

Advanced Rotating Machinery Dynamics

ARMD™

Version 6.0

THE COMPLETE SOFTWARE PACKAGE FOR

- Rotor Dynamics
- Torsional Vibration
- Fluid-Film Bearings
- Rolling-Element Bearings
- Lubricant Analysis



RBTS, Inc.

Rotor Bearing Technology & Software
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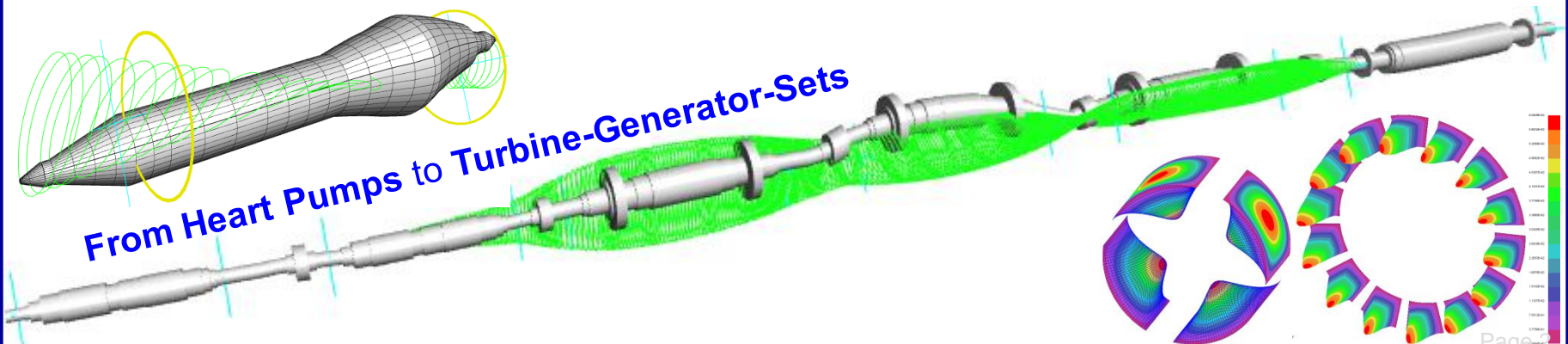
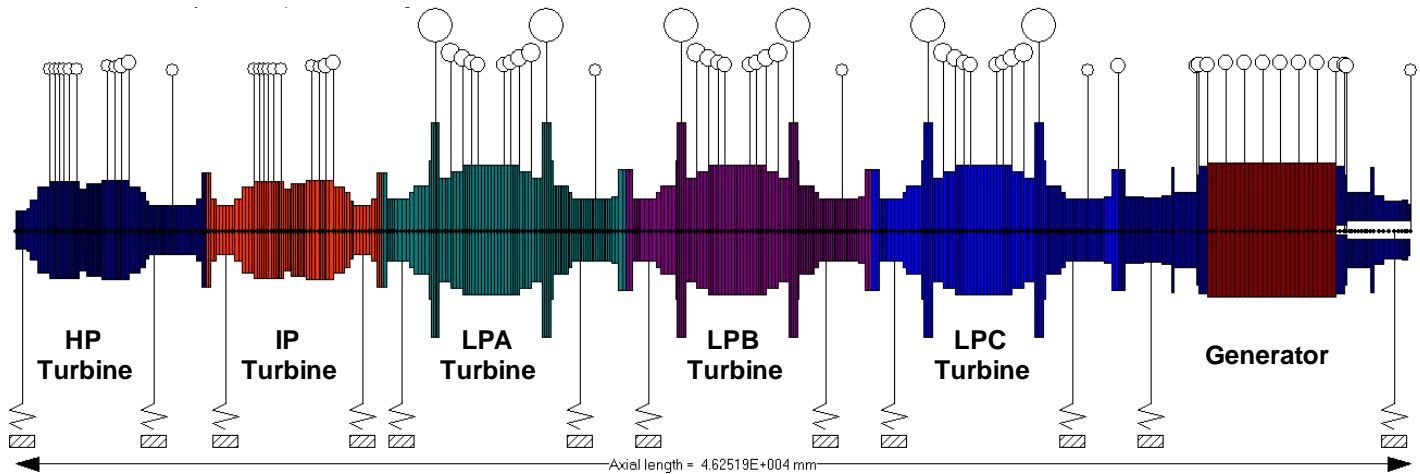
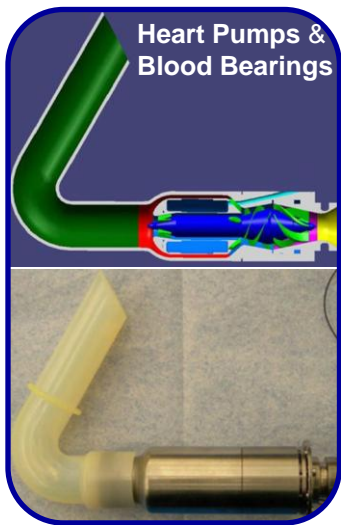
Rev:20190430

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Advanced Rotating Machinery Dynamics

ARMD™

THE COMPLETE SOFTWARE UTILIZED WORLDWIDE



Advanced Rotating Machinery Dynamics

ARMD is the most complete software package available to help you evaluate any bearing, rotor/bearing system, or mechanical drive train. Using leading edge technology and a host of valuable capabilities, **ARMD** has been proven effective and accurate in the design, analysis and trouble shooting of rotating machinery by machinery manufacturers, equipment packagers and end users around the world.

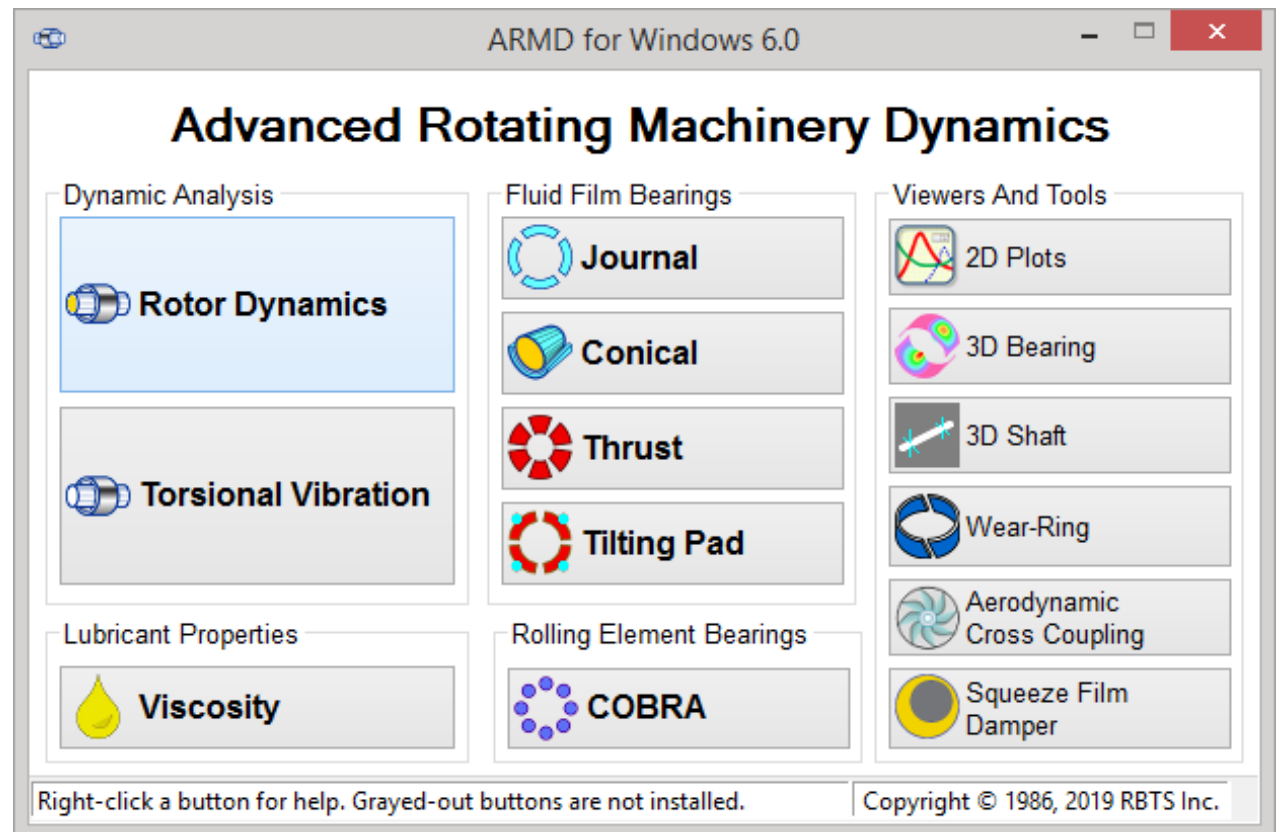
ARMD consists of five main modules:

- **Rotor Dynamics**
- **Torsional Vibration**
- **Lubricant Performance**
- **Bearing Analysis**
- **Utilities & Support Tools**

