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ACTIVE LUBRICATION FOR ELIMINATING INSTABILITY PROBLEMS IN ROTATING MACHINES

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ABSTRACT

When the hydrostatic and the hydrodynamic lubrication are simultaneously combined in a journal bearing, with the aim of reducing wear between rotating and stationary parts, one refers to the hybrid lubrication, which offers the advantages of both lubrication mechanisms. When part of the hydrostatic pressure is also dynamically modified by means of hydraulic control systems, one refers to the active lubrication. By the combination of fluid power, electronics and control theory, the active lubrication makes feasible the reduction of wear and the attenuation of rotor instabilities. Significant reduction of resonance peaks is demonstrated in a test rig, specially designed with the aim of experimentally exploring the potential of the active lubrication. Experiments are led in the frequency domain.

INTRODUCTION

High efficiency rotating machines, working at severe pressure and flow conditions, demand continuous monitoring and control of vibration levels. One of the ways of reducing vibration amplitudes in rotating machines is the use of hydrodynamic bearings. Among the hydrodynamic bearings, the tilting-pad bearings are those which show the best stability properties. Nevertheless, in many cases, due to aerodynamic excitations (cross-coupling effect) instabilities can occur, if the amount of bearing damping (at full load condition, i.e. high maximum continuous speed) is not enough to ensure a reasonable stability margin. One of the ways of improving this stability margin is by applying active lubrication [1] [2] [3]. The main contribution of the present work is of experimental nature, showing that the active lubrication is able to attenuate vibrations, towards achieving more stable rotating machines.

EXPERIMENTAL FACILITIES

A special test rig is designed [4] and built with the aim of experimentally investigating the attenuation of vibrations in rotating machines via active lubrication. The test rig is composed of three main subsystems:

(i) A 1,2 m long rotating shaft, weighting 70 Kg, supported by a ball bearing (pedestal) at one of its extremities and by a tilting-pad journal bearing (TPJB) near the other extremity (see bottom of figure 1). The shaft is connected to a DC motor by means of an universal joint. The pedestal, universal joint and motor are not shown in the picture.

(ii) The TPJB, composed of 4 pads in load-between-pads configuration. Such a bearing with a radial assembly clearance of 77 μm is conventionally lubricated (between pads) and actively lubricated using high response servo valves connected to orifices machined in the middle of the pads. The active lubricated TPJB is illustrated on the top of figure 1, but no details of the bearing interior can be seen. The natural frequency of the servo valves is approx. 320 Hz.

(iii) An active magnetic bearing [5] capable of generating forces up to 2000 N. The magnetic bearing is used to excite the rotor-bearing system and can be seen in the middle of figure 1.

Destabilizing forces can be intentionally generated with help of the magnetic bearing, inducing high levels of rotor vibrations. By turning on the active lubrication such vibration levels are strongly attenuate and the potential of the active lubrication verified.

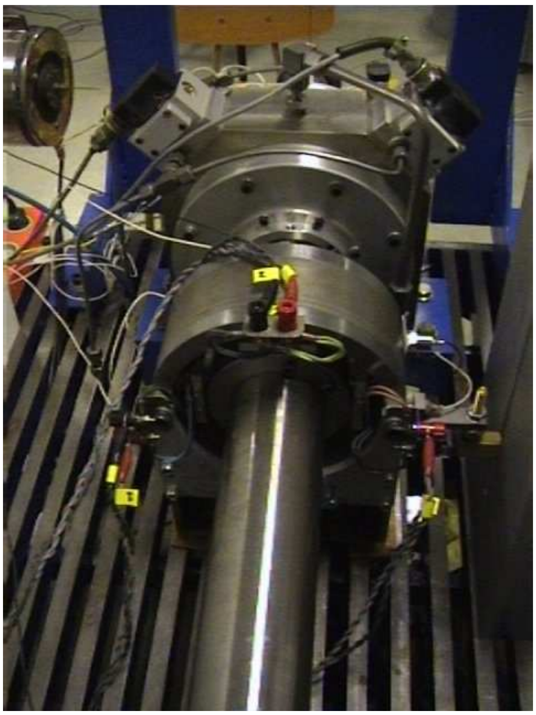

Figure 1. Test rig composed of shaft supported by a tilting-pad journal bearing actively lubricated with help of servo valves and an active magnetic bearing used as exciter.

EXPERIMENTAL RESULTS

The rotor-bearing system operates with an angular velocity of 600 rpm and is electromagnetically excited in the range of 0 until 100 Hz. The experimental vibration response of the rotor is measured using acceleration transducers attached to an auxiliary bearing fixed at one of the shaft extremities. The structure of the PD-controller is achieved by integrating digitally the acceleration signal. The gains of the PD-controller are carefully tuned aided by the mathematical model [2]. The experimental frequency response function (impedance) is measured and illustrated in figure 2. Two cases are compared: (a) the rotor-bearing system operating in the passive mode or under conventional hydrodynamic lubrication and (b) in the active lubrication mode. A significant vibration reduction of the rotor-bearing system is verified around its first resonance (68 Hz), i.e. a vibration reduction of approx. 60 % when the rotor-bearing system operates in the active mode with a supply pressures of 10 MPa.

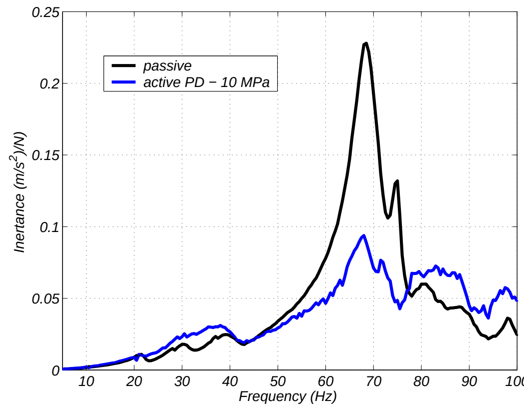

Figure 2. Experimental Frequency Response Functions – rotor-bearing system excited electromagnetically and operating under two lubrication regimes: conventional hydrodynamic lubrication (passive mode) and active lubrication using an PD controller and a supply pressure of 10 MPa.

CONCLUSIONS

Significant vibration reductions can be achieved using active lubrication. The efficiency of the active vibration towards reducing vibrations and stabilizing rotating systems is strongly dependent on the rotor angular velocity and on the supply pressure used. Generally speaking, the higher the rotor angular velocity is, the higher is the supply pressure needed to achieve significant reduction of vibration levels.

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