Advanced Rotating Machinery Dynamics

ARMD™

Version 5.8

THE COMPLETE SOFTWARE PACKAGE FOR

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

ARMD™

THE COMPLETE SOFTWARE UTILIZED WORLDWIDE

Heart Pumps & Blood Bearings

From Heart Pumps to Turbine-Generator-Sets
**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 four main modules:

- Rotor Dynamics
- Torsional Vibration
- Lubricant Performance
- Bearing Analysis

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.
**Rotor Dynamics (ROTLAT™)**

ROTLAT is finite element based software for performing damped and undamped 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 module messenger. The messenger control the sub-modules to provide a complete lateral vibration analysis environment.

ROTLAT’s modeling capabilities include solid, hollow, tapered and stepped type elements, cylindrical, conical, tilting-pad, and rolling element type bearings, gravitational loading, bearing elevation, gyroscopic effects, flexible coupling, casing, foundation flexibility, and material damping in the shaft and foundation.

ROTLAT results include (next page):
1- STABILITY ANALYSIS

- Natural frequencies & mode shapes
- Stability parameters (i.e. damping ratio, log dec.)
- Rotor orbit direction
- Stability & critical speed maps
- Bearing reaction forces, shaft weight, deflection, and centerline slope
- Shaft moment, shear, & fiber stress diagrams

2- UNBALANCE RESPONSE
(Synchronous response)

- Multiple unbalance 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

3- TIME-TRANSIENT RESPONSE
(Non-synchronous response)

- Gravitational and external forces: sinusoidal, step, ramp and pulse
- Vibratory amplitudes time history
- Rotor orbits
- Dynamic forces, moments
- Dynamic stresses
- Transmitted forces and moments
- Pedestal vibratory amplitudes
Various Options of Model & Mode Shape Presentation

Deflected Solid Shaft Model

With Mesh

Mesh Only

Shaft Center-Line Only

Animated Unbalance Response

Bearing

Disk
**Torsional Vibration (TORSION™)**

The torsional vibration module 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 module messenger. The messenger controls the sub-modules to provide a complete torsional vibration analysis environment. TORSION accepts models generated with ROTLAT and has the same basic modeling capabilities as well as the modeling of multi-shaft/multi-branch systems, coupling stiffness and damping, gear tooth flexibility, various types of external excitation, synchronous motor start-up torque, compressor torque, etc.

TORSION results include (next page):
**NATURAL FREQUENCY**
- Damped and undamped
- 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

![Torsional Critical Speed Map](G:\ARM\WIN32\TORSION\Sample\SYNC-MOT.TNC)

**Synchronous Motor Start-Up Torque**

**High Speed Compressor Shaft Start-Up Torque**

**Drive Train Passing Through 1st Torsional Natural Frequency**
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).
Bearings

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

The FLUID-FILM bearing modules (JURNBR, HYBCBR, TILTBR, 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, structural deformation, lubricant feed circuitry (JURNBR, HYBCBR) with specified pressures or restrictors (capillary, orifice, or flow control valve), groove geometry and chamfers.
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:

**Cylindrical & Conical Fixed Geometry** [JURNBR & HYBCBR]
- Plain
- Multi-groove
- Tapered land or pocket
- Rayleigh step or pocket
- Pressure dam
- Elliptical or lemon
- Lobe or canted lobe
- Multi-recess

**Cylindrical Tilting-Pad Geometry** [TILTBR]
- Tilting pad with user specified:
  - Pivot location
  - Preload

**Thrust Fixed and Tilting-Pad Geometries** [THRSBR]
- Plain
- Multi-groove
- Tapered land
- Tapered pocket
- Step land
- Step pocket
- Tilting pad
- Compound taper
4-Canted Lobe Journal Bearing Pressure Distribution For Concentric Operation @ 6000 RPM

90 Inch Diameter Hybrid Trunnion Bearing for Coal Pulverizer Operating at 12 Rpm
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
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.
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.
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:

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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.
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 XP, Vista, Windows 7, Windows 8 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.

RBTS’ software has gained international reputation for its:
- Technical Capabilities
- Completeness
- User Friendliness
- Support & Service