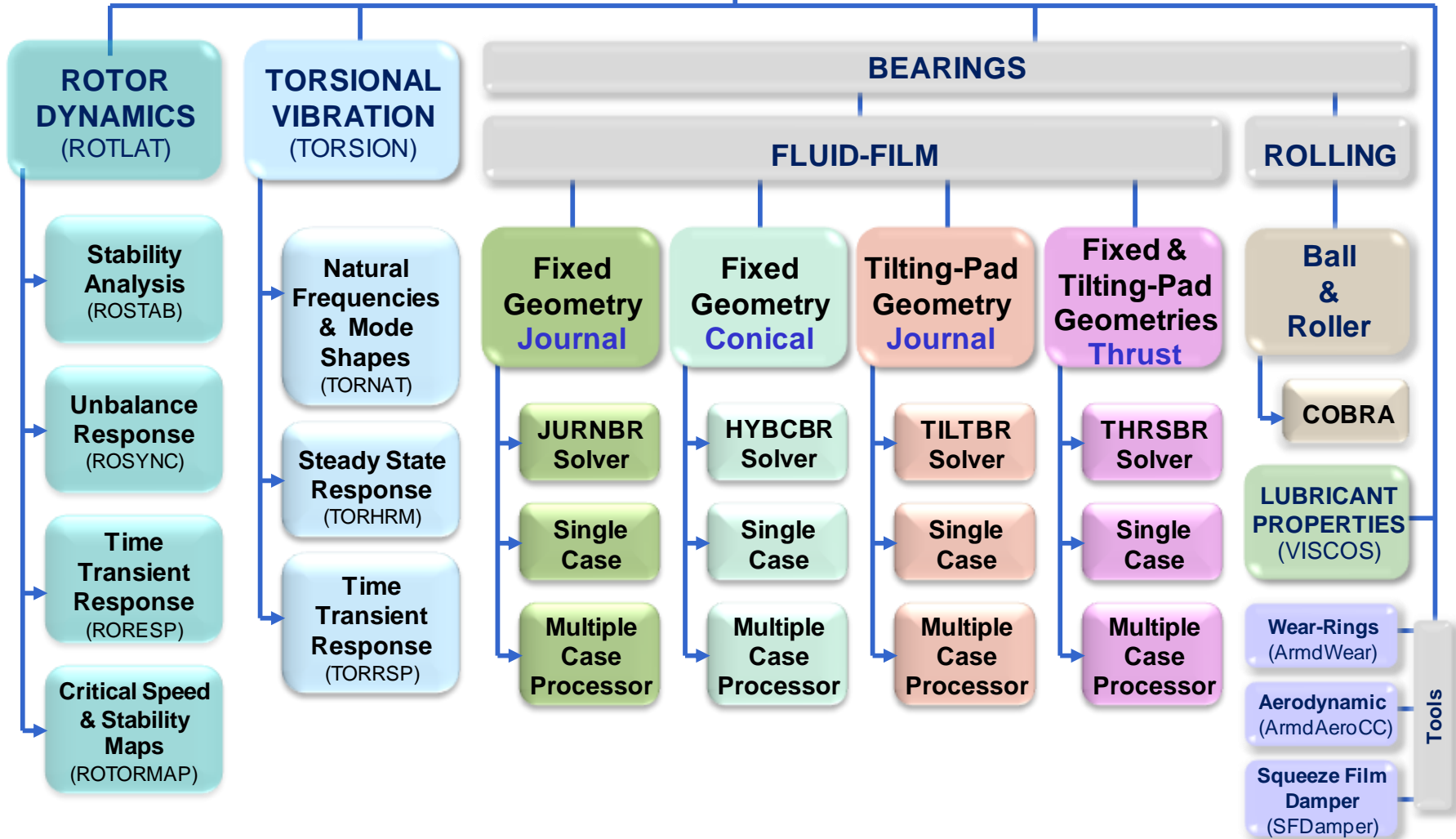
With a variety of features, including:

- **A user-friendly interface**
- **Advanced project and file management system**
- **Graphics/text capabilities**
- **Inter-module communication and data exchange**

All of which operate seamlessly
In an integrated environment.



ARMD



Rotor Dynamics (ROTLAT™)

The rotor dynamics lateral vibration analysis package ROTLAT is a finite element based software for performing damped and undamped natural-frequencies / critical-speeds, mode shapes, stability, unbalance response, and time-transient response. ROTLAT consists of four sub-modules: ROSTAB, ROTORMAP, ROSYNC, and RORESP integrated by ROTLAT's user interface. The user interface controls the sub-modules to provide a complete rotor/bearing system dynamic analysis environment integrating the rotating assembly with its support bearings, wear-rings, seals, aerodynamic effects, support structural flexibilities, etc.

ROTLAT incorporates advanced modeling features and capabilities including the following:

- Rotor of various configurations: Solid, Hollow, Tapered & Stepped.
- Shaft material damping.
- Gyroscopic effects (discs with angular degrees of freedom).
- Element geometry, stiffness diameter, or element stiffness (i.e. flexible connections or plates).
- Bearings of all types: Cylindrical, Conical, Tilting Pad & Rolling Element with/without moment stiffness or tilting-pad pitch degrees of freedom.
- Bearing models linked to rotating assembly at any station.
- Bearings vertical elevation for accurate bearings load computation of multi-bearing systems.
- Springs: wear-rings, seals, aero-dynamic effects, squeeze-film dampers, etc.
- Springs models linked to rotating assembly at any station.
- Bearings support systems; casing and foundations.
- Static foundation/pedestal flexibility (mass, stiffness and damping).
- Dynamic (frequency dependent) foundation flexibility.
- Discs: couplings, impellers, sleeves, etc.
- Moment release (pin-joint) at shaft stations.
- Multiple unbalance forces at any location and phase orientation along the shaft.
- External excitations and body forces: sinusoidal, step, ramp and pulse type functions.

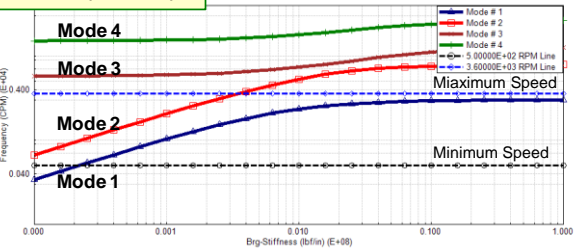
The screenshot shows the ROTLAT software interface. At the top, there are menu options: File, Edit, System, Options, Applied Loads, Run, View, Tools, Window, Project, Help. Below the menu is a toolbar with icons for New, Open, Save, Cut, Copy, Paste, and System Model. A 'Convert Units' checkbox is visible, with an 'Insert Value' field containing the mathematical expression $=((1.5^2+1.8^2)-3.13)$. The main window has several tabs: Materials, Elements, Discs, Bearings, Bearing Loads, Speeds, Static Pedestals, Dynamic Pedestals, Springs: Seals & More, Element Stiffness, and Station Moment Release. A table with columns for Material Number, Taper, Length, OD1, ID1, OD2, ID2, Use Stiffness Diam, Stiffness Diameter, User Specified Stiffness, and Name is displayed. A 'Shaft Element Selection Summary' dialog box is open, showing 'Shaft Length = 230.0 mm', 'Shaft Weight = 339.7528 kg', and 'Shaft Inertia (RR*) = 22.69731 kg-m²'. A 'Check for System Errors' button is highlighted with a red arrow labeled 'Data validation'. Other annotations include 'Auto Convert' pointing to the 'Convert Units' checkbox, 'Mathematical expressions evaluator' pointing to the 'Insert Value' field, 'Tabs' pointing to the main window tabs, and 'Tool Strip' pointing to the left-hand icons.

This screenshot shows two dialog boxes from the ROTLAT software. The 'Solver Options' dialog box has tabs for 'Solvers Options', 'Natural Frequencies / Mode Shapes', 'Unbalance Response', and 'Time Transient Simulation'. It contains sections for 'Features / Output Control' (with options to enable/disable automatic calculations), 'Gravitational body force factors' (with X and Y direction inputs), and 'Solver Options' (with checkboxes for stability analysis, unbalance response, steady state, time transient, critical speed map, and stability map). The 'Applied Loads' dialog box has tabs for 'Description', 'Solvers Options', 'Natural Frequencies / Mode Shapes', 'Unbalance Response', and 'Time Transient Simulation'. It displays a table of applied loads with columns for Station, Direction, Load, Frequency, Phase Angle, Start Time, End Time, and Name. The 'Natural Frequency' dialog box is also visible, showing 'Output Options' (Cycles/Minute, Hertz, Damping Ratio, Log Decrement) and 'Critical Speed/Stability Map Condensed Output'. A '9500 HP Motor Driving Reciprocating Compressor' diagram is shown at the bottom, with labels for 'Motor - 1 Bearing Support' and 'Compressor', and an 'Axial length = 6704.849 mm'.

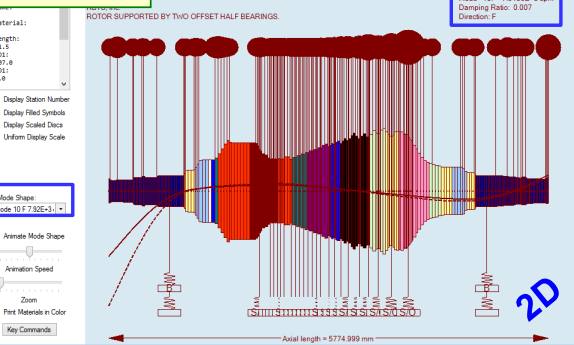
NATURAL FREQUENCY, MODE SHAPE & STABILITY

- Natural frequencies & mode shapes
- Damped and undamped simulation
- Stability parameters (damping ratio, logarithmic decrement)
- Rotor orbit direction (forward/reverse precession)
- Critical speed map
- Stability map / Campbell diagrams
- Bearing reaction forces
- Shaft weight, deflection, centerline slope
- Shaft moment, shear, & fiber stress diagrams

Critical Speed Map

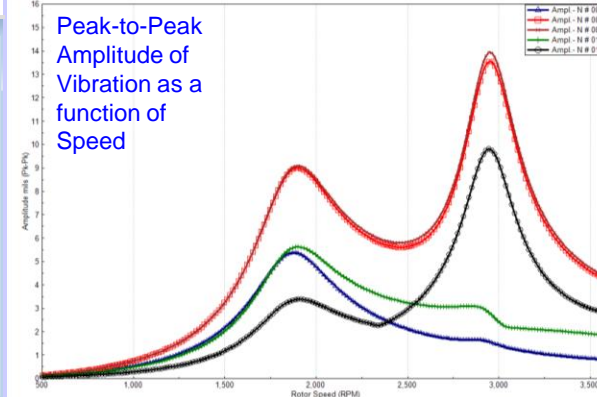
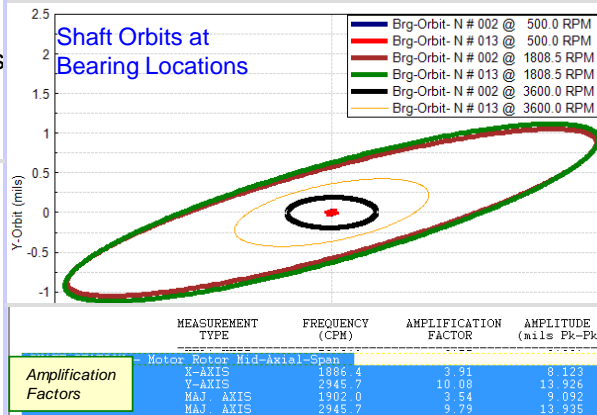


Mode Shape



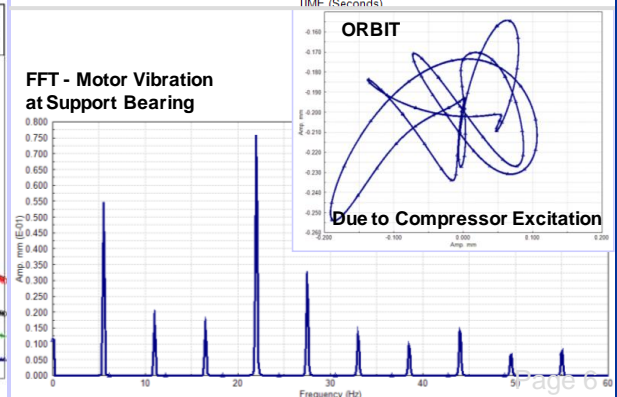
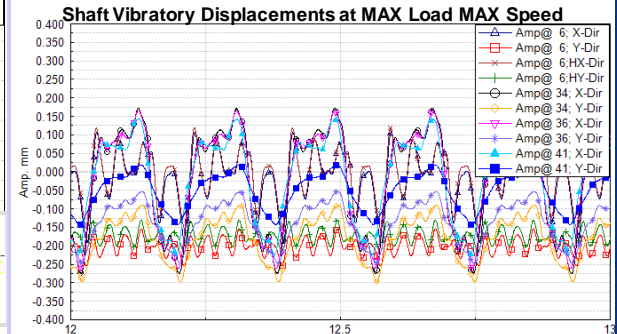
UNBALANCE RESPONSE (Synchronous response)

