E-02	1.779E+06	5.942E+01
6	66.999	1.017E-02	1.788E+06	6.294E+01
7	70.844	9.058E-03	1.797E+06	6.653E+01
8	74.601	8.132E-03	1.805E+06	7.010E+01
9	76.446	7.726E-03	1.809E+06	7.188E+01

Post-Processor

Description

GEARBOX Fluid-Film THRUST BEARING ANALYSIS.
14 PAD SHROUDED TAPERED LAND.
Bearing Performance Including Pressure Distribution @ 15000 RPM.

R-Outer	50.0	R-Inner	35.0	Number of Pads	14
Pad Angle	20.0	Orientation Angle	0.0	No. of Clearances	50
Min Clearance	0.00125	Rotational Speed	15000.0	Viscosity	6.894758e-03

Single Case | Multiple Cases | Lubricant Properties

9 of 12 | Lube/Chamfer | Run | 3D

Operating Conditions

Clearance 0.025 Speed 15000.0 Load 0.0

```
Operating C -----> 0.025000 (mm)    | Min.Film Thick.--> 0.025000 (mm)
Load Capacity ---> 4.318E+03 (N)    | Power-Loss  ----> 3.664E+03 (Watt)
Max. Pressure ---> 3.404E+06 Pascal | Side-Leakage QF -> 2.653E+00 (L/min)
|-----------------------------------|      through ID -> 1.038E+00 (L/min)
                                    |      through OD -> 1.614E+00 (L/min)
Supply-Oil Temp.>    50.001 (Deg.C) | Inlet-Flow   QI -> -1.463E+01 (L/min)
Supply Flow Rate>  5.000E+00 (L/min)|>Max. Reynolds # ->  6.328E+02
Film-Temp ------>    76.446 (Deg.C) |-----------------------------------|
Viscosity ------> 7.726E-03 (Pa-Sec)|> A  X  I  A  L
Groove Temp. --->    71.878 (Deg.C) |  Stiffness (Newton/m)   = 3.427E+08
Max. Temp. ----->    81.014 (Deg.C) |  Damping (Newton-Sec/m) = 4.707E+04
|-----------------------------------|-----------------------------------|
Max.Shear Stress=
```

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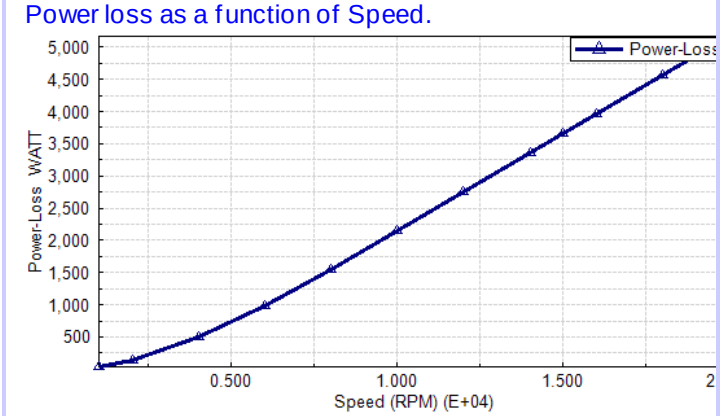
\TaperedLandShrouded14PadThrustBearingSample01.rpg

Power loss as a function of Speed.



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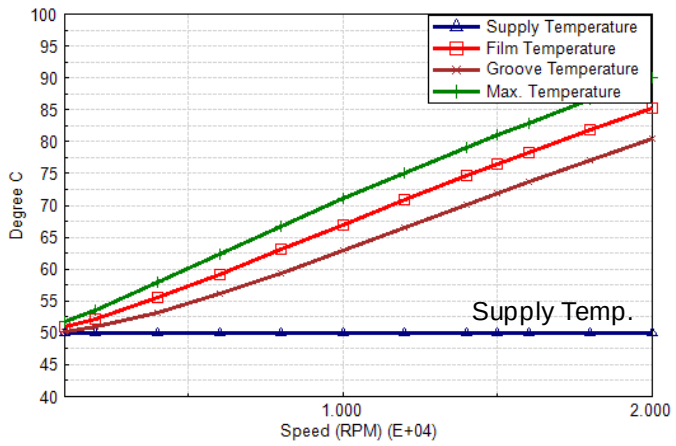
\TaperedLandShrouded14PadThrustBearingSample01.rpg

Lubricant temperatures as a function of Speed.



ARMD™ V6.2 – THRSBR Module

*The release of RBTS' **ARMD Version 6 THRSBR** module is a major milestone in the product's development history, rolling out a **completely new and improved** graphical user interface for the package with enhanced numerical capabilities and new technical features. THRSBR software's front end was redesigned with our customers' and industry's input to incorporate the most logical, efficient, and productive techniques to model and analyze common, as well as, complex bearing configurations with ease.*

ARMD THRSBR users will immediately see the improvements as bearing design data are presented in a flatter, more accessible format, with key fields and analysis options readily visible from the main data entry screens. Fluid-film bearing design and performance evaluation productivity is vastly improved as a wide selection of templates accompanied by a "wizard" style sequence of dialogs allows the user to setup and evaluate most of the commonly used bearings in industry with few key strokes. Tab selected grids and input forms allow the user to see all of the data on screen at the same time. Furthermore, the ability to simultaneously run multiple instances of the program permits rapid side-by-side comparison of results.

A vastly improved pad configuration tab, on the basic bearing design input data form, allows the user to select from many standard bearing types (Plain, Multi-groove, Rayleigh Step or Pocket, Tapered Land or Pocket, Tilting Pad, etc.), restricting input to only those fields pertinent to that type, along with a user-defined selection that allows the user complete freedom in configuring pad attributes.

By identifying new trends from industry, along with RBTS' involvement in bearings design, performance evaluation and troubleshooting, new technical capabilities were added to the software including the ability to define any bearing pad surface configuration and apply it to all pads in the bearing. This capability provides means for the user to model any pad surfaces they desire or would like to experiment with.

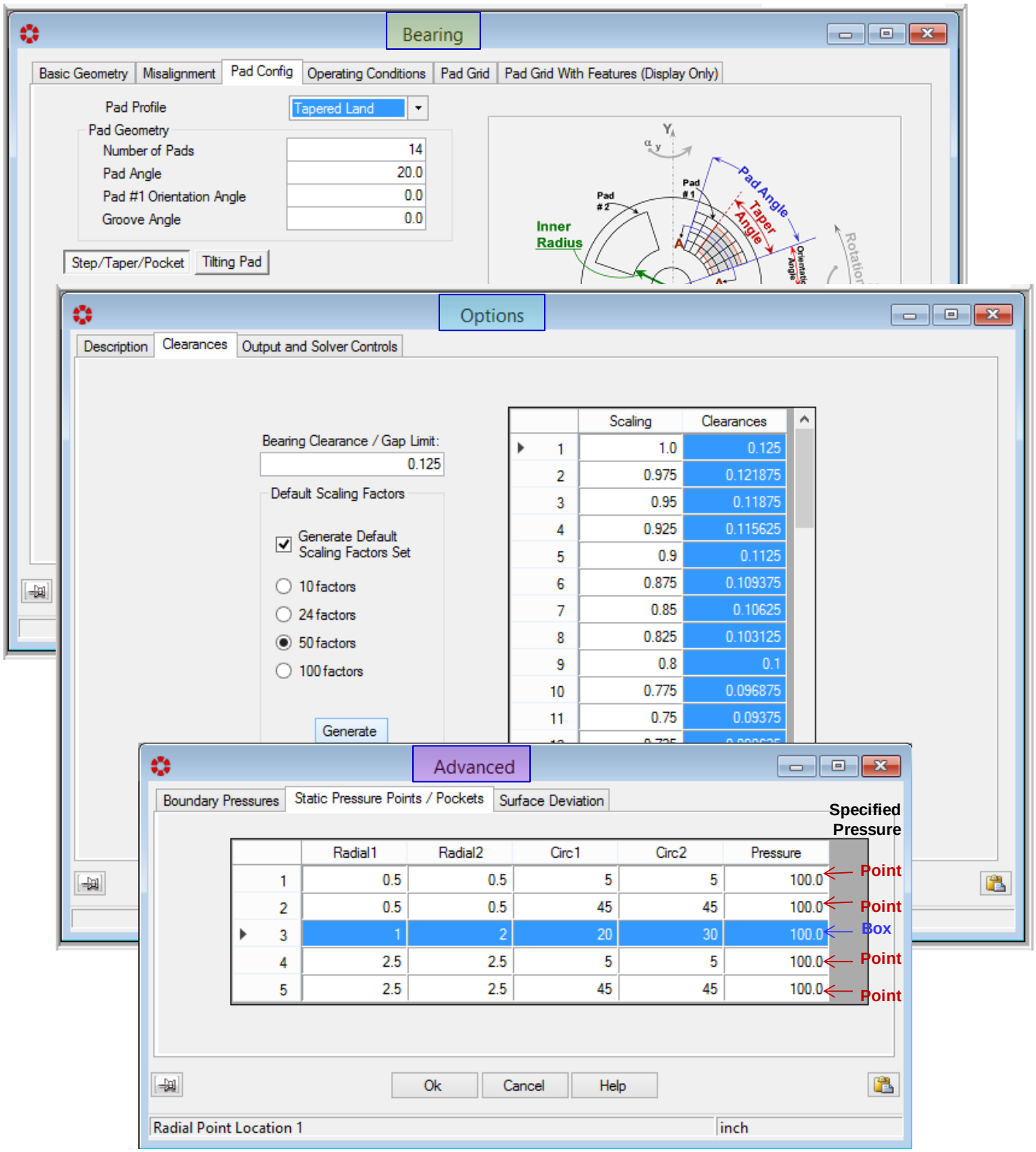
Version 6 THRSBR users need only pick an overall grid density or design, and the user interface built-in analytical routines will generate the required grid network for the overall design, automatically modified as needed to add additional grid points at feature locations. Previous versions required the user to carefully design the fluid-film grid network in order to place design feature locations (like steps, tapers, specified pressure regions, tec.) at existing grid points.

The grid design form now allows the user to specify grid locations by their physical positions instead of their incremental distance from their neighboring grid points. If a grid point increment is changed resulting in a mismatch between the size of the grid and the size of the bearing, a single button click will proportionately resize the grid to fit the bearing.

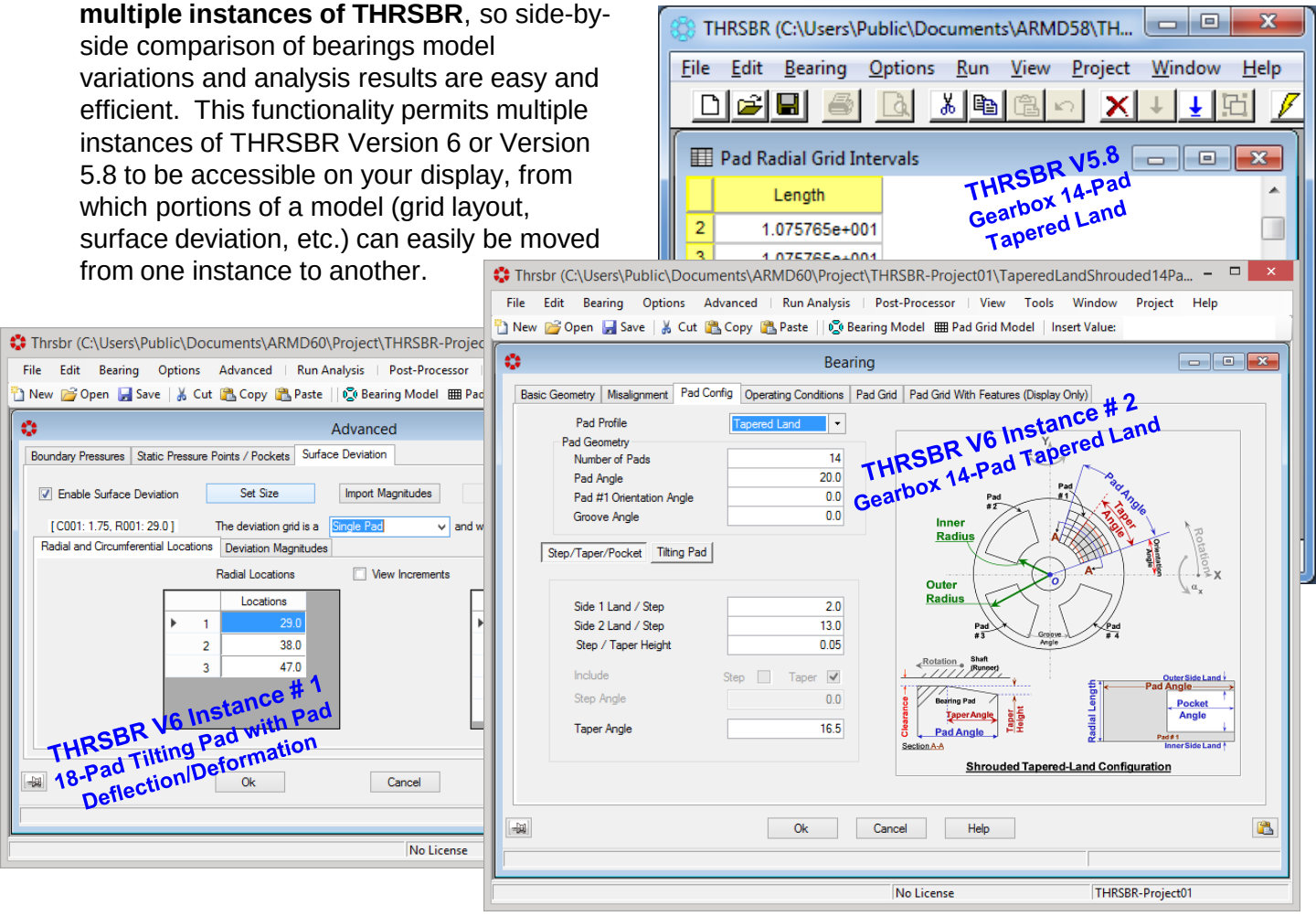
Surface deviation for customized and unique bearing internal clearances (compound tapers, special grooving, structural deflection/deformation, tilting pad deflection, full or partial radially tapered surfaces, etc.) incorporates import function of CSV (comma separated variables) files containing clearance deviations for the custom bearing design.

