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DAMPING OF RESONANT VIBRATION OF A RIGID ROTOR SUPPORTED ON JOURNAL BEARINGS WITH ELECTROFLUID

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Abstract

The paper is concerned with the problem of damping of resonant vibration in a rigid rotor system supported on journal bearings. The equations of motion of a such system are derived. Kinematic excitation is under investigation. Appropriate diagrams of amplitude and frequency in dependence of the system parameters as well as results and concluding remarks has been included.

1. Introduction

One of the importent problems that appear in exploitation of rotor systems in ensuring stable working. This is a condition of reliability and life of the kinematic pair called journal – oil film – bearing shell. One of the most important problems is damping of resonant vibration in such a system. The resonant vibration can appear due to rotation unbalance with respect to its axis or from the base of the machine. There are known many methods that allow damping of the resonant vibration. In recent years, special fluids that change their visco-elastic properties in the presence, of magnetic or electric fields have been introduced. The first are know as ferro-fluids. They are in fact ferromagnetic particles suspended in a electrically neutral carrier fluid. When exposed to magnetic field the particles adjust their dipoles along with polarization, which leads to appearance of the Lorentz inertia forces in the area filed with the electro-fluid.

In the second case we deal with electroviscosity. It is an instantaneous, revesible change of the apparent viscosity under application of an electric filed. This phenomenon was discovered long ago [1], but the phenomena called the electroheology was described for the first time by Winslow [2]. This effect is characterized by increasing resistance of the fluid flow when subjected to growing electric field. In [3], the authors examined electroviscous properties for silicon and calcium-titanate compounds and found them to be a function of such parameters as share percentage, share rate, electric filed, frequency of the filed, and fliud temperature.

In relation to that phenomena the electro-fluids were in use in different machines and devices for controlling systems with journal bearings. The main author's intentions is to continue the investigations [4] and concentrate on damping of resonant vibration of rigid rotors supported on journal bearings with electrofluids.

2. Assumed model of the system

In the considerations the plane model of a system consisting of a rigid rotor supported on a journal cylindrical bearing with an electro-fluid [is assumed]. The system is subjected to kinematic excitation. The scheme of the considered model is presented in Fig. 1.

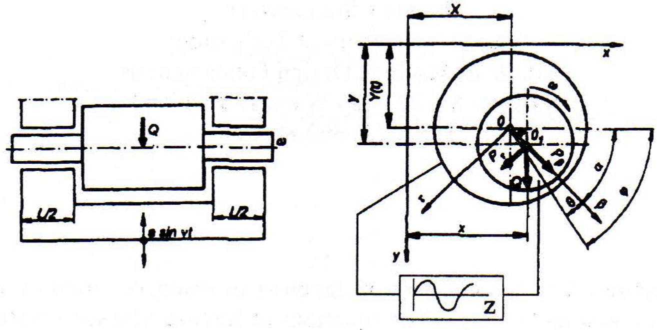


Fig.1 Model of the system

3. Equations of motion

For the assumed model and the kind of excitation, the equations of motion of the system can be presented as in [4] with modification due to transverse kinematic excitation.

$$\ddot{\xi}=-\frac{12\left(\mu_0+C+B\frac{E^2}{v_s}+A\frac{E^4}{v_s^2}\right)RL}{m\delta^2}\left\{\left(\frac{\beta^2(\omega-2\dot{\alpha})}{(1-\beta^2)(2+\beta^2)}+\right.\right.$$

$$\left.+\frac{\beta\dot{\beta}}{1-\beta^2}+\frac{2\dot{\beta}}{(1-\beta^2)^{3/2}}arctan\sqrt{\frac{1+\beta}{1-\beta}}\right)\cos\alpha-$$

$$\left.-\frac{6\pi\left(\mu_0+C+B\frac{E^2}{v_s}+A\frac{E^4}{v_s^2}\right)RL}{2m\delta^2}\cdot\frac{\beta(\omega-2\dot{\alpha})}{(1-\beta^2)(2+\beta^2)}\sin\alpha\right\} \tag{1}$$

