INVESTIGATION OF THE HYDRODYNAMIC BEHAVIOR OF NEW CONSTRUCTION HYDRODYNAMIC TILTING-PAD JOURNAL BEARING

Vladas Vekteris
Vilnius Gediminas Technical University, Faculty of Mechanics, Department of Machine Building, J. Basanavichiaus str. 28, Vilnius-9, LT-03224, Lithuania, tel. +370 5 2744734, fax +370 5 2745043, E-mail: vekteris@me.vtu.lt

Vadim Mokshin
Vilnius Gediminas Technical University, Faculty of Mechanics, Department of Machine Building, J. Basanavichiaus str. 28, Vilnius-9, LT-03224, Lithuania, tel. +370 5 2744733, fax +370 5 2745043, E-mail: vadim@me.vtu.lt

ABSTRACT
The paper describes features of new construction pad-type (segmental) hydrodynamic bearing with mobile ring and results of investigations of this bearing.

The researchers obtained complex method of interaction between the mobile ring and pads. Except the diagram of distribution of lubricant pressure on the surface of pad there are presented photos of the flowing lubricant in the bearing and graphs of trajectories of the rotor journal’s axis for various number of revolutions of the rotor.

Presented results of investigations show high stability of new construction hydrodynamic bearings in case of big number of revolutions of the rotor. Researchers hope that new construction bearings can be successfully used in tribological systems at the mentioned condition.

Keywords: bearing, mobile ring, rotor, lubricant.

INTRODUCTION
Serious mechanical problems due to the rotor instability and axis misalignment of bearings arise time to time in rotor systems [1-3]. Trying to minimize the instability of such a system, most diverse designs of bearings have been developed on the basis of self-adjustment including floating ring bearings, elliptical bearings, tilting-pad (segment) bearings and elliptical tilting-pad bearings. However, common radial flood-lubricated tilting-pad bearings have a serious exploitation problem. Intensive fatigue cracking of the babbit filling of pads occurs from time to time in the area of the front edge (in the direction of the lubricant flow) of the upper pads, which are free of static load (in case of horizontal rotor) [1,3]. Further structural development of bearings resulted in creation of mechanically actuated radial pad-type bearings.

MECHANICALLY ACTUATED BEARING
Bearings with convective self-cooling and viscoelastic damping are distinguished by the use of kinetic energy of the inter-segmental space by means of mobile elastic elements in the form of cylinders or a set of rings. For this purpose self-adjusting segments are manufacturing as composite ones featuring one of two tangential openings, through which elastic elements are passed. Self-adjusting segments are mounted on spherical supports or on supported pins by means of supporting surfaces or supporting craters.

HYDRODYNAMICS OF SEGMENTS
Bearings of the given type shown in Fig. 1 are vibration system, in which rolling elastic elements disrupts synchronized vibration of segments following in the motion of the rotor. Dynamic excitation of segments may be low-frequency or high-frequency. In the first case the proper motion of elastic elements is used in tangential openings of segments. In the second case the elastic elements are given high-frequency vibrations from an internal or external source, or the segments are rigidly attached to the outer ring by means of elastic stems.

The laws of changes in the rotation angles of segments in the course of time can be divided into several types: angle of rotation is composed of the static component $\Theta$ and overlying sine-shaped component $\Theta \sin \omega_3 t$; perturbation acts on the rotation angle of segments in the form of impulses; excitation is stochastic. Compression of films under the effect of a random or harmonic vibration perturbation is discussed in literature [2], therefore it is not analyzed in this work. The state of the supporting lubricant layer will be determined by the rotation angles of pads. In the case of harmonic excitation the thickness of supporting lubricant layer is determined by the following differential equation:

$$\frac{dh}{(r + h) d\varphi} = -(\Theta + \Theta \sin \omega_3 t),$$

where $h$-thickness of the lubricant film, $r$-rotor radius, $t$-time, $\Theta$-angle of rotation of the tilting pad, $\varphi$-angular coordinate, $\omega_3$-angular velocity of the tilting pad.
Calculation is carried out in terms of hydrodynamics equation “Eq. (2)” for separate segments and then the results can be generalized for the whole bearing.

