

Advanced Rotating Machinery Dynamics

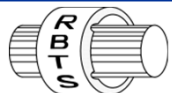
ARMDTM

Version 6.2

THE COMPLETE SOFTWARE PACKAGE FOR

- **Rotor Dynamics**
- **Torsional Vibration**
- **Fluid-Film Bearings**
- **Rolling-Element Bearings**
- **Lubricant Performance**
- **Dynamic Tools/Utilities**

Workstation and Enterprise Licensing Available



RBTS, Inc.

Rotor Bearing Technology & Software

1041 West Bridge Street

Phoenixville, PA 19460, USA

Tel: 610-415-0412

Fax: 610-415-0413

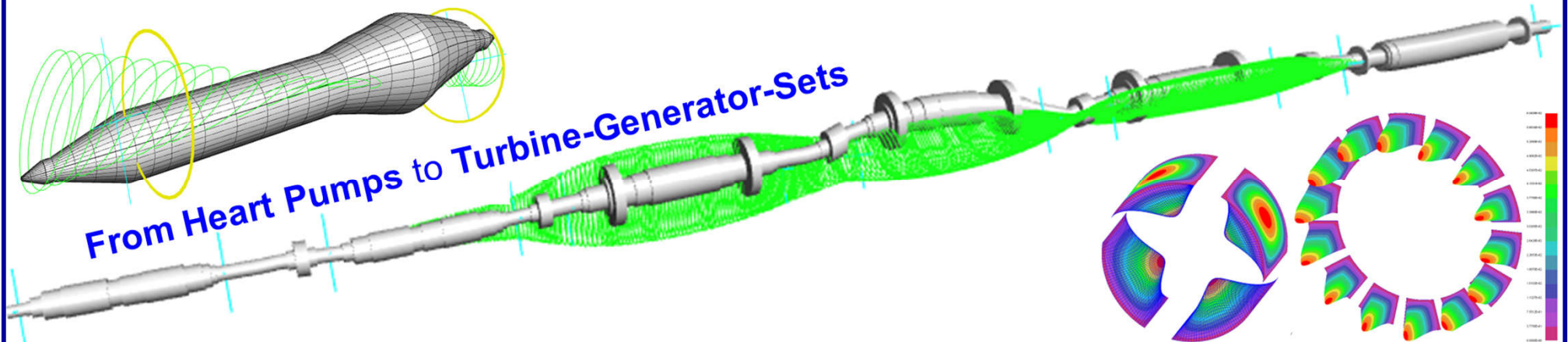
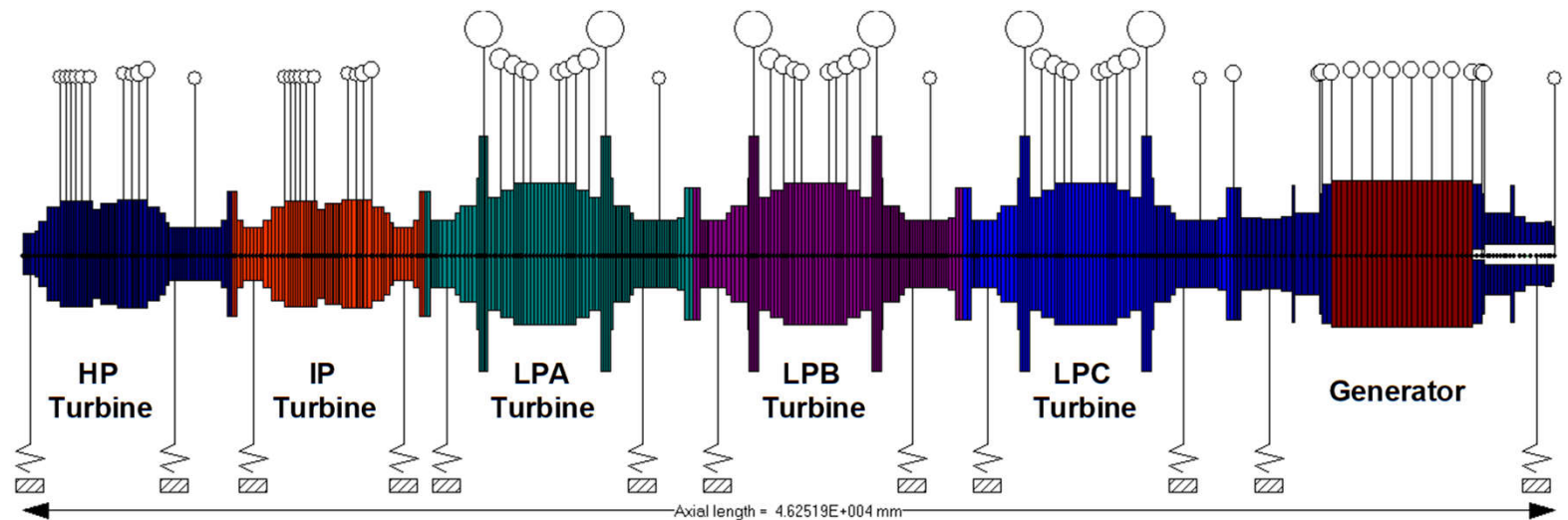
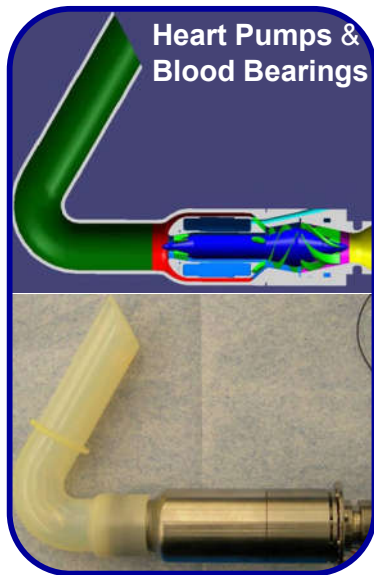
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Advanced Rotating Machinery Dynamics

ARMTMD

**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.

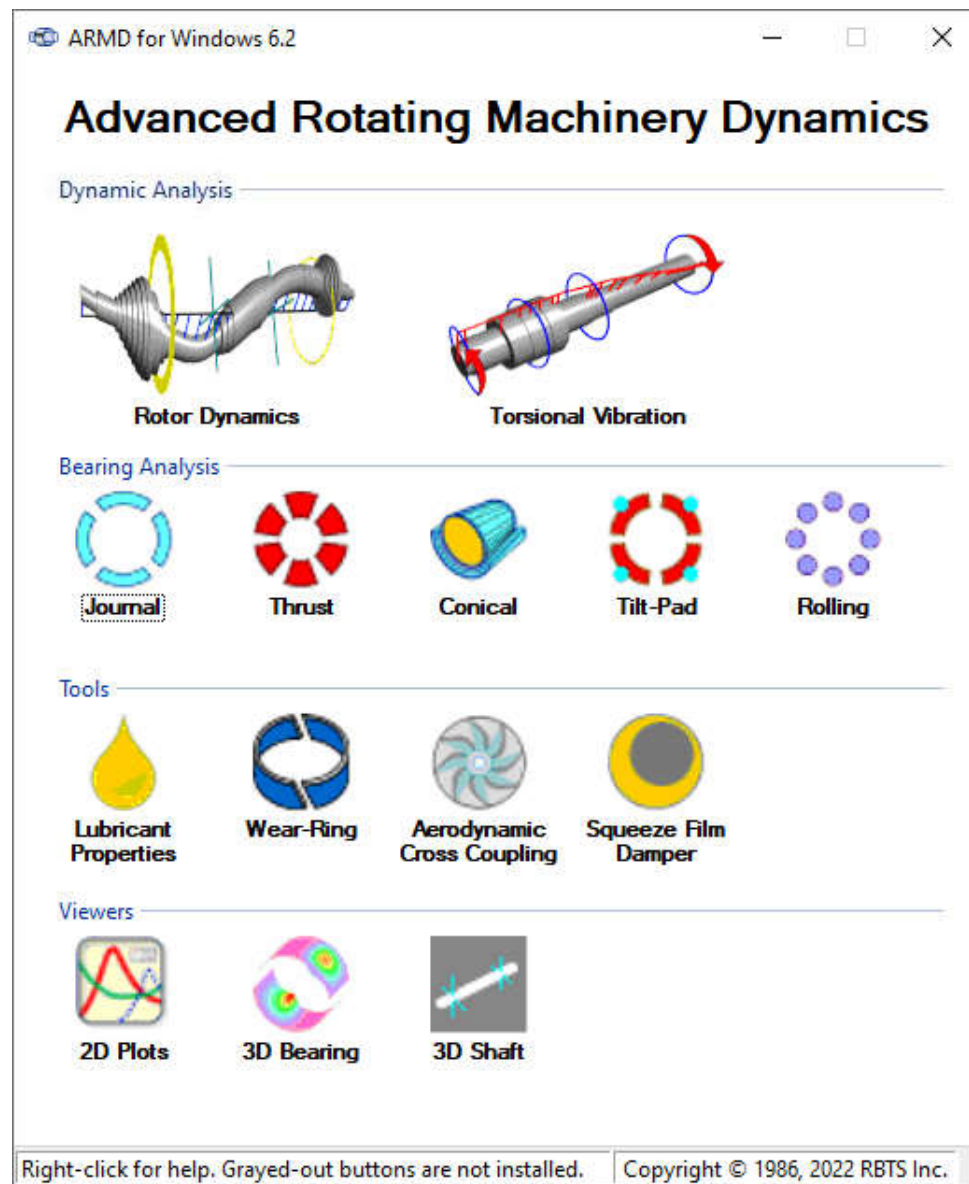
ARMD consists of five main modules:

- **Rotor Dynamics**
- **Torsional Vibration**
- **Fluid-Film Bearings**
- **Rolling-Element Bearings**
- **Lubricant Performance**
- **Utilities & Support Tools**

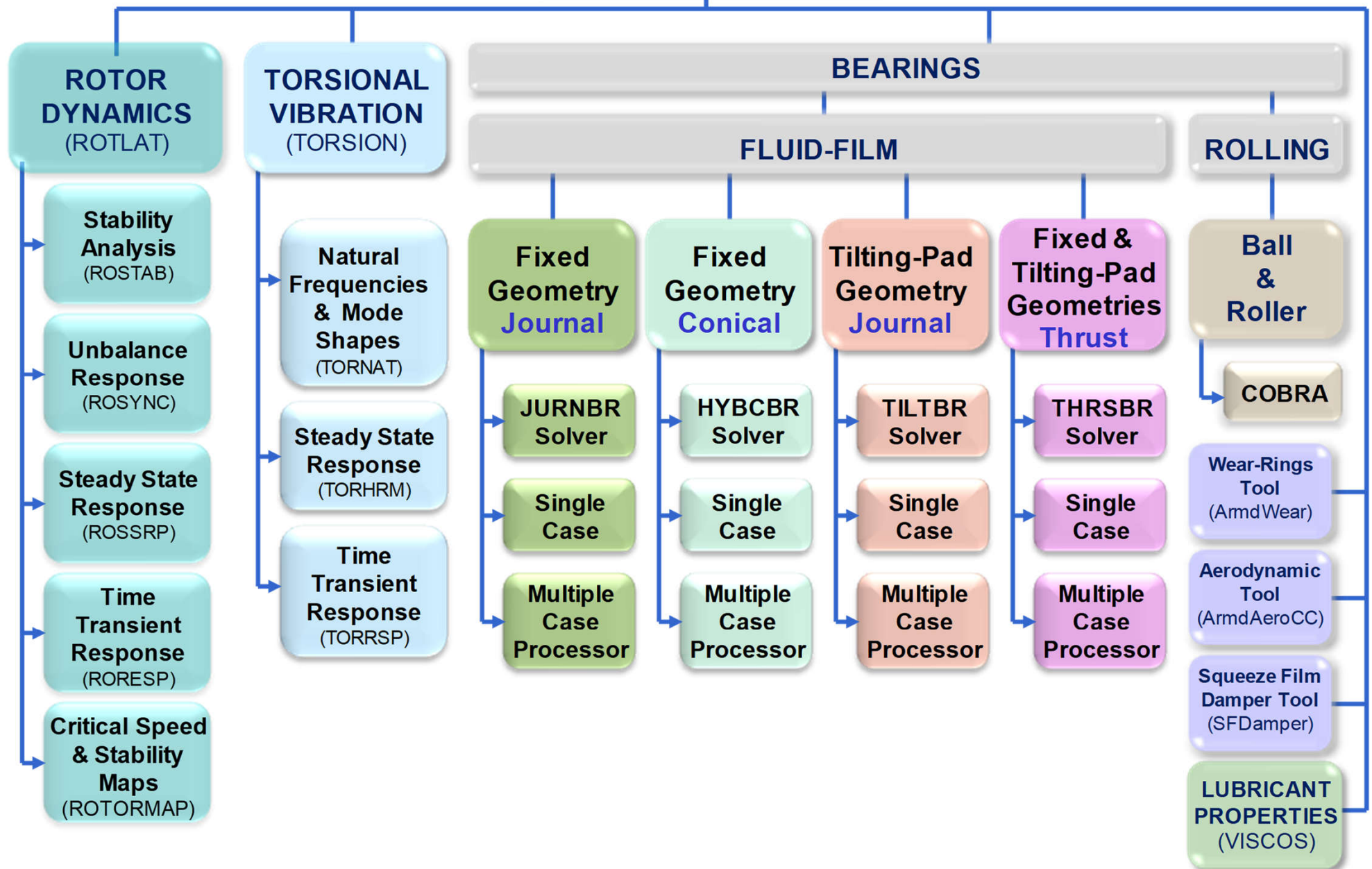
With a variety of features, including:

