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ROTATING MACHINERY DYNAMICS

SOFTWARE MODULE LIST

Fluid Film Bearings

Featuring embedded finite element models and lubrication properties

The bearing dynamic characteristics are determined using the bearing geometry, load, operating speed, and lubricant properties. The analysis provides both the static and the dynamic characteristics of the bearing. Performance characteristics such as lubricant film thickness, power loss, operating temperature and temperature rise, and oil flow are calculated. Oil flow rates and orifice sizes are calculated to complete the design. The dynamic characteristics are the eight stiffness and damping coefficients that are used in rotor dynamic analysis to study vibration and rotor system stability.

- Plain Journal
- Shaft Seals
- Oil Ring Lubricated Journal
- Elliptical
- Axial Groove
- Multi Lobe
- Pressure Dam
- Tilting Pad
    1. Configurable for 3,4,5, or up to 12 pads
    2. Load on pad or load between pads or any angle
- Tilting Pad with Embedded Pocket
    1. Thermohydrodynamic solution, e.g. Reynold's equation and the Energy equation solved simultaneously to give the 2D temperature distribution.
    2. Multiple pad and load angles

The FEA model of the pad also includes Hertzian contact analysis of the pad pivot point. The stiffness of the pivot point, in series with the pad deflection, produced by the hydrodynamic loading is used to correct the fluid film thickness and the dynamic characteristics. Highly accurate bearing dynamic characteristics are calculated by iterating on the film thickness and the pivot deflection until the sum of the forces is equal to zero.

Thrust Bearing Analysis includes Generalized Fluid Film Bearing Analysis, such as new hybrid bearings.

Rolling Element Bearings

Featuring embedded high accuracy models

- Ball
    1. Angular Contact
    2. Deep Groove
- Tapered Roller
- Roller

Rotor Dynamics

Featuring embedded high accuracy analysis

- Lateral Critical Speed (including critical speed map)
- Torsional Critical Speed
- Response to Unbalance
    1. Damped Critical Speed and Stability

A systematic design audit of a rotor-bearing system can be made to check for unacceptable design conditions and to identify potential problems before manufacture. The same analysis capability can be utilized to study a field problem and assist in the detection of the root cause. The design audit can determine that:

- the bearings can support the rotor loading with acceptable power losses,
- the rotor critical speeds are sufficiently removed from the running speed,
- the rotor system possesses well controlled response to residual unbalance,
- the rotor system is stable and free of subsynchronous vibration at operating speed.

Detailed Rotor Modeling Capability

The rotor is modeled for analysis along the shaft axis using “super rotor elements” which define the mass and stiffness properties along the length of the shaft. Stations are declared at locations of special interest such as bearings, shaft seals, impellers, and changes in shaft cross-section. Inertia properties are calculated for all masses. Components which can produce aerodynamic excitation, such as impellers, shaft seals, and long close clearance regions, are identified in the model. All rotor dynamic analysis programs use the same rotor model enabling any rotor analysis to be performed with minimum effort and minimizing errors.

Bearing Load Analysis

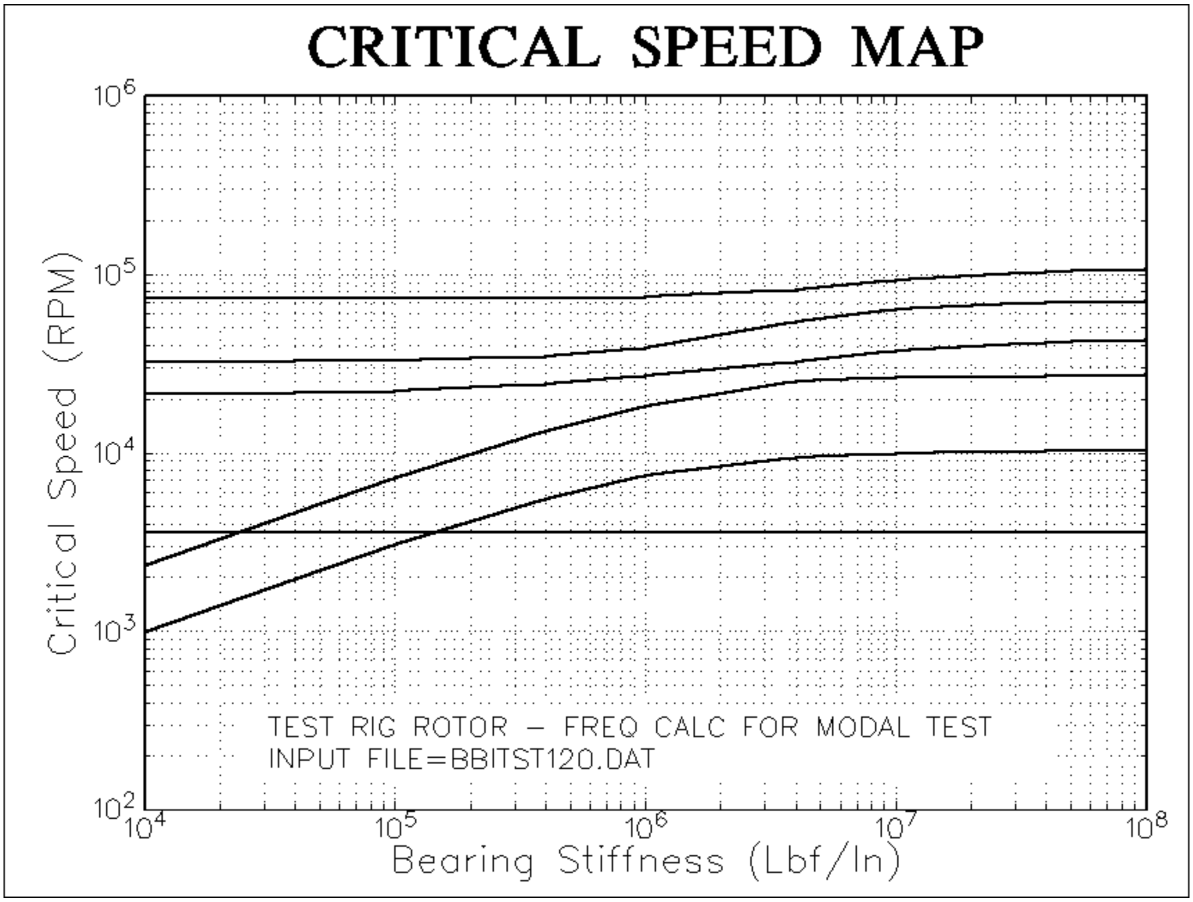
The loading of a bearing is the sum contribution of many system forces including gear reaction forces, aerodynamic loads, hydraulic forces, and the rotor weight. The rotor model is analyzed as a statically indeterminate system in order to compute the bearing reactions for any number of bearings in a system. This program can also be used to perform an alignment calculation since each bearing can be set to any elevation and the loads on all bearings calculated.