$$\ddot{\eta}=-\frac{12\left(\mu_0+C+B\frac{E^2}{v_s}+A\frac{E^4}{v_s^2}\right)RL}{m\delta^2}\left\{\left(\frac{\beta^2(\omega-2\dot{\alpha})}{(1-\beta^2)(2+\beta^2)}+\right.\right.$$

$$+\frac{\beta\dot{\beta}}{1-\beta^2}+\frac{2\dot{\beta}}{(1-\beta^2)^{3/2}}arctan\sqrt{\frac{1+\beta}{1-\beta}}\Bigg)\sin\alpha-$$

$$-\frac{6\pi\left(\mu_0+C+B\frac{E^2}{v_s}+A\frac{E^4}{v_s^2}\right)RL}{2m\delta^2}\cdot\frac{\beta(\omega-2\dot{\alpha})}{(1-\beta^2)(2+\beta^2)}\cos\alpha\Big\}+\frac{Q}{m}+a\,v^2\sin vt \qquad (2)$$

To investigate the movement of the journal center O_1 in Cartesian coordinate system, equations (1) and (2) should be completed with the following particular quantities:

$$\beta=\frac{\sqrt{\xi^2+\eta^2}}{\varepsilon};\quad \dot{\beta}=\frac{\xi\cdot\dot{\xi}+\eta\cdot\dot{\eta}}{\beta\cdot\varepsilon^2};\quad \dot{\alpha}=\frac{\eta\cdot\dot{\xi}-\xi\cdot\dot{\eta}}{\beta^2\cdot\varepsilon^2};$$

$$\cos\alpha=-\frac{\eta}{\beta\cdot\varepsilon};\qquad \sin\alpha=-\frac{\xi}{\beta\cdot\varepsilon} \qquad (3)$$

4. Results of numerical simulations

Equations of motion (1) and (2) with dependences (3) is strongly nonlinear and coupled together. Their analysis is possible only by numerical simulation. On the grounds of the carried out numerical simulations one can evaluate the effect of electric field on the resonant vibration for different clearances and amplitudes of the base displacement. Exemplary results are presented in Figs 2 to 5.

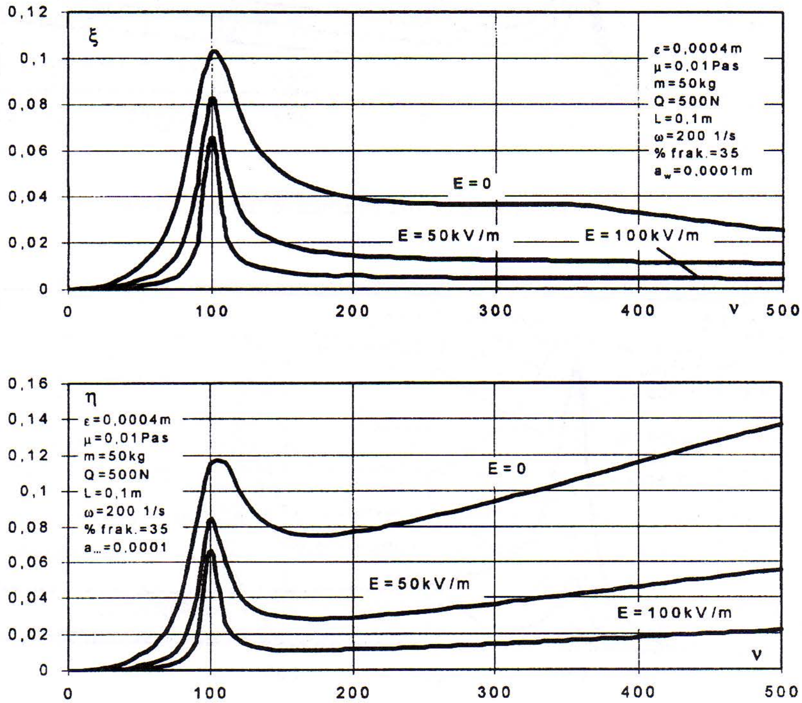
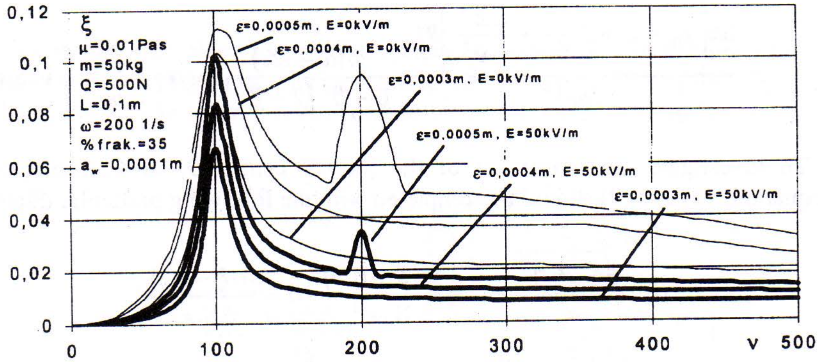