- **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

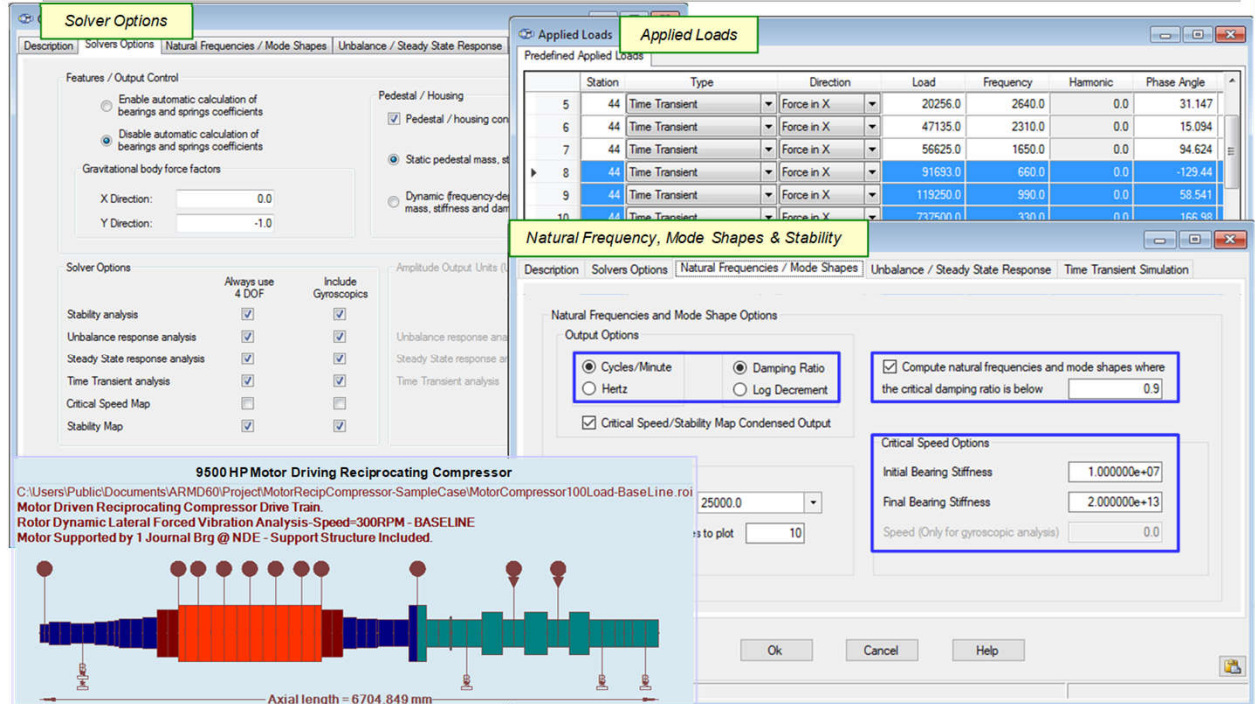
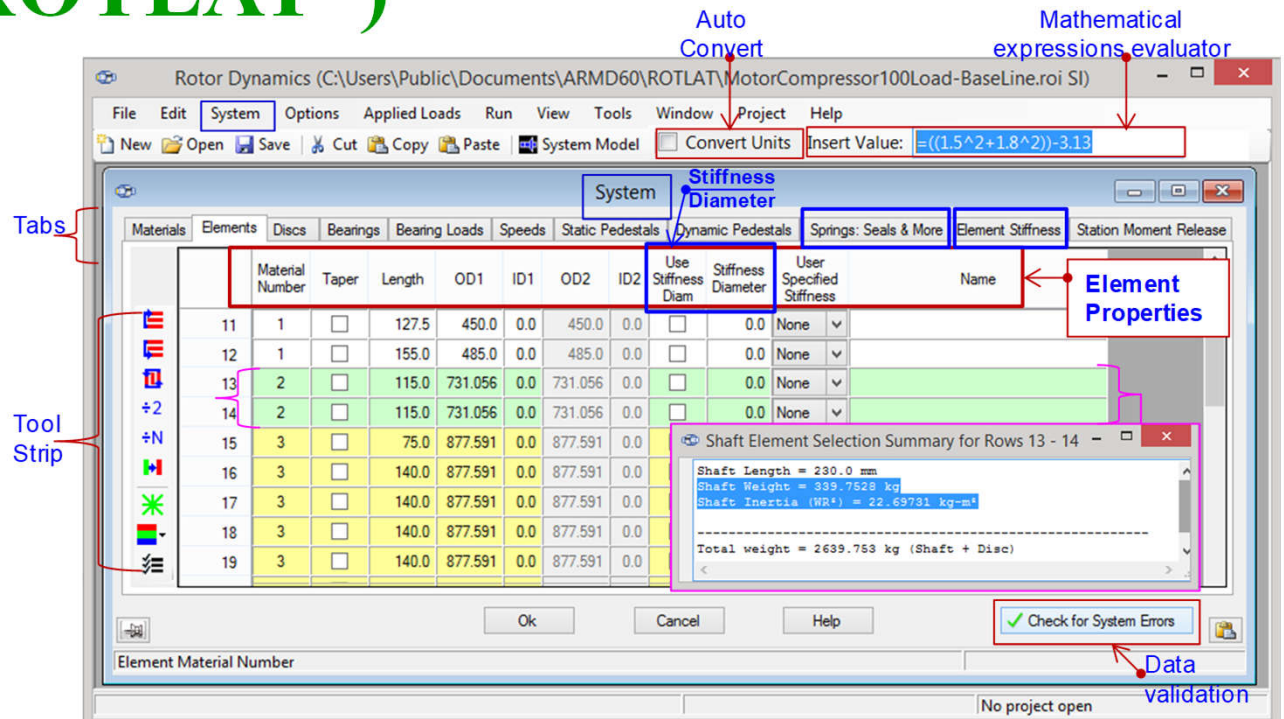


Rotor Dynamics (ROTLAT™)

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.

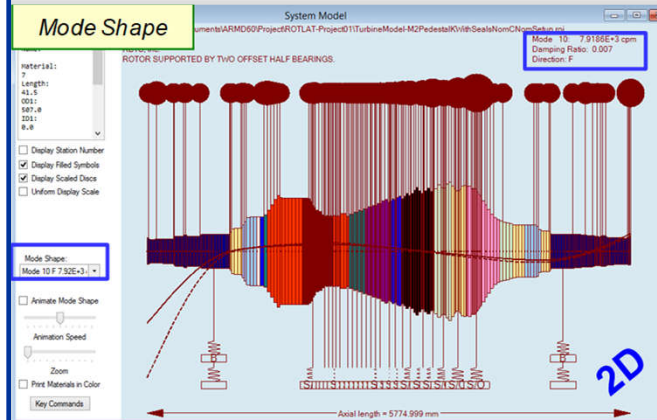
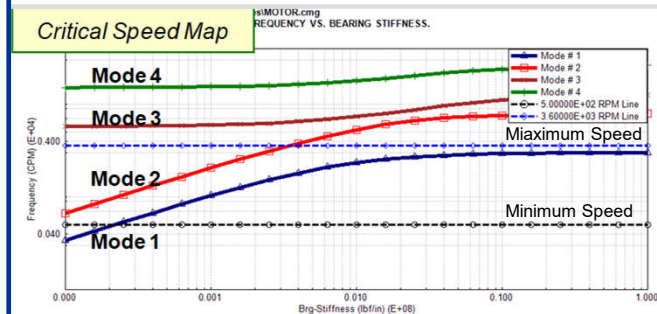
ROTLAT incorporates advanced modeling features and capabilities including the following:

- 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.



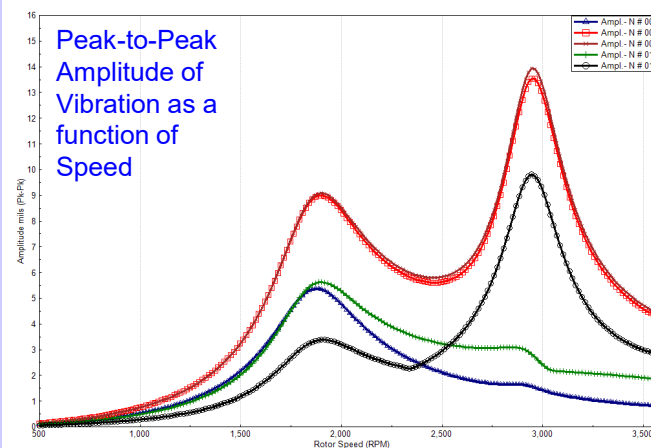
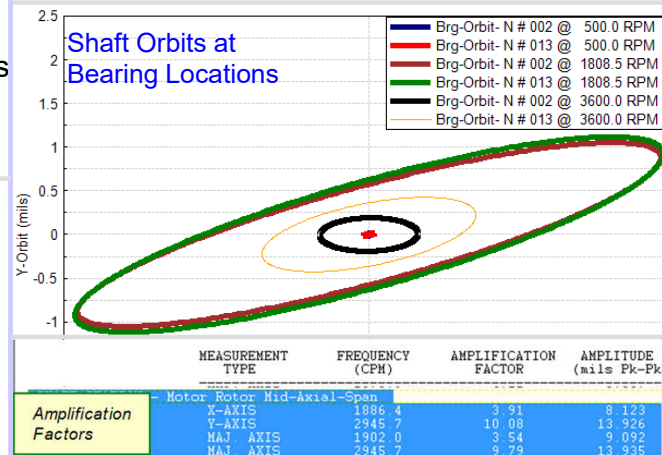
NATURAL FREQUENCY, MODE SHAPE & STABILITY

- 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



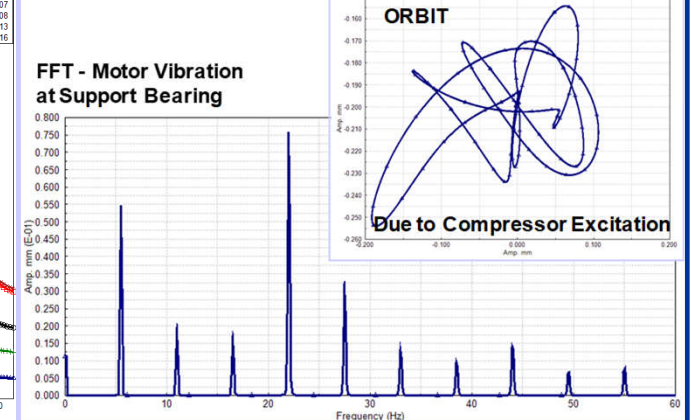
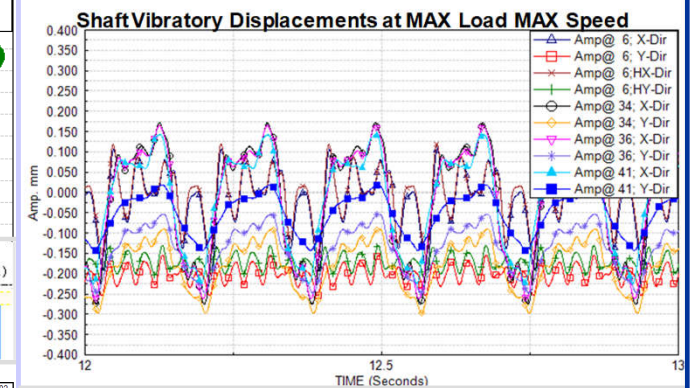
Synchronous UNBALANCE & STEADY-STATE RESPONSE

- Multiple unbalance planes/forces
- Various types of external excitations & body forces including sinusoidal/harmonic
- Magnitude and phase (Bode plot)
- Dynamic forces and moments
- Vibratory amplitudes and orbits
- Forces and moments transmitted to bearing and foundation
- Foundation vibratory amplitudes
- Rotor shape plots (amplitude & phase)
- API Amplification factors



TIME-TRANSIENT RESPONSE (Non-synchronous response)

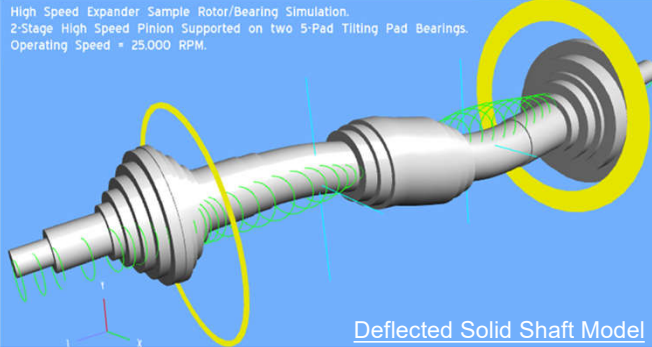
- Gravitational and external forces: Multiple sinusoidal, step, ramp, pulse and unbalance
- Vibratory amplitudes time history
- Rotor orbits
- Dynamic forces and moments
- Dynamic stresses
- Transmitted forces and moments
- Pedestal vibratory amplitudes



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

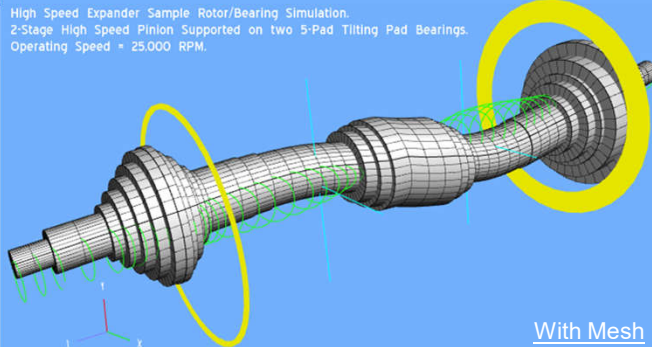
Various Options of Model & Mode Shape Presentation

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.



