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Investigations of Transient Oscillations of Rotors Supported by Magnetorheological Squeeze Film Dampers Using Bilinear Material to Model the Lubricant

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Abstract: Magnetorheological squeeze film dampers are added to the rotor supports to reduce lateral vibrations of rotating machines with the possibility to control the damping effect. In mathematical models magnetorheological oils are usually represented by Bingham or Herschel-Bulkley theoretical materials. Here the magnetorheological oil is modelled by bilinear material with the yielding shear stress depending on magnetic induction. Its flow curve is continuous which contributes to reducing nonlinear character of the motion equations. The new mathematical model was applied to investigate several operating regimes of rotating machines.

Introduction

The main parts of magnetorheological squeeze film dampers for rotordynamic applications are two concentric rings between which there is a layer of magnetorheological oil. The rings are coupled with the damper casing, the outer one directly, the inner one by a squirrel spring and with the shaft through a rolling element bearing. The damping device is equipped with an electric coil generating magnetic flux passing through the lubricating oil. As resistance against its flow depends on magnetic induction, changing the applied current makes it possible to control the damping force.

In mathematical models magnetorheological liquids are usually represented by Bingham or Herschel-Bulkley theoretical materials characterized by a discontinuous flow curve. In this paper a mathematical model of a short magnetorheological squeeze film damper based on bilinear material is reported and applied for investigation of transient phenomena occurring during several operating regimes of rotating machines. Its main advantage is a continuous flow curve of bilinear material.

Determination of the damping force

The developed mathematical model of a short magnetorheological squeeze film damper is based on assumptions of the classical theory of lubrication accept those for the lubricant. Derivation of the governing equation for the pressure distribution in the thin film of lubricating oil starts from the equation of equilibrium of an infinitesimal element specified in the oil layer, the equation of continuity and from the constitutive relationship referred to bilinear material. After performing a series of manipulations one obtains the Reynolds equation modified for bilinear material. In areas where the core extends up to the rings surfaces the pressure is governed by a classical Reynolds equation referred to Newtonian fluid. In regions where the thickness of the damper gap rises with time a cavitation is assumed. In cavitated areas pressure of the medium remains constant. The components of the damping forces are calculated by integration of the pressure distribution around the circumference and along the length of the damper. More details on determination of the yielding shear stress in dependence on the applied current can be found in [1].

Results of the computational simulations

The investigated rotor is rigid. It consists of a shaft carrying one disc and at each its end it is supported by one magnetorheological squeeze film damper. The rotor is loaded by its weight and by the disc unbalance. The system can be considered as symmetric relative to the disc middle plane perpendicular to the shaft centre line. In the computational model the rotor is represented by an absolutely rigid body and the dampers by springs and force couplings.

Because of the symmetry vibration of the system is governed by a set of two nonlinear motion equations. For their solving a step by step Adams-Moulton integration method was applied.

In the first operating regime the rotor rotates at constant angular speed of 80 rad/s and at the moment of time of 0.5 s it starts to accelerate for the period of 0.2 s. The time history of the rotor vibrations in the horizontal direction can be seen in Fig. 1a. No current was applied.

In the second operating regime the rotor turns at constant angular velocity of 80 rad/s. At the point of time of 0.5 s the current feeding the magnetorheological dampers is switched on (its rising from 0.0 to 0.5 A lasts for 0.1 s). The corresponding response is evident from Fig. 1b. Application of the currect reduces amplitude of the oscillations significantly.

In the last operating regime the dampers are fed by the current of 0.5 A. At the moment of time of 0.2 s the rotor starts to accelarate to increase its angular velocity from 80 rad/s to 160 rad/s during the time interval of 0.2 s. Comparing Fig. 1a and 1c the applied current incereases the damping effect which arrives at increased reduction of the oscillations amplitude.

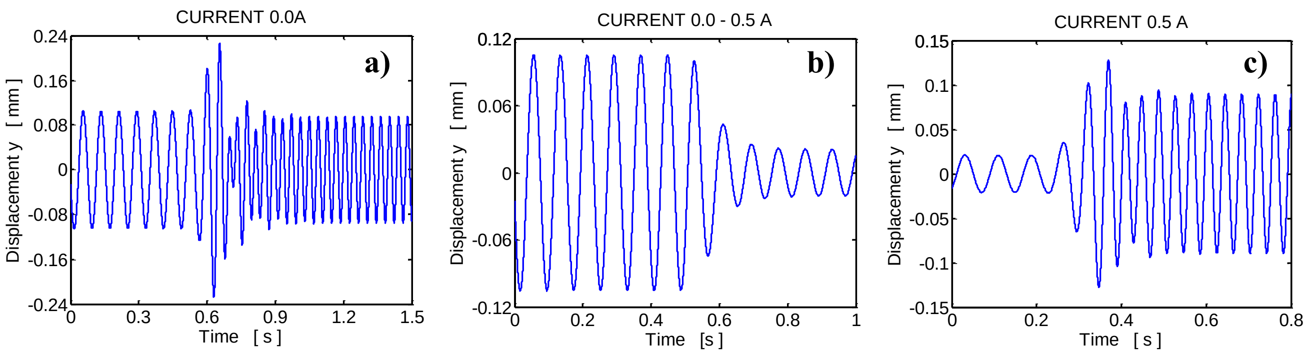

Fig. 1: Rotor center displacement in the horizontal direction.
a) rotor acceleration, 0.0 A b) constant speed, 0.0 – 0.5A c) rotor acceleration, 0.5 A

Summary

The principal contribution of the presented paper consists in development of a new mathematical model of a short squeeze film damper for the rotordynamic applications. The magnetorheological oil is represented by bilinear material whose yielding shear stress depends on magnetic induction. Its behaviour is described by a continuous flow curve which reduces nonlinear character of the governing equations and thus increases computational stability of the calculations. The developed mathematical model and consequently, the carried out computational simulations enabled to learn more about the vibrations attenuation of rigid rotors damped by controllable magnetorheological squeeze film dampers.

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References

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