- Multiple unbalance planes/forces
- Magnitude and phase (Bode plot)
- Dynamic forces and moments
- Vibratory amplitudes and orbits
- Forces and moments transmitted to bearing and foundation
- Foundation vibratory amplitudes
- API Amplification factors



TIME-TRANSIENT RESPONSE (Non-synchronous response)

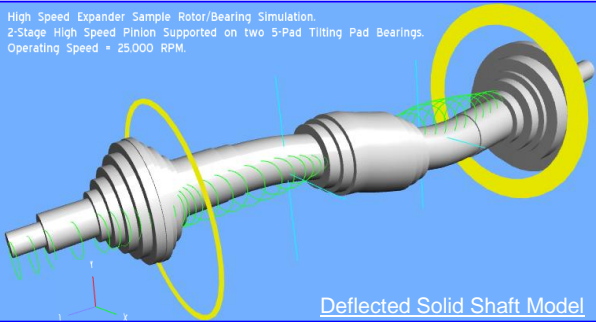
- Gravitational and external forces: Multiple sinusoidal, step, ramp, pulse and unbalance
- Vibratory amplitudes time history
- Rotor orbits
- Dynamic forces and moments
- Dynamic stresses
- Transmitted forces and moments
- Pedestal vibratory amplitudes



3-Dimensional Presentations of Lateral Rotor Dynamic Simulation Results for Enhanced Visualization & Diagnostics

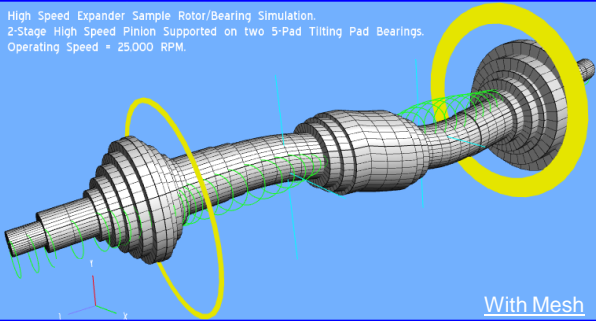
Various Options of Model & Mode Shape Presentation

High Speed Expander Sample Rotor/Bearing Simulation.
 2-Stage High Speed Pinion Supported on two 5-Pad Tilting Pad Bearings.
 Operating Speed = 25,000 RPM.



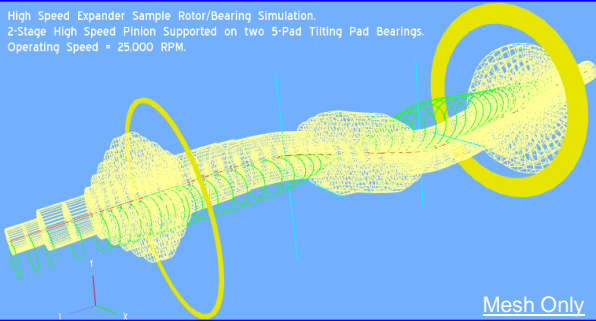
Deflected Solid Shaft Model

High Speed Expander Sample Rotor/Bearing Simulation.
 2-Stage High Speed Pinion Supported on two 5-Pad Tilting Pad Bearings.
 Operating Speed = 25,000 RPM.



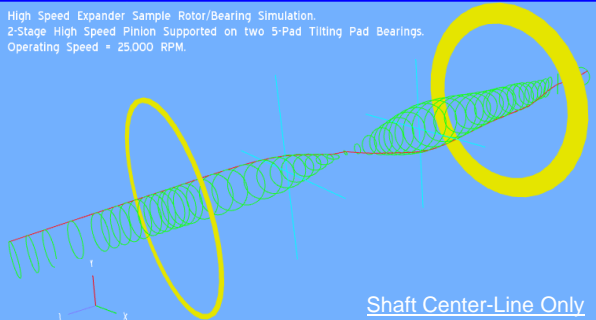
With Mesh

High Speed Expander Sample Rotor/Bearing Simulation.
 2-Stage High Speed Pinion Supported on two 5-Pad Tilting Pad Bearings.
 Operating Speed = 25,000 RPM.



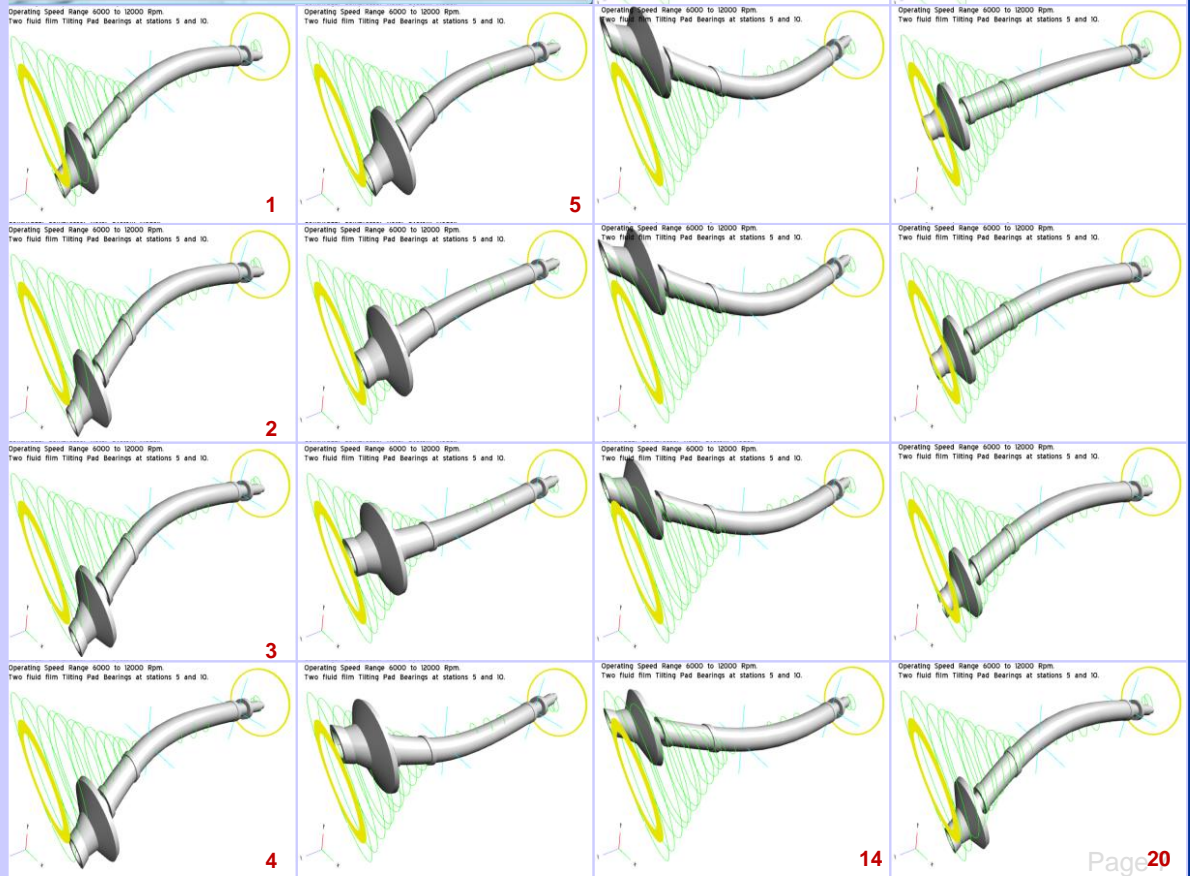
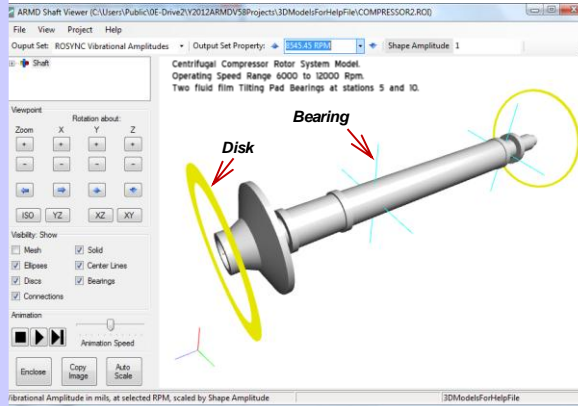
Mesh Only

High Speed Expander Sample Rotor/Bearing Simulation.
 2-Stage High Speed Pinion Supported on two 5-Pad Tilting Pad Bearings.
 Operating Speed = 25,000 RPM.



Shaft Center-Line Only

Animated Unbalance Response



Torsional Vibration (TORSION™)

The torsional vibration package uses a finite-element based formulation for performing damped and undamped torsional natural frequencies, mode shapes, steady-state and time-transient response of mechanical drive trains. TORSION consists of three sub-modules: TORNAT, TORHRM and TORRSP integrated by TORSION's user interface. The user interface controls the sub-modules to provide a complete torsional vibration analysis environment.

TORSION accepts/imports models generated with the rotor dynamics package "ROTLAT" and has the same advanced modeling features and capabilities including the following:

- Modeling of multi-shaft/multi-branch systems
- Coupling torsional stiffness and damping
- Gear tooth flexibility
- Element stiffness/mass/inertia diameter
- Torsional springs to ground
- Various types of external excitations
- Synchronous motor start-up torque
- Load torques from such equipment as compressors, pumps, fans, mills, etc.
- Electrical faults for motor and generator
- User specified time varying torques
- Many more...