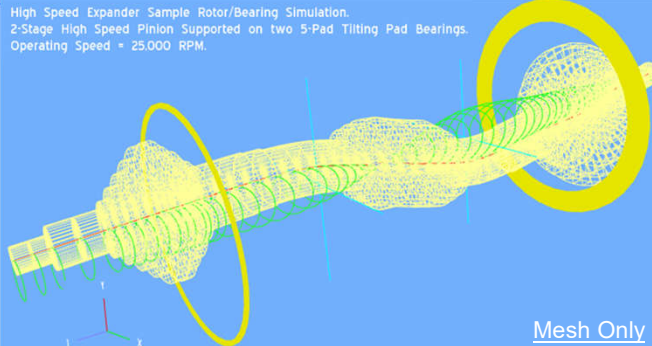
Deflected Solid Shaft Model

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.



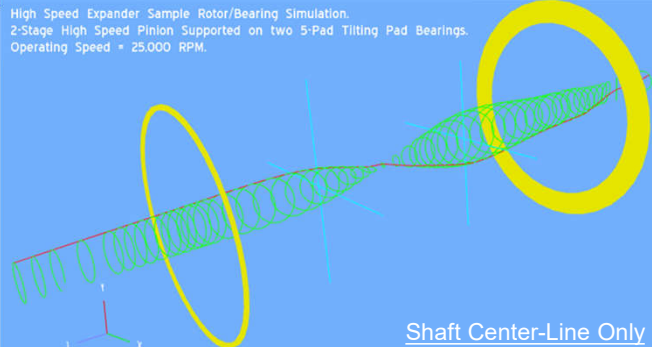
With Mesh

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.



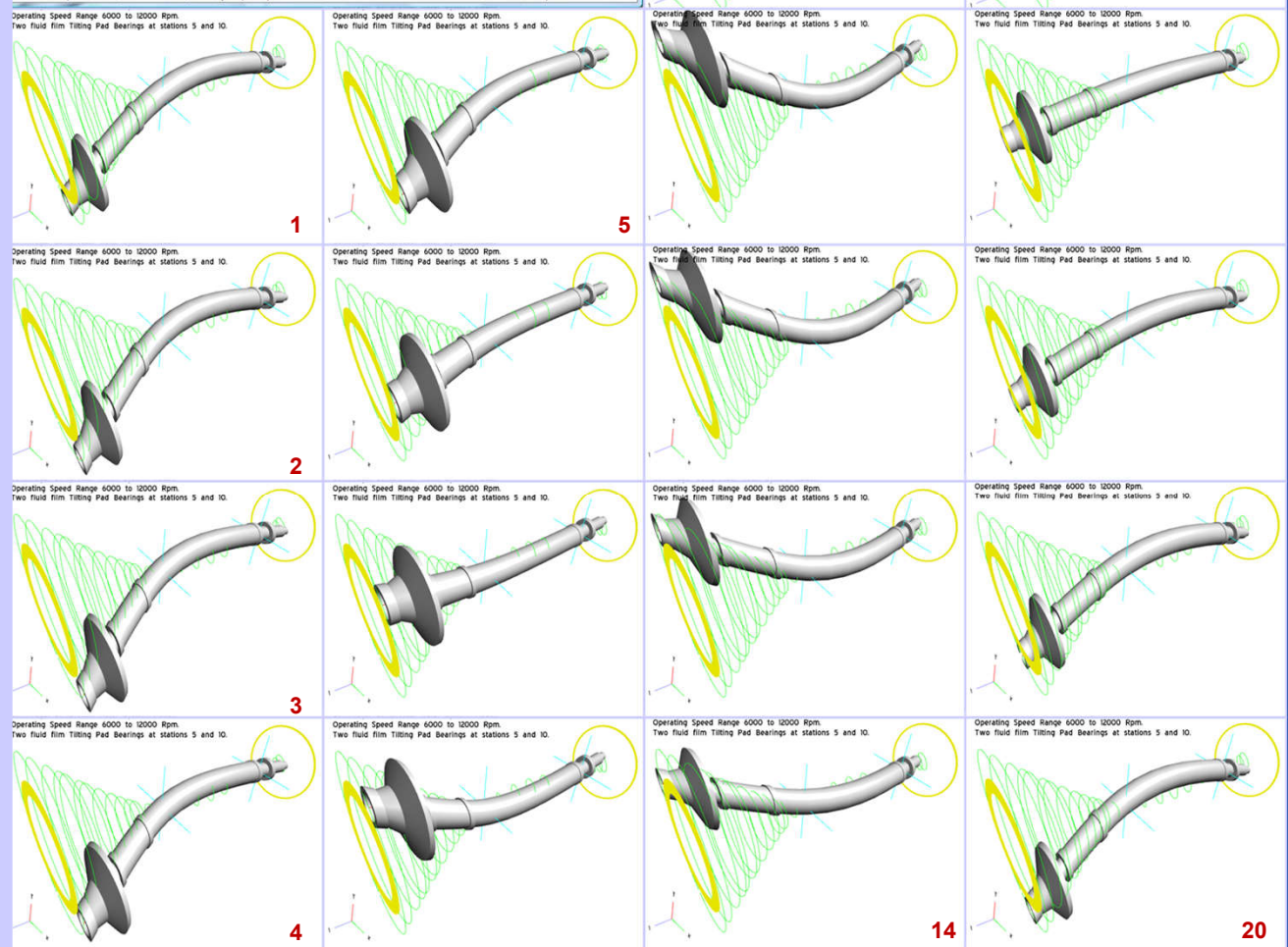
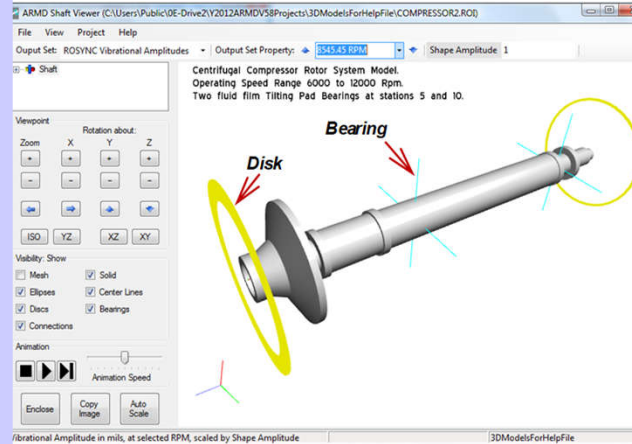
Mesh Only

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.



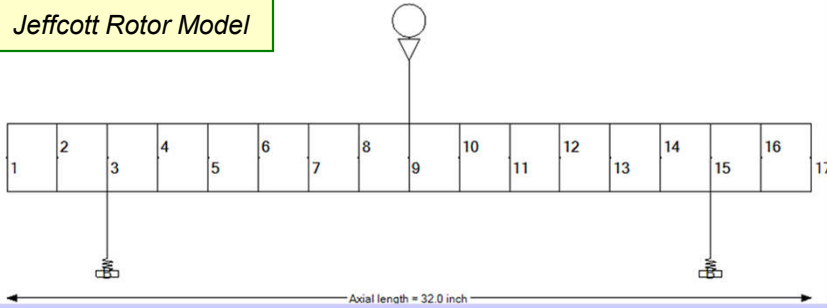
Shaft Center-Line Only

Animated Unbalance Response

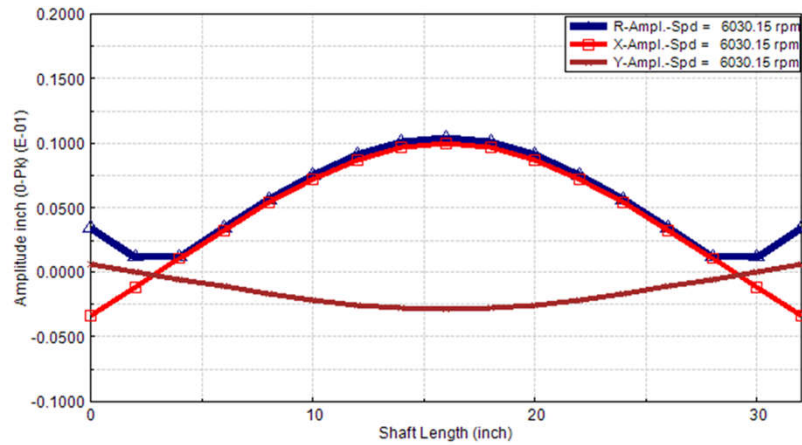


C:\Users\Public\Documents\ARM61\ROT\LA1\Samples\SSResponseSample01-JeffcottRotor.roi
 STEADY STATE SIMULATION EXAMPLE - Single Disc Rotor System Model
 Operating Speed Range 1,000 to 10,000 Rpm - 1st Critical Around 6250 RPM
 Two Bearings Support at Stations 3 and 15.

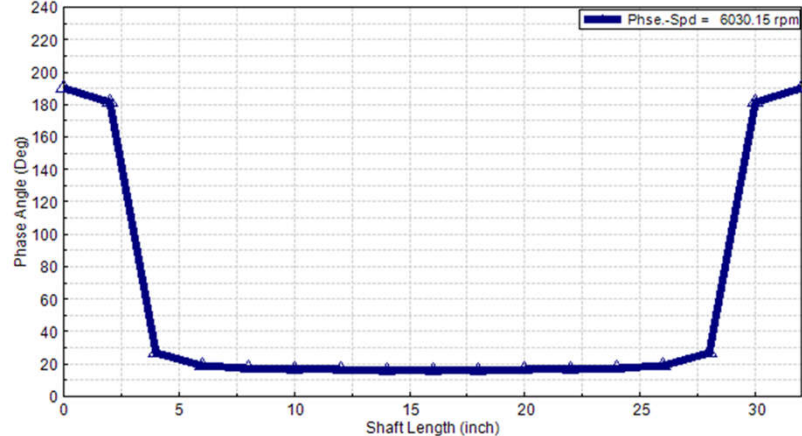
Jeffcott Rotor Model



Graph: Default
 C:\Users\Public\Documents\ARM61\Project\ROT\LA1\Samples\Folder\SteadyStateResponseSampleCases\SSResponseSample01-JeffcottRotor.sxg
Rotor Shape Plot At Select Speed – Displacements.

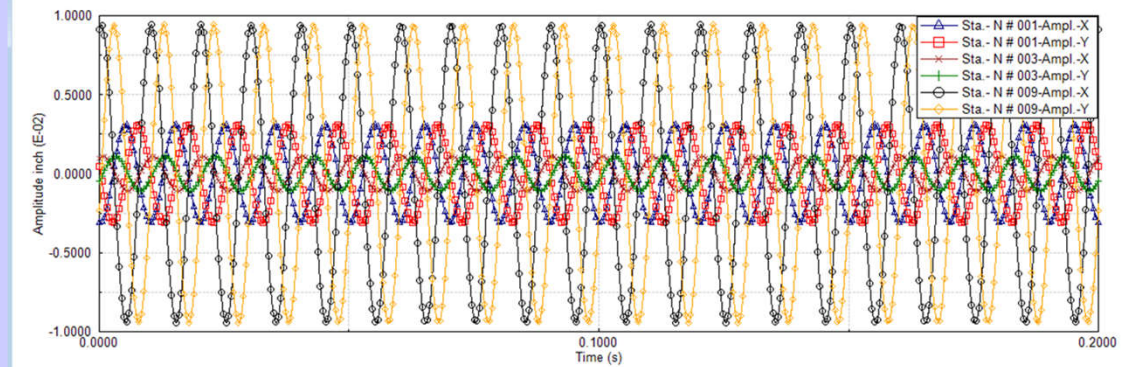


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Rotor Shape Plot At Select Speed – Phase Angle.

