EFFECTS OF MAGNETIC LUBRICANT IN A ROTOR-BEARING SYSTEM

Anna Perek[*a)], Włodzimierz Kurnik[*], Piotr M. Przybyłowicz[*]

*Warsaw University of Technology, Institute of Machine Design Fundamentals, Warsaw, Poland

Summary This paper presents a dynamic analysis of rotors supported by hydrodynamic lubricated bearings with rheological properties controlled by an external magnetic field. Traditional lubricating oil was replaced by an active liquid with an adaptive effective viscosity equated with the magnetic fluid. As a result, an additional parameter was obtained by which, through a magnetic field, it is possible to actively influence the dynamics of the rotor.

INTRODUCTION

The paper is concerned with the development of hybrid rotor support techniques exploiting the idea of combining the hydrodynamic uplift force from journal bearings with magnetic control to finally form active bearings ensuring smooth rotation and desired vibro-insulating properties.

The usage of magnetic lubricating fluids in plain bearings opens up the possibility of dynamic control by the viscosity of the bearing behavior. Experimental study of bearings with the “intelligent lubricating fluid” showed that the liquid with the Bingham model has strong maneuverable characteristics at moderate intensity of magnetic fields (up to 40 kA/m) (Urreta et al., 2009). Further, the performance of the bearing may be improved by accurate changing the viscosity (Spur, 1998). The pioneering research on the application of a magnetic liquid in a plain bearing was conducted by (Tichy, 1991).

This paper presents dynamic analysis of journal bearings with active lubricating fluid. The active parameter is the effective viscosity of the liquid with a value dependent on the magnetic field intensity. A Bingham model and homogeneous magnetic field were adopted.

HYDRODYNAMIC BEARING MODEL, THE MAGNETIC FIELD MODEL

This paper concerns a rigid rotor symmetrically supported by two plain bearings with the round outline of a journal and a sleeve. A plain, isothermal bearing model is taken into account. Pressure distribution, with assumptions of classic theory of hydrodynamic lubrication, is described by the Reynold’s equation.

The axis symmetry distribution of the magnetic field was ensured by a current in a wire, located in concentric way inside the journal.

The unitary magnetic force induced in the liquid, assuming the liquid is dielectric and for linear scope of liquid magnetisation (thus low values of magnetic field), may be expressed in terms of the formula: $f_m = \mu_0 X_m h_m \,\mathrm{grad}\, h_m$, where: μ_0 – is magnetic permeability of the vacuum, X_m – is magnetic permeability of the liquid, h_m – magnetic field strength. With the axis symmetry layout of the magnetic field, the component of the resultant magnetic force at the circumferential direction is naught, and the radial component is assumed to be naught. As a result, the magnetic force is not taken into account in the equations of plane motion.

During plane motion, a journal has two degrees of freedom, and the following is its motion equation in the pole coordinates (β, α):

$$mc\left(\ddot{\beta} - \beta\dot{\alpha}^2\right) = P_r + Q\sin\alpha$$
$$mc\left(\beta\ddot{\alpha} + 2\dot{\alpha}\dot{\beta}\right) = P_\tau + Q\cos\alpha$$

Magnetic fluid rheology describes the Bingham model. For this purpose, an effective viscosity determined according to equations :

$$\mu_{eff} = \tau/\dot{\gamma} = \mu_N + \tau(H)/\dot{\gamma}$$

has been introduced to the equations of hydrodynamic force components.The parameter by which we control the viscosity of oil is a yield stress in a function of the strength of the magnetic field τ(H). Besides it the viscosity strongly depends on shear rate $\dot{\gamma}$ of the liquid (the rotor speed).

RESULTS AND CONCLUSIONS:

(1) By decreasing the fluid’s base viscosity (μ_N) a rise of critical threshold is influenced. Fig.1 depicts approximately a 10% increase in critical speed caused by decreasing the lubricating fluid’s viscosity by half.

(2) Increase in magnetic field H and thus yield stress τ(H) results in high effective viscosity of magnetic fluid at low rotor speed, assuring as a result, a faster lifting of the rotor during a startup.

[a)] Corresponding author. Email: laniabase@o2.pl

(3) Increase in rotor speed, despite the field presence, results in a decreased the fluid's effective viscosity, up to value of the fluid's base viscosity μ_N, what favours the rotor's stability.
(4) When rotor startup under inertia a strong positive impact of the field H and thus $\tau(H)$ on the damping of vibrations in the resonant and post-resonant area is observed. Growth of damping is limited by effective viscosity of stability threshold, Fig.2.
(5) Bifurcation analysis (Hopf's bifurcation) has shown behavior of a rotor near critical speed.

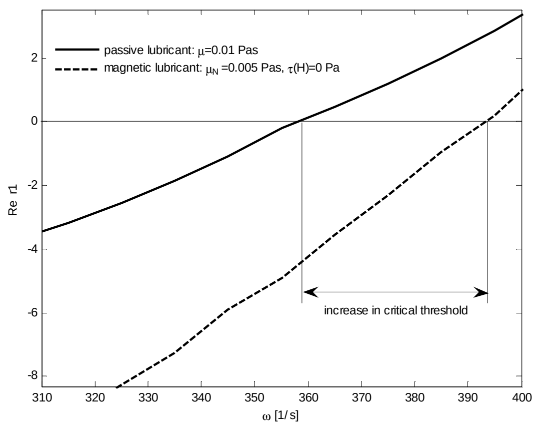

Fig.1

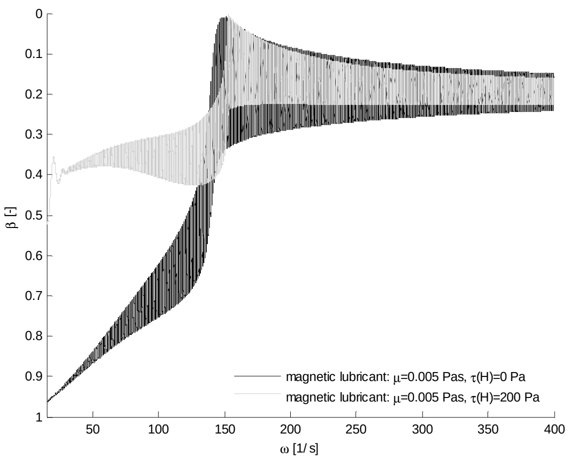

Fig. 2

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