Enhanced Modeling, Usability and Technical Features Include:

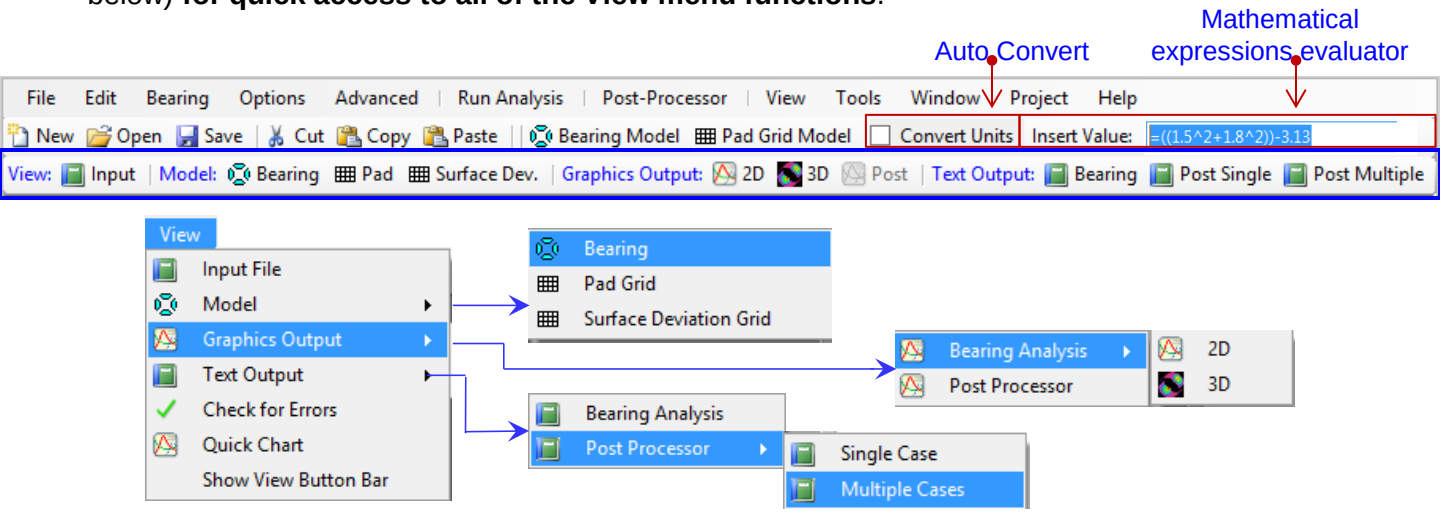
- **TAB layout**. Redesigned for more direct and faster access to data input locations, and results. Important functionality is brought forward into the TAB structure, thereby eliminating the need to select from drop down menu lists or mouse right-click pop-up menu lists.



➢ **Multiple instances of THRSBR**. The newly developed package can now **open simultaneous multiple instances of THRSBR**, so side-by-side comparison of bearings model variations and analysis results are easy and efficient. This functionality permits multiple instances of THRSBR Version 6 or Version 5.8 to be accessible on your display, from which portions of a model (grid layout, surface deviation, etc.) can easily be moved from one instance to another.



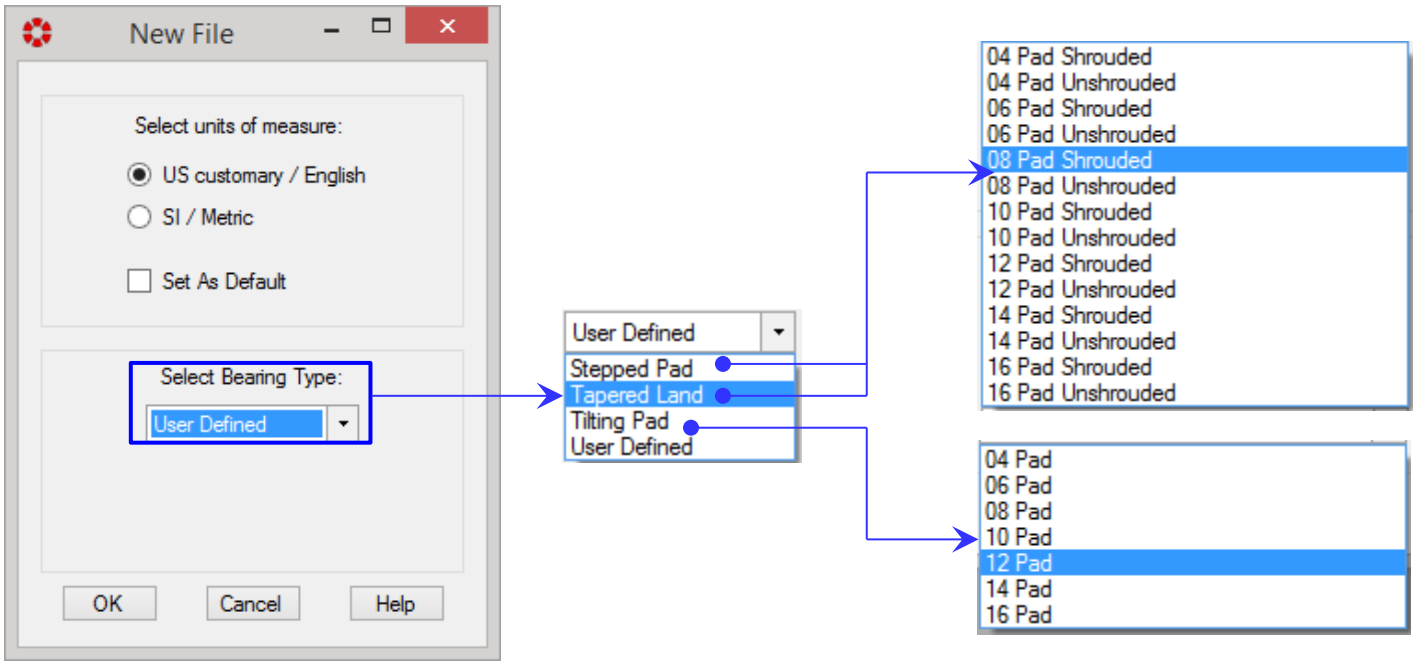
➢ **User Configurable Expanded Toolbar**. The main toolbar contains controls used to access frequently used functions (these functions are usually accessible from a menu as well). When a function is not available, its control on the toolbar will be disabled and displayed in a faded gray color. A user configurable **expanded Toolbar** has been added (second row of the toolbar shown below) **for quick access to all of the View menu functions**.



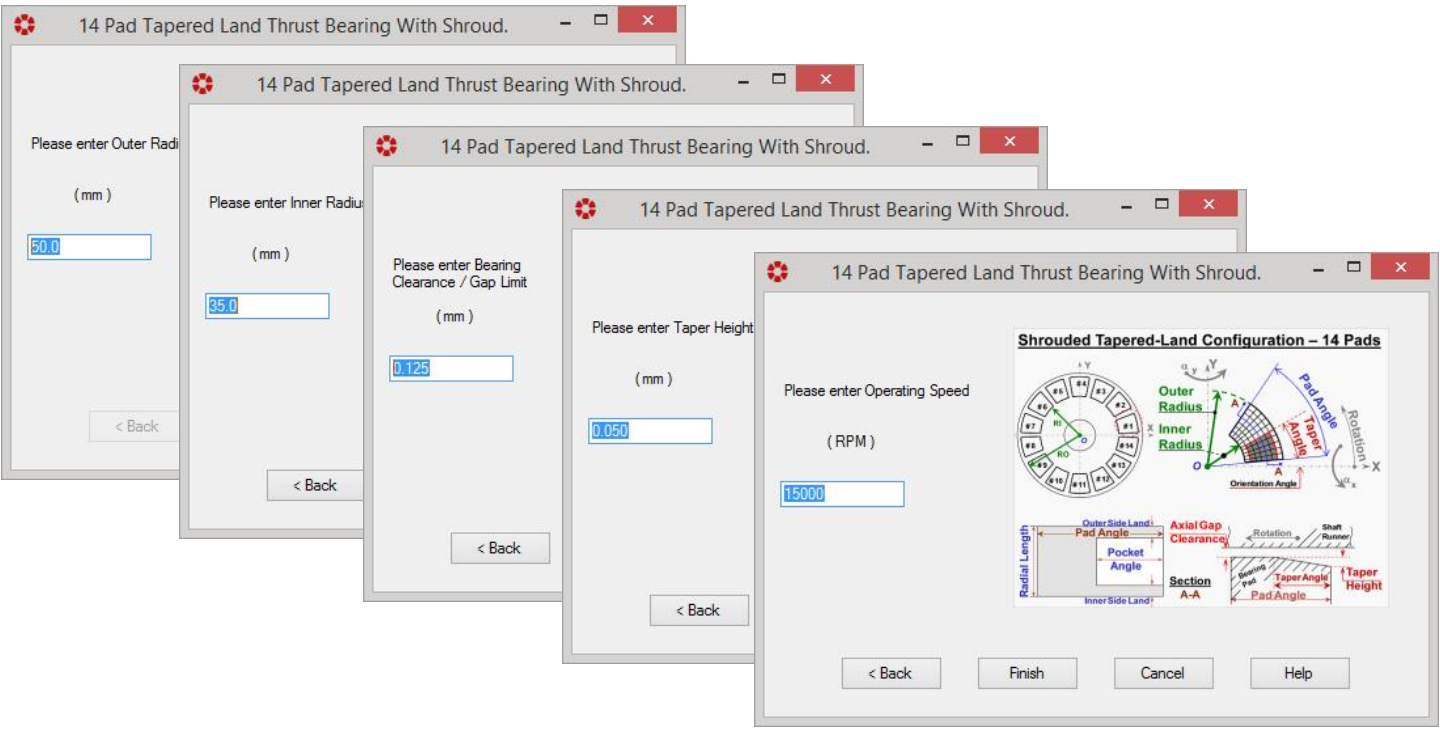
ARMD™ V6.2 – THRSBR Module

Many of the improvements incorporated into ARMD THRSBR Version 6 are specifically directed towards simplicity, increasing usability and productivity as illustrated bellow:

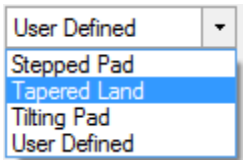
- **Pre-Configured Bearing and Types**. The newly developed package incorporates a significant number of preconfigured bearing types (templates) used in industry. When creating a new bearing model the built-in wizard and templates expedite the creation of bearing models and provide bearing performance results in few keystrokes. Users can create additional templates of their specific bearing configurations and utilize them during their normal work flow.

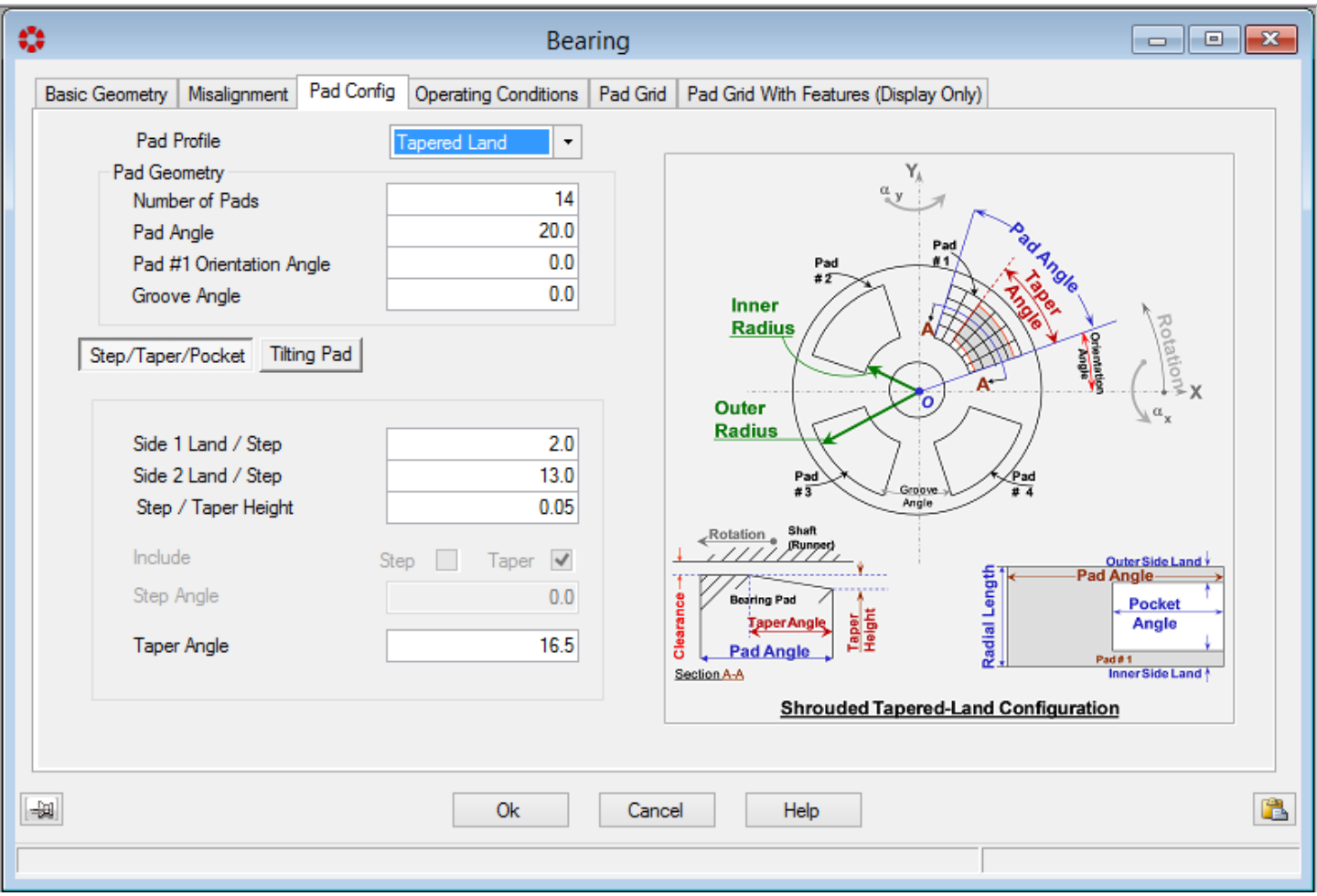


As an illustration (shown below) it takes only five steps utilizing templates/wizard to model a bearing with its geometry and operating speed and provide a complete solution of bearing performance.