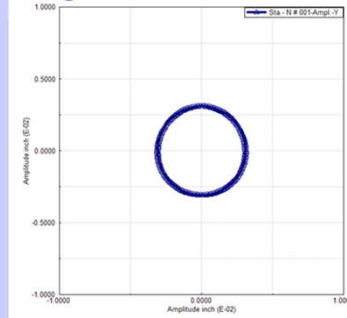


Graph: Default
 C:\Users\Public\Documents\ARM61\ROT\LA1\Samples\SSResponseSample01-JeffcottRotor.sxg
Steady state Response – Amplitude Vs. Time @ 6030 rpm

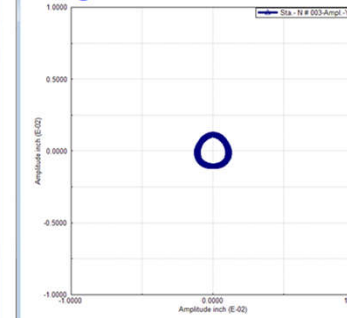
Steady-State Response



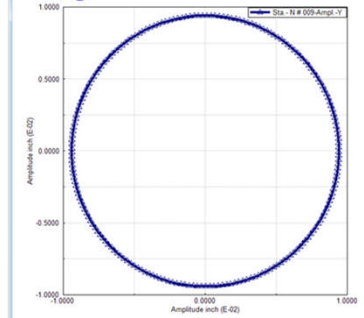
Graph: Default
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Orbit @ Station 1



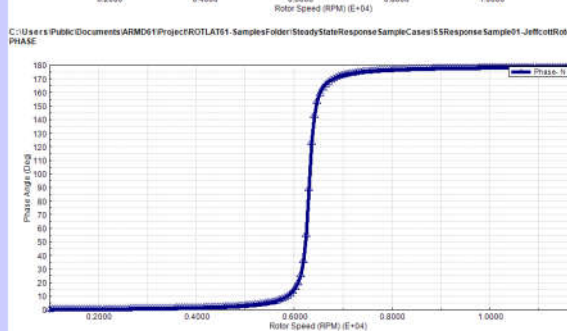
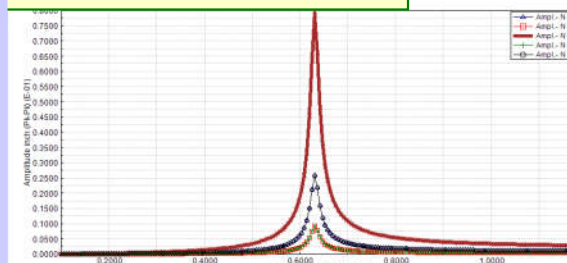
Graph: Default
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Orbit @ Station 3



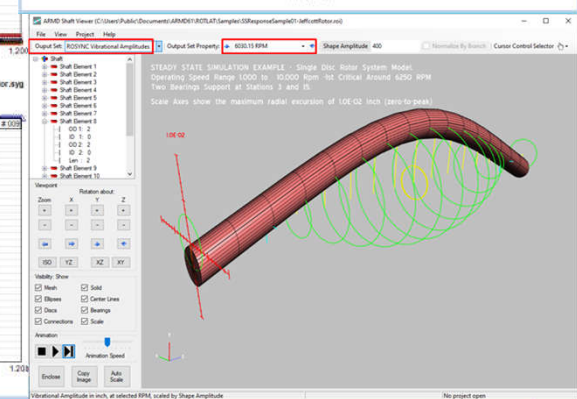
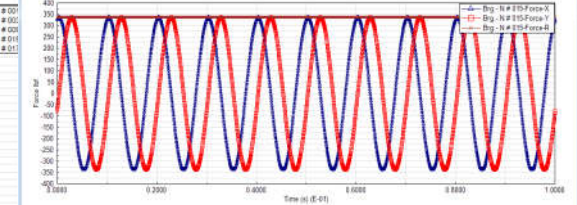
Graph: Default
 C:\Users\Public\Documents\ARM61\ROT\LA1\Samples\SSResponseSample01-JeffcottRotor.sxg
Orbit @ Station 9



Amplitude & Phase Vs. Speed



Graph: Default
 C:\Users\Public\Documents\ARM61\ROT\LA1\Samples\SSResponseSample01-JeffcottRotor.sxg
Steady State Response – Transmitted Forces to Bearing Vs. Time @ 6030 rpm



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...

System

Branches Materials Elements Connections Discs Springs

All Elements Branch 1 Elements Branch 2 Elements

	Branch Number	Material Number	Use Geometry	Taper	Length	OD1	ID1	OD2	ID2	Use Stiffness Diam	Stiffness Diameter	Stiffness	Damping	Inertia
1	1	1	✓		11.0	7.5	2.36	7.5	2.36		0.0	0.0	0.0	0.0
2	1	1	✓		14.0	8.0	2.36	8.0	2.36		0.0	0.0	0.0	0.0
3	1	1	✓		10.0	9.0	2.36	9.0	2.36		0.0	0.0	0.0	0.0
4	1	1	✓	✓	20.0	9.0	2.36	11.0	2.36		0.0	0.0	0.0	0.0
5	1	2	✓		15.0	14.0	0.0	14.0	0.0		0.0	0.0	0.0	0.0
6	1	2	✓		20.0	14.0	0.0	14.0	0.0		0.0	0.0	0.0	0.0
7	1	2	✓		15.0	14.0	0.0	14.0	0.0		0.0	0.0	0.0	0.0
8	1	1	✓	✓	20.0	11.0	0.0	9.0	0.0		0.0	0.0	0.0	0.0
9	1	1	✓											
10	1	1	✓											
11	1	1	✓											
12	1	3	✓											
13	1	1	✓											
14	1	1	✓											
15	2	1	✓											
16	2	1	✓											
17	2	3			20.0	3.2	0.0	3.2	0.0		0.0	5.50000e+06	0.0	0.0
18					4.0	0.0	4.0	0.0			0.0	0.0	0.0	0.0
19					4.5	0.0	4.5	0.0			0.0	0.0	0.0	0.0

Branch #1

Branch #2

Stiffness Diameter

Shaft Element Selection Summary for Rows 8 - 11

Shaft Length = 54.0 inch
 Shaft Weight = 967.4572 lbf
 Shaft Inertia (WR²) = 10222.04 lbf-in²
 Shaft Stiffness = 1.194514e+08 in-lbf/radian

 Total Inertia (WR²) = 10222.04 lbf-in² (Shaft + Disc)

Options

Description Natural Frequencies / Mode Shapes Steady State Response Time Transient Response Output Options

Branch#1 Speed Range Options

☐ Compute steady state response at branch #1 speed (885.0 RPM)

☐ Compute steady state response at 885.0 RPM

☒ 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

Applied Torque Tables

Steady State Harmonic Torques Time Transient Torques Harmonic Torque Import Files

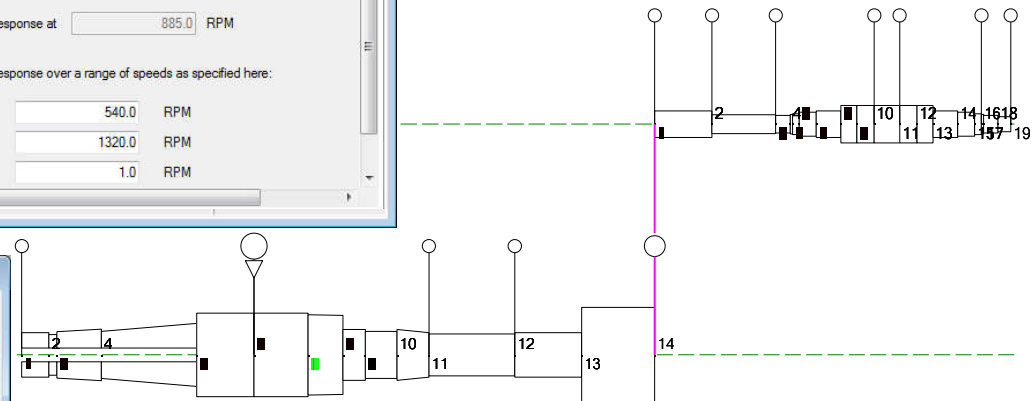
Branch	Station	Harmonics	Edit Table	Import File #	Table No.	Phase
1	1	5	1	Manual	Manual	0.0
2	1	5	1	Manual	Manual	1st Order Excitation @ Station 5
3	1	5	1	Manual	Manual	
4	1	5	1	Manual	Manual	
5	1	5	1	Manual	Manual	

Harmonic Torque Branch Location

Steady State Torque Effort 2

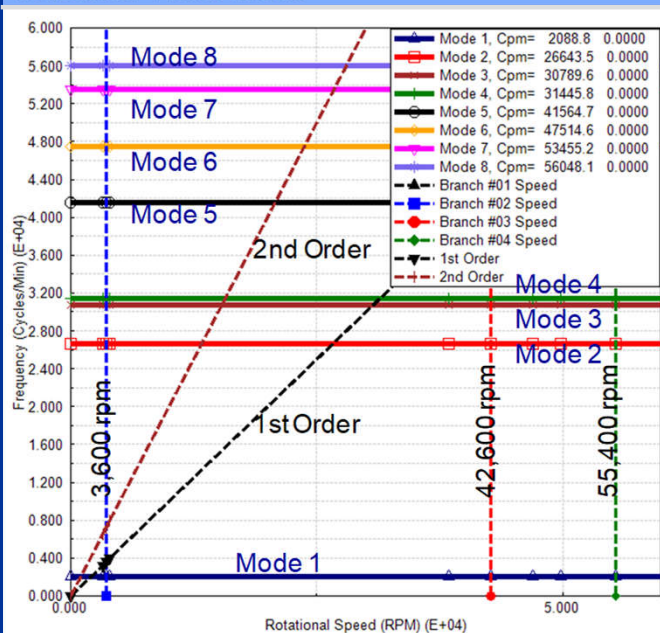
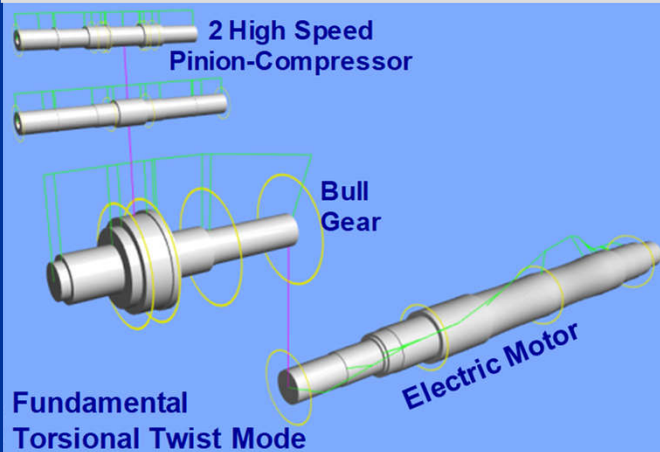
Harmonic Order	Sine Component	Cosine Component
1	2.0	275652.0
		0.0

Harmonic Order dimensionless



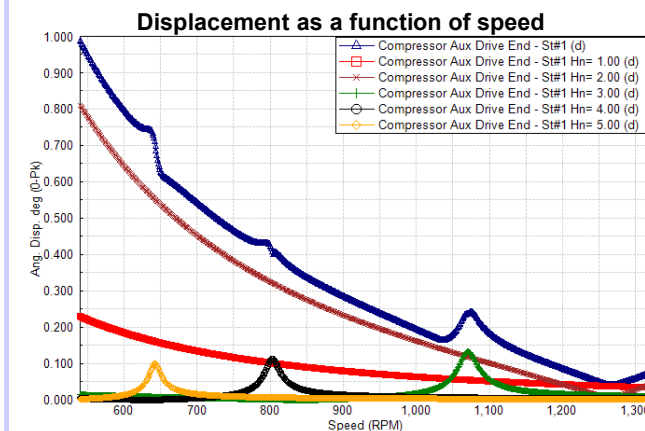
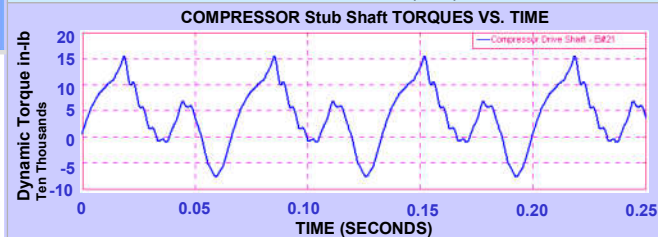
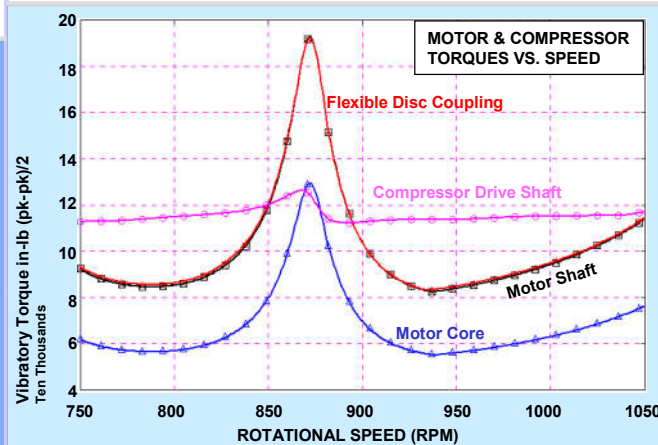
NATURAL FREQUENCIES & MODE SHAPES

