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Reducing amplitude of nonlinear vibration of rotors induced by imbalance forces and the disc collisions using magnetically sensitive fluids

JAROSLAV ZAPOMĚL[1*], PETR FERFECKI[2], JAN KOZÁNEK[3]

1. Institute of Thermomechanics, Department of Dynamics and Vibration
   VŠB - Technical University of Ostrava, Department of Applied Mechanics
2. VŠB - Technical University of Ostrava, Department of Applied Mechanics
   VŠB - Technical University of Ostrava, IT4Innovations
3. Institute of Thermomechanics, Department of Dynamics and Vibration

* Presenting Author

Abstract: Rotors of rotating machines are often supported by hydrodynamic bearings. The unbalance, ground vibration, assembling inaccuracies, and eccentric position of the rotor journal in the bearing hole may arrive at collisions of the discs with the machine casing. This can be avoided by changing position of the rotor journal in the bearing hole by increasing stiffness of the oil film. This is offered by application of magnetically sensitive fluids. The control of stiffness of the rotor support elements by a magnetic field was examined by computational simulations. The results show that application of a magnetic field makes it possible to prevent impacts and maintain quite running of rotating machines in a certain velocity interval.

Keywords: hydrodynamic bearings, magnetically sensitive lubricant, oil film stiffness control

1. Introduction

Rotors are often supported by hydrodynamic bearings. The design of a number of rotating machines requires very narrow gaps between the discs and the inner wall of the stationary part (e.g. propellers of pumps or fans to minimize leakage of media from the working space). The assembling inaccuracies, imbalance of rotating parts, and eccentric position of the rotor journal in the bearing hole may arrive at collisions between the discs and the rotor casing. Then the hydrodynamic bearings and impacts become the source of highly nonlinear vibration of the rotor and of increase of forces transmitted between the rotating and stationary parts. The change of the rotor journal position in the hydrodynamic bearings gives the possibility how to avoid these undesirable working conditions. This manipulation requires to change the bearing stiffness.

A new approach to control stiffness of hydrodynamic bearings consists in using magnetically sensitive oils. Application of magnetorheological fluids is reported by Wang et al. [1]. The simulation results show that the magnetorheological fluids are applicable for suppressing vibration of rotor systems and for altering their critical speed. The proposal of the bearing and investigation of its response on the change of the current powering the electric coil that is the source of the magnetic flux is reported in [2]. This paper focuses on changing position of the rotor journal in the bearing gap by changing stiffness of the oil film utilizing action of a magnetic field on magnetically sensitive oil with the aim to prevent collisions between the rotor and its casing.

2. Effect of the magnetically controllable bearing on collisions suppression

The investigated rotor consists of a shaft and of one disc. At both its ends it is supported by magnetically controlled hydrodynamic bearings. The rotor rotates at constant angular speed, is loaded by its weight and is excited by the disc imbalance. The disc is placed in the hole between two parallel vertical walls.

In the computational model the hydrodynamic bearings are represented by force couplings. The pressure distribution in the oil layer is governed by the Reynolds equation, which has been significantly modified to be applicable for lubricants exhibiting the yielding shear stress. The integration of the pressure profile gives components of the hydraulic forces. The Kirchhoff and Hopkinson laws were used to determine distribution of the magnetic field intensity in the bearing gap. The details are reported in [2].

Fig. 1 shows the orbits of the disc centre for two angular speeds of the rotor rotation. If the oil is not affected by a magnetic field, the collisions between the disc and the stationary part take place. Application of the magnetic field shifts the orbits toward the bearing centre, which avoids the impacts. The shape and size of the orbits depend on angular speed of the rotor rotation, application of the magnetic field, and on interaction between the disc and the stationary part.

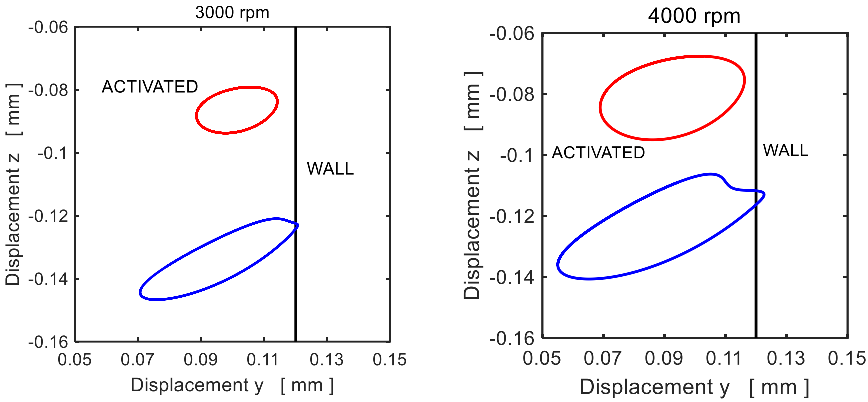

Fig. 1. The disc centre orbit (non-activated and activated bearing)

3. Conclusions

The results of the computational simulations show that (i) if the disc motion is not limited then the vibration bifurcates after exceeding the critical speed and a subharmonic component of large amplitude occurs, (ii) if the disc motion is limited then after exceeding a critical speed the impacts start to take place but increasing angular speed of the rotor rotation does not lead to inducing the subharmonic vibration, and (iii) application of the magnetic field prevents impacts in a certain velocity interval.

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