Fig. 2 Effect of the electric field on resonant curves in the ξ, η - directions



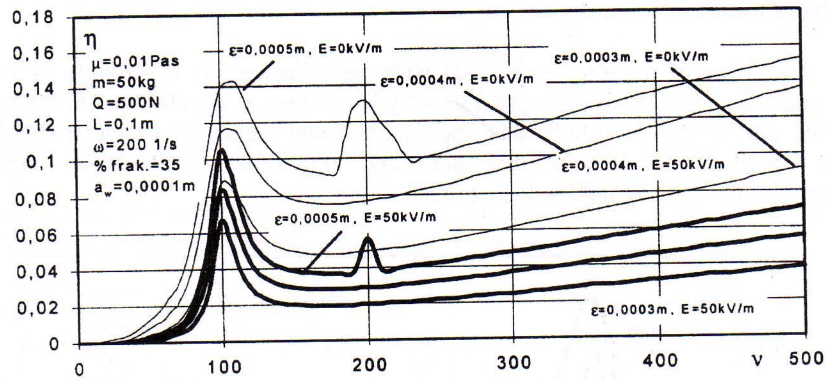
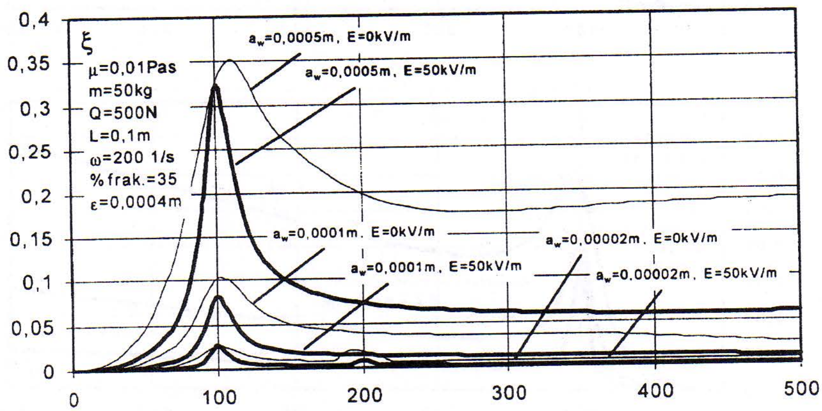


Fig. 3. Effect of the bearing clearance on resonant curves



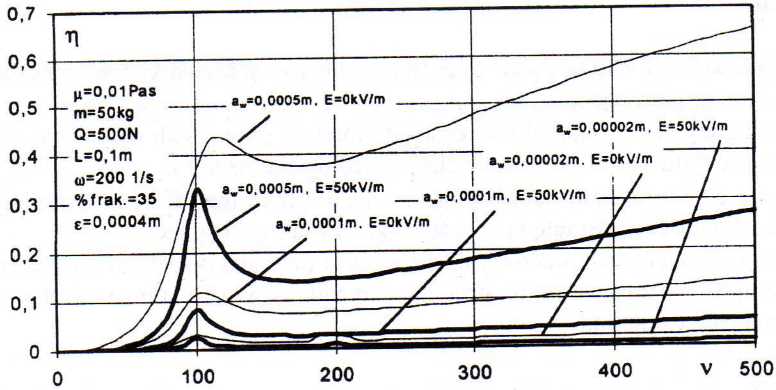


Fig. 4. Resonant curves for various amplitudes of kinematic excitation and lack of the electric field.