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



STEADY STATE RESPONSE

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

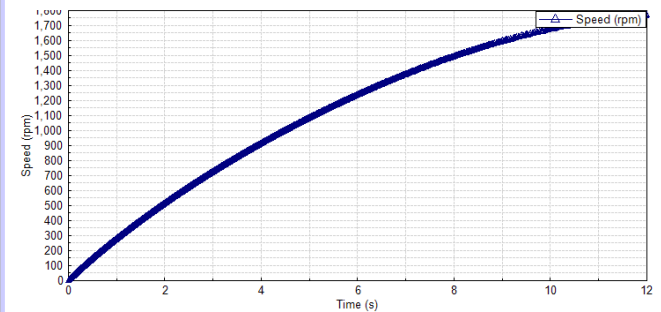


TIME-TRANSIENT RESPONSE

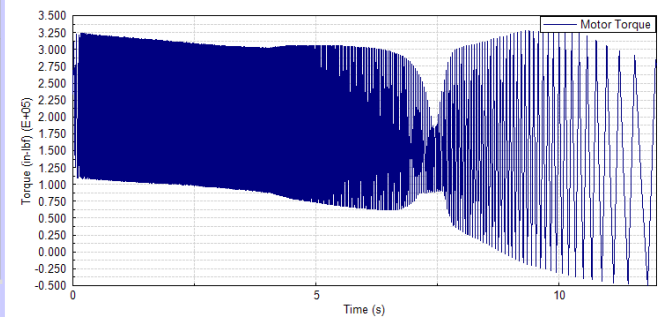
- Dynamic shaft-torque time-history
- Dynamic stresses
- Fatigue life

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

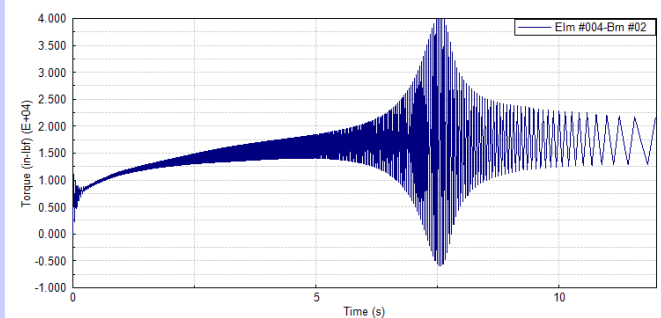
Motor Startup Speed



Motor Startup Average Torque



High Speed Shaft Torque

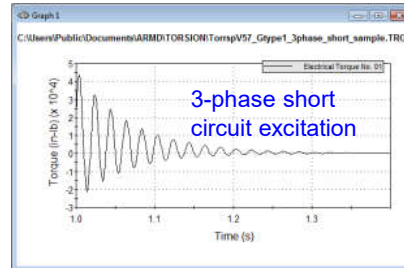


Time varying excitations include:

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

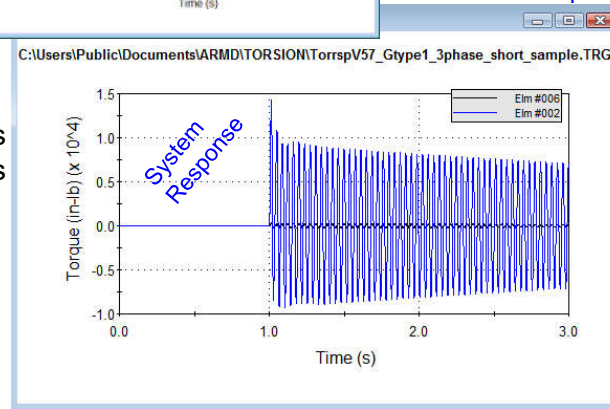
Generator

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



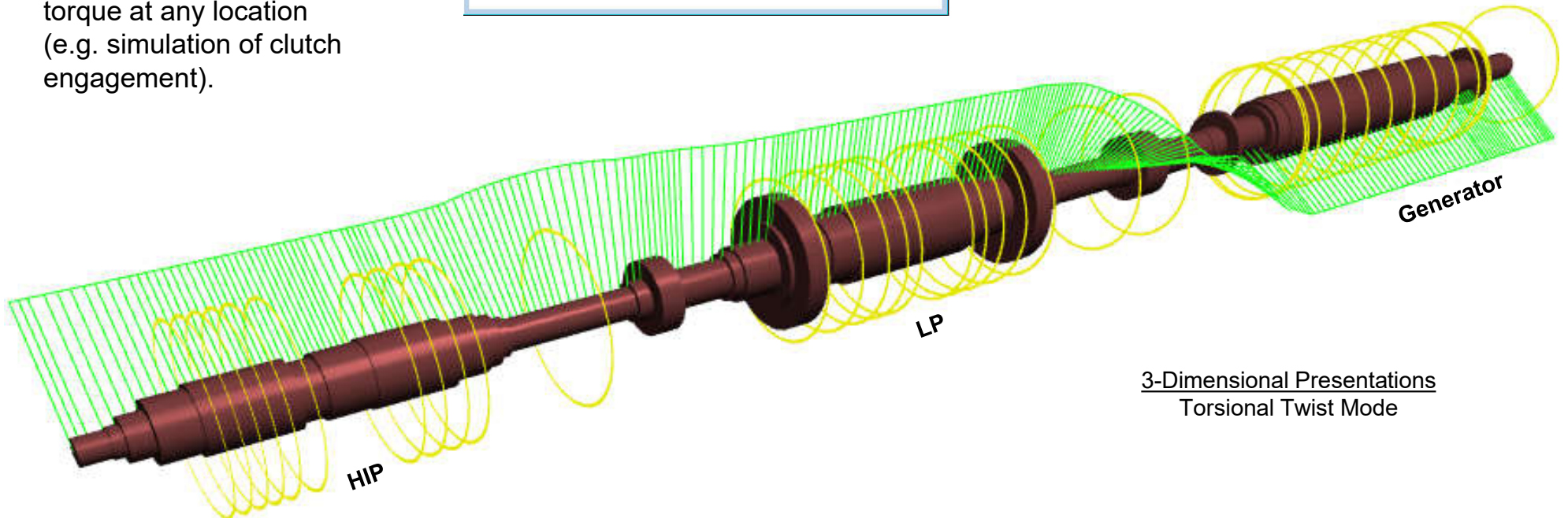
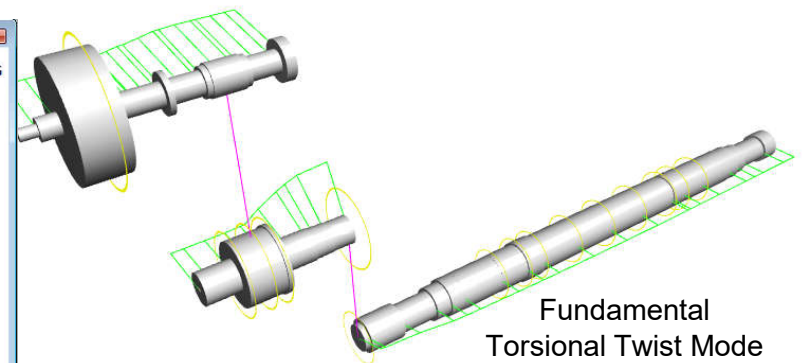
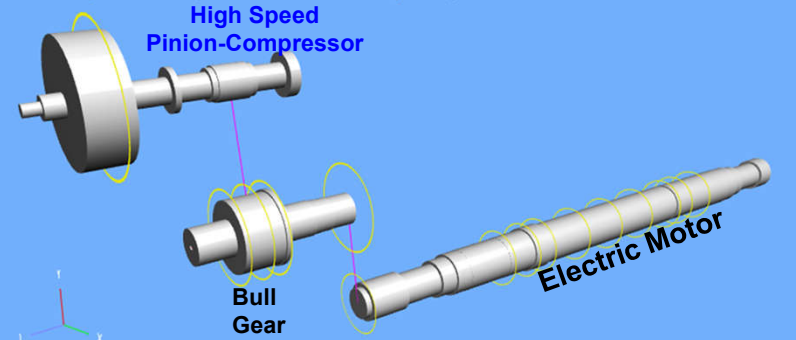
Induction Motor

- 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

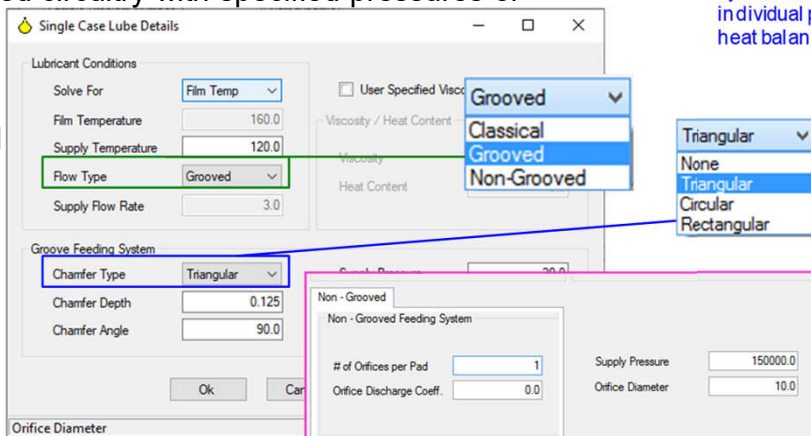


The ARMD software package has the capabilities of evaluating both fluid-film and rolling-element bearings. Practically any bearing or bearing system available in the industry can be modeled and evaluated with one of the bearing solution modules.

The FLUID-FILM bearing modules (JURNBR, HYBCBR, TILTB, 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.

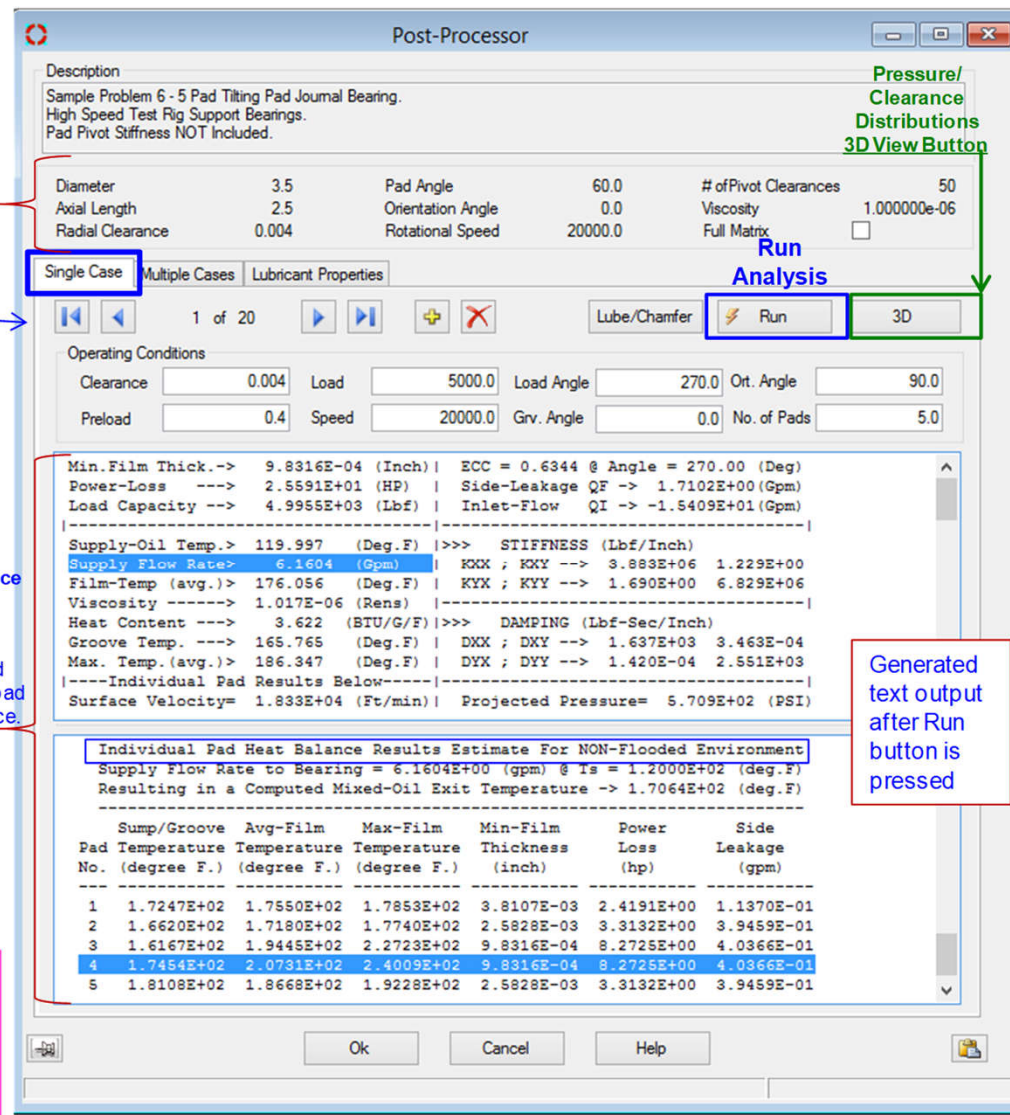
Simulation capabilities include such effects as misalignment, pressurized boundaries or grooves, cavitation, surface deviations (structural deformation), lubricant feed circuitry with specified pressures or restrictors (capillary, orifice, or flow control valve), groove geometry and chamfers.



Modeled Bearing Details

Scroll through cases.

