Dynamics of Rotors on Hydrodynamic Bearings

R. Eling[1]

[1]Mitsubishi Turbocharger & Engine Europe, Almere, The Netherlands

Abstract

Introduction
Fluid film journal bearings are widely used to support the movements of rotating machine elements such as engine crankshafts and turbocharger rotors (Figure 1). The bearing has a certain carrying capacity which originates from the pressure distribution of the fluid film (Figure 2). Forced by the rotational motion of the shaft, the fluid is sheared into converging sections causing a local increase of pressure. The converging sections can be formed by purpose-made wedges or can also be caused by the shaft rotating in an eccentric position.

When the resulting force from the pressure distribution is not aligned with the shaft displacement, self-induced vibrations called whirling can be triggered. When the whirling frequencies of the bearing are equal to the rotor eigenfrequencies, resonance in the rotor-bearing system can occur (Figure 3). This resonance, so-called oil whip, can cause violent vibrations leading to noise and even catastrophic failures. Therefore, for proper design evaluation, it is crucial to analyze the stability of the coupled rotor-bearing system. In addition, coupled rotor-bearing analysis facilitates design optimization for sufficient carrying capacity at a minimum of shear flow losses in the bearing.

Use of COMSOL Multiphysics®
The physics of the rotor and the bearing are coupled and therefore both the fluid and structural physics need to be analyzed simultaneously. The flow in fluid film bearings is usually characterized by incompressible liquids at low Reynolds numbers. Additionally, the film height is small compared to the tangential and axial bearing dimensions and hence the computationally inexpensive Thin Film Flow Interface can conveniently be used.

The rotor dynamics has been added to the model using the ODE input Interface. Although no exact analytical solutions exist for the pressure field in a finite length journal bearing, approximate analytical solutions and numerical solutions can be compared (Figure 4). Furthermore, due to the considerable amount of shear stress in the fluid, heat is generated in the film. This effect can be included using the Conjugate Heat Transfer Interface.

In order to describe a complex rotor in discrete terms, the Modal Reduction Interface is used. As the dynamics of the rotor are rotation speed dependent, the reduced model for the rotor becomes rotation speed dependent.

Results

The coupled rotor-bearing model is used to analyze critical design aspects such as bearing friction losses, maximum operational deflections and the threshold values of instability. As a case study, a turbocharger rotor-bearing system is evaluated over its entire operational speed range. In conclusion, these simulations enable the rotating machinery engineer to predict the dynamic performance of a rotor-bearing design at a very early stage of development.

Figures used in the abstract

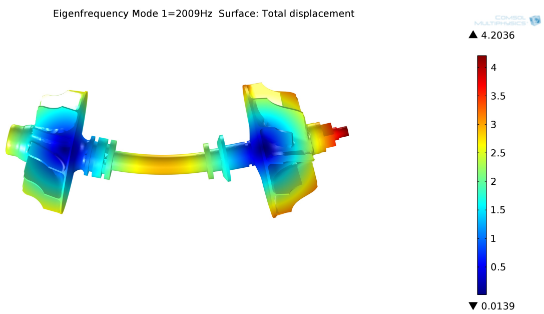

Figure 1: An automotive turbocharger rotor vibrating in its first radial eigenmode: a bending mode at 2kHz.

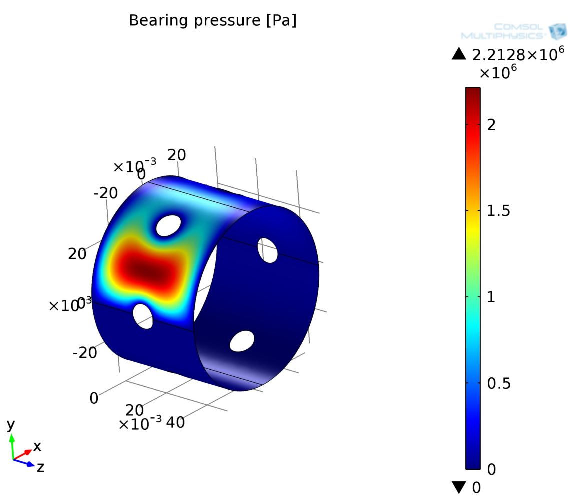

Figure 2: The pressure field in a fluid film journal bearing with oil feed holes.

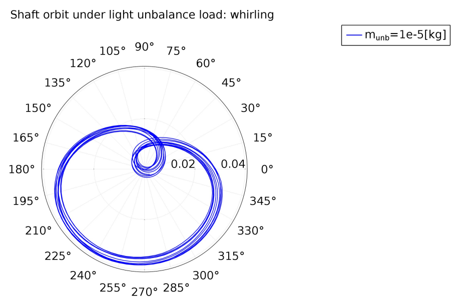

Figure 3: Rotor orbit under rotating unbalance load showing half-rotation-speed whirling behavior.

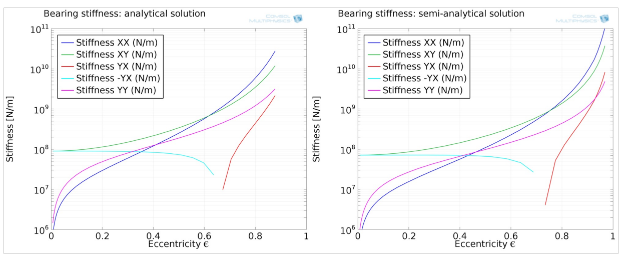

Figure 4: Evaluation of the bearing stiffness under increasing eccentricity ratio using an approximate analytical solution and a semi-analytical solution using the numerically calculated pressure field.