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Experimental investigation on dynamic characteristics of journal bearing

The aim of this experimental investigation is to investigate the dynamic characteristics of journal bearing. The process involves lubrication using couple stress fluid. The theoretical study has been analyzed based on the dynamic Reynolds governing equation for various lengths to diameter ratios, ratio of eccentricity, damping coefficient and stiffness of the systems and the results have been reported. The work involves using Newton's multivariate interpolation, the empirical relationship is derived at different ratio of eccentricity, L/D ratio as well as dynamic coefficients. It is observed that beyond 0.7 eccentricity ratio, small disturbances affect in a higher stability in the journal bearing system. The theoretical study results have been compared to experimental test kit result for various L/D ratios. The dynamic characteristics such as displacement, velocity and acceleration values have been noted from the test kit and the instability conditions of the system have been verified from the theoretical results.

Keywords: Stiffness co-efficient, frequency, L/D ratio, eccentricity ratio.

1.0 Introduction

Several investigators have worked on the stability of journal bearings and their hydrodynamic behaviour. Under a variable rotating load and constant load, the characteristics of stability related to journal bearings under submerged conditions were reported by Jonnadula et al, 1997. The influence of surface roughness on the constancy of journal bearings under submerged conditions were evaluated (Raghunandana and Majumdar, 1999). Further they investigated on the effects of non-Newtonian lubricant with reference to the stability of oil film bearings subjected to a defined load applied in a single direction. The journal bearings' stability was reported while (Kakoty and Majumdar, 2000) worked on the influence of inertia of fluid. But the investigations were limited to the stability of the plain journal bearings. Dwivedi, 2012 applied fuzzy logics to predict the dynamic analysis of fluid film journal bearing. Different models of journal bearings were reported for various speeds and ratios of eccentricity for analyzing the contact amid elastic behaviour pertaining to bearing and the fluid (Dhande et al, 2013). Computational fluid dynamics approach was used by Sahu et al,2012 for determining the performance characteristics related to a plain journal bearing, while some researchers (Daniel and Cavalca, 2013) worked on the thermal variations in the bearing during its operation. The gear and bearing structure was studied for knowing its dynamic behaviour when Chang-Jain and Hsu, 2012 were investigating on the systematic analysis of the bearing and gear combination by considering the effect of turbulent flow, suspension in non-linear direction while the oil and film force was considered in non-linear way; the force of gear mesh was also assumed to be not in a linear way. The damping and stiffness features were found on ball bearings under lubricated conditions (Sarangi et al, 2004). The behaviour of the dynamic co-efficient pertaining to journal bearing involving rotating furrows was analysed by Zirkelback and San Andre, 1998. The bearings in their study were operated in a hydrodynamic state.

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2.0 Experimental procedure

2.1. Stability Analysis of Journal Bearing

Newton's interpolation was effectively used by Dinakaran and Ramesh,2015 for studying the stability of a journal in hydrodynamic condition.

Various lengths to diameter ratios and ε were used for finding the dynamic characteristics related to journal bearing. Co-efficient of damping and stiffness were found as well as different correlations were analyzed through a graph. The association among ratio of eccentricity and length to diameter ratio were reported from the obtained values with the help of results that were obtained theoretically.

2.2. Experimental Investigation of Journal Bearing

Several investigational tests have been conducted on the dynamic characteristics of journal bearings. The common of these have been the tests on small-scale bearings. Few tests on dynamic characteristics have been conducted on big bearings.

Journal bearing test rig (Fig.1) is designed and fabricated for investigating the experimental dynamic characteristics such as displacement, velocity, acceleration and noise. The test rig results have been verified with the theoretical results based on past research (Dinakaran and Ramesh, 2015).

Fig.1: Journal bearing test rig

2.3 Dynamic characteristic analysis

The test rig comprises test prototype, cooling system, lubrication and a set up for measurement. The test prototype primarily consists of oil pump, oil bearing assembly, journal bearing and shaft. The measurement system includes electric motor, speed and dynamic transmission system such as noise, displacement, velocity and acceleration. Three different geometries of bearing have been considered for this analysis with eccentricity ratio ε=e/c as 0.7. Here ε represents eccentricity in mm and c represents radial clearance in mm. The design model is represented in Fig.2.