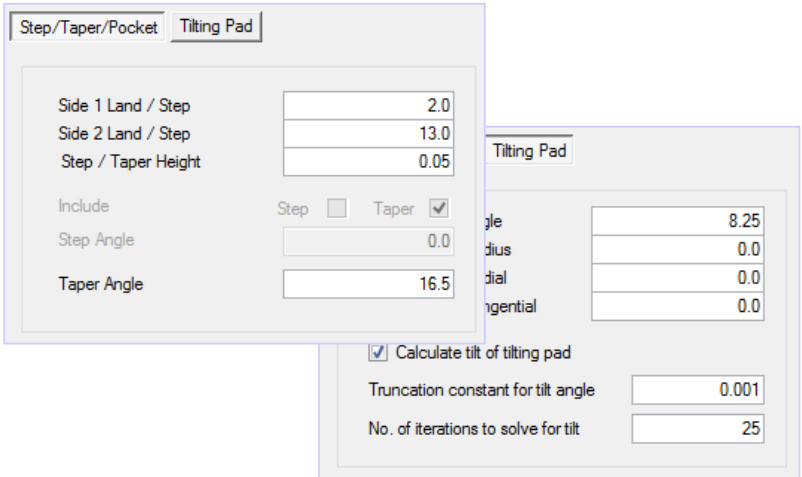


➢ **Bearing Pad Configuration**. A vastly improved pad configuration tab allows the user to select from many standard bearing types, including special options, while restricting input to only those fields/cells pertinent to that type. To assist the user when a pad profile has been selected, various fields/cells in the form will appear and be accessible or grayed out as shown below for the tapered land profile. When a "*User Defined*" pad profile is selected, the user has complete freedom in configuring pad attributes.

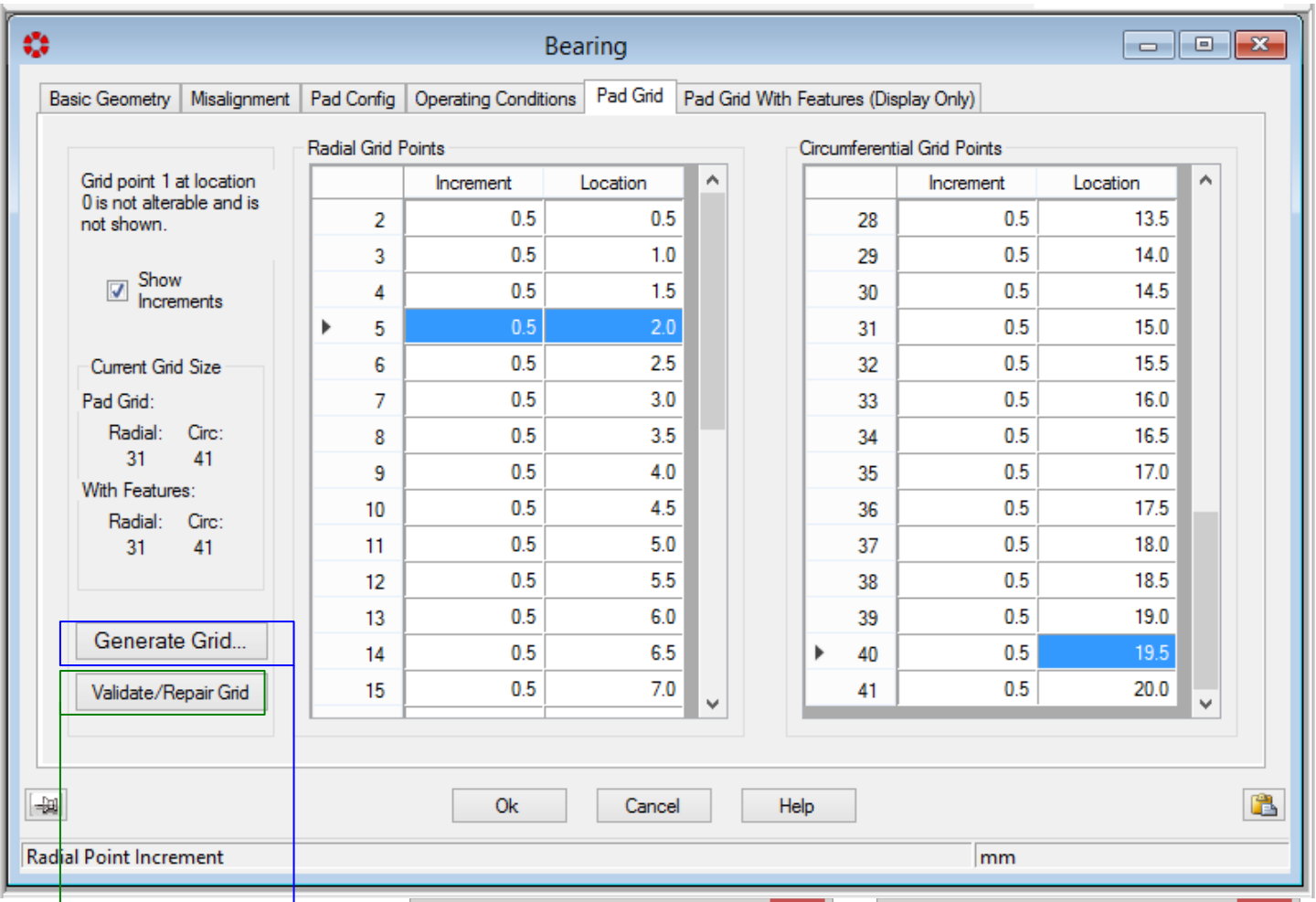




➢ **Features Defined by Geometry**. The newly developed package incorporates built-in analytical routines to accommodate bearing pad design **feature locations** (like steps, tapers, and lube feed specified pressure regions) locations by their physical location in normal design length units (**millimeter**, **inch**, **degree**, etc.), not by grid point index as in previous versions. This significantly enhances bearing/pad model development and provides the user with an efficient means to incorporate bearing/pad design features of interest.

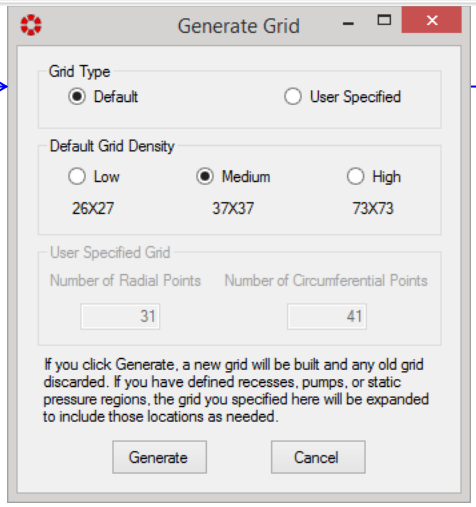


- **Bearing Pad Grid**. The pad grid network is utilized for formation and solution of the lubrication equations resulting in the overall bearing performance results. In previous versions of the software the grid network was defined by the user. The new version, by default, automatically generates the grid network with user option of low, medium, or high density gridding. User Specified grid network can be selected to override default setting. As illustrated below, the new version allows the user to specify grid locations by their physical positions instead of just their incremental distance from their neighboring grid points.

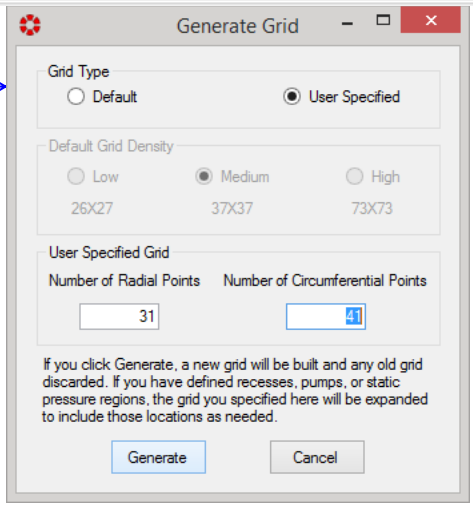


If a grid point increment is changed resulting in a mismatch between the size of the grid and the size of the bearing, a single button click will proportionately resize the grid to fit the bearing

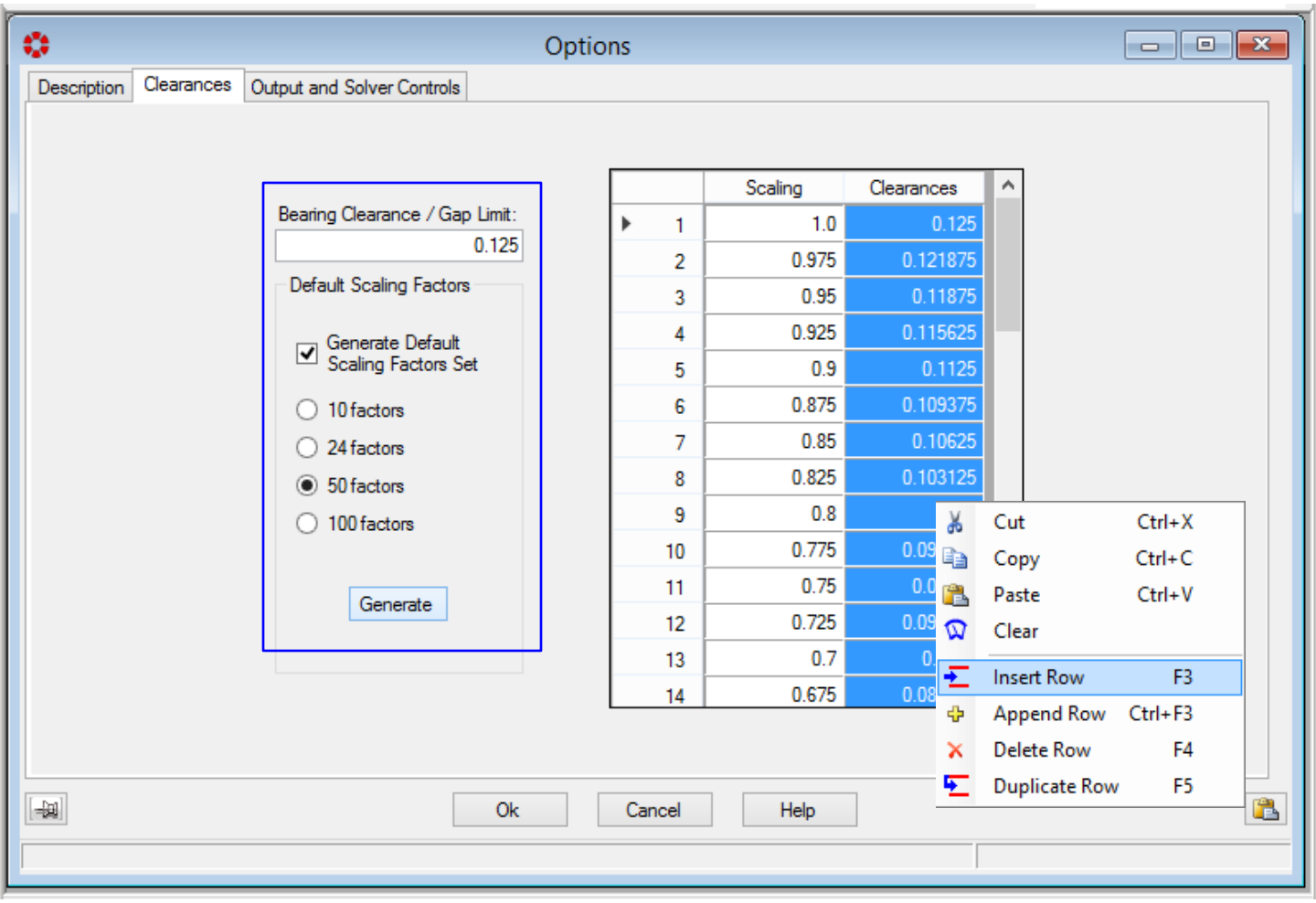
Default Setting



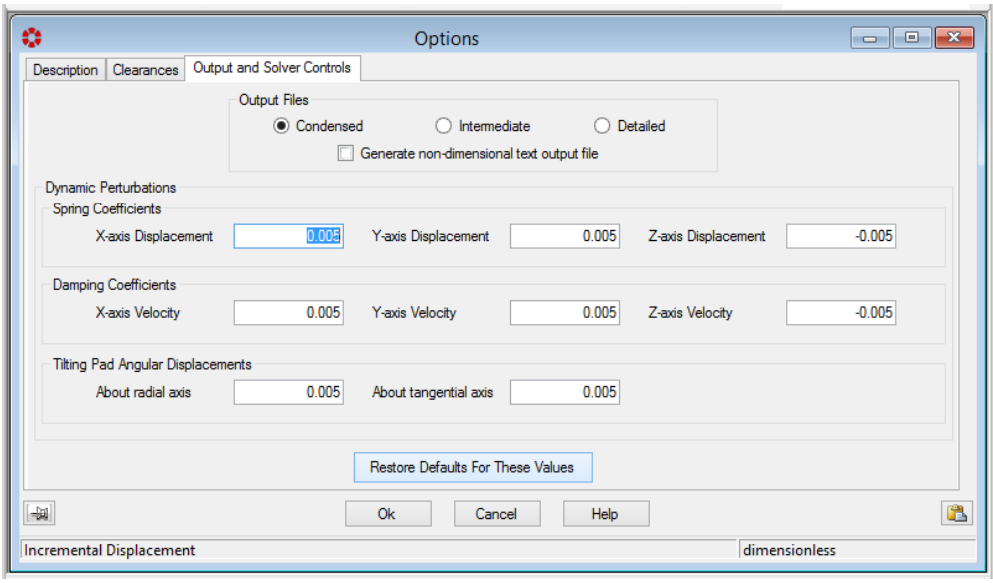
User Specified



- **Clearances – Options Form**. Thrust runner to bearing surface clearances/gaps for bearing performance simulation is specified in the *Options* form shown below. Clearances are automatically generated (10, 24, 50 default, 100 clearances, or can be specified by the user) for user specified axial clearance/gap limit and pressing the Generate button. Modified axial gaps can simply be entered and clearances for simulation updated with the Generate button at any time.