The screenshot displays the TORSION software interface. The main window is titled "System" and contains a table of elements. A dialog box titled "Shaft Element Selection Summary for Rows 8 - 11" is open, showing the following data:

Shaft Length = 54.0 inch	
Shaft Weight = 967.4572 lbf	
Shaft Inertia (WR ⁴) = 10222.04 lbf-in ⁴	
Shaft Stiffness = 1.194514e+08 in-lbf/radian	

Total Inertia (WR ⁴) = 10222.04 lbf-in ⁴ (Shaft + Disc)	

The "Options" dialog box is also open, showing the "Steady State Response" tab. The "Branch#1 Speed Range Options" section is selected, with the following settings:

- Compute steady state response over a range of speeds as specified here:
- Minimum speed: 540.0 RPM
- Maximum speed: 1320.0 RPM
- Speed increment: 1.0 RPM

The "Applied Torque Tables" window shows a table of harmonic torques:

Branch	Station	Harmonics	Edit Table	Import File #	Table No.	Phase
1	1	5	1	Manual	Manual	
2	1	5	1	Manual	Manual	
3	1	5	1	Manual	Manual	
4	1	5	1	Manual	Manual	
5	1	5	1	Manual	Manual	

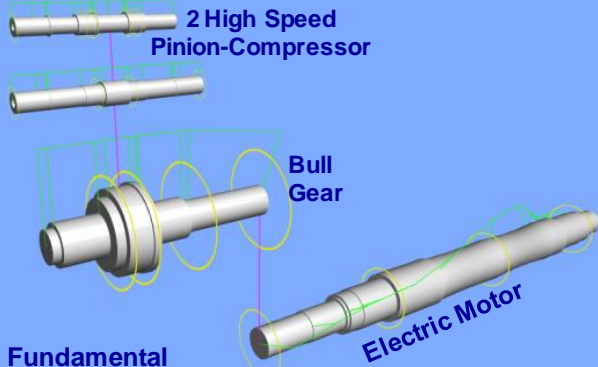
The "Steady State Torque Effort 2" dialog box shows the following data:

Harmonic Order	Sine Component	Cosine Component
1	2.0	275652.0

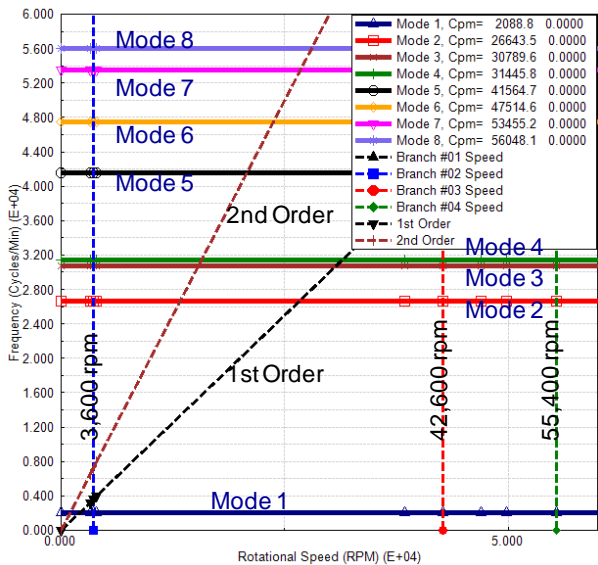
A shaft diagram is visible at the bottom of the interface, showing a shaft with 17 stations and various components.

NATURAL FREQUENCIES & MODE SHAPES

- Damped and undamped simulation
- Natural frequencies
- Growth factors and damping ratios
- Vibration mode shapes
- Critical speed map / Campbell diagrams

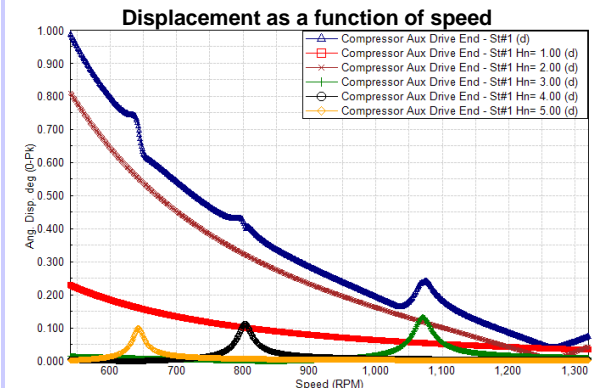
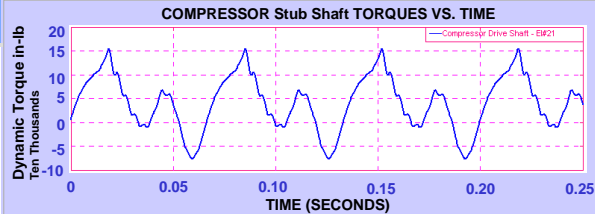
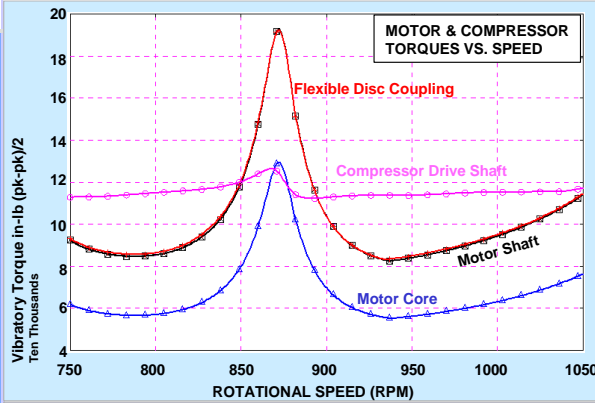


Fundamental Torsional Twist Mode



STEADY STATE RESPONSE

- Vibratory amplitudes (displacement, velocity and acceleration)
- Dynamic torques
- Dynamic stresses
- Dynamic heat dissipation

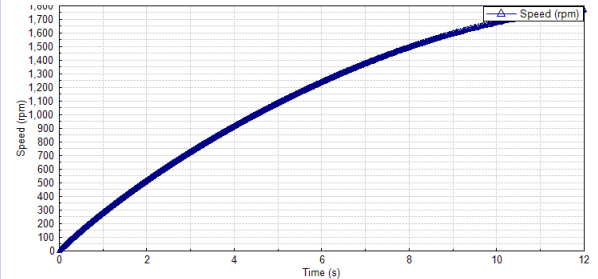


TIME-TRANSIENT RESPONSE

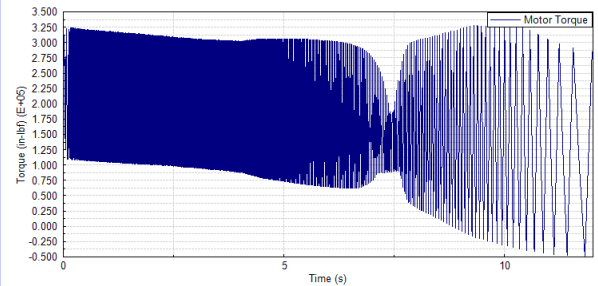
- Dynamic shaft-torque time-history
- Dynamic stresses
- Fatigue life

Sample of synchronous motor-gearbox-compressor time-transient startup and calculated system response torques.

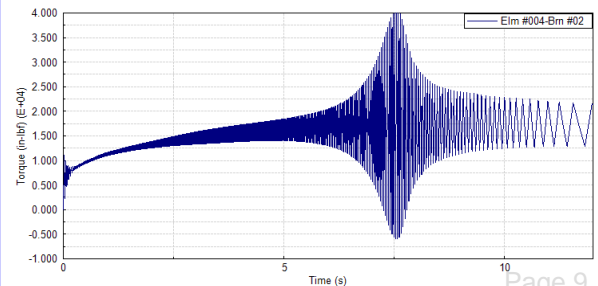
Motor Startup Speed



Motor Startup Average Torque



High Speed Shaft Torque

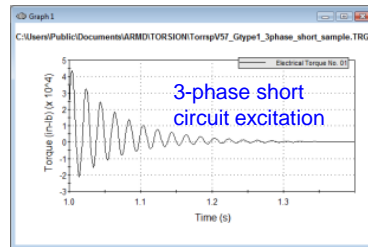


Time varying excitations include:

- Electrically induced exciting torques, associated with generator and induction motor operation, can be considered in the time-transient response simulation module.

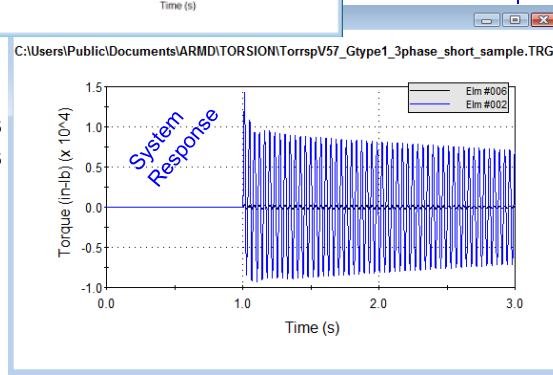
Generator

- Type 1: 3-phase short circuit
- Type 2: Line-to-Line short circuit
- Type 3: False-coupling short circuit



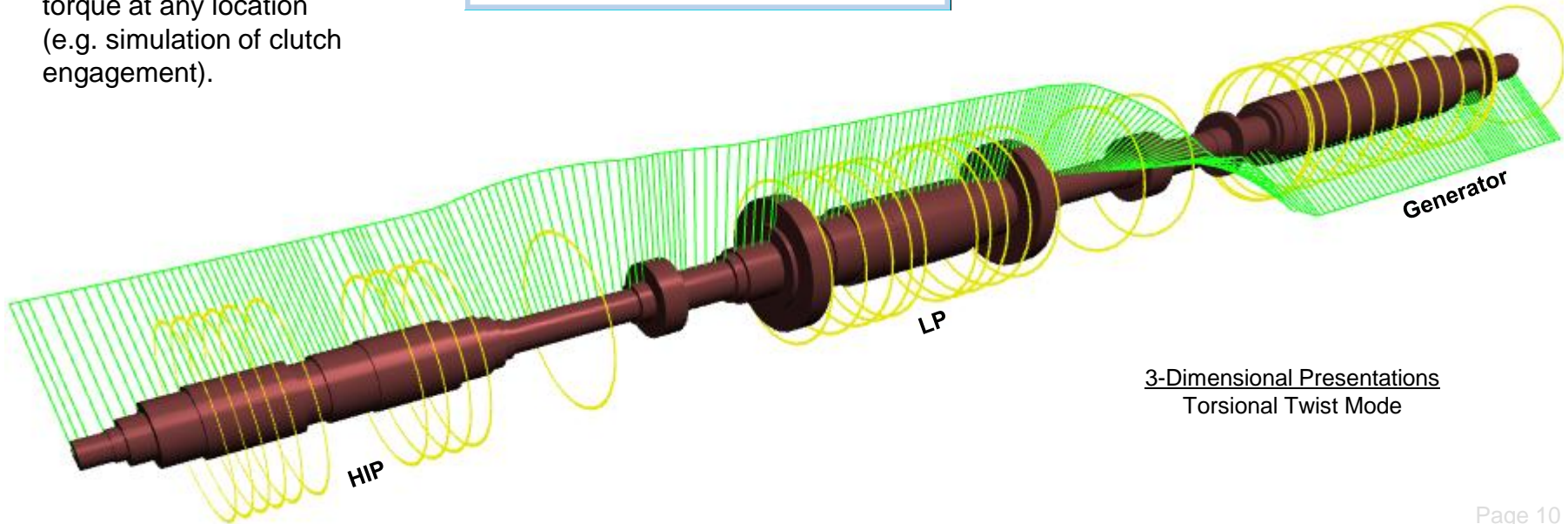
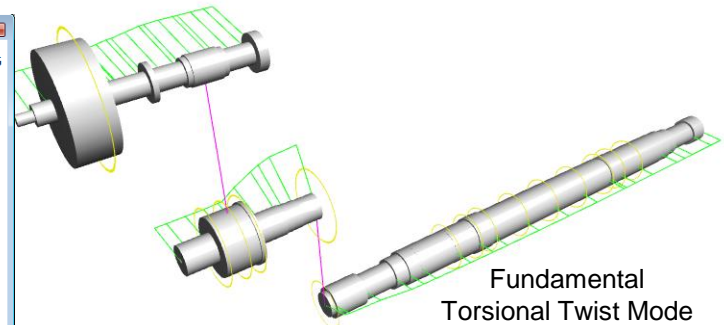
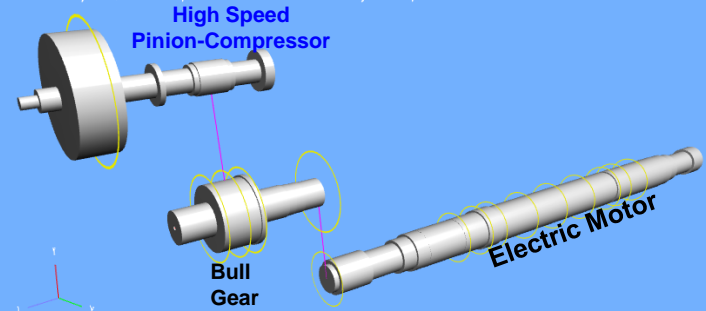
Induction Motor

- Type 4: Start from standstill (across the line start)
- Type 5: 3-phase short circuit at terminals
- Type 6: 2-phase short circuit at terminals
- Type 7: High-speed automatic reclosing



- User torque table (.csv file format) representing time-varying exciting torque at any location (e.g. simulation of clutch engagement).

