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Design concepts of controllable hydrodynamic bearings lubricated by magnetically sensitive oils for the vibration control of rotors

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The rotors are often mounted in hydrodynamic bearings. To achieve their optimum performance in a wide range of running velocities, their stiffness and damping parameters must be adaptable to the current operating conditions. This is offered by application of magnetically sensitive lubricating oils.

Application of magnetorheological fluids to lubricate the hydrodynamic bearings is reported by Wang et al. [3]. The study on lubricating a floating ring bearing by magnetorheological fluid to design a controllable support element can be found in [4].

Several design concepts of hydrodynamic bearings lubricated by ferromagnetic fluids were introduced in literature. Nevertheless, the detailed analysis shows that their practical application for the vibration control of rotors is not technologically feasible. It implies the ferrofluids cannot be used as tunable lubricants to get an active journal bearing, because its rheological change is very low [2].

This paper deals with a design concept of a hydrodynamic bearing lubricated by ferromagnetic fluid-based magnetorheological oil and its applicability for controlling the rotor vibration. Addition of the micrometer-sized iron particles to a concentrated ferrofluid represents a simple way to control its magnetorheological and magnetoviscous behavior, which is sufficient to change the stiffness and damping in a hydrodynamic bearing [1].

The housing of the proposed bearing consists of a cylindrical part that forms a bushing and of a cylindrical pin (Fig. 1). The rotor journal is hollow, made of non-ferromagnetic material, and is inserted into the hole of the bearing bushing. The gap between the bushing and the rotor journal is filled with the magnetically sensitive oil. The electric coil mounted on the pin generates magnetic flux passing through the pin, the cylindrical part of the bearing, the oil layer, and returns back to the pin through the rotor journal. Because the rotor journal is not magnetic, it is not attracted to the bearing bushing.

The pressure distribution in the bearing gap is described by the modified Reynolds equation, which has been derived on the following assumptions: (i) the oil layer is divided in the sublayers in the radial direction, (ii) the liquid in each sublayer behaves as Newtonian, (iii) the applied boundary conditions require that the velocity and the shear stress at location of the contact of two neighboring sublayers are the same, and (iv) the apparent viscosity in the individual sublayers is constant in the radial direction and is determined from the flow curve for the average sublayer velocity rate in dependence of the circumferential position.

The bearing housing is considered to be consisted of a set of meridian segments and each segment as a divided core of an electromagnet. Magnetic induction in the lubricating layer is calculated by application of the Hopkinson law. The reluctance of the ferromagnetic parts of the magnetic circuit was neglected.

The influence of the hydrodynamic bearing lubricated by the ferrofluid based magnetorheological oil on vibration of a rigid rotor (Fig. 2) was examined by means of computational simulations. The rotor (mass 430 kg) was rotating at speed of 300 rad/s. It was loaded by its weight, by a stationary force (15 kN) acting in the vertical direction, and by the disc imbalance. The diameter of the rotor journal was 60 mm. The electric coil was formed by 900 turns. Relations for the determination of the yielding shear stress of the lubricating oil and the appopriate material parameters were taken from [1].

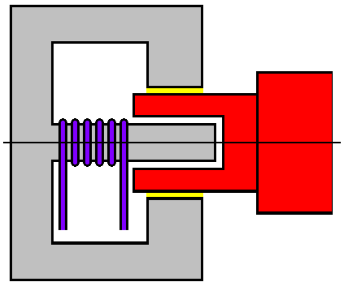

Fig. 1 The proposed bearing design

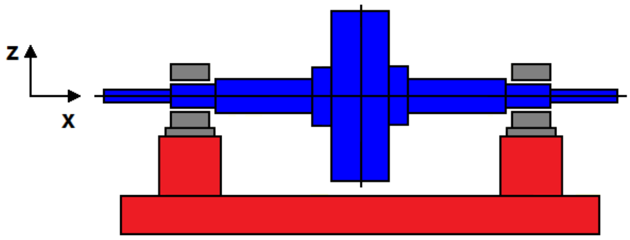

Fig. 2 The studied rotor system

Fig. 3 and 4 show dependence of magnetic induction in bearing gap and the yielding shear stress of the applied current. In Fig. 5 there are depicted the steady state orbits of the rotor journal for three magnitudes of the current. It is evident that increasing current shifts the orbits towards the bearing centre, which means the bearing load capacity rises.

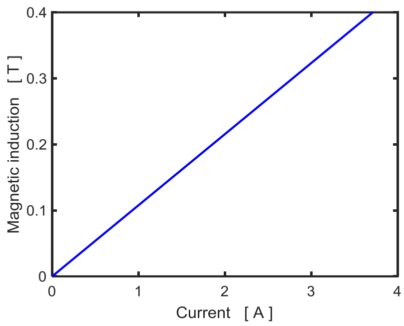

Fig. 3 Magnetic induction in bearing gap

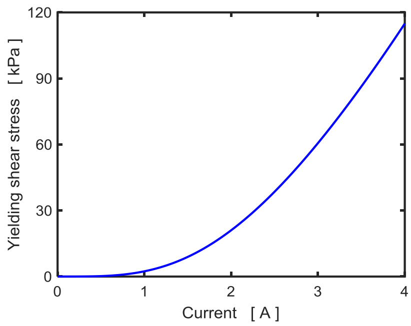

Fig. 4 The lubricant yield shear stress

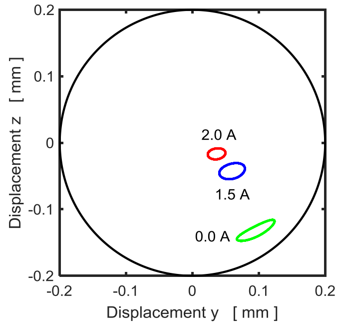

Fig. 5 The orbits position

The carried out research demonstrated that the appropriate control of hydrodynamic bearings lubricated by ferrofluid based magnetorheological oils can change dynamical parameters of rotors in sufficinently large extent and thus to adapt their performance to the current operating conditions.

Acknowledgements

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