Torsional Critical Speed Analysis

The power delivered by a rotor system is usually in the form of a torque. Changes in load, speed, or operating temperature can excite the rotor system in a torsional way. For this reason, the rotor system can be studied using the torsional critical speed analysis capability. Torsional excitation present during machine operation can be catastrophic if the torsional resonances are too closely aligned with running speed or an excitation
frequency. The system torsional critical speeds are calculated and examined to determine that they are not positioned at or near a multiple of running speed, blade pass frequency, or some other known excitation mechanism

Lateral Critical Speed Analysis

The rotor model is analyzed to determine its undamped critical speeds (natural frequencies), and the mode shape associated with each natural frequency. The critical speeds are plotted on a log-log graph as a function of bearing stiffness. The bearing stiffness is cross plotted on the same graph. The resulting plot is called a “critical speed map”. The critical speeds are defined by the intersection of the rotor critical speed curves with the bearing stiffness curves. The modes shapes associated with any critical speed can also be calculated and plotted.



Response to Unbalance Analysis

The response of the rotor bearing system to known amounts of residual unbalance with a known distribution is conducted to establish the sensitivity of the rotor system design to unbalance. This technique is normally used to establish residual unbalance requirements for manufacturing of a new design. This analysis is a valuable complement to the critical speed analysis, since the response analysis produces information in engineering units. The most sensitive locations along the rotor can be readily determined. Amplitudes are calculated which can be used to make judgments about design features such as overhung rotors and impellers, bearing design, and rotor weight reduction.

The analysis uses the rotor model together with unbalances placed at locations known to introduce unbalance such as couplings, impellers, balance pistons, and thrust plates, etc. Unbalance locations are also selected to accentuate rotor amplification at critical speeds. The analysis determines the amplitude of vibration (response) in mils peak to peak at selected locations along the shaft. In addition, bearing dynamic loading, and the dynamic forces and energy dissipated by the system are calculated. Elastic bearing pedestals can be included which further enhance the simulation accuracy and provide the forces transmitted through the bearing into the foundation.

Damped Critical Speed and Stability Analysis

As turbomachinery designs are pushed to higher speeds to achieve greater power densities, the incidence of a severe vibration phenomenon known as dynamic instability has increased. A significant capability of the Rotating Machinery Analysis System is its ability to determine if a rotor system is stable, marginally stable, or unstable and its ability to evaluate the relative merit of design alternatives. The analysis utilizes the rotor model together with the frequency dependent dynamic characteristics from the bearing analysis. The system damped natural frequencies and associated mode shapes are calculated together with the associated logarithmic decrement. The log decrement is a measure of the relative stability for each mode. A log decrement of approximately 0.05 indicates a marginally stable system. As the log decrement tends towards zero, that particular mode tends towards instability. The rotor system becomes more susceptible to the influences of external forces such as fluid pulsations, changes in loading, and shaft flexure.

Shaft Crack Analysis

The rotating machinery dynamics analysis software is designed to accept input data from the shaft crack analysis software, in order to calculate the effects of the crack on the shaft system natural frequencies. The resulting system natural frequencies are calculated and a comparison can be made to the uncracked system natural frequencies. The shift in system natural frequencies is known from the analysis so that the depth of the crack can be correlated with the new natural frequencies. In addition, the crack growth rate, and remaining life can be determined using this data.