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Vibration Characteristics of Journal Bearing with Various Damping Materials

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ABSTRACT:

This paper presents an overview of the vibration problems which are experienced in running journal bearing. High vibration levels in machinery and components are usually undesirable as they often generate excessive noise and can lead to cyclic fatigue damage. The drive to reduce component mass, particularly in the aerospace and automotive industries, makes items more susceptible to vibration problems. In addition, many new high strength/high stiffness designs rely on 'single piece' welded metallic or fibrous composite constructions that have very little inherent damping. Damping materials have long been used to reduce vibration levels - examples vary from optimized constrained layer dampers on aircraft panels to bitumen spread on the underside of a metallic kitchen sink. Initially, most damping materials used were polymers with viscoelastic characteristics. In this work, a bearing testing apparatus is used for experimental studies to obtain displacement, velocity and acceleration from a journal bearing. Journal bearings are widely used to support the shaft of industrial machinery with heavy loads, such as compressors, turbines and centrifugal pumps. Vibration as a consequence of improper damping materials in journal bearing results in economic loss and creates high safety risks. So, it is necessary to reduce vibrations by selecting appropriate damping materials to the journal bearing and to achieve cost benefits to industry. Plywood, fibre, butadiene rubber and mud flap rubber was used to dampen the vibrations in the journal bearing. From the results, it is shown that the mud flap rubber possesses very good damping characteristics for journal bearing applications.

KEYWORDS:

Journal bearing; Speed; Displacement; Acceleration; Damping material; Rotating machineries

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1. Introduction

The properties of damping materials vary considerably with operating temperature and frequency, the range in which effective damping can be achieved is narrow (often less than a 40°C range). In the last two decades, the research community has shown considerable interest in the damping that can be achieved using a variety of so called smart materials that couple mechanical behaviour with electrical or magnetic fields applied to them [1-2]. These materials can be used to reduce vibration levels in either passive or active mode and have been used in conjunction with traditional damping materials to increase their effective range. The primary problem is that of resonance, where response levels under dynamic loading can be 100 or 1000 times greater than the levels resulting from static loading of the same magnitude. These resonances can be caused by steady and non-oscillatory forces being applied to a rotating disc. Their prediction and observation from measurement under running conditions are essential capabilities for the machinery dynamics engineer [3-4].

Additional problems can arise if instabilities are encountered, either from aerodynamic sources (flutter) or from rotor dynamics. In all cases where severe vibrations are encountered, they must be controlled by the introduction of extra damping to the critical components, usually by incorporating friction devices. In a gradient polymer material, the mechanical properties such as the Young's modulus and the damping factor vary at least along one direction, usually the thickness if the materials are used as a coating. The variation of properties can be either discrete or continuous. Discrete gradients are produced by applying several layers of polymer that are successively increasing in stiffness. Different proportions of the same chemical components are used to vary the properties for each layer [5]. In principle, any desired property distribution can be achieved in this way. In fact, the time required to produce the necessary number of layers is usually the limiting factor.

A more satisfying approach is to produce a truly continuous gradient of material properties in one step using, for example, a diffusion process. For materials produced in this way, the shape of the material property distribution is dictated by the physics of the process. Linear and exponential gradients have been produced in this way. The primary area of application for a gradient material is damping coating. The advantage of using a gradient material over a uniform one can be illustrated using a simulation that compares the performance of a family of polymers individually with that of a gradient coating that combines their properties. For a coating, the damping performance depends on its loss modulus (i.e. the imaginary part of the complex modulus). The damping achieved when uniform and gradient coatings based on this polymer family are applied to a vibrating structure [6-9]. It is clear that the effect of the gradient coating is to extend the range of useful damping considerably. In this work, a bearing testing apparatus is used for experimental studies to obtain displacement, velocity and acceleration from a journal bearing. Plywood, fibre, butadiene rubber and mud flap rubber was used to dampen the vibrations in the journal bearing. From the experimental results, the best damping material is selected for vibration suppression in journal bearings.

2. Damping materials & test rig setup

The damping properties of a material represent its capacity to reduce the transmission of vibration caused by the mechanical disturbances to a structure. The following materials were used to obtain the acceleration through experimental set up. Table 1 shows materials used and their properties with damping ratio. The developed test rig has three subsystems namely mechanical system, an electrical control system and a measurement system. The mechanical system has the ability to simulate typical bearing operating conditions. The electrical control system allows the mechanical subsystem to be controlled for different tests. The measurement system allows both operating conditions of the data and the dynamic response data of the test bearing which was recorded for the vibration analysis. The vibrometer is placed over the journal bearing to measure the acceleration. Fig. 1 shows experimental setup to collect the data.