$$\frac{\partial}{\partial \phi} \left( \frac{h^3}{\mu} \frac{\partial \rho}{\partial \phi} \right) + \frac{\partial}{\partial z} \left( \frac{h^3}{\mu} \frac{\partial \rho}{\partial z} \right) = 6 \left( 1 + 2 \frac{\omega_2}{\omega_1} \right) \frac{\partial}{\partial \phi} v h -$$

$$- \frac{\partial}{\partial \phi} \left( \frac{\rho k h^2}{\mu} \frac{\partial v_x}{\partial t} dy \right) - \frac{\partial}{\partial z} \left( \frac{\rho k h^2}{\mu} \frac{\partial v_z}{\partial t} dy \right).$$

where $h$-thickness of the lubricant film, $k = 0...4$-coefficient with an account of the amount of inertial forces, $p$-pressure, $r$-rotor radius, $t$-time, $v$-velocity of viscous fluid flow, $v_x, v_z$-peripheral and centerline linear velocity, $x, y, z$-coordinates, $\mu$-dynamic viscosity of lubricant, $\rho$-lubricant density, $\varphi$-angular coordinate, $\omega_1$-angular velocity of the rotor, $\omega_2$-angular velocity of the rotor in case of non-stationary rotation.

Static characteristics of segments are presented in Fig. 2.

**EXPERIMENTAL RESULTS**

Analytical and experimental research is always carried out by using approximate mathematical simulators are not always capable of taking into account the phenomena occurring in real systems. In this connection a further deepening of theory as well as a wider development of experimental research are needed for a thorough analysis of the phenomenon. That is why deficiency of accuracy in assigning original and boundary conditions and approximations of mathematical simulators to real phenomena (reduced to 2-D systems) necessitates application of experimental methods of research. Experimental research is usually carried out at experimental installations where the phenomena that occur in real system are simulated. Such methods of experimental are characteristic of high potentiality and efficiency.

The prevailing type of non-stationary rotation of rotor journal observed in the course of investigation (Fig. 2) is represented by the case of $\omega_2 \leq \omega_1$.

The trajectories demonstrate the non-ergodic character of the stochastic process and tendency toward orderly motion. Tendency toward a regulated trajectory is a characteristic of adaptive bearings. Changes in oscillograms in such cases are less noticeable. Excitement of pads transferred from mobile elastic ring disrupts the local stability of the system. Trajectories of conditions and oscillograms of the rotor motion in such bearings acquire a stochastic form at various frequencies (Fig. 3).

At high rotary frequencies of the rotor bearings even reduce vibrations, which occur due to unbalance of the electric motor.

**CONCLUSIONS**

1. Hydrodynamic tilting-pad journal bearings of a new design with freely moving elastic element in cavities of bearing pads are created the elastic elements unable to rise the subynchronous self-excited vibrations of unloaded bearing pads.

2. Experimental research shows that at correct selection of parameters of freely moving elastic element is possible to stabilize rotation of a rotor at high speeds.

**REFERENCES**


---

**FIGURES**

Figure 1. A hydrodynamic fluid friction bearing with a mobile elastic element: 1-rotor, 2-pads, 3-supports, 4-elastic element, $\omega_1$-angular velocity of the rotor.

Figure 2. Static characteristic of bearings with mechanically excited pads: $F$-friction force in the supporting lubricant film, $h$-thickness of the lubricant film, $N$-load capacity of lubricant film, $p$-pressure, $\omega_1$-angular velocity of the rotor, $\omega_2$-angular velocity of the rotor in case of non-stationary rotation.

Figure 3. Trajectories and oscillograms of the rotor motion.