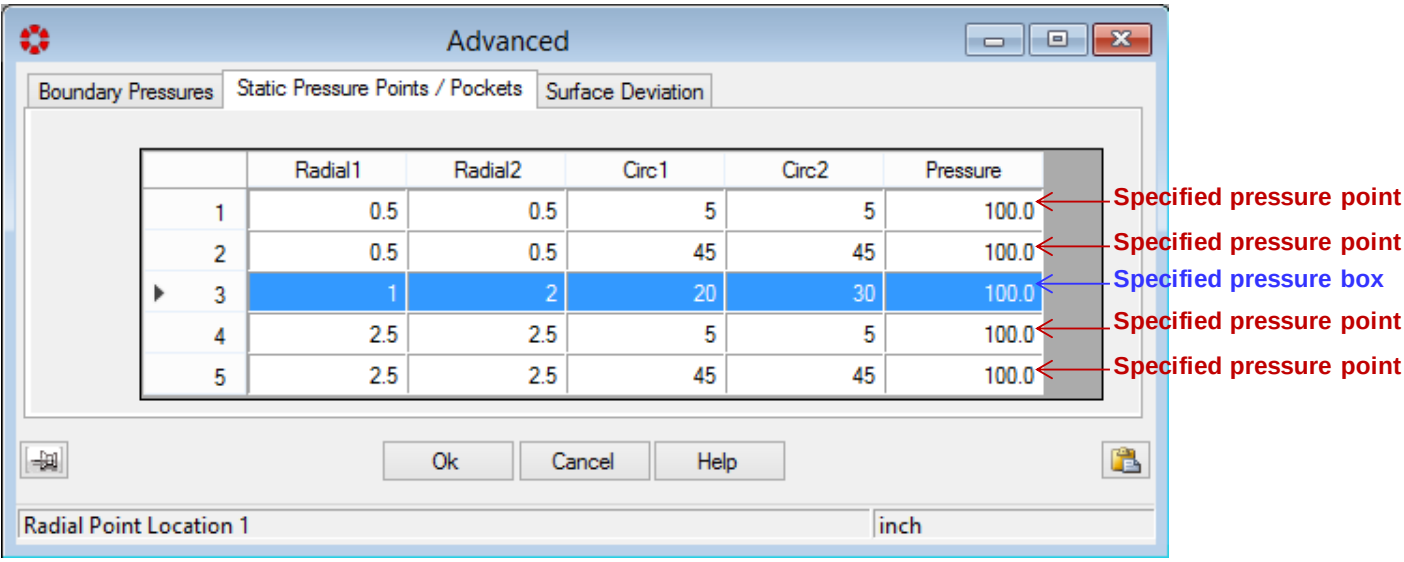
- **Output and Solver Controls – Options Form**. Version 6 provides the user with condensed, intermediate and detailed output results of the solution with simply selecting the appropriate radio button. Additionally and unlike previous version **restore default button** provides default settings on increments for stiffness and damping coefficients to be generated.



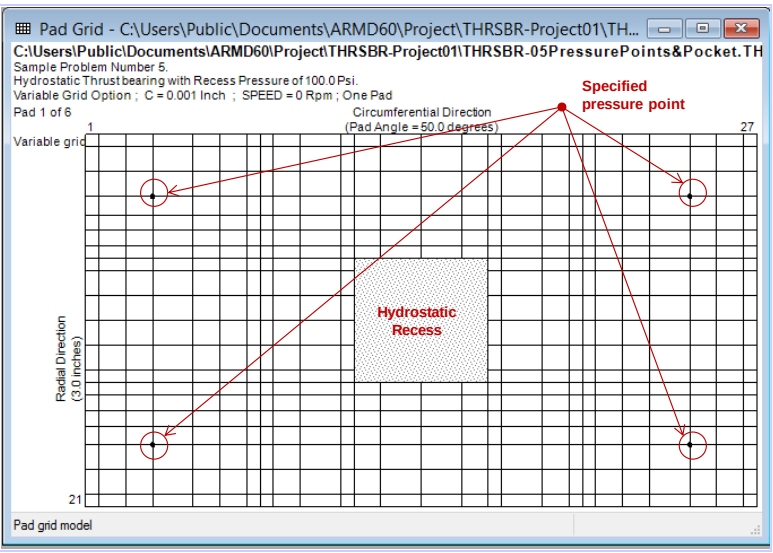
➢ **Static Pressure Points / Lines / Pockets – Advanced Form**. New features implemented in version 6 provide the user with means to specify pressure conditions, some of which include:

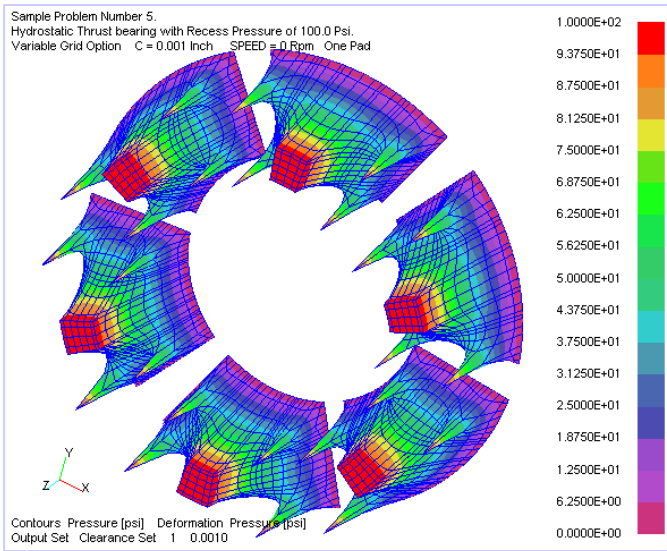
- Pressure point at a intersection of a radial and circumferential location in the pad surface area.
- Pressure line in either radial or circumferential direction in the pad surface area.
- Pressure pocket/box in the pad surface area.

Pressurized points, lines, or pockets are specified by their physical geometry (of radial and circumferential positions) in the bearing pad surface area, unlike previous versions which permitted only the specification of pressures at already established grid points.



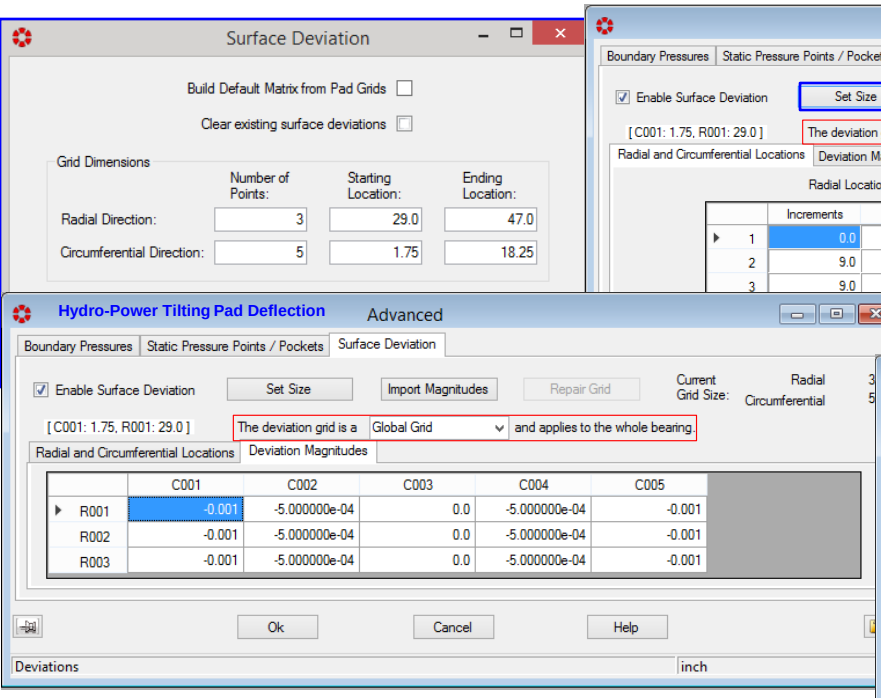
The above specified conditions illustrate (shown pictorially below with the display of the pad grid layout) the specification of points pressure at a radial location of 0.50 inches and located at 5 and 45 degrees circumferentially, points pressure at a radial location of 2.5 inches and located at 5 and 45 degree circumferentially, as well as pressurized pocket/box bounded radially at 1.0 and 2.0 inches, and circumferentially at 20.0 and 30.0 degrees.





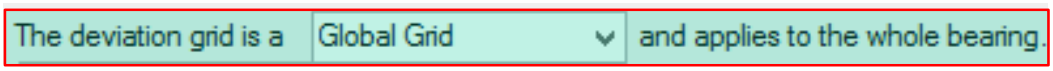
- **Surface Deviation – Advanced Form**. Surface deviation is defined as modification to the bearing fluid-film clearance distribution. The surface deviation magnitudes are superimposed clearances to the geometrical clearance distribution of the bearing surface. This surface deviation is a fixed magnitude of superimposed clearances to the geometrical clearance distribution of the bearing or pad surfaces regardless of shaft/runner position in the bearing clearance due to applied load, speed, viscosity, etc. **With this capability** and in addition to standard configuration bearings such as step, step pocket, tapered-land, tapered-pocket, tilting pad, etc., **practically any bearing/pad surface geometry imagined** (compound taper, full or partial radial/circumferential tapered or wavy surfaces, structural deformation or deflection, etc.) **can be modeled and evaluated with the software**.

When surface deviation feature is enabled by checking the "Enable Surface Deviation" box (shown below), the form expands allowing grid network size to be specified and grid intervals in the radial and circumferential directions computed. Surface deviation may also be imported from external comma-separated-files (.CSV files).



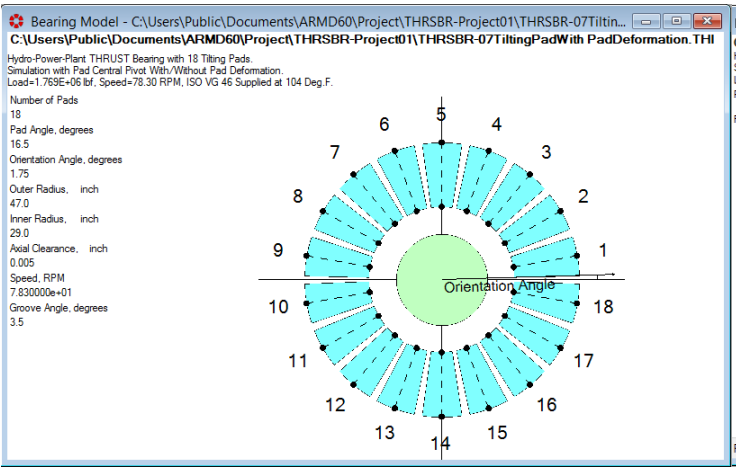
Two options are available for defining the surface deviation in version 6 of the thrust bearing Module:

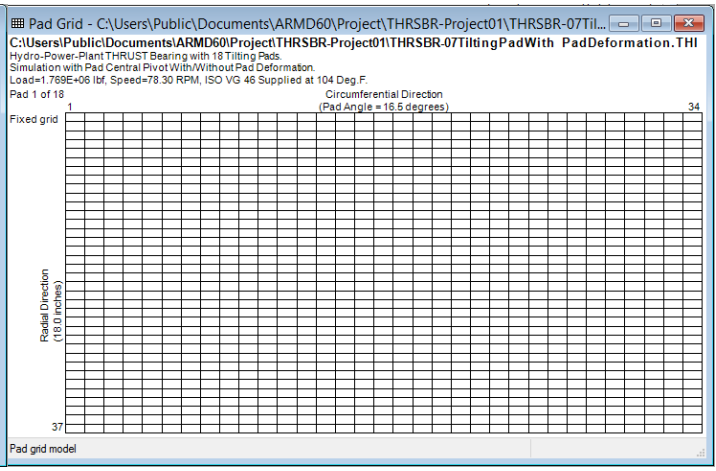
1- By default (shown above) the surface deviations are specified in the global bearing coordinate system "Global Grid" and not the individual pad grid network.