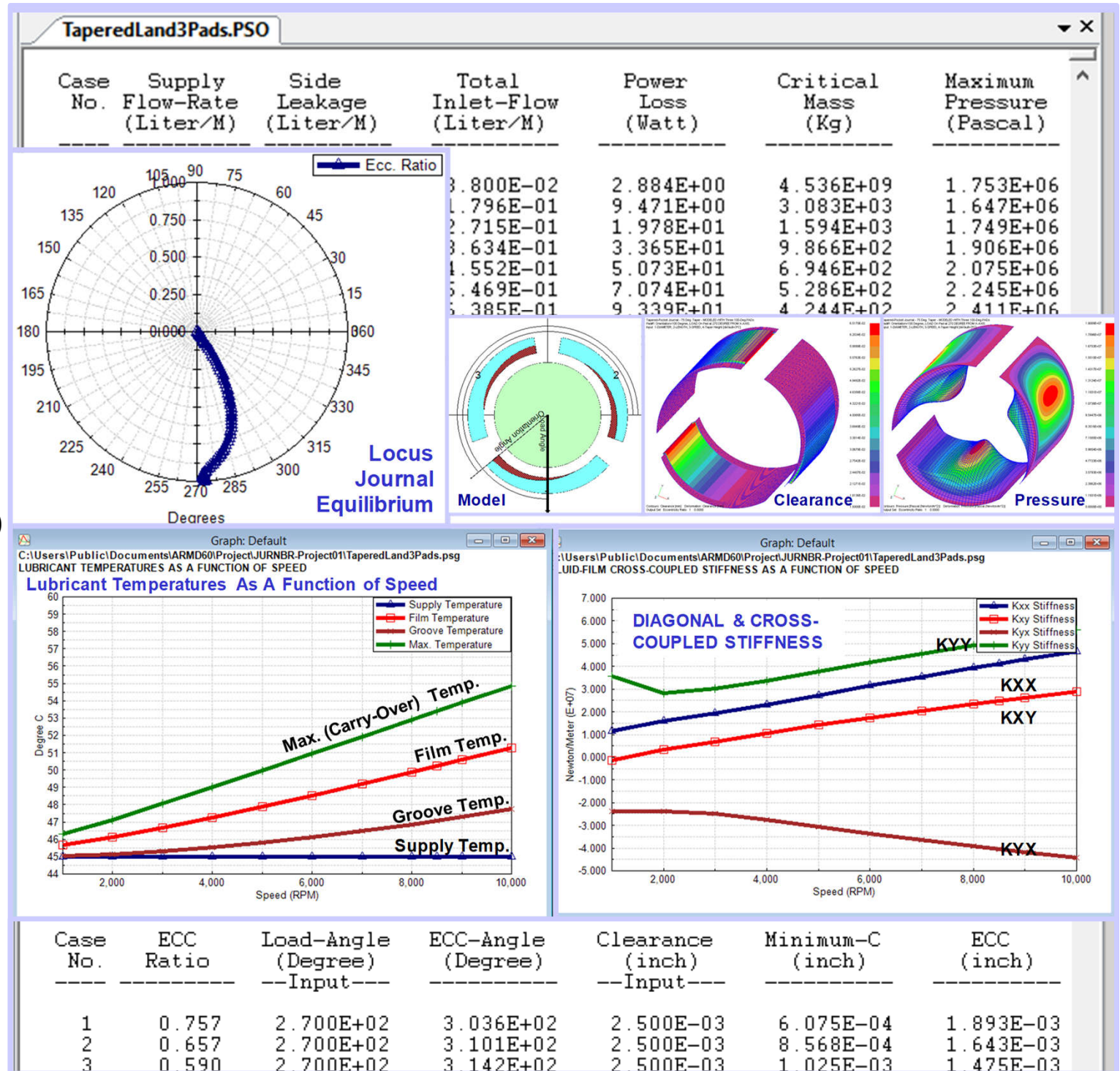
Complete Bearing Performance Results including bearing system and individual pad heat balance.



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)

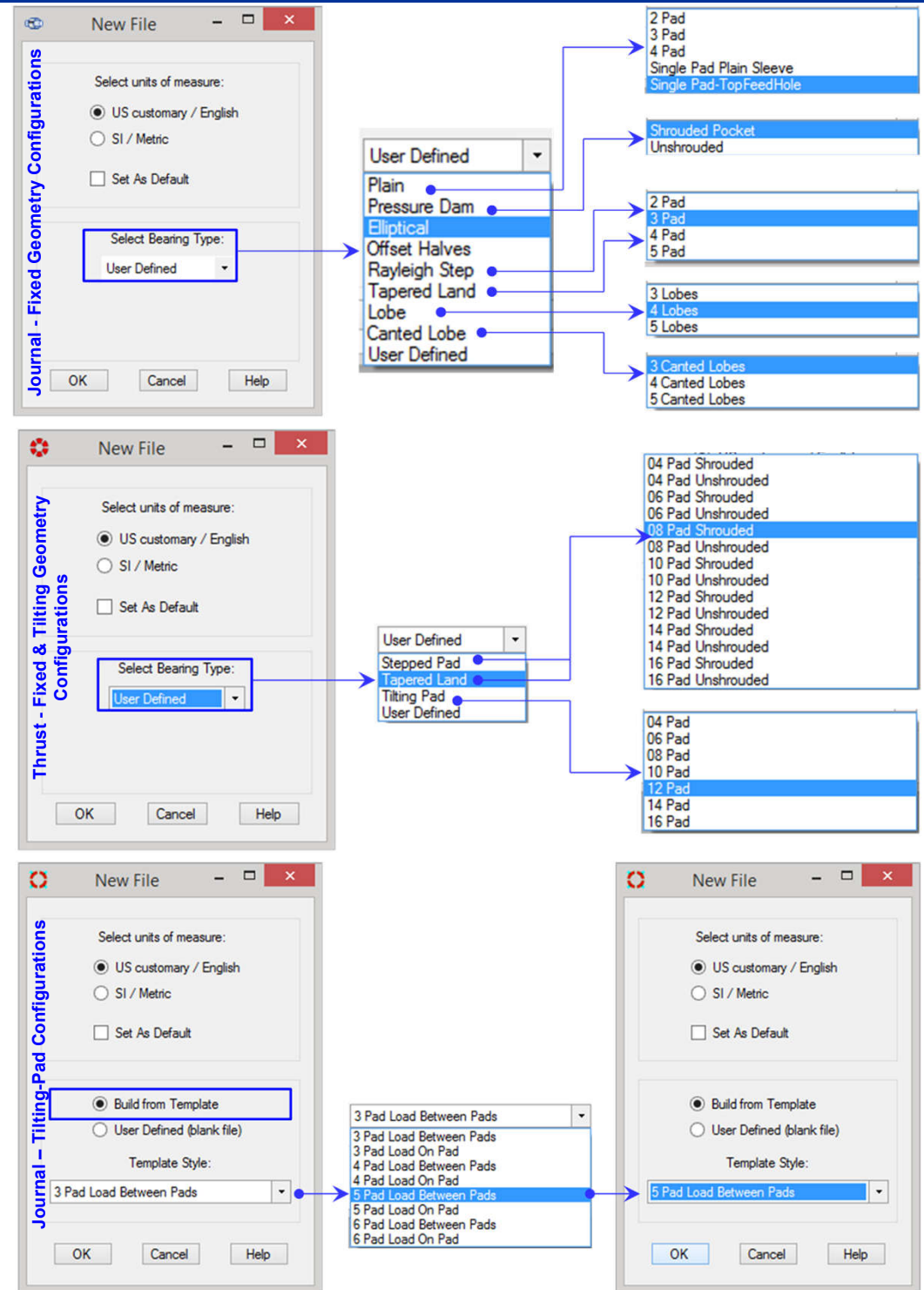
- Plain surface
- Multi-groove
- Pressure dam
- Elliptical or lemon
- Rayleigh step or pocket
- Tapered land
- Lobe or canted lobe
- Any configurable pad surfaces
- Multi-recess

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

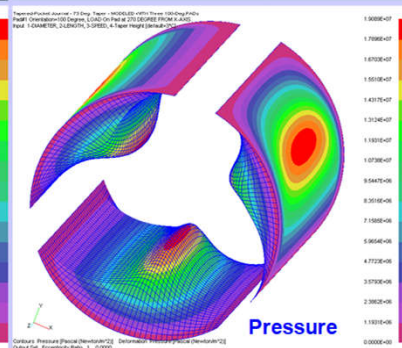
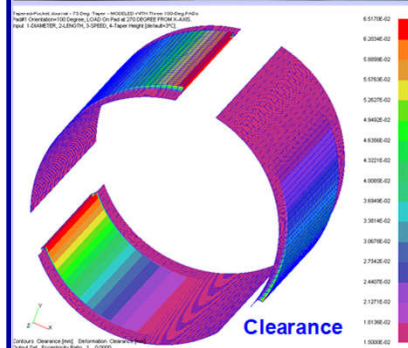
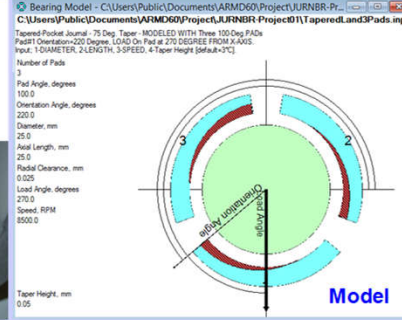
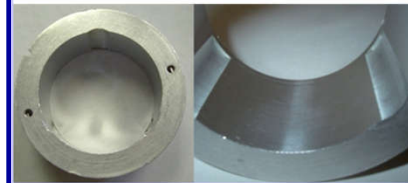
Tilting-Pad Journal Bearings (TILTBR)

- 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

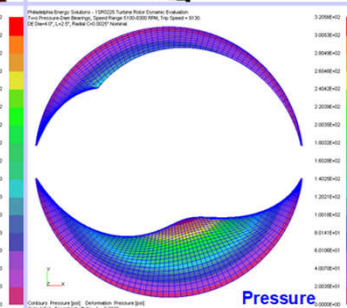
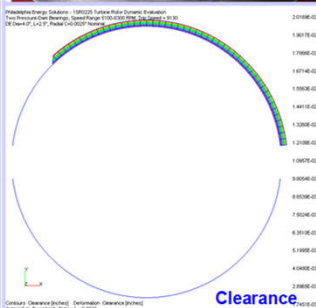
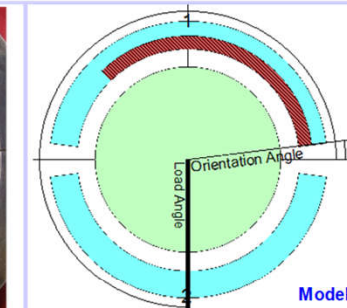
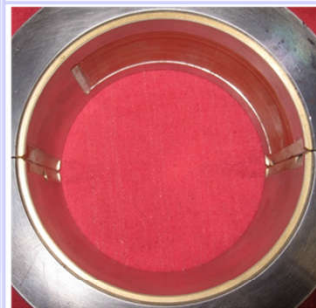


Sample Presentations – 3D Fluid-Film Bearing Pressure & Clearance Distributions.

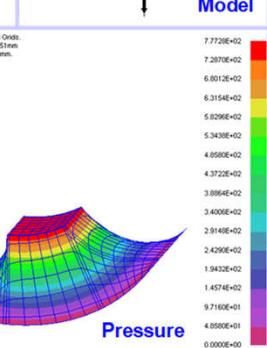
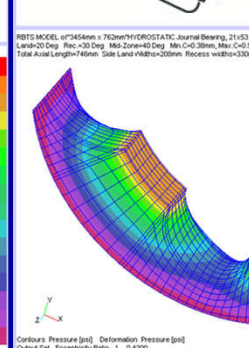
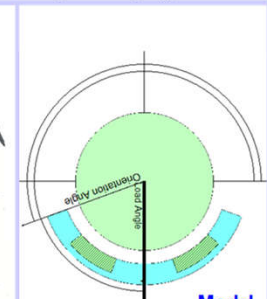
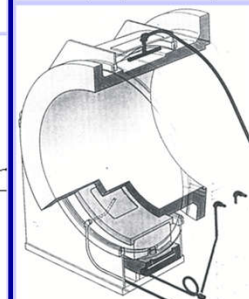
Sample - Three (3) pad, fixed geometry cylindrical journal bearing, with tapered pocket configuration for high speed multi-stage centrifugal compressor operating at 8500 rpm.