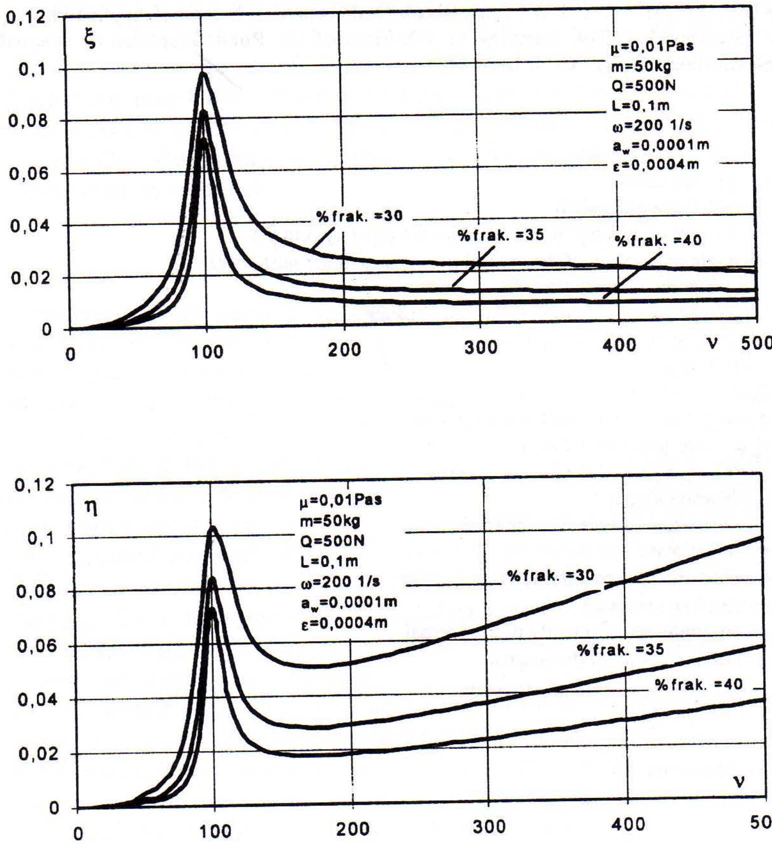


Fig. 5. Resonant curves for a constant electric field and various shared of the electrorheological medium.

Conclusions

- Application of electrorheological fluids effectively decreases the vibration amplitudes in both ξ,η directions.
- Efficiency of damping of the resonant vibration grows with increasing intensity of the electric field and density of the electrorheological medium.
- For a given constant intensity of the electric field the effect of damping of resonant vibration is considerable in a wide range of bearing clearances.
- For a given constant intensity of the electric field and density of the electrorheological medium the resonance is strongly damped in a wide range of the amplitude of kinematic excitation.

References

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Notation

O - journal center
O_l – of the bearing shell
P_β, $P\tau$ - hydrodynamic uplift forces in the polar system β,τ
α - angle of position of the journal center O_l and the bushing O
$Y(t)$ – kinematic excitation
$X(t)$ – transverse excitation (assumed constant)
ω - angular velocity of the rotor
e – eccentricity
Q – transverse load
a – amplitude of the kinematic excitation
θ, φ - coordinate as in Fig. 1
ξ, η - coordinate of the journal center O_l
L – bearing length
μ_0 – viscosity without electric filed
m – rotor mass
β - e/ε - relative eccentricity
ε - absolute clearance
$\dot{\alpha}$ - circumferential velocity of the journal
$\dot{\beta}$ - radial velocity of the journal
A, B, C – experimental coefficients
E – electric field
v_s – rate of the shear stress
δ - clearance ratio
v - excitation frequency