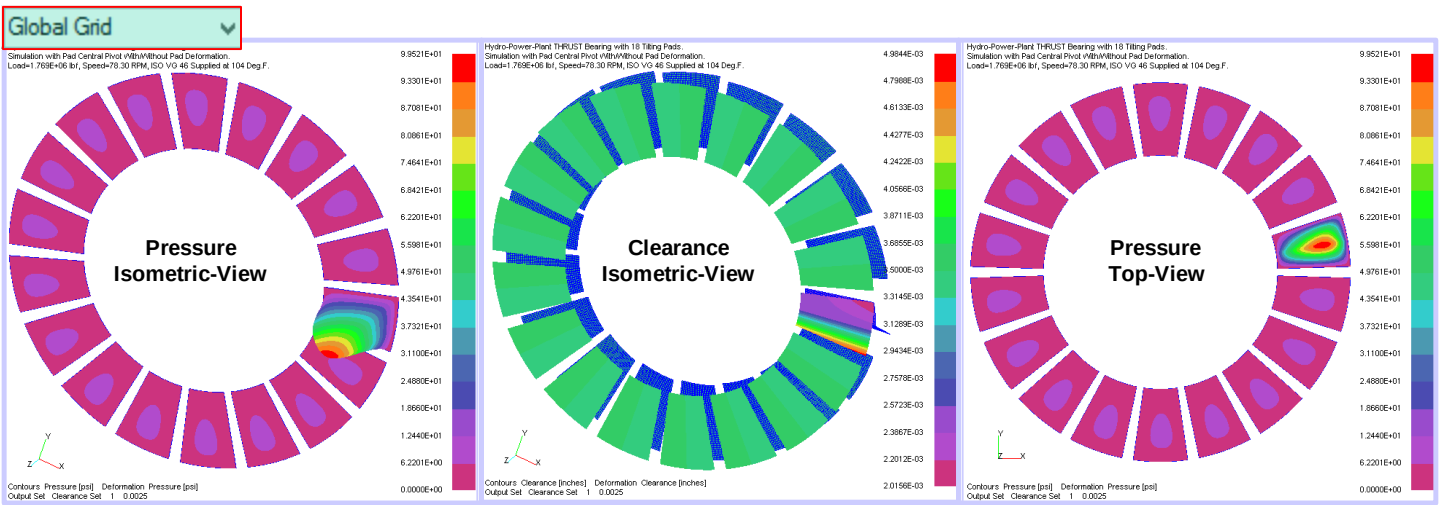
2- Surface deviations may be specified over one pad surface area (1st pad closest to the X-axis) and applied to all pads in the bearing when selecting the "Single Pad" option.

A view of the pad grid network and the bearing graphical presentation are shown below.

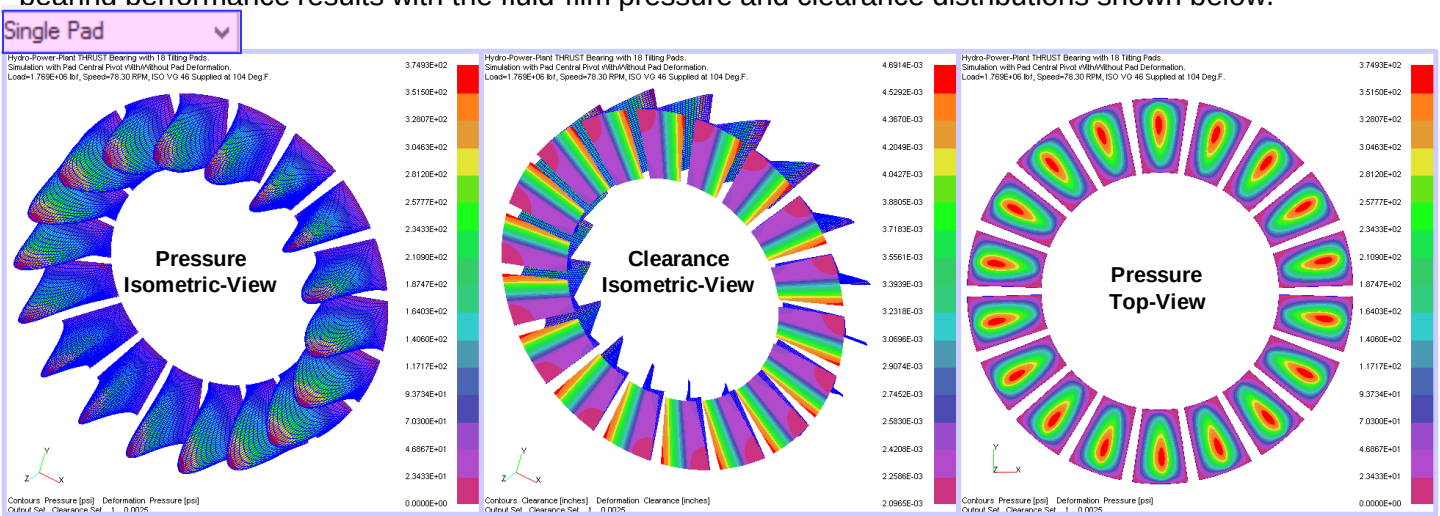




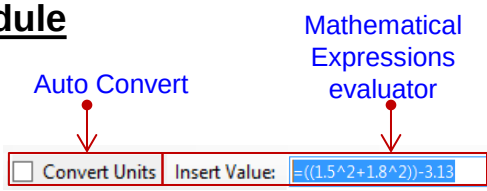
Specified surface deviations/deformation applied in the global coordinate system (Global Grid) and the actual surface deviation extended in the circumferential direction to cover one pad only. Performing the bearing solution, generating the bearing performance results, and viewing the fluid-film pressure/clearance distributions, the surface deviations will be considered in the 1st bearing pad only as shown below.



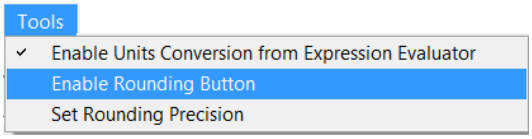
If the specified surface deviations (pad deformation) is used on all pads by simply selecting the "Single Pad" option, performing the bearing solution will consider the deviations in each of the pads and produce the bearing performance results with the fluid-film pressure and clearance distributions shown below.



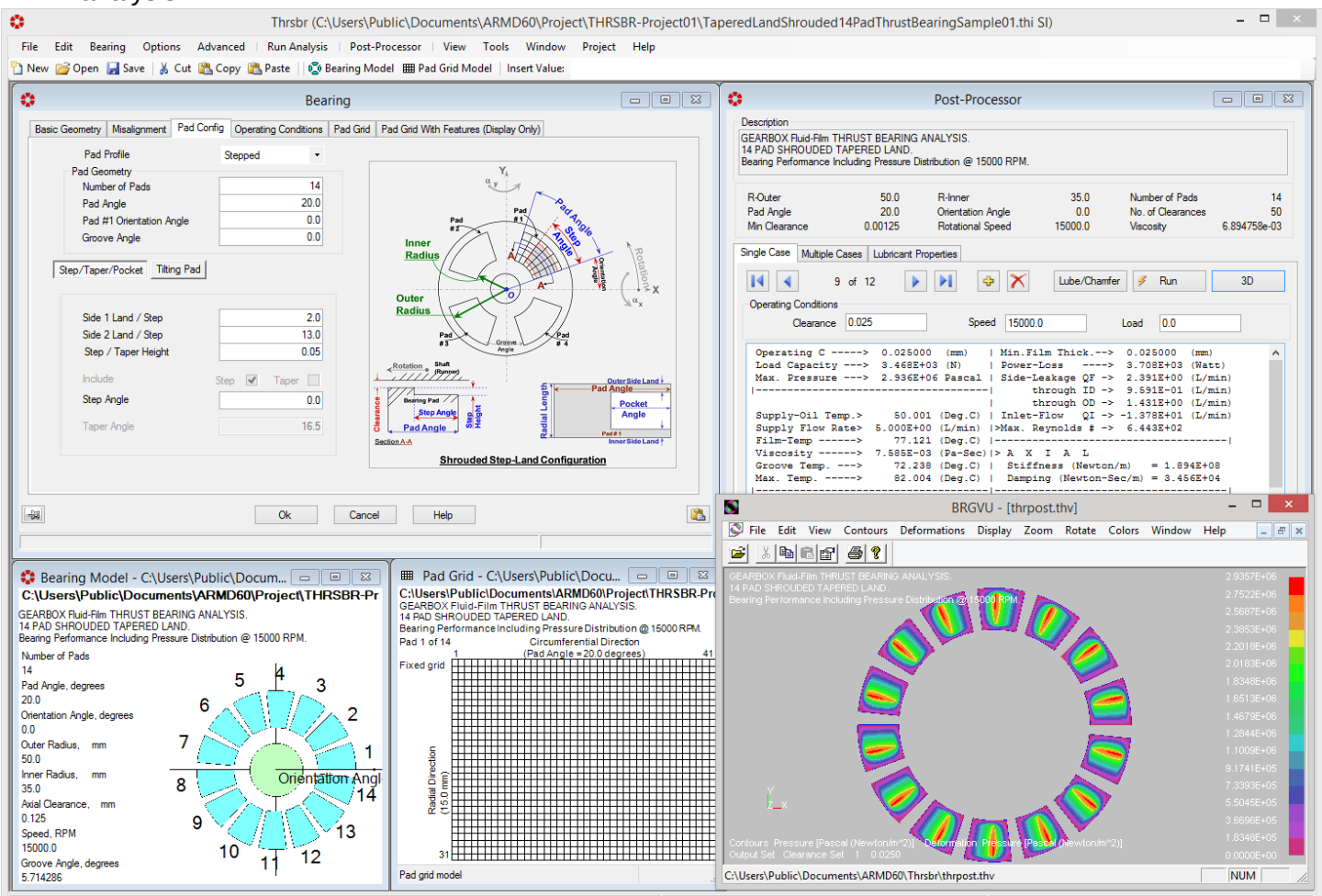
ARMD™ V6.2 – THRSBR Module



- **Evaluate Mathematical Expressions**. When entering data to cells, this data entry field has the ability to evaluate mathematical expressions, without having to launch a calculator app.
- **Whole Number**. Display for improved legibility, defaulting to scientific notation when required. Trailing zeros are implied out to seven significant digits.
- **Auto Convert Units**. Automatically computes the units conversion when modeling a system with different components using mixed SI and English units. Example: You have a few inch dimensions to enter amongst hundreds of mm values, just check the box for auto conversion.
- **Data validation**. Performed at Data Entry time. The program now reviews data grids for incomplete, invalid, or nonsensical entries, providing an Error Flag and correction recommendation.
- **Error diagnostics**. Quickly walks user through any model input errors. A mouse click navigates the user to the next error found.
- **Round Function**. Round function for data entry fields is accessible from the Tools menu, and can be declared for all data fields.



- **Data Entry Grids**. All data entry grids can be open simultaneously for ease of model building & analysis.



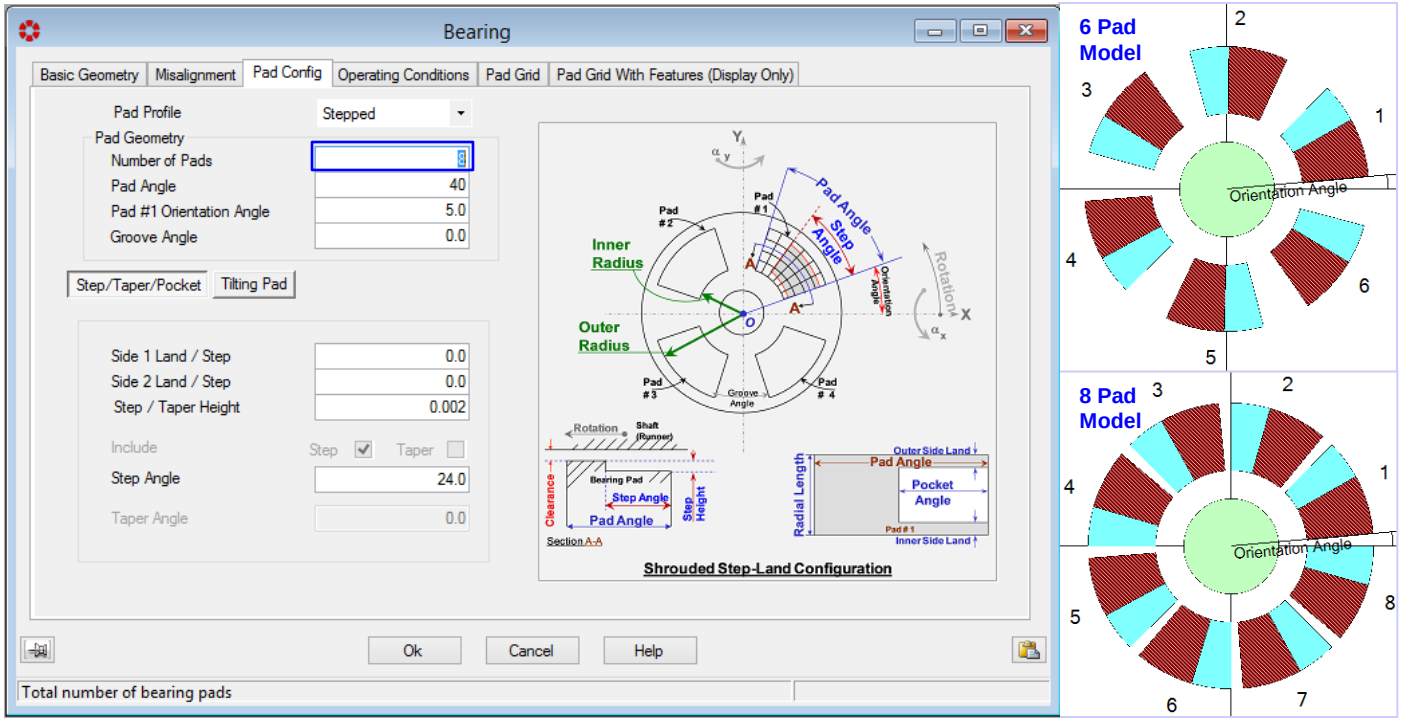
ARMD™ V6.2 – THRSBR Module

- **Data Entry Menus**. All data entry menus are visible at the Grid input page. Grids now feature selection check boxes and editing buttons where appropriate.