Torsional Vibration Analysis - Natural Frequency, Mode Shapes & Response
Three Branch System, 1 to 8 Speed Increaser For Centrifugal Compressor.



3-Dimensional Presentations
Torsional Twist Mode

Bearings

Fluid-Film Lubricated Journal & Thrust Bearings with Fixed or Tilting-Pad Configurations
Practically any Bearing or Bearing System Available in the Industry can be Analyzed

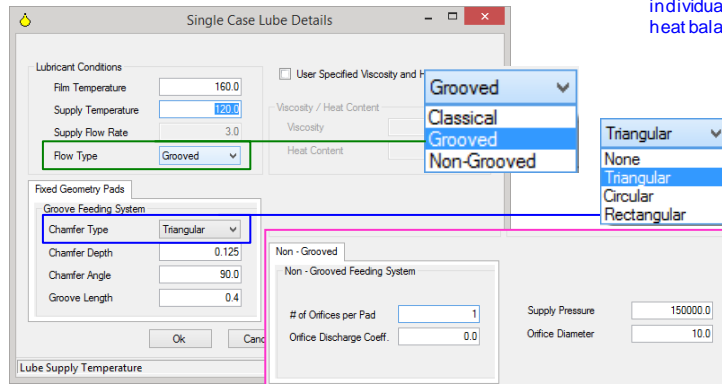


The ARMD software package has the capabilities of evaluating both fluid-film and rolling-element bearings. Practically any bearing or bearing system available in the industry can be modeled and evaluated with one of the bearing solution modules.

The FLUID-FILM bearing modules (JURNBR, HYBCBR, TILTR, and THRSBR) solve the lubrication problem in two dimensions eliminating any approximation typically associated with one dimensional analysis or with look-up table methods.

Complete performance predictions of hydrodynamic, hydrostatic, and hybrid lubricated journal, conical and thrust bearings operating in the laminar and/or turbulent regime can be generated.

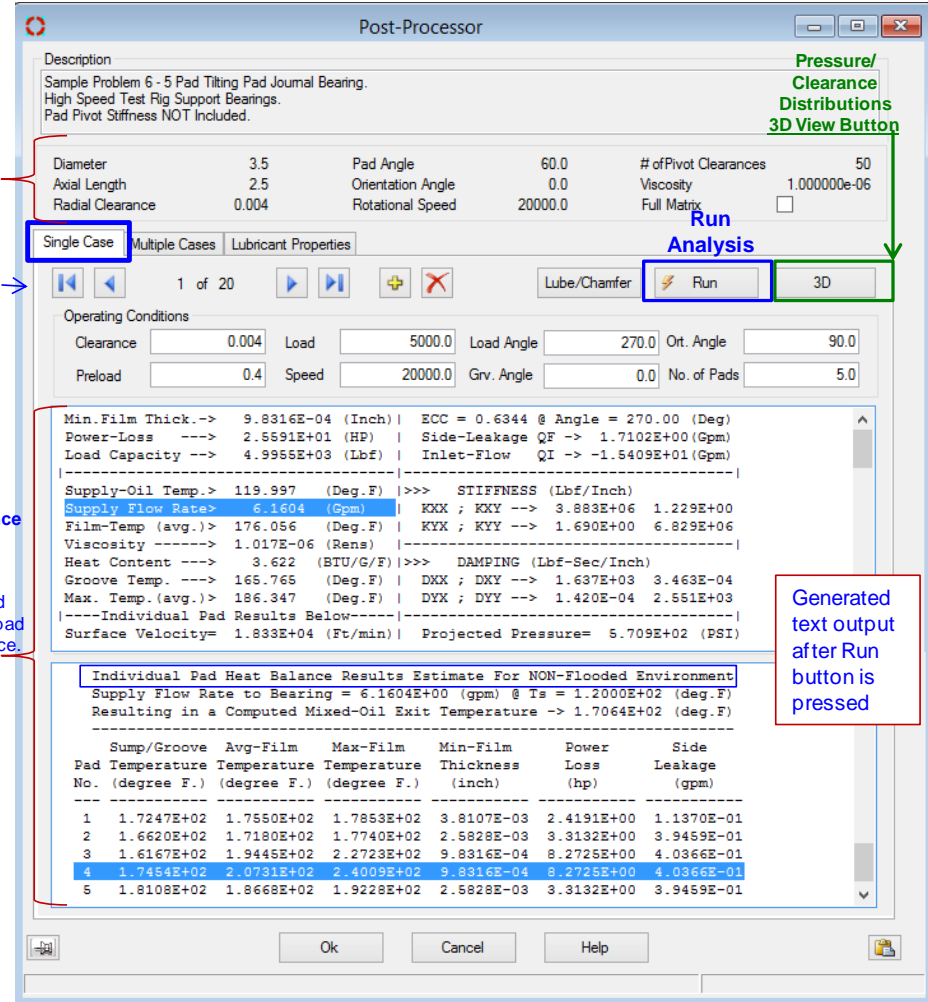
Simulation capabilities include such effects as misalignment, pressurized boundaries or grooves, cavitation, surface deviations (structural deformation), lubricant feed circuitry with specified pressures or restrictors (capillary, orifice, or flow control valve), groove geometry and chamfers.



Modeled Bearing Details

Scroll through cases.

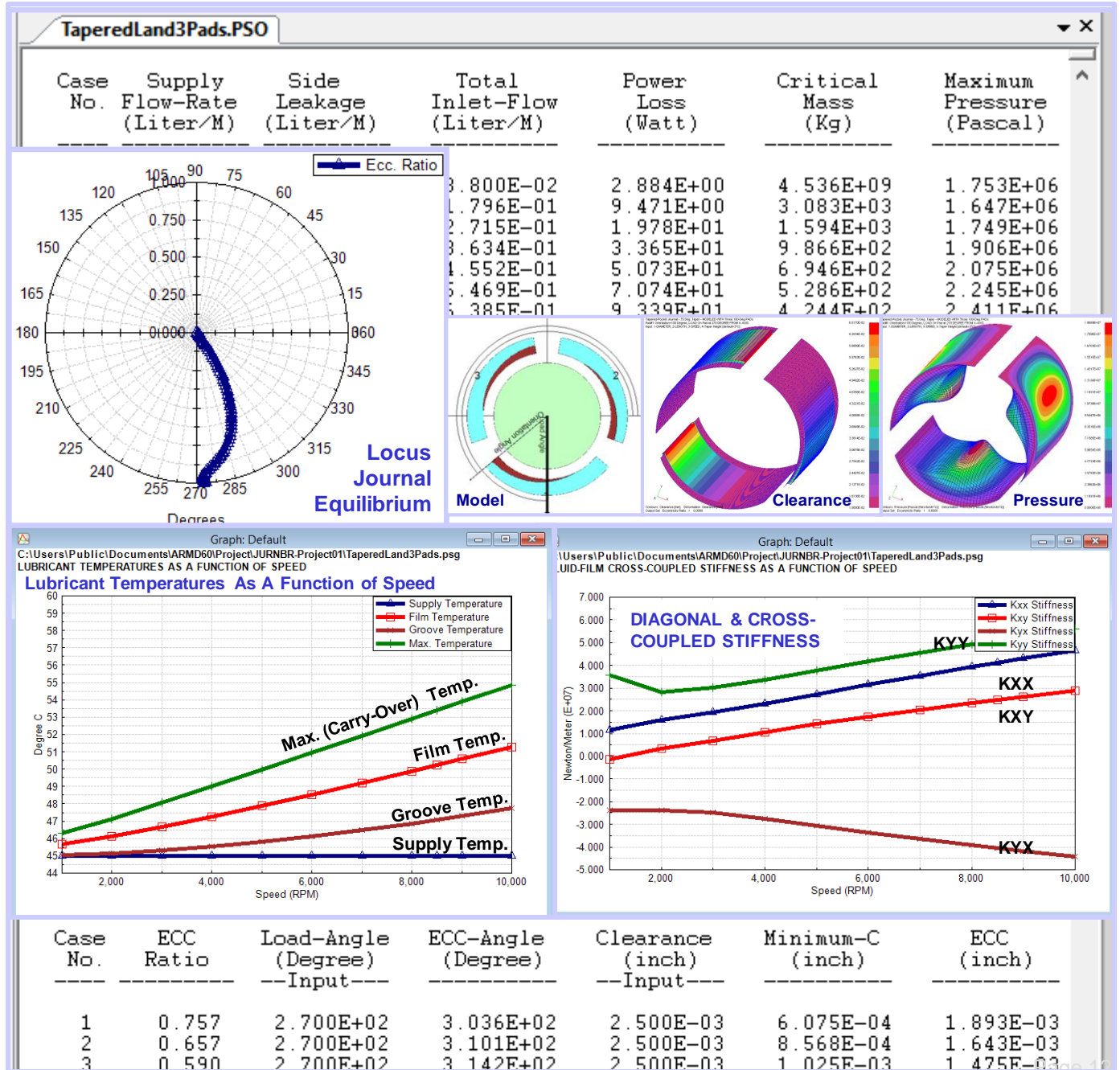
Complete Bearing Performance Results including bearing system and individual pad heat balance.



