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MATHEMATICAL MODELLING OF A DAMPING ELEMENT WORKING ON THE PRINCIPLE OF SQUEEZING TWO LAYERS OF NORMAL AND MAGNETORHEOLOGICAL OILS ARRANGED IN SERIES AND ITS APPLICATION FOR VIBRATION ATTENUATION OF A RIGID ROTOR

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Abstract: *In this paper there is proposed a new concept of a damping device working on the principle of squeezing two lubricating layers that are formed by normal and magnetorheological oils mutually separated by a movable ring. Unlike to previous solutions, the magnetorheological layer decreases the total amount of damping and this decrease can be controlled according to the current operating conditions. In the developed mathematical model the normal and magnetorheological oils are represented by Newtonian and Bingham materials respectively. A big advantage of the proposed damping element is that it does not require a complicated and expensive control system for its operation.*

Keywords: ***Controlled damping, new semiactive damping element, modified Reynolds equation.***

1. Introduction

Unbalance of rotating parts is one of the main sources of time variable forces that are transmitted between the rotor and its casing. Their magnitude can be significantly reduced if the rotor is flexibly supported and if the damping devices are added to the coupling elements. The theoretical analyses, confirmed by practical experience, show that to achieve the optimum performance of the rotating machines during their steady state running, the damping devices must be controllable.

2. Mathematical model of the new damping element and of the investigated rotor system

The principal parts of the proposed damping element (Fig.1) are the inner and outer rings between which there are two mutually separated layers of lubricating liquids. The inner ring is coupled with the damper's body by a squirrel spring and supports the rolling element bearing, in which the rotor journal is mounted. The outer ring is fixed to the damper housing. The lubricating films are formed by normal (inner) and magnetorheological (outer) oils and a ring flexibly coupled with the damper's body is used for their separation. The damping device is equipped with an electric coil generating magnetic field whose change makes it possible to control the damping effect.

Magnitude of the pressure in the oil layers is governed by the Reynolds equations. Components of the damping forces are calculated by integration of the pressure distributions around the circumference and along the length of the damping element taking into account a cavitation in the lubricating films.

The investigated rotor (Fig.2) consists of a shaft and of one disc and at both its ends it is flexibly coupled by the proposed damping element with the stationary part. The rotor is considered to be absolutely rigid, is unbalanced, turns at constant angular speed and is loaded by its weight. The system is symmetric relative to the plane perpendicular to the shaft axis. The squirrel springs are prestressed to be eliminated their deflection caused by the rotor weight.

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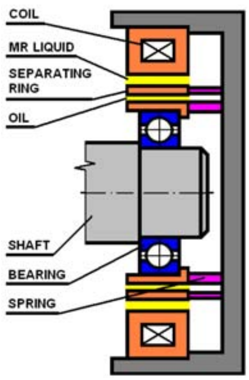


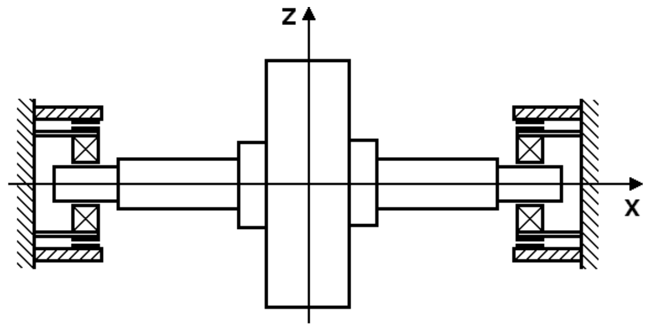


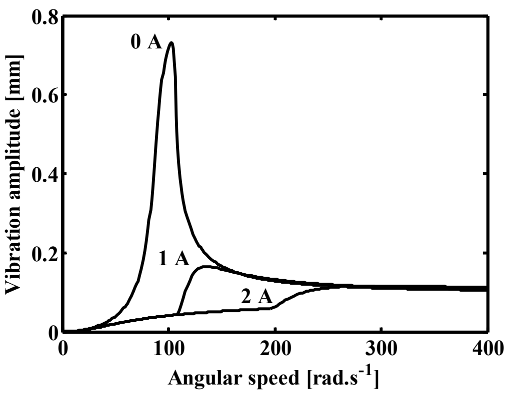
Fig. 1: The proposed damping element

Fig. 2: The investigated rotor

The steady state solution of the equations of motion is obtained by a trigonometric collocation method. As the system is symmetric and the squirrel springs are prestressed, it can be assumed that trajectories of the centres of the rotor rings are circular. The whole computational procedure leads to solving a set of four nonlinear algebraic equations.

3. Principal results of the computational simulations

Figures 3 and 4 depict the frequency response characteristic of the rotor centre and dependence of amplitude of the force transmitted into the rotor casing through the squirrel springs and the damping layers on angular speed of the rotor rotation for several magnitudes of the applied electric current.



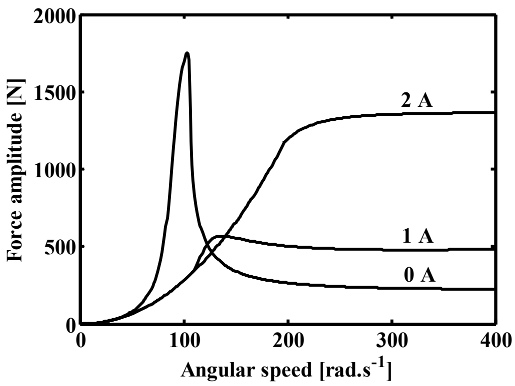


Fig. 3: Response characteristics

Fig. 4: Force - angular speed relationship

It is evident that in the region of low angular velocities a higher damping effect is needed to suppress both the vibration and the transmitted force. In the interval of higher velocities large amount of damping arrives at a strong increase of the transmitted force but only at a very small attenuation of the rotor oscillations. This implies that for these operating conditions it is desirable to switch off the magnetorheological damping or to apply only a very small electric current.

4. Conclusions

Results of the carried out computational simulations show that appropriate setting of magnitude of the applied current makes it possible to reach the optimum compromise between efficient attenuation of the rotor vibration and minimization of the force transmitted in the stationary part and in the foundation plate.

Acknowledgement

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