Table 1: Materials and its properties

Damping material	Young's modulus (GPa)	Density (kg/m^3)	Damping ratio
Mud flap rubber	0.04	1600	0.03
Plywood	12.4	615	0.001
Butadiene rubber	2.0	1000	0.05
Fibre	4.8	1246	0.07

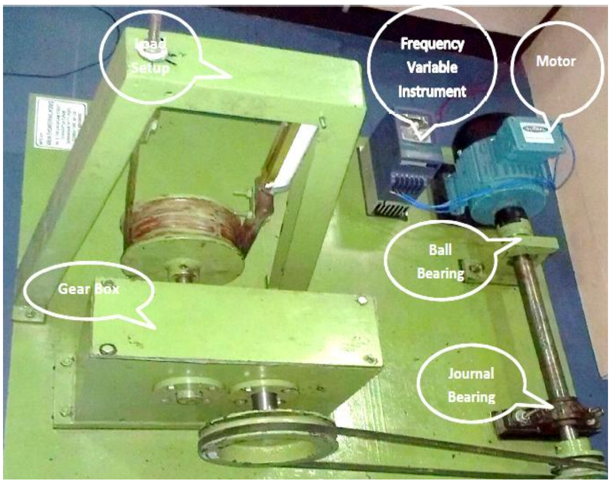

Fig. 1: Experimental set up

3. Results and discussion

The shaft was rotated at various speeds such as 600, 800, 1000, 1400 rpm to measure the speed, velocity and acceleration of the journal bearing. Various damping materials are used for the journal bearing vibration suppression. Three trials, T1, T2 and T3, were taken to obtain the mean value using vibrometer. Table 2 to 4 give the experimental results for damping materials used as mud flap rubber, plywood, butadiene rubber and fibre respectively. The average accelerations for the cases of plywood and fibre sheet as a damping material are close to one another. When compared to mud flap rubber, plywood and fibre sheet, vibrations are more when butadiene rubber was used as a damping material.

Table 2: Results for mud flap rubber sheet

Results	Trials	Mud flap damper at speed (rpm)			
		1400	1000	800	600
Max. Disp. (mm)	T1	0.094	0.065	0.028	0.026
	T2	0.096	0.069	0.032	0.029
	T3	0.098	0.070	0.029	0.026
	Mean	0.096	0.068	0.030	0.027
Min. Disp. (mm)	T1	0.045	0.032	0.019	0.024
	T2	0.043	0.035	0.017	0.026
	T3	0.047	0.033	0.018	0.022
	Mean	0.045	0.033	0.018	0.024
Max. Velocity (mm/s)	T1	4.8	4.2	1.5	2.2
	T2	4.6	4.0	1.9	2.0
	T3	5.0	4.4	1.7	2.4
	Mean	4.8	4.2	1.7	2.2
Min. Velocity (mm/s)	T1	3.2	3.7	1.3	1.7
	T2	3.0	3.8	1.0	1.5
	T3	3.4	3.6	1.6	1.3
	Mean	3.2	3.7	1.3	1.5
Max. Accel. (mm/s^2)	T1	8.6	5.4	4.5	3.9
	T2	8.8	5.9	4.1	3.7
	T3	9.0	5.8	4.3	3.8
	Mean	8.8	5.7	4.3	3.8
Min. Accel. (mm/s^2)	T1	6.5	5.0	3.6	2.4
	T2	6.6	4.8	3.3	2.2
	T3	6.7	5.2	3.6	2.6
	Mean	6.6	5.0	3.5	2.4

Table 4 shows the experimental results from trials - T1, T2, T3 and average readings for normal journal bearing without any damping material at various speeds such as 600, 800, 1000 and 1400 rpm. Large vibrations are generated due to absence of damping material and values of the average acceleration are higher than that of mud flap rubber sheet, butadiene rubber sheet, plywood sheet and fibre sheet. From the results, it can be seen that as the experiment progressed on normal journal bearing without damping material, the contact between the shaft and the bearing increased and higher frequency components appeared. These components got their peak values near the middle of the time axis where the maximum contact was reached. This increased frequency is due to the combination of sub harmonics and inter-harmonics for mechanical looseness. This looseness was developed due to absence of damping material in the journal bearing.