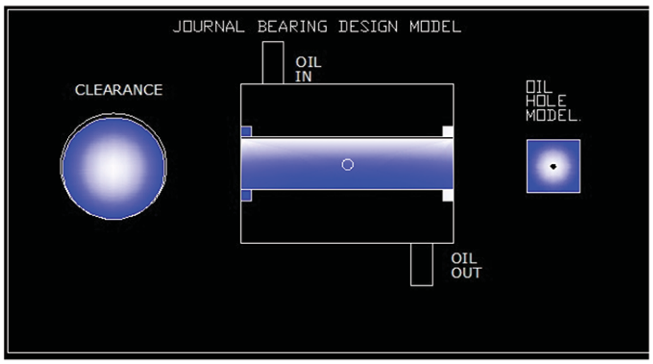

Fig.2: Journal bearing design model

Mild steel 1020 bearing material is selected having a density of 7830kg/m^3 and circumferentially 4 holes have been made to feed the lubricants inside the bearing case. One end is bearing case with lubricant feed pump set up and another end is the driving motor unit. Three different L/D ratio of bearing design have been chosen, i.e., L/D ratio=1.0, 1.5 and 2.0. The length and diameter of the bearing have been taken as 12.66mm for L/D ratio of 1.0 and for each set, different geometry bearings have been tested depending upon the ratios.

Table 1: Design parameters selected for the test

Parameters	Value	Remarks
Length of the bearing (LB)	12.66 mm	Varying based on L/D Ratio
Inner diameter of the bearing (DB)	12.66 mm	
Thickness of the bearing (tB)	5 mm	
Youngs modulus • of bearing	200 GPa	
Poisson's ratio of bearing	0.3	
Number of circumferential holes	4 (each 90 deg one)	
Bearing material	Mild steel 1020	
Density of the bearing	7830 kg/m^3	
Journal radial load (W)	9.6N	To be applied at inner surface of the bearing
Lubricant viscosity (μ)	2.5×10^{-2} kg/ms	
Lubricant density (ρ)	860 kg/m^3	
Lubricant specific heat (Cp)	2000 J/kg ^{o}C	
Inlet pressure (p)	120 kPa	

The mentioned design parameters (Table 1) have been considered for each set of analysis with different L/D ratio.

3.0 Results and discussion

3.1 Theoretical Results

The study has been made for various L/D ratios and various parameters are compared. Based on the different L/D ratios, the coefficient of damping and stiffness have been found while the empirical relations are derived by using Matlab. This shows different dynamic behaviour against various L/D and ε ratios for the full journal bearing. The variation of co-efficient of stiffness has been varied differently at $\varepsilon > 0.7$ and it affects the stability.

3.2. Experimental Results

Experiments were conducted in the framework model test rig. Different sizes of journal and bearings were used in the test rig. The rotor comprises oil pump sends oil to the bearing.

For each bearing set up (L/D = 1, 1.5, 2) the displacement, velocity, acceleration, noise and frequency have been noted using RS 232 software. In every set, the above mentioned characteristics have been plotted and the maximum values are found. The maximum values of the above noted characteristics have been tabulated in Table 2 and the critical frequency and damping co-efficient of this test rig is found in the following steps.

Calculation

Output for critical case (i.e max elliptical deflection of shaft in critical speed)

Displacement = δ, in mm

Velocity = v, in mm/sec

Acceleration = a, in mm/sec^2

TABLE 2: EXPERIMENTAL RESULTS (CONSOLIDATED READING)

	L/D Ratio	Min/max/mean	Displacement (d) mm	Velocity (v) mm/sec	Acceleration (a) mm/sec^2	Noise (db)	Frequency (f_n) Hz
1	1.0	Min	1.443	54.1	202.4	83.2	850
		Max	2.606	85.7	371.7	88.2	
		Mean	1.907	71.2	295.1	85.0	
2	1.5	Min	0.927	40.4	20.1	83.1	450
		Max	1.406	70.2	293.3	86.6	
		Mean	1.129	56.6	125.8	84.4	
3	2.0	Min	1.132	35.2	90.1	78.2	600
		Max	2.487	61.9	250.2	83.0	
		Mean	1.698	49.0	143.2	79.4	

Calculation and final result:

Force F = m x a

= density x volume x acceleration

Stiffness K = F/δ

= Force/displacement in N/mm

Frequency = fn = √k/m

$=\frac{\sqrt{stiffness}}{mass}$ = of the bearing in cycle/sec or Hz

Damping co-efficient D = F / v

= Force/velocity in N/mm/sec

The experimental final results such as stiffness (K) and damping co-efficient (D) is found to be maximum at eccentricity ratio ε=0.7 and they are compared with theoretical results (Dinakaran and Ramesh, 2015).

4.0 Conclusion

The dynamic characteristics study on Journal bearing model have been performed through a test rig for different L/D ratio set up. The effect of the stiffness, damping co-efficient and frequencies of the test rig have been studied and the maximum critical point is found at different operating conditions. The frame work has been interlinked with the software and the dynamic characteristics has been performed. It is observed that the maximum critical limit of this study has reached at eccentricity ratio ε = 0.7. The same have been compared to the theoretical results. This investigation allows to identify the critical limit of the dynamic characteristics during working conditions of the bearing.

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