Generated text output after Run button is pressed

Results include:

- Load capacity / journal position
- Attitude angle
- Viscous power loss
- Righting moments
- Flow requirements
- Stability (bearing whirl)
- Spring and damping coefficients
- Clearance and pressure distribution
- Recess pressures and flows
- Heat balance and temperature rises



The **FLUID-FILM** bearing modules incorporate numerous templates for common bearings used in industry. In addition, bearing configurations that can be evaluated with the various solution modules include but not limited to:

Fixed Geometry Cylindrical and Conical Journal Bearings (JURNR & HYBCBR)

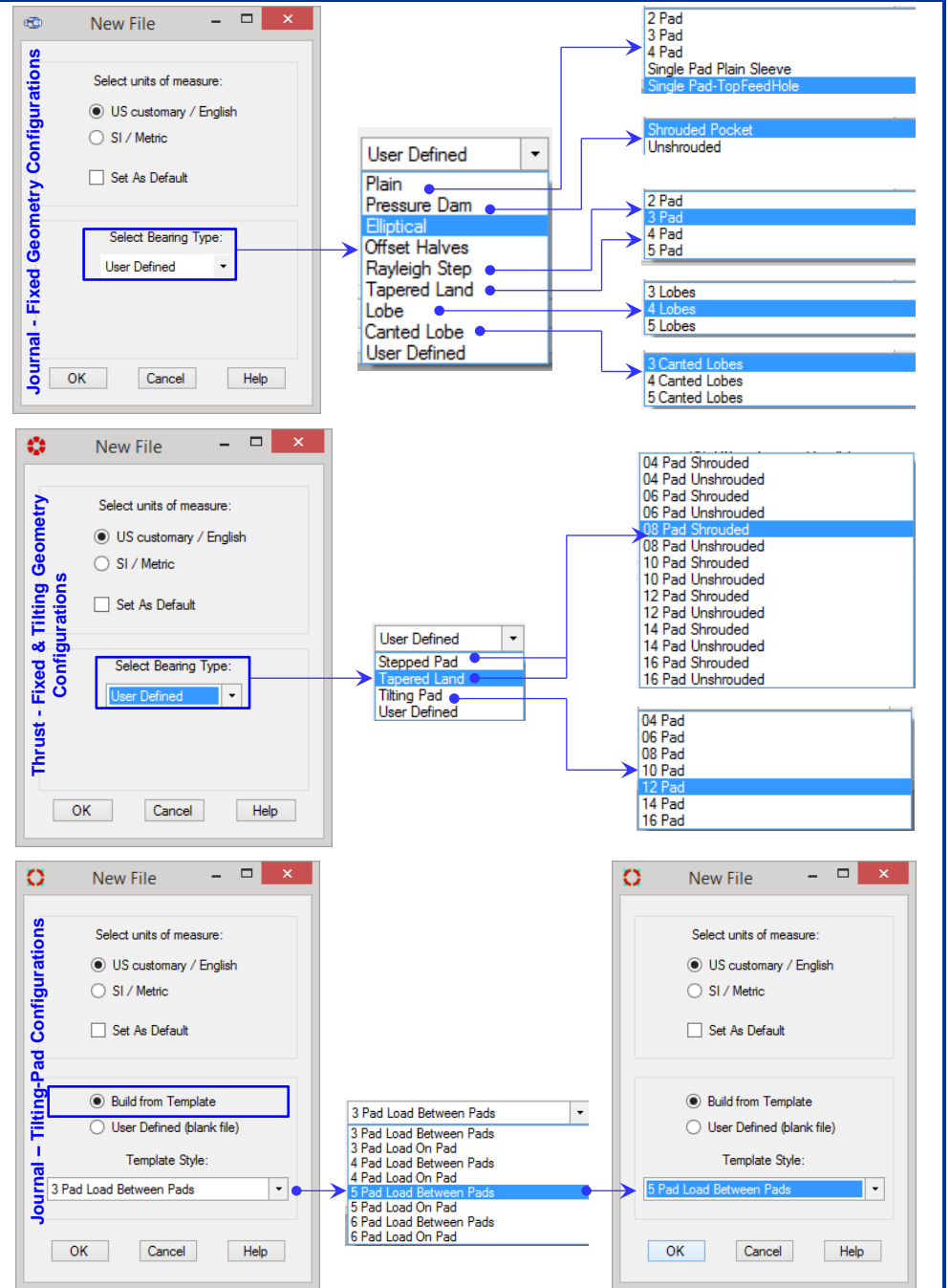
- Plain surface
- Multi-groove
- Pressure dam
- Elliptical or lemon
- Rayleigh step or pocket
- Tapered land
- Lobe or canted lobe
- Any configurable pad surfaces
- Multi-recess

Fixed and Tilting-Pad Geometry Thrust Bearings (THRSBR)

- Plain surface
- Multi-groove
- Step land
- Step pocket
- Tapered land
- Tapered pocket
- Tilting pad
- Compound taper
- Any configurable pad surface

Tilting-Pad Journal Bearings (TILTBR)

- Central pivot
- Offset pivot
- Evenly spaced pads
- Grouped pads
- Load between pads
- Load on pad
- Any load direction
- Any preload
- Leading/trailing edges taper
- Fluid-inertia force effects

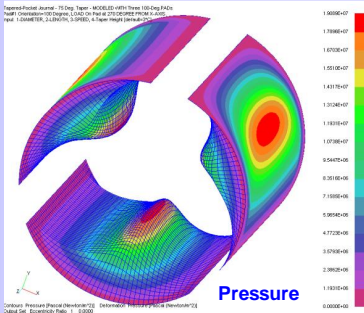
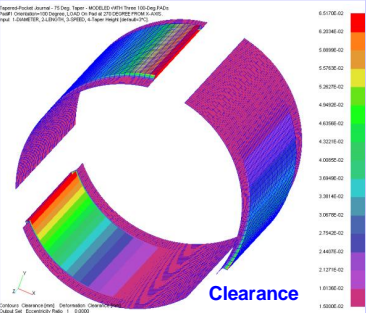


Sample Presentations – 3D Fluid-Film Bearing Pressure & Clearance Distributions.

Sample - Three (3) pad, fixed geometry cylindrical journal bearing, with tapered pocket configuration for high speed multi-stage centrifugal compressor operating at 8500 rpm.

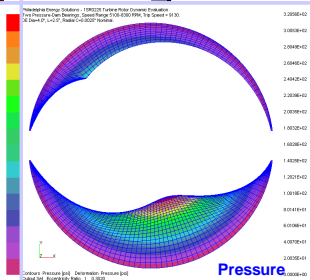
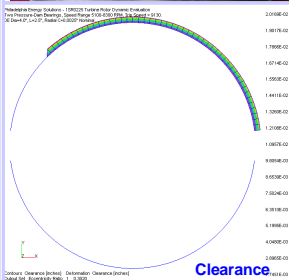
Bearing Model: C:\Users\Public\Documents\ARM6060\Project\URNRBR.Prj
 Tapered Pocket Journal - 75 Deg. Taper - MODELED WITH Three 100 Deg Pads
 Pad(s) Orientation: 200 Degree, LOAD On Pad at 270 DEGREE FROM X AXIS
 Inlet: 1.0 DIAMETER, 2 LENGTH, 3 SPEED, 4 Taper Height (MFA=1) C1
 Number of Pads: 3
 Pad Angle, degree: 75
 Orientation Angle, degree: 100.0
 Clearance, mm: 25.0
 Axial Length, mm: 25.0
 Radial Clearance, mm: 0.200
 Load Angle, degree: 270.0
 Speed, RPM: 8500.0
 Taper Height, mm: 0.05

Model



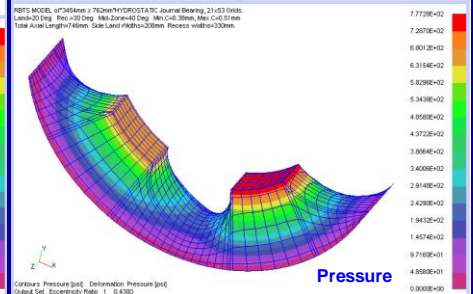
Sample – Pressure-Dam Journal Bearing for High Speed Turbine Application Operating at 9300 rpm

Model



Sample Hydrostatic/Hybrid Bearing for Mining Application

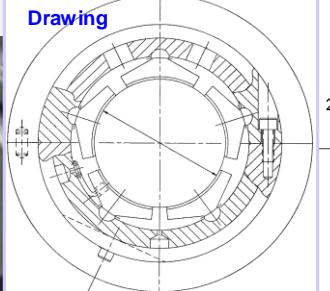
Model



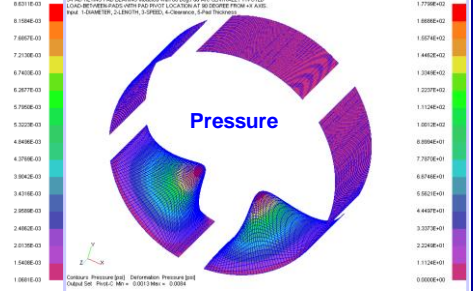
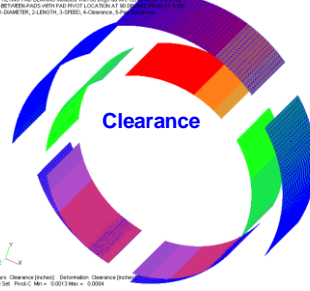
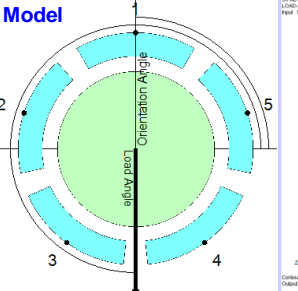
Journal Bearing – Unloaded Half



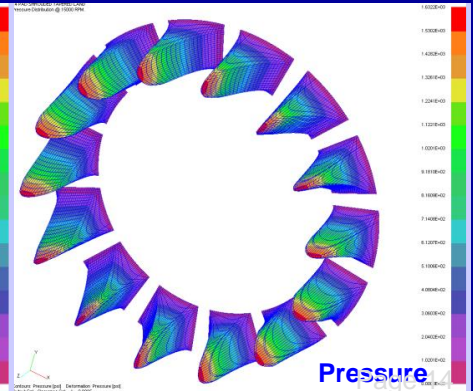
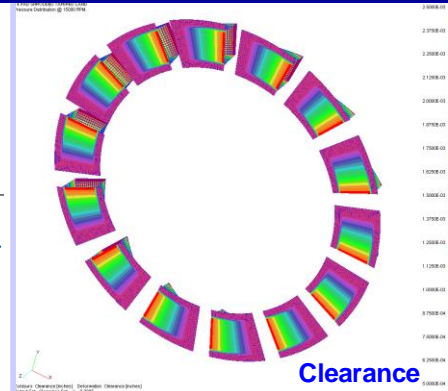
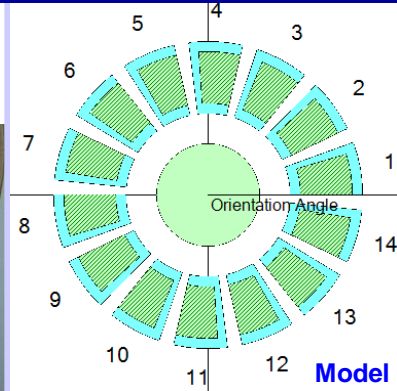
Drawing