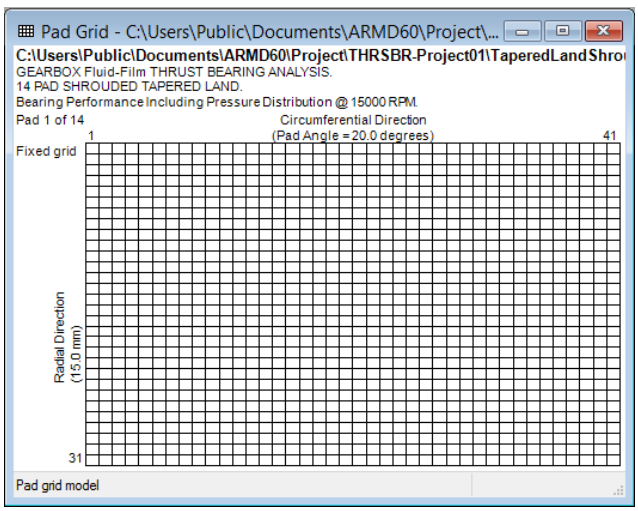
- **Quick Chart**. This feature rapidly displays an X-Y graph of entered tabular data for visual verification of correctness. ARMD Graph software is still available for complete graphic analysis capabilities.

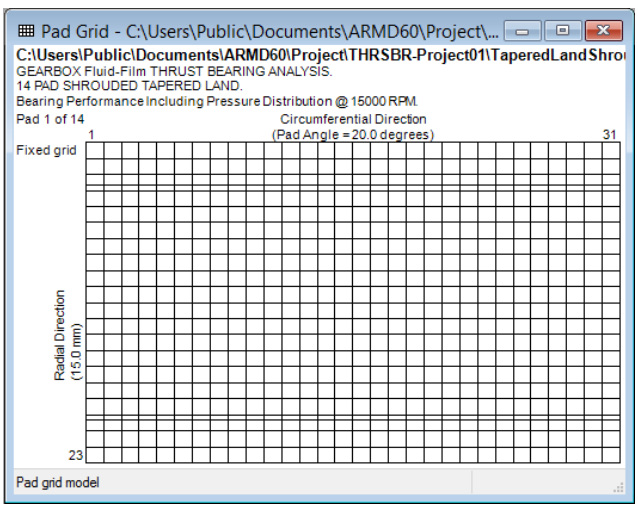
- **Live 2-D GRAPHICS MODELS**.

  Real-time graphics update of the 2-D image corresponding to numeric data input in data grids provides visual confirmation of model correctness while building the bearing model. Changing the number of pads from 6 to 8 will automatically modify the graphics model as shown below.



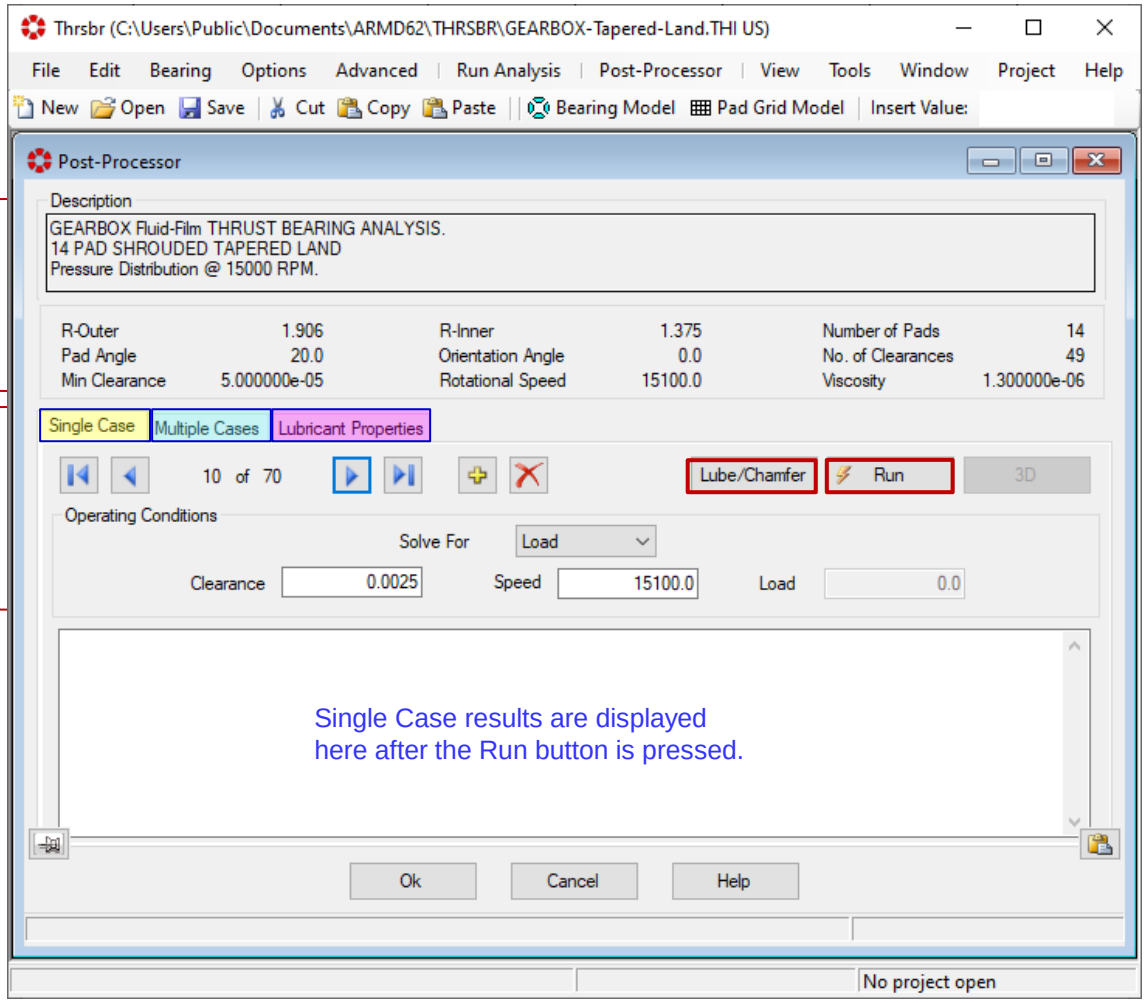
Modifying pad grid network size from 31 X 41 to 23 X 31 (shown below for axially symmetric grid) displays new grid model, including its feature of shrouded tapered land configuration added to the specified grid size.



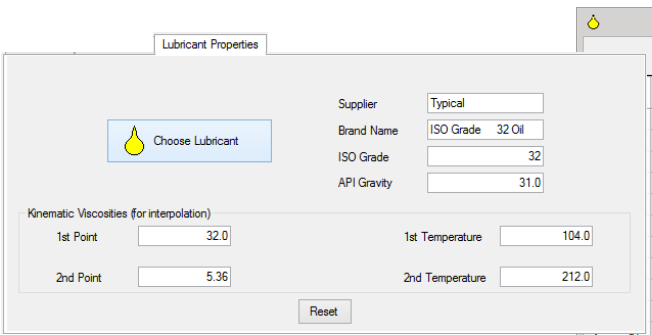


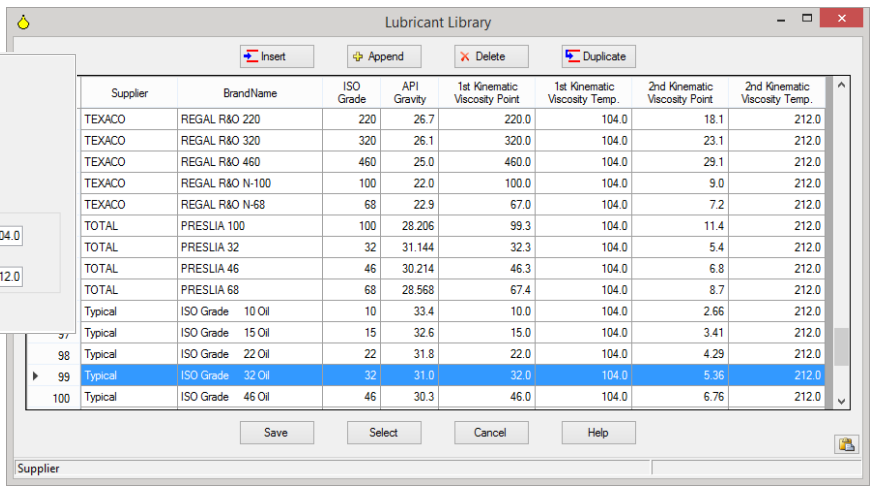
- **Metafile enabled copy and paste** of bearing and pad grid graphics models for better reporting.

- **Post-Processor**. Following a complete bearing modeling and performance map solution as a function of axial clearance/gap, the post processor illustrated below immediately provides bearing performance results when the Run button is pressed. The complete bearing performance results can be generated for a *Single-Case* or *Multiple-Cases* with user specified operating conditions of Clearance or Load, Speed, Viscosity, Flow Rate, Temperatures, Pressure, Chamfers geometry, etc.



Lubricant Properties can be selected from the built-in lubricant database or specified by the user. User specific lubricants, not available in the database, can be added for later retrieval / use.

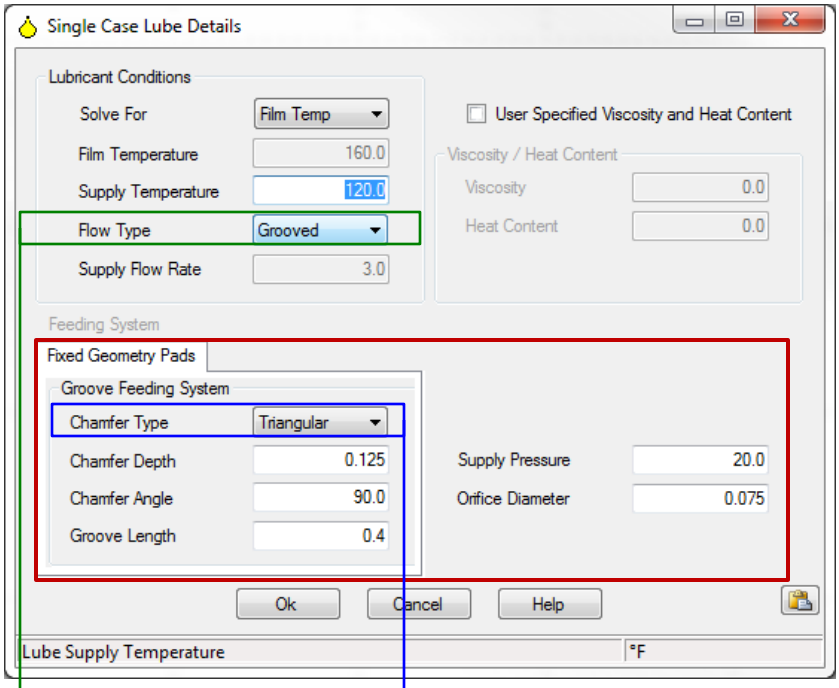


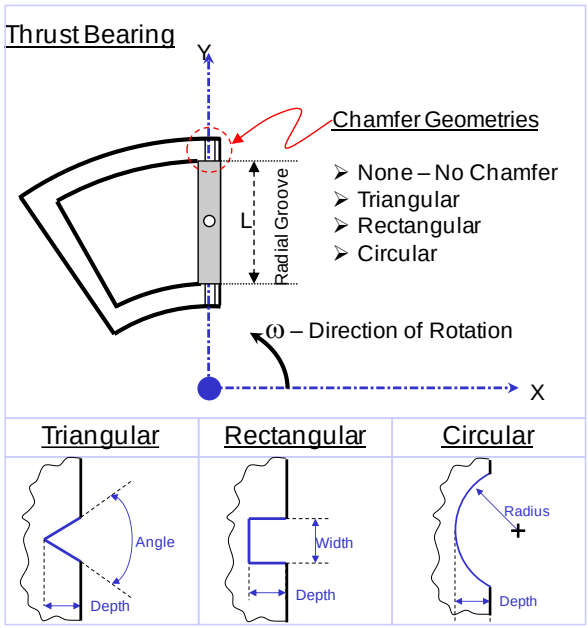


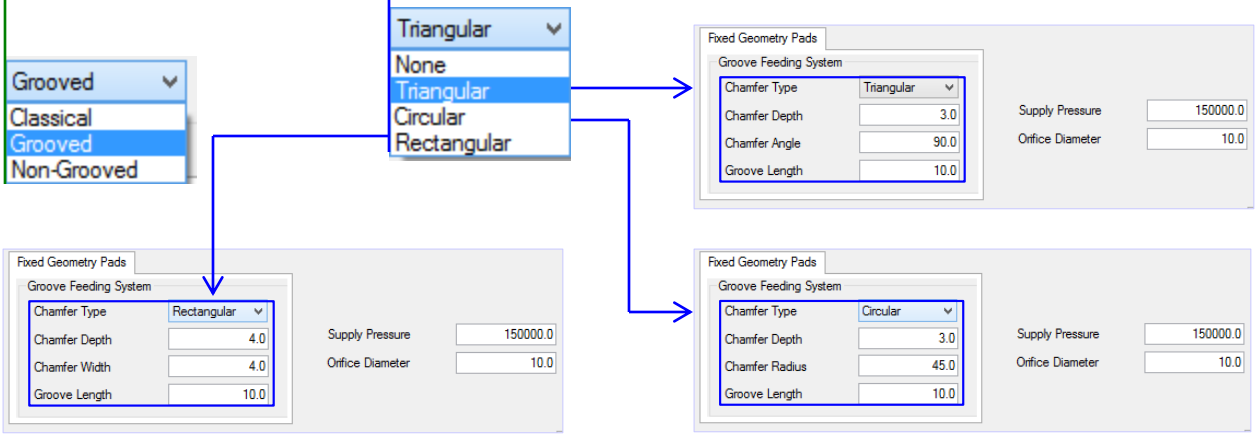
Lube / Chamfers / Feed-Nozzles: Both fixed geometry bearings oil grooves feeding-system and their geometrical chamfers as well as tilting pad bearings feed nozzles numbers and orifice geometry, may influence the bearing performance significantly. In the fixed geometry bearings the flow rate through the bearing is controlled by both the bearing internal clearances and groove's resistance to flow, while in the tilting pad feed nozzles the flow is controlled by the number of feed nozzles and their orifice diameter. Due to supply lubricant pressure, these flow rates impacts the heat balance and temperature rise through the bearing which in turn influences the oil film viscosity thus affecting bearing performance.