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



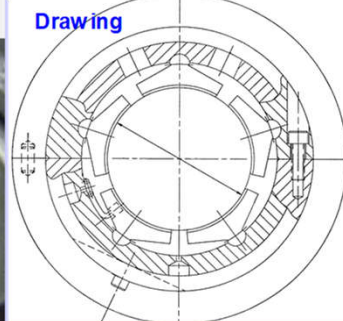
Sample Hydrostatic/Hybrid Bearing for Mining Application



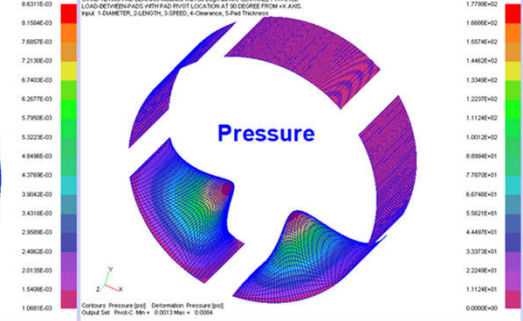
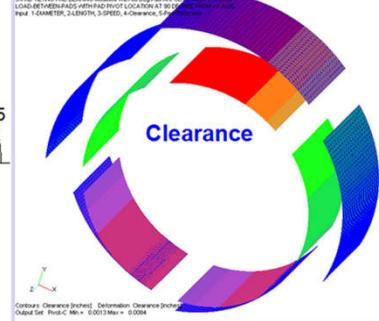
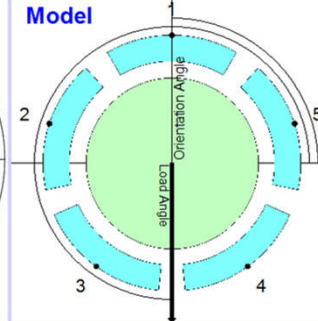
Journal Bearing – Unloaded Half



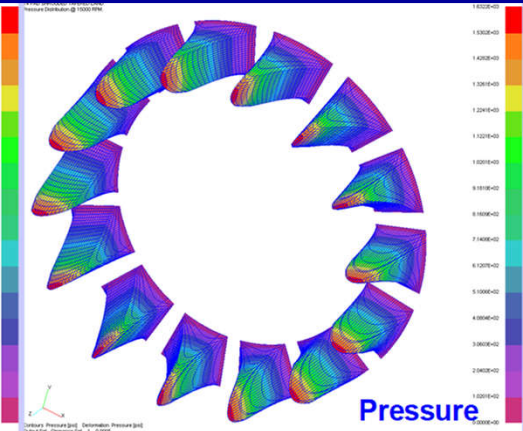
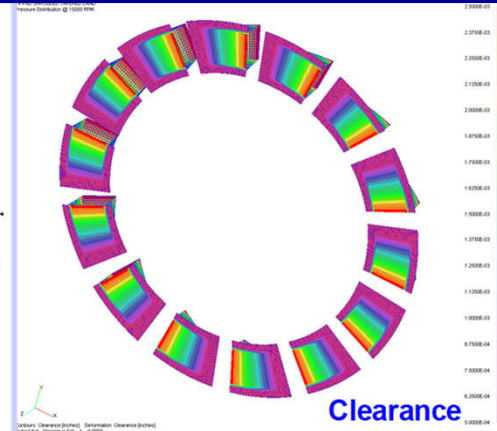
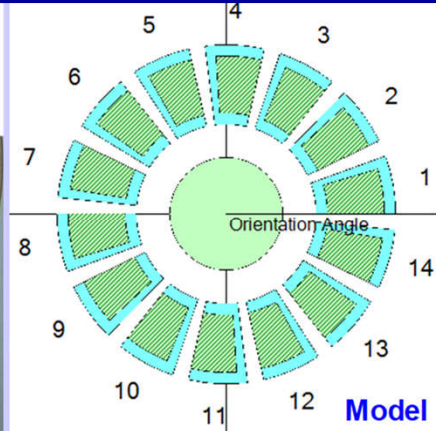
Drawing



Model



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



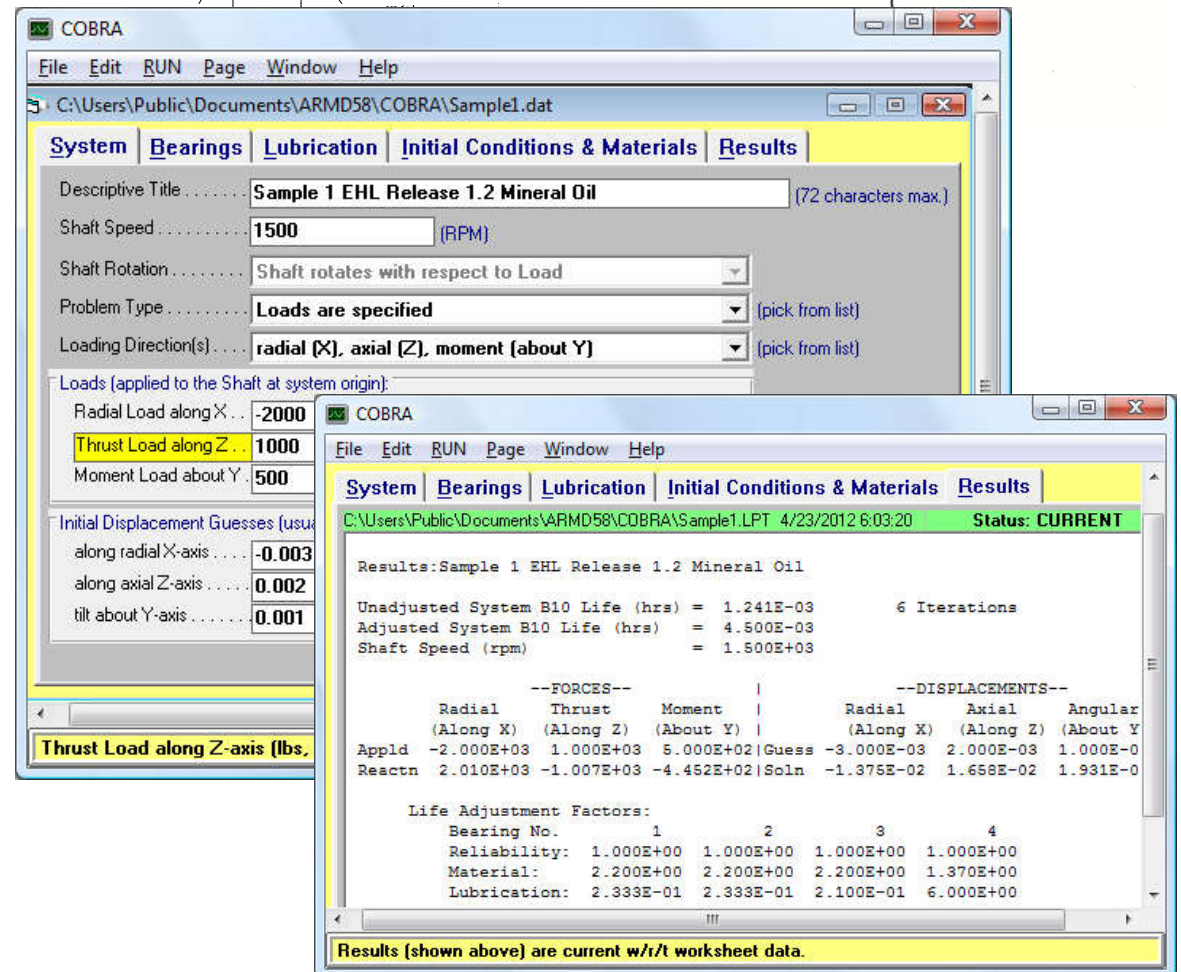
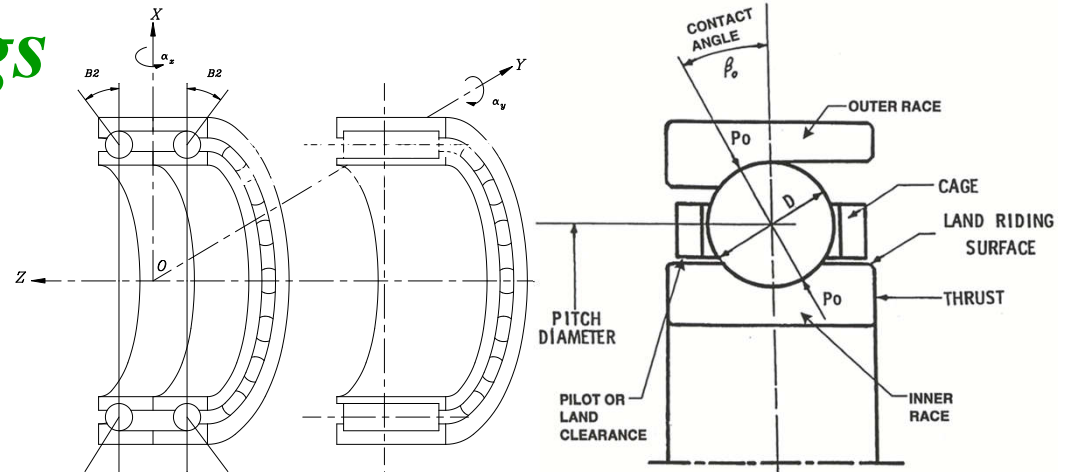
Rolling-Element Bearings

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



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

Description / Report Title
Sample Problem Number 1.
MOBIL DTE 797 Oil for 1800 rpm Turbine bearings
Last line of problem description.

Lubricant Product
Supplier: MOBIL
Brand Name: DTE 797 Turbine Oil

Properties
ISO Grade: 32 API Gravity: 32.6
First Centistoke: 32.0 at 104.0 °F

Lubricant Library

Insert Append Delete Duplicate

	Supplier	BrandName	ISO Grade	API Gravity	1st Kinematic Viscosity Point	1st Kinematic Viscosity Temp.	2nd Kinematic Viscosity Point	2nd Kinematic Viscosity Temp.
32	MOBIL	DTE 10 Excel Series	68	32.65	68.4	104.0	11.17	212.0
33	MOBIL	DTE 10 Excel Series	100	29.845	99.8	104.0	13.0	212.0
34	MOBIL	DTE 10 Excel Series	150	29.113	155.6	104.0	17.16	212.0
35	MOBIL	DTE 797 Turbine Oil	32	32.6	32.0	104.0	5.4	212.0
36	MOBIL	DTE AGMA 1	30	30.6	43.7	104.0	6.5	212.0
37	MOBIL	DTE Heavy Medium Oil	68	31.14	65.1	104.0	8.7	212.0
38	MOBIL	DTE Heavy Oil	100	29.3	95.1			
39	MOBIL	DTE Light Oil	32	34.97	31.0			

Last line of problem description.

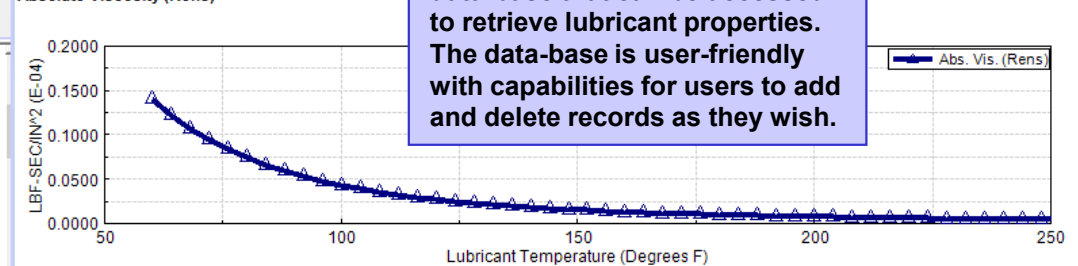
*** Units of Measure for this Run are --> US (English)

TABLE WAS GENERATED FOR THE FOLLOWING LUBRICANT:

Supplier --> MOBIL Brand Name --> DTE 797 Turbine Oil
API Gravity [@ 60°F/15.556°C] = 0.32600E+02 ISO Grade Number --> 32
1st Viscosity point (Centistoke) = 0.32000E+02 @ Temp. (°F) = 0.10400E+03
2nd Viscosity point (Centistoke) = 0.54000E+01 @ Temp. (°F) = 0.21200E+03
Computed SUS sec. @ 100°F/37.778°C = 0.16509E+03
Computed SUS sec. @ 210°F/98.889°C = 0.44359E+02

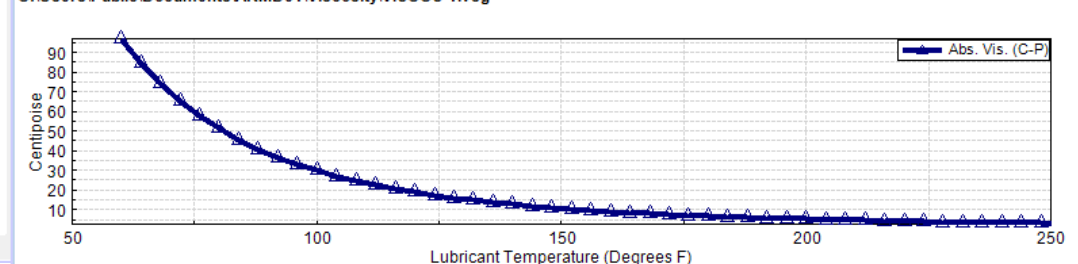
Temperature Degrees F.	Absolute - Viscosity		Kinematic Viscosity Centistoke= (M ² /s)*E+6	Saybolt Universal Viscosity (Sec.)	Specific Gravity (Gm/C ³)*E-3
	(Rens) Lb-Sec/In ²	Centipoise= (Pa-s*1000)			
60.000	0.14063E-04	0.96961E+02	0.11245E+03	0.51976E+03	0.8623
64.000	0.12268E-04	0.84583E+02	0.98266E+02	0.45439E+03	0.8608
68.000	0.10752E-04	0.74131E+02	0.86276E+02	0.39913E+03	0.8592
72.000	0.94654E-05	0.65261E+02	0.76089E+02	0.35220E+03	0.8577
76.000	0.83685E-05	0.57699E+02	0.67391E+02	0.31217E+03	0.8562

Absolute Viscosity (Rens)



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\ARM61\Viscosity\VISCOS-1.vsg



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 'Wear' software window, titled 'Wear (C:\Users\Public\Documents\ARMD61\ArmdWear\Samples\WearUS.WIN US) - [DataForm]'. The interface includes a menu bar (File, Edit, Data, Run, View, Tools, Project, Help) and a toolbar with icons for New, Open, Save, Cut, Copy, Paste, Run, and Insert Value.