Model



Sample - Gearbox Thrust Bearing 14 pad shrouded tapered land configuration operating at 15KRPM



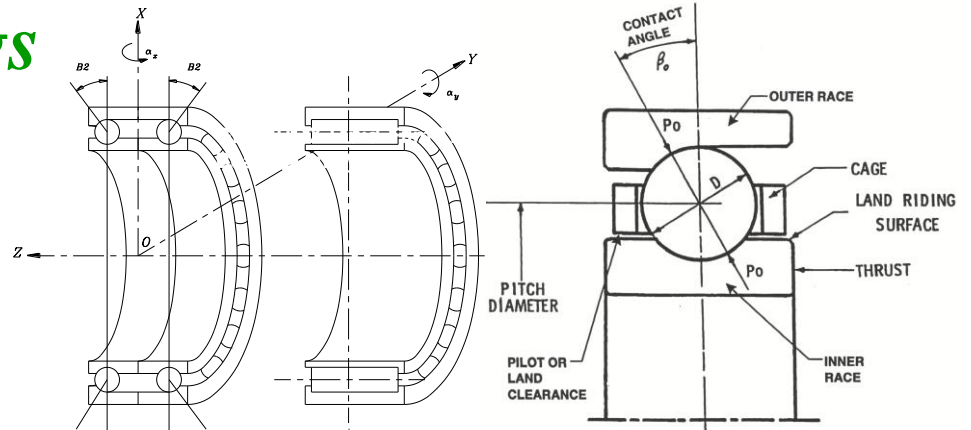
Rolling-Element Bearings

The **ROLLING-ELEMENT** bearing module [**COBRA**] predicts the performance of up to six bearings of different types mounted on a shaft and experiencing radial, thrust and moment loading. Bearing types include:

- Conrad (radial) ball
- Angular contact ball
- Cylindrical roller
- Tapered roller
- Spherical roller

The program allows the evaluation of misalignment, offsets, preload, clearance, or end-play on bearing performance. Bearing preload from spacer grinding or shimming, as well as preload springs is included. Individual bearings can be made to "float". Results include:

- Ball load distribution
- Stress distribution
- Bearing reaction loads & displacements
- System reaction loads & displacements
- Hertz contact stress
- B10 life
- Contact angles
- Spring/stiffness rate



COBRA Input Parameters:

- Descriptive Title: Sample 1 EHL Release 1.2 Mineral Oil
- Shaft Speed: 1500 (RPM)
- Shaft Rotation: Shaft rotates with respect to Load
- Problem Type: Loads are specified
- Loading Direction(s): radial (X), axial (Z), moment (about Y)
- Loads (applied to the Shaft at system origin):
 - Radial Load along X: -2000
 - Thrust Load along Z: 1000
 - Moment Load about Y: 500
- Initial Displacement Guesses (usual):
 - along radial X-axis: -0.003
 - along axial Z-axis: 0.002
 - tilt about Y-axis: 0.001

COBRA Output Results:

Results: Sample 1 EHL Release 1.2 Mineral Oil

Unadjusted System B10 Life (hrs) = 1.241E-03 6 Iterations
 Adjusted System B10 Life (hrs) = 4.500E-03
 Shaft Speed (rpm) = 1.500E+03

--FORCES--			--DISPLACEMENTS--		
Radial (Along X)	Thrust (Along Z)	Moment (About Y)	Radial (Along X)	Axial (Along Z)	Angular (About Y)
Appld -2.000E+03	1.000E+03	5.000E+02	Guess -3.000E-03	2.000E-03	1.000E-0
Reactn 2.010E+03	-1.007E+03	-4.452E+02	Soln -1.375E-02	1.658E-02	1.931E-0

Life Adjustment Factors:

Bearing No.	1	2	3	4
Reliability:	1.000E+00	1.000E+00	1.000E+00	1.000E+00
Material:	2.200E+00	2.200E+00	2.200E+00	1.370E+00
Lubrication:	2.333E-01	2.333E-01	2.100E-01	6.000E+00

Results (shown above) are current w/r/t worksheet data.

Lubricant Module (VISCOS)

The **LUBRICANT** module [VISCOS] calculates temperature dependent properties of lubricating fluids. The program requires the user to specify lubricant published properties or to select them from the built-in lubricant database.

VISCOS generates, as a function of temperature, such parameters as:

- ◆ Absolute viscosity
- ◆ Kinematic viscosity
- ◆ Saybolt universal viscosity
- ◆ Specific gravity
- ◆ Weight density
- ◆ Specific heat
- ◆ Heat content
- ◆ Thermal conductivity

Viscosity Data

Heading:
 Sample Problem Number 1.
 SHELL TURBO Oil T 32 for 18000 rpm Turbine bearings
 Last line of problem description.

Supplier: SHELL
 Brand: TURBO Oils T 32
 ISO Grade: 32 API gravity: 32.200
 First centistoke: 32.00 at 104.00 °F

Library Help

Lubricant Properties Library

LUBRICANT		VISCOSITY					
Supplier	Brand Name and No.	ISO Grade	API @60.0°F	cSt	@°F	cSt	@°F
SAE	40	140	25.550	140.00	104.00	14.70	212.00
SAE	5W-20	38	32.270	38.00	104.00	6.92	212.00
SHELL	Diala AX	10	28.380	9.30	104.00	2.60	
Shell	Omala 100	100	28.600	100.00	104.00	11.40	
SHELL	OMALA 150EP	150	27.000	150.00	104.00	14.50	
SHELL	TELLUS/TURBO 32	32	30.500	32.00	104.00	5.70	
SHELL	TURBO Oils T 32	32	32.200	32.00	104.00	5.48	
SHELL	TURBO 46	46	29.700	46.00	104.00	6.80	
SHELL	TURBO Oils T 46	46	31.800	46.00	104.00	6.90	
SHELL	TURBO 68						
SHELL	TURBO Oils						
SHELL	TURBO Oils						

VISCOS has a built-in lubricant data-base that can be accessed to retrieve lubricant properties. The data-base is user-friendly with capabilities for users to add and delete records as they wish.

C:\Users\Public\Documents\ARM58\VISCOS\VISCOS-1.vso

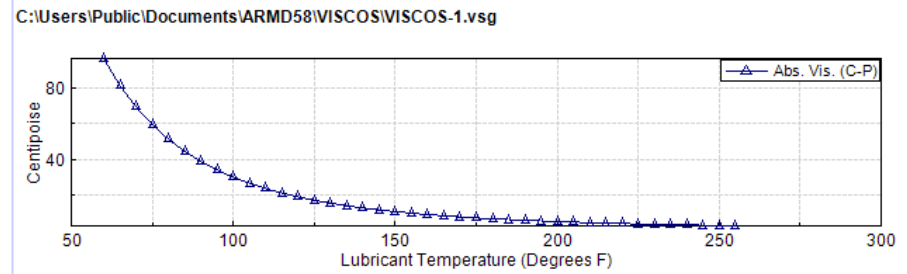
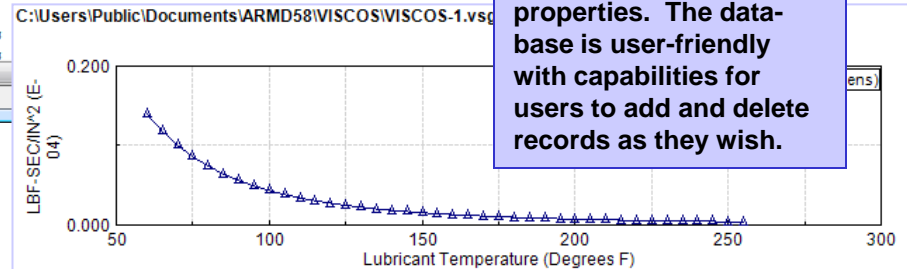
Last line of problem description.

*** Units of Measure for this Run are --> US (English)

TABLE WAS GENERATED FOR THE FOLLOWING LUBRICANT:

Supplier --> SHELL, Brand Name --> TURBO Oils T 32
 API Gravity [@ 60°F/15.556°C] = 0.32200E+02 ISO Grade Number -> 32
 1st Viscosity point (Centistoke) = 0.32000E+02 @ Temp. (°F) = 0.10400E+03
 2nd Viscosity point (Centistoke) = 0.54500E+01 @ Temp. (°F) = 0.21200E+03
 Computed SUS sec.@ 100°F/37.778°C = 0.16498E+03
 Computed SUS sec.@ 210°F/98.889°C = 0.44522E+02

Temperature Degrees F.	Absolute - Viscosity		Kinematic Viscosity Centistoke= (M ² /s)*E+6	Saybolt Universal Viscosity (Sec.)	Specific Gravity (Gm/C ³)= (Kg/m ³)*E-3
	(Rens) Lb-Sec/In ²	(Pa-s*1000)			
60.000	0.13958E-04	0.96239E+02	0.11134E+03	0.51463E+03	0.8644
65.000	0.11794E-04	0.81315E+02	0.94280E+02	0.43601E+03	0.8625
70.000	0.10036E-04	0.69196E+02	0.80407E+02	0.37209E+03	0.8606



Wear-Rings tool

ArmdWear is an ARMD utility for computing wear-ring/seal performance properties including dynamic coefficients (stiffness and damping) of incompressible fluids such as those found in boiler feed pumps.

The computation is based on Black and Jenssen "Effect of High Pressure Ring Seals on Pump Rotor Vibrations". The simulation in ArmdWear can be performed for a single point of operation or as a function of operating parameters such as Diameter, Length, Clearance, Pressure Drop, Speed, Fluid Viscosity or Density.

Wear-ring input data files can also be linked to ARMD rotor

models developed in the rotor dynamic package ROTLAT, for automatic wear-ring dynamic coefficients (stiffness & damping) calculations and inclusion in the rotor dynamic simulations.

The screenshot displays the ArmdWear software interface. The window title is "ArmdWear (C:\Users\Public\Documents\ARMD58\ArmdWear\Samples\WearUS.WIN US)". The menu bar includes File, Edit, Run, View, Project, and Help. The main area is divided into several sections:

- Heading:** Header 1: Impeller Wear Ring Stiffness & Damping Calculations; Header 2: Prepared for Texaco, LA, CA; Header 3:
- Case Selection:** Single Case (selected) and Multiple Case.
- Parameters:** Diameter (4.73500E+000), Length (8.68500E-001), Clearance (2.50000E-002), Pressure Drop (3.00000E+002), Speed (3.60000E+003), Entrance Loss (0.00000E+000), Viscosity (3.04530E-007), Density (8.13430E-001).
- Case Information:** Case 15 of 20.
- Run Case:** A button to execute the simulation.
- Computed Results:** A text area showing performance results for Case 15. A blue box highlights the text: "User Specified Operating Conditions and Lubricant Properties".
- Generated Text:** A blue box highlights the text: "Generated Text Output after Run Button Pressed".