Table 3: Results for plywood sheet and butadiene rubber sheet

Results	Trials	Plywood sheet damper at speed (rpm)				Butadiene rubber damper at speed (rpm)			
		1400	1000	800	600	1400	1000	800	600
Max. Disp. (mm)	T1	0.039	0.035	0.032	0.033	0.050	0.063	0.053	0.128
	T2	0.037	0.032	0.031	0.034	0.049	0.062	0.057	0.127
	T3	0.041	0.033	0.032	0.035	0.051	0.064	0.055	0.129
	Mean	0.039	0.033	0.032	0.034	0.050	0.063	0.055	0.128
Min. Disp. (mm)	T1	0.032	0.025	0.020	0.027	0.040	0.024	0.026	0.075
	T2	0.034	0.027	0.019	0.027	0.042	0.023	0.026	0.077
	T3	0.033	0.026	0.021	0.027	0.041	0.025	0.025	0.073
	Mean	0.033	0.026	0.020	0.027	0.041	0.024	0.026	0.075
Max. Velocity (mm/s)	T1	5.6	3.6	3.4	1.7	5.0	4.8	2.2	3.5
	T2	5.4	3.7	3.5	1.9	5.4	4.7	2.3	3.7
	T3	5.8	3.5	3.3	1.8	5.2	4.9	2.4	3.6
	Mean	5.6	3.6	3.4	1.8	5.2	4.8	2.3	3.6
Min. Velocity (mm/s)	T1	4.3	3.3	2.8	1.6	4.9	3.3	1.8	3.0
	T2	4.8	3.2	2.9	1.8	5.1	3.2	1.9	3.2
	T3	4.4	3.4	3.0	1.7	5.0	3.1	2.0	2.8
	Mean	4.5	3.3	2.9	1.7	5.0	3.2	1.9	3.0
Max. Accel. (mm/s^2)	T1	10.5	7.5	6.4	6.4	12.4	9.4	7.8	5.7
	T2	10.6	7.9	6.2	4.1	12.0	9.3	7.6	5.3
	T3	10.7	7.7	6.3	4.3	12.2	9.2	8.0	5.5
	Mean	10.6	7.7	6.3	4.9	12.2	9.3	7.8	5.5
Min. Accel. (mm/s^2)	T1	10.1	7.2	5.9	4.0	11.3	8.8	7.0	5.2
	T2	10.3	7.3	5.8	3.8	11.1	8.9	7.4	4.7
	T3	10.2	7.4	6.0	3.9	11.2	8.7	7.2	4.6
	Mean	10.2	7.3	5.9	3.9	11.2	8.8	7.2	4.8

Table 4: Results for fibre sheet and normal bearing without damper

Results	Trials	Fibre sheet damper at speed (rpm)				Bearing without damper at speed (rpm)			
		1400	1000	800	600	1400	1000	800	600
Max. Disp. (mm)	T1	0.07	0.018	0.015	0.016	0.105	0.050	0.047	0.025
	T2	0.074	0.018	0.016	0.015	0.104	0.060	0.048	0.029
	T3	0.072	0.018	0.019	0.017	0.106	0.070	0.046	0.023
	Mean	0.072	0.018	0.017	0.016	0.105	0.060	0.047	0.026
Min. Disp. (mm)	T1	0.055	0.013	0.014	0.012	0.083	0.034	0.027	0.014
	T2	0.054	0.017	0.016	0.099	0.087	0.033	0.026	0.018
	T3	0.056	0.015	0.016	0.01	0.085	0.032	0.025	0.016
	Mean	0.055	0.015	0.015	0.040	0.085	0.033	0.026	0.016
Max. Velocity (mm/s)	T1	4.8	2.0	1.4	1.7	4.9	2.0	1.4	1.1
	T2	4.6	1.9	1.3	1.9	4.6	1.9	1.6	1.3
	T3	5.0	2.1	1.5	1.8	5.0	2.1	1.5	1.2
	Mean	4.8	2.0	1.4	1.8	4.8	2.0	1.5	1.2
Min. Velocity (mm/s)	T1	4.5	1.6	1.3	1.6	4.2	1.9	1.2	1.0
	T2	4.4	1.8	1.2	1.8	4.4	1.8	1.4	1.2
	T3	4.9	2.0	1.4	1.7	4.3	2.0	1.3	1.1
	Mean	4.6	1.8	1.3	1.7	4.3	1.9	1.3	1.1
Max. Accel. (mm/s2)	T1	10.2	6.0	4.1	2.8	24.3	18.8	13.0	12.5
	T2	10.0	6.2	4.2	2.9	24.2	18.9	13.3	12.1
	T3	10.4	6.1	4.0	3.0	24.5	18.7	13.0	12.3
	Mean	10.2	6.1	4.1	2.9	24.3	18.8	13.1	12.3
Min. Accel. (mm/s2)	T1	9.6	5.5	3.6	2.6	21.8	16.9	12.4	10.0
	T2	9.7	5.3	3.8	2.6	21.5	16.8	12.3	10.1
	T3	9.6	5.7	3.7	2.6	21.6	16.9	12.4	10.5
	Mean	9.6	5.5	3.7	2.6	21.6	16.9	12.4	10.2

4. Conclusion

The performance of the various damping materials for journal bearing vibrations was studied. The experimental results show that the average velocity for mud flap rubber sheet material is 4.8 m/s and the average acceleration is 8.8 m/s^2. When compared to other materials such as plywood sheet, butadiene rubber sheet, fibre sheet, mud flap sheet shows good performance. Hence, the mud flap rubber is recommended to use as a damping material for journal bearing in order to reduce the excessive vibrations.

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