Simulation with the latest version can include the influence of either a pressurized grooved feeding system, pressurized nozzle feeding system, or classical flow assumption (flooded environment). By default, classical flow is simulated by assuming that the bearing's supply flow rate is equal to its side leakage flow rate (non-starved lubrication).

When the flow type is set to "**Grooved**" shown below, the supply pressure and groove details (including chamfer type and dimensions) are to be specified by the user. Depending on the chamfer type selected (triangular, rectangular and circular), the required data will be displayed as illustrated.







For flow type is set to "**Non-Grooved**" shown below, pressurized lubricant is supplied through sharp-edge orifices or nozzles (typically incorporated in tilting pad bearings) the supply pressure, number of orifices/nozzles per pad and orifice/nozzle geometry are to be specified by the user.

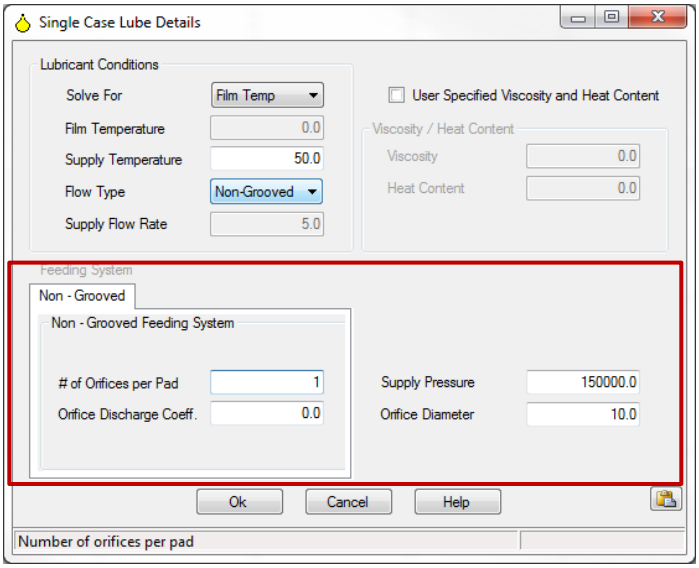


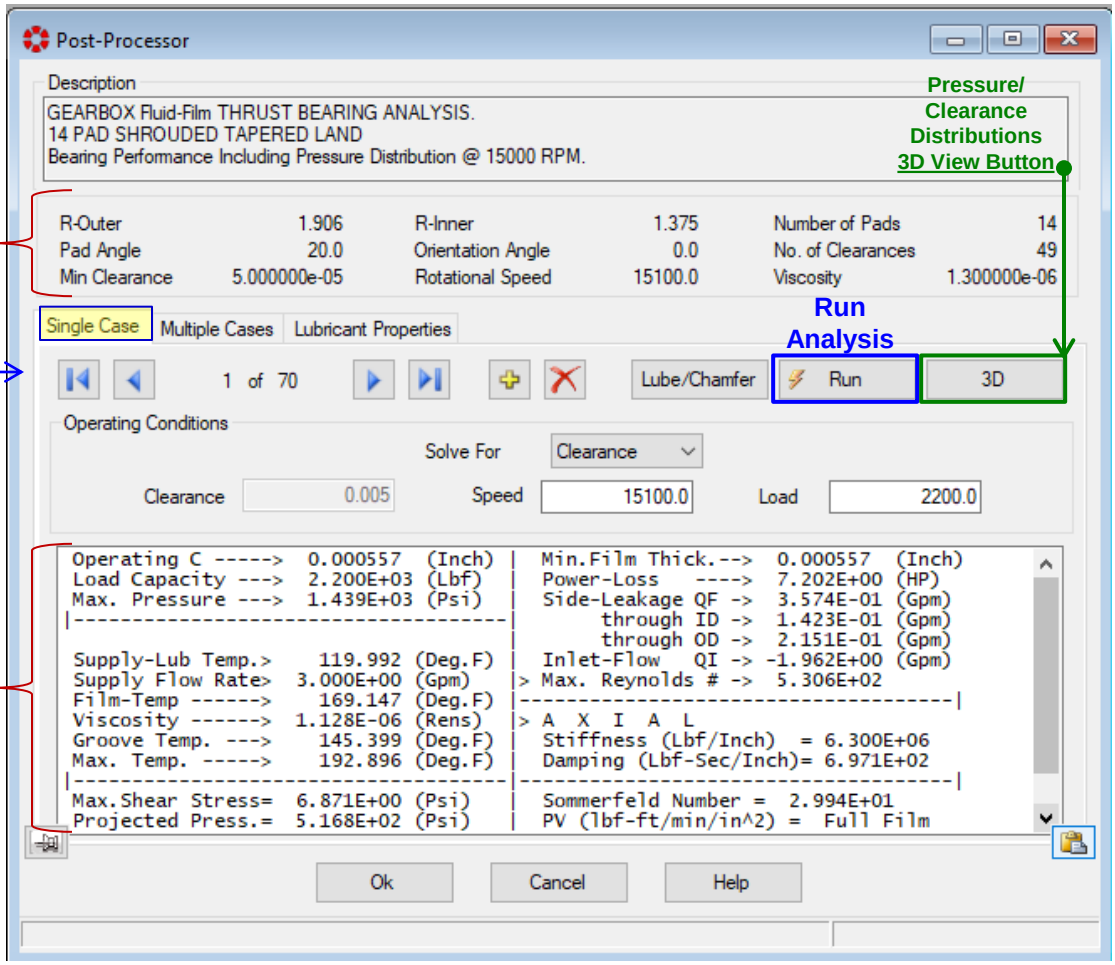
Illustration of Three Feed Orifices/Nozzles per Pad

Single Case: Illustrated below, complete bearing performance results are generated when the *Run* button is pressed. The solution is performed for user specified operating conditions taking into consideration the pressurized feeding system. Heat balance is performed for the overall bearing system.

Modeled Bearing Details

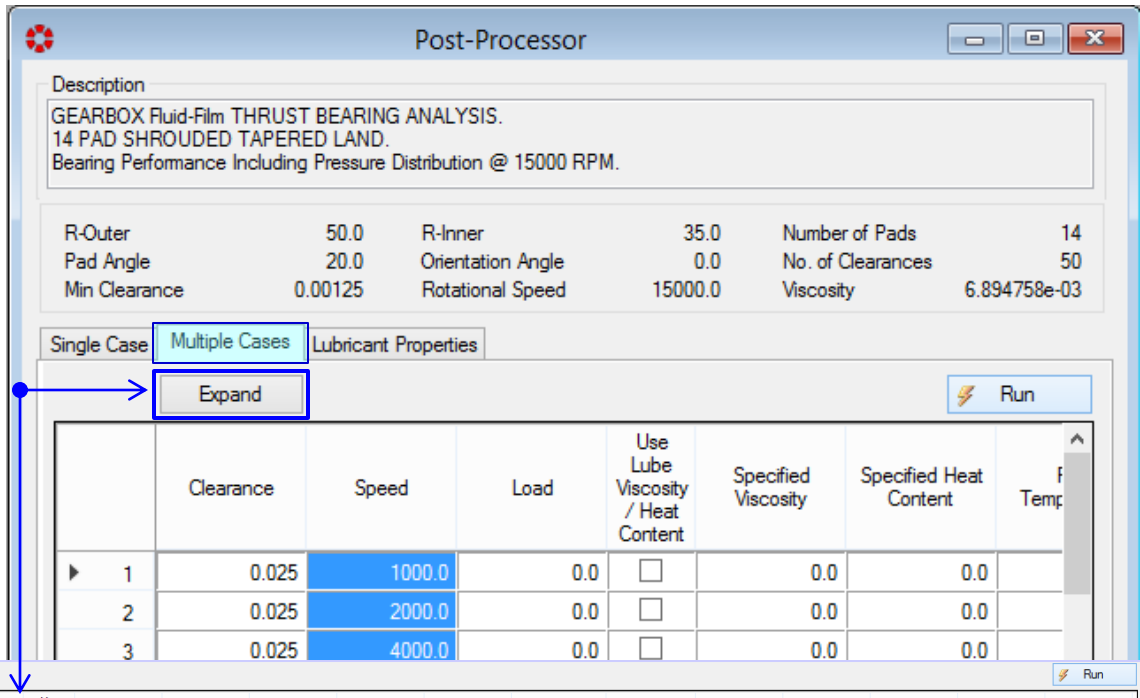
Scroll through cases.

Complete Bearing Performance Results including bearing system heat balance and supply pressure considerations.



Multiple Cases / Parametric Evaluation : Multiple case bearing performance evaluation can be performed as a function of any combination of user defined operating conditions of Clearance, Speed, Load, Viscosity, Flow Rate, Temperatures, Pressure, Chamfers geometry, etc.

Parametric evaluation of bearing performance is accomplished efficiently.



Expand button if pressed will expand the window to the full width of the parent window which provides a quick view of all the columns for efficient data entry and modifications.

Restore

Run

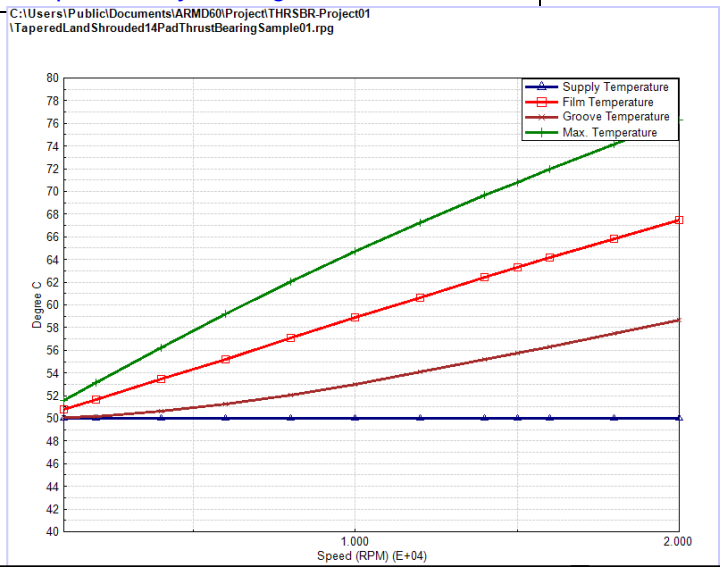
	Clearance	Speed	Load	Use Lube Viscosity / Heat Content	Specified Viscosity	Specified Heat Content	Film Temperature	Supply Temperature	Flow Rate	Flow Type	Chamfer Type	Supply Pressure	Orifice Diameter	Groove Length (Grooved)	Chamfer Depth (Grooved)	Chamfer Size (Grooved)
1	0.025	1000.0	0.0	☐	0.0	0.0	0.0	50.0	5.0	Grooved	Triangular	100000.0	3.0	10.0	1.25	90.0
2	0.025	2000.0	0.0	☐	0.0	0.0	0.0	50.0	5.0	Grooved	Triangular	100000.0	3.0	10.0	1.25	90.0
3	0.025	4000.0	0.0	☐	0.0	0.0	0.0	50.0	5.0	Grooved	Triangular	100000.0	3.0	10.0	1.25	90.0
4	0.025	6000.0	0.0	☐	0.0	0.0	0.0	50.0	5.0	Grooved	Triangular	100000.0	3.0	10.0	1.25	90.0
5	0.025	8000.0	0.0	☐	0.0	0.0	0.0	50.0	5.0	Grooved	Triangular	100000.0	3.0	10.0	1.25	90.0
6	0.025	10000.0	0.0	☐	0.0	0.0	0.0	50.0	5.0	Grooved	Triangular	100000.0	3.0	10.0	1.25	90.0
7	0.025	12000.0	0.0	☐	0.0	0.0	0.0	50.0	5.0	Grooved	Triangular	100000.0	3.0	10.0	1.25	90.0
8	0.025	14000.0	0.0	☐	0.0	0.0	0.0	50.0	5.0	Grooved	Triangular	100000.0	3.0	10.0	1.25	90.0
9	0.025	15000.0	0.0	☐	0.0	0.0	0.0	50.0	5.0	Grooved	Triangular	100000.0	3.0	10.0	1.25	90.0
10	0.025	16000.0	0.0	☐	0.0	0.0	0.0	50.0	5.0	Grooved	Triangular	100000.0	3.0	10.0	1.25	90.0
11	0.025	18000.0	0.0	☐	0.0	0.0	0.0	50.0	5.0	Grooved	Triangular	100000.0	3.0	10.0	1.25	90.0
12	0.025	20000.0	0.0	☐	0.0	0.0	0.0	50.0	5.0	Grooved	Triangular	100000.0	3.0	10.0	1.25	90.0

Multiple case bearing performance results are automatically displayed in text format as illustrated below. The ARMD graphics utility can be used to display X-Y plots of any of the generated results.