The bottom section of the screenshot shows a table of input data for multiple cases:

	Diameter	Length	Clearance	Pressure Drop	Speed	Entrance loss	Viscosity	Density
1	4.73500E+000	8.68500E-001	2.50000E-002	2.00000E+001	3.60000E+003	0.00000E+000	3.04530E-007	8.13430E-001
17	4.73500E+000	8.68500E-001	2.50000E-002	3.40000E+002	3.60000E+003	0.00000E+000	3.04530E-007	8.13430E-001

The bottom status bar shows "Wear-ring/seal diameter" in "inch" and "Project not open".

Aerodynamic Cross Coupling tool

ArmdAeroCC is an ARMD utility for computing gas compressor Aerodynamic Cross Coupling Destabilizing Effects. The computation can be based on one of the following:

- A- API 617 for centrifugal impeller.
- B- API 617 for axial flow rotor.
- C- ALFORD's equation.
- D- WACHEL's equation.

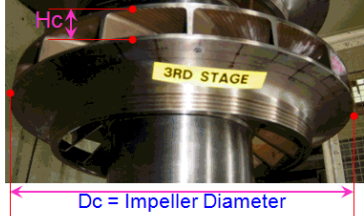
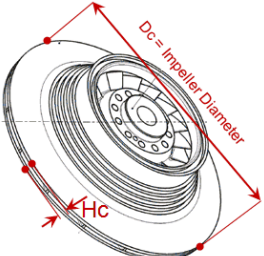
The simulation can be performed for a single point of operation or as a function of input parameters such as power, impeller diameter, impeller discharge clearance, ratio of discharge to suction densities, etc.

Created input data files can be linked to ARMD rotor models developed in the rotor dynamic package ROTLAT, for automatic aerodynamic cross-coupling coefficients calculations and destabilizing effects inclusion in the rotor dynamic simulations.

Equation - API 617 Centrifugal

**Aerodynamic Cross Coupling Destabilizing Effects
Per API Standard 617 (7th Edition)**

A- [For CENTRIFUGAL compressors:](#)

Anticipated cross coupling effects (QA per API 617), entered as +KXY and -KXY stiffness in the rotor dynamic software module ROTLAT, is defined/computed by the following procedures:

$$QA = [(HP \times Bc \times C) / (Dc \times Hc \times N)] \times (RHOD / RHOs)$$

ArmdAeroCC (C:\Users\Public\Documents\ARMD58\Ar

File Edit Run View Project Help

Heading

Header 1 Centrifugal Impeller Aerodynamic Cross-Coupling Eff

Header 2 Power=1500HP (1.11855MW), Speed=20Krpm, Dia

Header 3 Disch.Width=0.787inch(20mm),Gas Density AVG=3

Single Case Multiple Case

Parameters				
Power	1.42135E+003	Impeller Diameter	1.09000E+001	Imp. Discharge Width
Rotor Speed	2.50000E+004	Discharge Gas Density	1.00478E-006	Suction Gas Density

Case 9 of 14

Run Case

ArmdAeroCC computed performance results for case 9 of 14:
Formula used: API Standard 617 (Centrifugal compressors).

```
>>> STIFFNESS (lbf/inch)  Kxx ; Kxy ->  0.00000E+000  2.18191E+003
                          Kyx ; Kyy -> -2.18191E+003  0.00000E+000
>>> DAMPING (lbf-sec/inch) Dxx ; Dxy ->  0.00000E+000  0.00000E+000
```

ArmdAeroCC (C:\Users\Public\Documents\ARMD58\ArmdAeroCC\Samples\ArmdAeroCCperAPI617CentrifugalUS.sin US)

File Edit Run View Project Help

Heading

Header 1 Centrifugal Impeller Aerodynamic Cross-Coupling Effects @ Design Speed

Header 2 Power=1500HP (1.11855MW), Speed=20Krpm, Diameter=12inch (304.8mm)

Header 3 Disch.Width=0.787inch(20mm),Gas Density AVG=3.0E-04Lbf/in^3(8.30kg/m^3)

Single Case Multiple Case

	Power	Pitch Diameter	Imp. Discharge Width	Speed	Discharge Gas Density	Suction Gas Density
1	1.42135E+003	1.09000E+001	7.65354E-001	1.00000E+004	1.00478E-006	5.93156E-007
2	1.42135E+003	1.09000E+001	7.65354E-001	1.20000E+004	1.00478E-006	5.93156E-007
17	1.42135E+003	1.09000E+001	7.65354E-001	3.30000E+004	1.00478E-006	5.93156E-007

Equation

API 617 (Centrifugal)

API 617 (Axial)

Alford's Equation

Wachel's Equation

Slope of efficiency vs. clearance to vane height ratio dimensionless Project not open

Advanced Rotating Machinery Dynamics

ARMD Documentation

ARMD package is supplied with a printed quick start manual that covers installation, sample cases, features, and capabilities. The package also has a comprehensive electronic user's manual that includes the following sections:

ARMD™	Introduction, Set-up, Installation and Operation	<i>Brochure</i>	<i>Manual</i>	
ROTLAT™	Rotor Dynamics Lateral Vibration	<i>Overview</i>	<i>Manual</i>	<i>Samples</i>
TORSION™	Torsional Vibration	<i>Overview</i>	<i>Manual</i>	<i>Samples</i>
JURNBR™	Cylindrical Fluid-Film Fixed Geometry Journal Bearings	<i>Overview</i>	<i>Manual</i>	<i>Samples</i>
HYBCBR™	Conical Fluid-Film Fixed Geometry Journal Bearings	<i>Overview</i>	<i>Manual</i>	<i>Samples</i>
TILTBR™	Fluid-Film Tilting-Pad Geometry Journal Bearings	<i>Overview</i>	<i>Manual</i>	<i>Samples</i>
THRSBR™	Fluid-Film Fixed and Tilting-Pad Geometry Journal Bearings	<i>Overview</i>	<i>Manual</i>	<i>Samples</i>
COBRA™	Rolling-Element Bearings	<i>Overview</i>	<i>Manual</i>	<i>Samples</i>
VISCOS™	Lubricant Temperature Dependent Properties	<i>Overview</i>	<i>Manual</i>	<i>Samples</i>

Advanced Rotating Machinery Dynamics

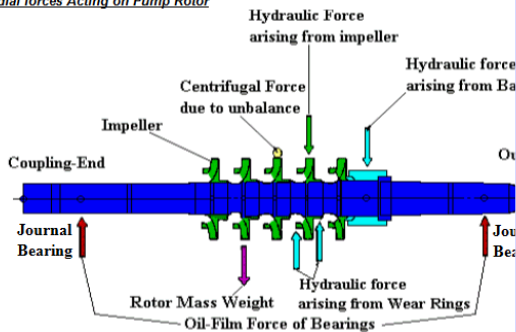
ARMD incorporates advanced technical and user interface features with built-in help utilities in each of its modules to simplify modeling, analysis, presentation, and interpretation of results. Tutorials and step by step sample sessions with advanced graphical presentation are among the many features implemented in the new version.

Modeling Concepts

Rotor-dynamic analysis principle objective is to system. The analysis is one aspect of a total analysis must include the effects of a large number of external and internal sources of loading (including hydraulic process media forces, unbalance forces transmitted through the couplings from one part of the system to another).

Five Stage Boiler Feed Pump Schematic Representation

Radial forces Acting on Pump Rotor



Sample Session For ROTLAT

INTRODUCTION

When the ROTLAT software is launched for the first time, [TUTORIAL](#) is activated to familiarize the user with ROTLAT. When exiting this session the ROTLAT software top level menu (shown below) is displayed.

[\[Click here for more details\]](#)

Linking a bearing to rotor model

Rotating assembly support bearing's dynamic coefficients (*stiffness and damping characteristics*) can be automatically generated under the speed and loading conditions being examined for rotor dynamic simulation.

Fluid-Film Bearings: To link a fluid-film bearing to the rotor model the bearing model and its performance results as a function of speed and loading conditions are generated with one of the [ARMD software](#) fluid-film bearing models: *FLYBCBR* for cylindrical fixed-geometry journal bearings, *TILTBFR* for cylindrical tilting-pad-geometry journal bearings, or *HYBCBR* for cylindrical fixed-geometry journal bearings.

Once the rotor model (shaft elements) is specified in the Element tab of the System form select the Bearings Tab (shown below) specify the bearing type to be linked as shown below. This selection will not affect any of the rotor or bearing data.

[Click on the tab/portion of the chart for which you want more information]

Station	DOF	Type	Coefficients Source	Input File (e.g. Non-dimensional or other)	File Status	Browse to File	Edit
1	3	Manual Bearing	Manual		
2	17	Manual Bearing	Manual		

Dropdown menu options: Manual Bearing, Manual Bearing, Fixed journal, Fixed conical, Tilted pad.

Tutorial

The following procedure contains the basic seven (7) steps to use ROTLAT. Online help can be accessed any time by either pressing the F1 key or clicking the Help button (if available).

ROTLAT - Rotor Dynamics / Lateral Vibration Analysis

1. Create NEW .ROI file or OPEN an existing file
2. System
3. Options
4. Applied Loads
5. Verify model graphically or in text format
6. Run Analysis
 - > Static Deflection & Load
 - > Stability
 - > Unbalance Response
 - > Steady State Response
 - > Time Transient Response
 - > Critical Speed Map
 - > Stability Map
7. View results graphically or in text format

[Click on the portion of the chart for which you want more information]

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 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

Microsoft Windows 7, 8 10 or higher (32 or 64 bit).

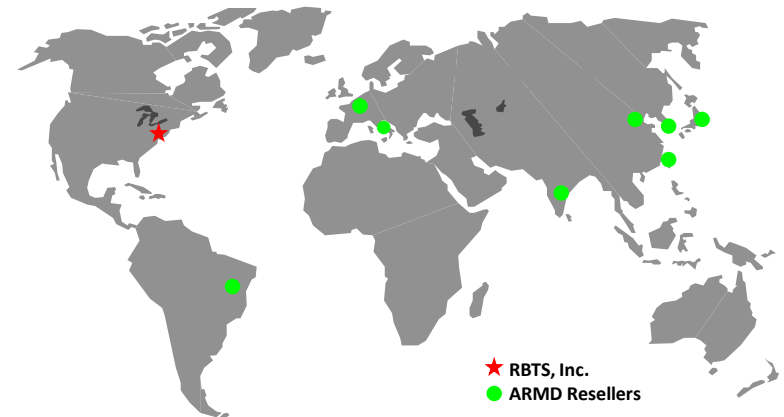
Remember, with **RBTS**, you get

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

ARMD™

The Worldwide Leading Software For Rotating Machinery Analysis

Advanced Rotating Machinery Dynamics



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