The 'Description' field contains: 'Impeller Wear Ring Stiffness & Damping Calculations Prepared for Texaco, LA, CA'. A callout box labeled 'User Specified Operating Conditions and Lubricant Properties' points to the 'Operating Conditions' section.

The 'Operating Conditions' section includes input fields for: Diameter (4.735), Length (0.8685), Clearance (0.025), Pressure Drop (300.0), Speed (3600.0), Entrance Loss (0.0), Viscosity (3.045300e-07), and Density (8.134300e-05).

The 'Single Case' tab is selected. Below the input fields, a 'Run' button is visible. A callout box labeled 'Generated Text Output after Run Button Pressed' points to the output section.

The output section displays the following text:

```
CIRCUMFERENTIAL Reynolds number -----> 5.96007E+03
AXIAL Reynolds number -----> 2.93769E+04
FRICTION coefficient -----> 6.10490E-03
Fluid Axial Velocity (inch/sec)-----> 2.19961E+03

>>> STIFFNESS (Lbf/Inch)  Kxx ; Kxy -> 7.49605E+03  3.12560E+03
                          Kyx ; Kyy -> -3.12560E+03  7.49605E+03
>>> DAMPING (Lbf-Sec/Inch) Dxx ; Dxy -> 1.65818E+01  6.04234E-02
                          Dyx ; Dyy -> -6.04234E-02  1.65818E+01

Fluid Mass Coefficient (lbf) Mxx=Myy -> 6.18814E-02
                              Mxy=Myx -> 0.00000E+00
```

Below the output section, a table of results is displayed. The table has columns: Case No., DIMENSIONAL KXX, SPRING KXY, COEFFICIENTS KYX, and (lbf/inch) KYX. The table contains 20 rows of data. A callout box labeled 'Generated Text Output after Run Button Pressed' points to the table.

Case No.	DIMENSIONAL KXX	SPRING KXY	COEFFICIENTS KYX	(lbf/inch) KYX
1	5.70469E+02	7.08723E+02	-7.08723E+02	5.70469E+02
2	1.11694E+03	1.05017E+03	-1.05017E+03	1.11694E+03
3	1.64519E+03	1.32666E+03	-1.32666E+03	1.64519E+03
4	2.15945E+03	1.54408E+03	-1.54408E+03	2.15945E+03
14	7.02720E+03	3.01731E+03	-3.01731E+03	7.02720E+03
15	7.49605E+03	3.12560E+03	-3.12560E+03	7.49605E+03
16	7.96258E+03	3.22982E+03	-3.22982E+03	7.96258E+03
17	8.42868E+03	3.33564E+03	-3.33564E+03	8.42868E+03
18	8.89335E+03	3.43966E+03	-3.43966E+03	8.89335E+03
19	9.35640E+03	3.54120E+03	-3.54120E+03	9.35640E+03
20	9.81852E+03	3.64218E+03	-3.64218E+03	9.81852E+03

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.

AeroCC (C:\Users\Public\Documents\ARMD61\ArmdAeroCC)

File Edit Data Run View Tools Project

New Open Save Cut Copy Paste

Description

Centrifugal Impeller Aerodynamic Cross-Coupling Effects @ Design Power=1500HP (1.11855MW), Speed=20Krpm, Diameter=12inch, Disch. Width=0.787inch(20mm), Gas Density AVG=3.0E-04Lbf/ft³

Single Case Multiple Cases

9 of 14

Run

Parameters

Power 1421.35 ImpellerDiameter 10.9 Impeller Discharge Width 0.765354

Rotor Speed 25000.0 Discharge Gas Density 1.004780e-06 Suction Gas Density 5.931560e-07

AeroCC 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
Dyx ; Dyy -> 0.00000E+000 0.00000E+000

Single Case Multiple Cases

Expand Run

Case No.	<<< DIMENSIONAL KXX	Stiffness COEFFICIENTS (lbf/inch) KXY	KYX	KYY >>>
1	0.00000E+000	5.45476E+003	-5.45476E+003	0.00000E+000
2	0.00000E+000	4.54564E+003	-4.54564E+003	0.00000E+000
3	0.00000E+000	3.89626E+003	-3.89626E+003	0.00000E+000
4	0.00000E+000	3.18718E+003	-3.18718E+003	0.00000E+000
5	0.00000E+000	2.47810E+003	-2.47810E+003	0.00000E+000
6	0.00000E+000	1.76902E+003	-1.76902E+003	0.00000E+000
7	0.00000E+000	1.05994E+003	-1.05994E+003	0.00000E+000
8	0.00000E+000	2.27282E+003	-2.27282E+003	0.00000E+000
9	0.00000E+000	2.18191E+003	-2.18191E+003	0.00000E+000
10	0.00000E+000	2.09597E+003	-2.09597E+003	0.00000E+000

Equation - API 617 Centrifugal

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

A- For CENTRIFUGAL compressors:

Hc

Dc = Impeller Diameter

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

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

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

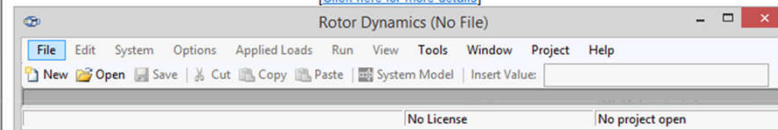
ARMD incorporates advanced technical and user interface features with built-in help utilities in each of its modules to simplify modeling, analysis, presentation, and interpretation of results. Tutorials and step by step sample sessions with advanced graphical presentation are among the many features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

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.

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

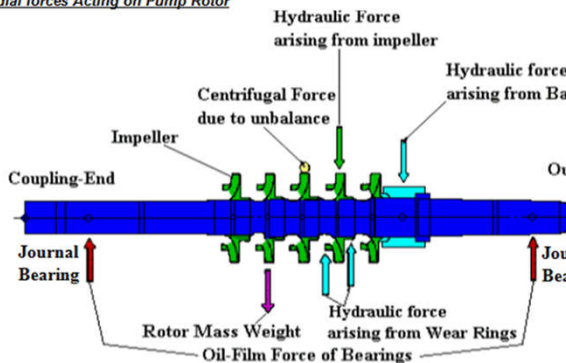


Modeling Concepts

Rotor-dynamic analysis principle objective is to system. The analysis is one aspect of a total r are feasible because of the computational capa analysis must include the effects of a large nur water pump rotor/system (shown below) consis balancing drums, thrust bearing runners, couplings, etc.), the journal bearings and foundati 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

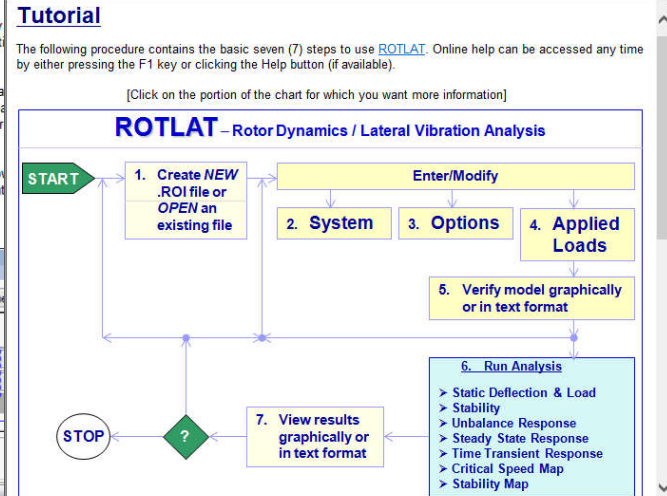
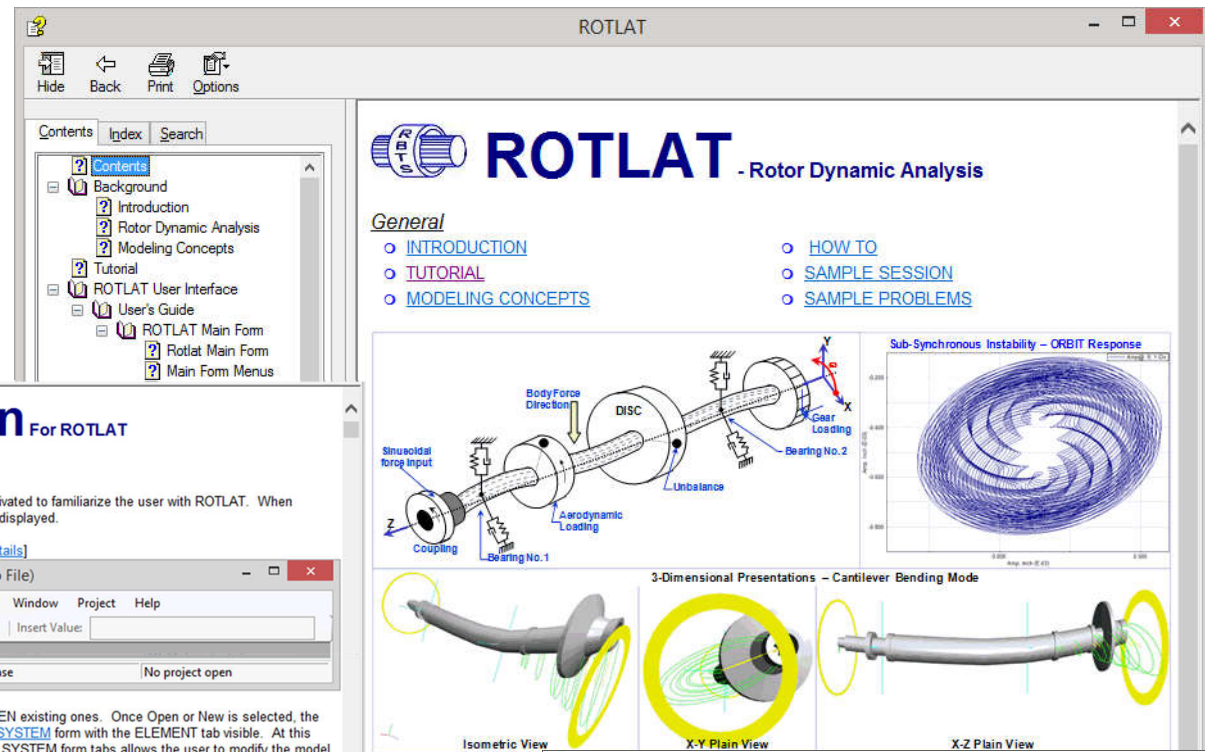
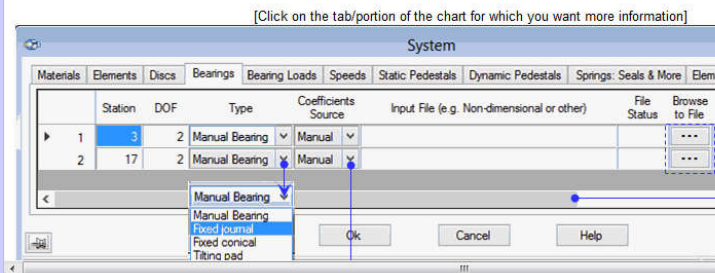


Linking a bearing to rotor model

Rotating assembly support bearing's dynamic coefficients ([stiffness and damping characteristics](#)) can be automatically rotor dynamic evaluation. Fluid-film and rolling-element bearings can be linked to the rotor model for automatic generat 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 and its performance results as a must first exist. The bearing model and performance results are generated with one of the [ARMD software](#) fluid-film bea cylindrical fixed-geometry journal bearings, [TILTB](#) for cylindrical tilting-pad-geometry journal bearings, or [HYBCB](#) for bearings.

Once the rotor model (shaft elements) is specified in the Element tab of the System form select the Bearings Tab (sho menu specify the bearing type to be linked as shown below. This selection will not affect any of the rotor or bearing dat [Coefficients Source](#) is selected to be [Auto or Linked](#).



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

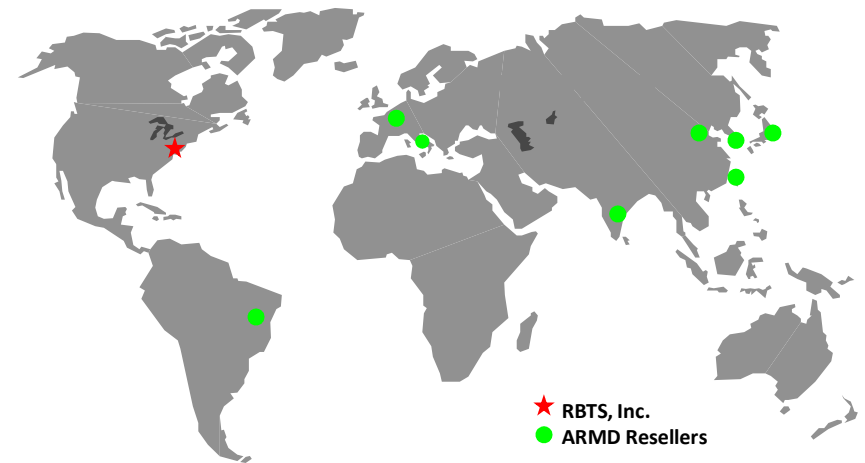
Microsoft Windows 8, 10, 11 or higher (32 or 64 bit).

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*



RBTS' software has gained international reputation for its:

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