"Bearing Performance Including Pressure Distribution @ 15000 RPM."

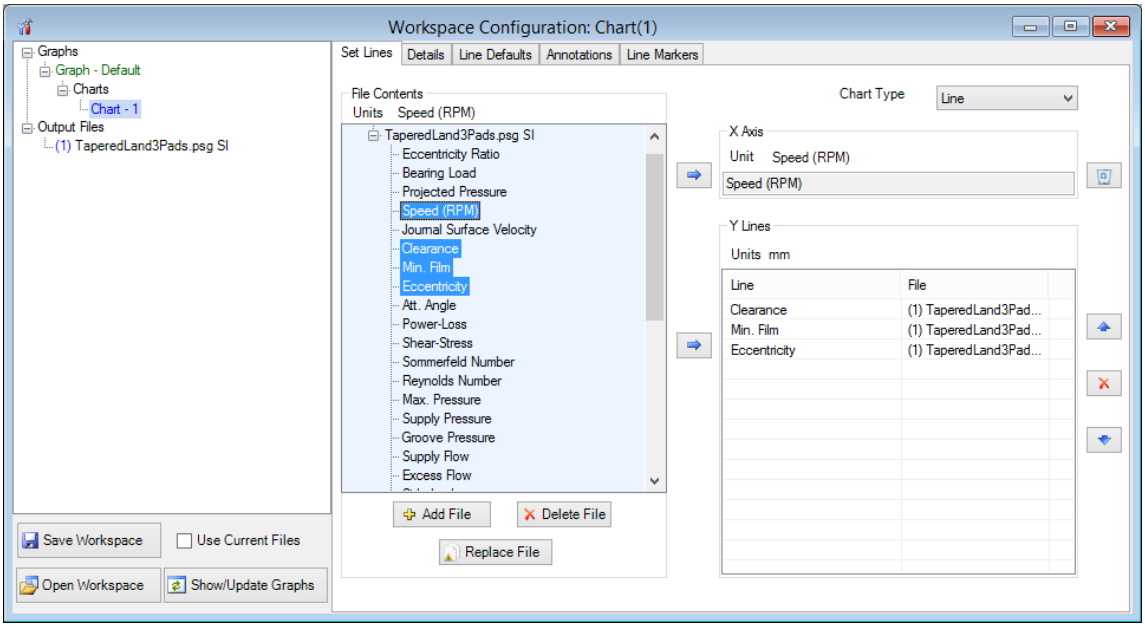
Case No.	Film-Temp (Deg-C)	Applied Load-NEWTON	Projected Pressure (Pascal)	Speed (rpm)	Surface Velocity (m/sec)	Reynolds Max.Number
1	50.803	5.376E+02	1.725E+05	1.000E+03	5.236E+00	1.887E+01
2	51.658	1.041E+03	3.342E+05	2.000E+03	1.047E+01	3.897E+01
3	53.427	1.951E+03	6.263E+05	4.000E+03	2.094E+01	8.319E+01
4	55.236	2.742E+03	8.802E+05	6.000E+03	3.142E+01	1.332E+02
5	57.055	3.430E+03	1.101E+06	8.000E+03	4.189E+01	1.893E+02
6	58.864	4.029E+03	1.293E+06	1.000E+04	5.236E+01	2.518E+02
7	60.653	4.553E+03	1.462E+06	1.200E+04	6.283E+01	3.208E+02
8	62.409	5.015E+03	1.610E+06	1.400E+04	7.330E+01	3.965E+02
9	63.277	5.224E+03	1.677E+06	1.500E+04	7.854E+01	4.369E+02
10	64.135	5.422E+03	1.740E+06	1.600E+04	8.378E+01	4.790E+02
11	65.823	5.784E+03	1.857E+06	1.800E+04	9.425E+01	5.683E+02
12	67.479	6.107E+03	1.960E+06	2.000E+04	1.047E+02	6.645E+02

Case No.	Clearance (mm)	Minimum-C (mm)	Shear-Stress Max.(Pascal)	Sommerfeld Avg.Number	Power Loss (watt)	Maximum Pressure (Pascal)
1	2.500E-02	2.500E-02	4.152E+03	3.093E+01	3.832E+01	4.551E+05
2	2.500E-02	2.500E-02	8.043E+03	3.093E+01	1.485E+02	8.814E+05
3	2.500E-02	2.500E-02	1.507E+04	3.093E+01	5.564E+02	1.652E+06
4	2.500E-02	2.500E-02	2.118E+04	3.093E+01	1.172E+03	2.321E+06
5	2.500E-02	2.500E-02	2.650E+04	3.093E+01	1.956E+03	2.904E+06
6	2.500E-02	2.500E-02	3.112E+04	3.093E+01	2.872E+03	3.411E+06
7	2.500E-02	2.500E-02	3.517E+04	3.093E+01	3.895E+03	3.855E+06
8	2.500E-02	2.500E-02	3.873E+04	3.093E+01	5.005E+03	4.245E+06
9	2.500E-02	2.500E-02	4.035E+04	3.093E+01	5.587E+03	4.422E+06
10	2.500E-02	2.500E-02	4.188E+04	3.093E+01	6.184E+03	4.590E+06
11	2.500E-02	2.500E-02	4.468E+04	3.093E+01	7.422E+03	4.896E+06
12	2.500E-02	2.500E-02	4.717E+04	3.093E+01	8.707E+03	5.170E+06



2-D Graphics Utility (ARMDGraph)

ARMDGraph is a graphics utility that employs a Workspace concept to manage multiple graphs with associations to single or multiple graphics output files. The workspace environment contains all user defined plot and chart configuration settings for graphics output files generated by ARMD solvers. The workspace configuration form consists of two panels. The left panel contains a tree view of the graphs, charts, and graphic output files. The right panel contains all chart and graph settings.

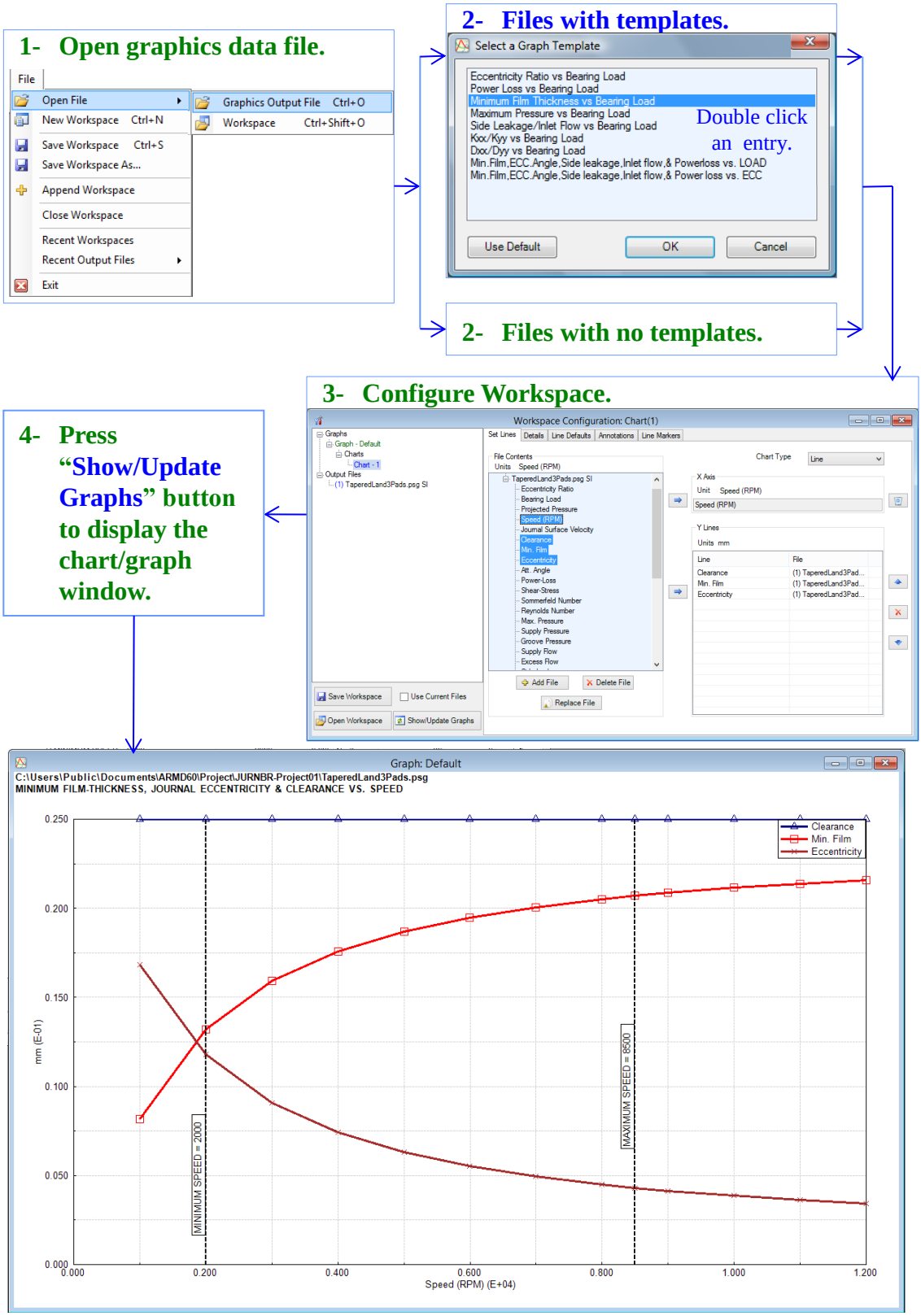


ARMDGraph features include:

- Workspace concept that contains all graph settings and linked graphics output files in one form customized by the user.
- Existing workspace can be easily applied to newly generated graphics output files.
- New graphical user interface to access and customize graphs.
- New file format (*.usrx) allows more customization of graphics data than previous (*.usr) format.
- Ability to create multiple graphs each of which may contain multiple charts.
- Ability to plot from two or more graphics output files.
- Backwards compatible with files generated by RBTSGRAF (*.usr) graphing utility.
- Customizable annotations and line markers.
- Automatic detection of graphics data file changes and updates.
- Plots can be rotated and copied to the clip board as bitmaps or enhanced metafiles.
- Utilizes GUI help system.
- Accelerator keys (hot keys) for accessing menu items and switching between charts.
- Multiple plots per window (1, 2, 3 or 4) including line, polar, and FFT plots.
- Templates for automatic configuration of graphs.
- Save/restore user options (*.USRX), for custom graphs, including:
  - Log, semi-log or linear axis scaling.
  - Automatic or manual axis scaling.
  - Grid lines (ON or OFF).
  - Legend position (hidden, inside or outside right).
  - Draw curves with lines, symbols or both.
  - Macro strings for flexible title assignment.

Graphics Utility **(ARMDGraph)**

With ARMDGraph, in few simple steps a workspace can be set up, saved and a graphical representation of simulation results from ARMD solvers can be generated as illustrated below.



Purchasing Options

ARMD is constructed from various solution modules. It can be tailored to suit your needs and budget. You may purchase any combination of programs/modules or all if you wish. Licensing is available as a single seat or multi-seat network configuration. With your purchase, the package includes the software (CD or download), quick start manual, electronic user's manual, technology transfer and training session (optional), updates, maintenance, and support.

System Requirements:

Personal computer with Microsoft Windows 8, 10, 11 or higher (32 or 64 bit).

Remember, with **RBTS**, you get more than just the programs, you get the company with more than 50 years of experience in the areas of tribology and machinery dynamics.

For further information, please contact us.

RBTS, Inc.

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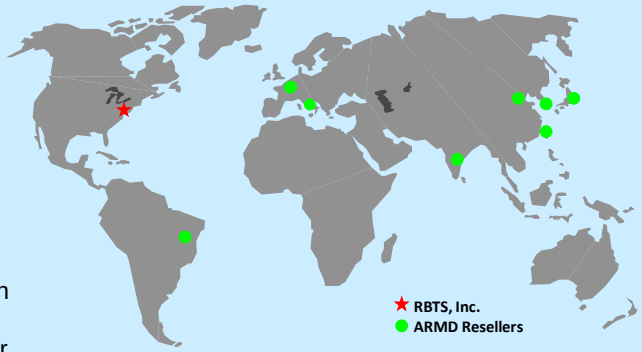
ARMD™ - The Worldwide Leading Software For Rotating Machinery Analysis

***A**dvanced **R**otating **M**achinery **D**ynamics*

ARMD is a well established software package used worldwide to perform complete rotating machinery dynamic analysis. ARMD employs a user-friendly interface and window environment with pull-down menus and context-sensitive help. ARMD integrates the most advanced and complete rotor dynamics, torsional vibration, and bearing analysis programs under one environment in a seamless fashion to give you the power to model your rotating machinery with ease, efficiency, and above all accuracy. Some applications in which ARMD has been utilized include rotating machinery such as a miniature air turbine for a dental drill, a large turbine generator set for a power plant, a small compressor for an air conditioner, a pump for an artificial heart, a fuel pump for a jet engine, an electric motor and spindle for a miniature computer hard disk, a canned pump for petrochemical processing plant, synchronous motor driven drive-trains, and a gear box for an Uranium enrichment plant.



RBTS' software has gained international reputation for its:

- **Technical Capabilities**
- **Completeness**
- **User Friendliness**
- **Support & Service**

RBTS, *Inc.*

Rotor Bearing Technology & Software
1041 West Bridge Street
Phoenixville, PA 19460, USA

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