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Study of Journal bearing performance at different loading conditions

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Abstract - *Journal bearings are critical components in rotating machinery, influencing the performance, reliability, and longevity of the system. This study investigates the performance of journal bearings under variable load conditions, and lubrication mechanisms., we analyze the response of journal bearings to fluctuating loads, which mimic real-world operating conditions.*

Key performance indicators such as pressure distribution, film thickness, temperature rise, and friction coefficients were monitored and analyzed. The study reveals how varying load magnitudes and frequencies impact the stability and efficiency of the bearing. We also examine the influence of different lubrication regimes and oil viscosities on the bearing's performance under these conditions.

The results indicate that journal bearings exhibit significant changes in performance metrics under variable loads, highlighting the importance of accurate load predictions in design and maintenance practices. The findings provide valuable insights into optimizing bearing designs and selecting appropriate lubrication strategies to enhance the operational stability and lifespan of rotating machinery. This research contributes to a better understanding of the complex interactions within journal bearings, paving the way for advancements in predictive maintenance and reliability engineering.

***Key Words*:** Journal Bearing, Temperature, lubrication, coefficient of friction etc.

1.INTRODUCTION *(Size 11 , cambria font)*

Journal bearings are fundamental components in a wide range of rotating machinery, including turbines, compressors, pumps, and automotive engines. Their primary function is to support radial loads and facilitate smooth rotational motion by reducing friction between the rotating shaft and the stationary bearing surface. The performance and reliability of journal bearings are critical to the overall efficiency and longevity of these machines.

The operation of journal bearings is inherently complex, involving interactions between the bearing surfaces, lubricant film, and varying load conditions. In real-world applications, journal bearings are seldom subjected to constant loads. Instead, they experience variable loads due to changes in operational conditions, start-stop cycles, and transient events. These variable load conditions can significantly impact the performance characteristics of journal bearings, influencing factors such as pressure distribution, film thickness, temperature, and friction.

Understanding the behaviour of journal bearings under variable load conditions is essential for several reasons. Firstly, it aids in the design and optimization of bearings to ensure they can withstand the dynamic loading experienced during operation. Secondly, it helps in selecting appropriate lubrication strategies to maintain an adequate lubricant film, preventing metal-to-metal contact, and reducing wear. Finally, it supports predictive maintenance practices by providing insights into the conditions that may lead to bearing failure, thereby enhancing the reliability and safety of machinery.

1.1 Experimental Details

Test procedure of Journal Bearing Experimental setup is as follows.

We followed the following steps-

Step i) For this project we selected the journal bearing.

Step ii) Then we selected the material of bearing.

Step iii) Filled the oil reservoir which is kept at height of 70 cm from bearing and checked whether the mountings are properly fixed or not.

Step iv) First we have done experimentation on journal bearing (without fin) for various load conditions. The temperature of bearing surface at specified points is taken by using thermocouples. Also, temperature of oil is measured by thermometer & corresponding values of oil viscosity are taken from the standard chart of SAE grade oil. Pressure is measured in cm i.e the height of oil raised in the tubes provided on board then converted into Pascal. This procedure is examined for various load conditions.

Step v) Now we applied the trapezoidal fin on the external surface of bearing. The procedure explained in the Step iv is followed for the bearing with fin provided on its external surface and the values of pressure, temperature and viscosity are taken under various load conditions.

Step vi) Compared the results with fin journal bearing by using experimental and CFD analysis & the validated the experimental results.

Step vii) From experimental and CFD values we calculated coefficient of friction and Sommerfeld Number and then the relation between coefficient of friction and Sommerfeld Number are shown by plotting graphs for various load conditions.

1.2 Specification of Journal bearing and oil used

Table No. 01- Specification Of Journal Bearing

Sr.No	Specification	Dimension
1	Diameter of Journal	54 mm
2	Diameter of Bearing (With 16 radial tapping)	57 mm
3	Bearing width	85 mm
4	Weight Set	1kg,2kg,3kg,4kg,5kg
5	Motor DC	0.5HP, 1500rpm, variable speed
6	Manometer board with tubes having suitable scales and adjustable oil tank.	No.16
7	Length of trapezoidal fin	85 mm
8	Thickness of fins (at base, at top)	6mm , 3mm
9	No of fins	12

Table No 02- Oil specification of SAE 30

Temp[°C]	Dyn.Viscosity[mPa.s]	Kin.Viscosity [mm²/s]	Density[g/cm³]
0	1124.1	1257.25	0.8941
10	491.1	553.2	0.8878
20	239.39	271.56	0.8815
30	128.42	146.7	0.8754
40	74.55	85.76	0.8693
50	46.43	53.8	0.863
60	30.58	35.69	0.8569
70	21.17	24.89	0.8506
80	15.28	18.1	0.8444
90	11.42	13.62	0.8383
100	8.8	10.58	0.8322

1.3 Material Details

For journal bearing the material selected material is mild steel. Mild steel is the least expensive of all steel and the most common steel used. Used in nearly every type of product created from steel, it is weld able, very hard and, although it easily rusts, very durable. Containing a maximum of 0.29% carbon, this type of steel can be magnetized and used in almost any project that requires a vast amount of metal. Its structural strength prevents it from being used to create load-bearing girders and structural beams. Many of the everyday objects that are created of steel are made using mild steel, including automobile chassis, motorcycle frames, and most cookware. Due to its poor corrosion-resistance, it must be painted or otherwise protected and sealed to prevent rust from damaging it. A light coat of oil or grease can seal this steel and aid in rust control. Unlike high-carbon steel, mild steel is easily welded. The properties of the steel allow the electrical current to travel through the metal without distorting the makeup of the material. Some types of high-carbon steel, such as stainless steel, require special techniques to properly weld the material. Being less brittle than high-carbon steels, the mild variant is able to flex and give in construction projects where a higher-carbon version could simply break.

Mild steel (steel containing a small percentage of carbon, strong and tough but not readily tempered), also known as plain-carbon steel, is now the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. Low-carbon steel contains approximately 0.05–0.25% carbon making it malleable and ductile. Mild steel has a relatively low tensile strength, but it is cheap and easy to form; surface hardness can be increased through carburizing. It is often used when large quantities of steel are needed, for example as structural steel. The density of mild steel is approximately 7.85 g/cm3 (7850 kg/m3 or 0.284 lb/in3) and the Young's modulus is 200 GPa (29,000,000 psi).

1.4 CAD Model of bearing

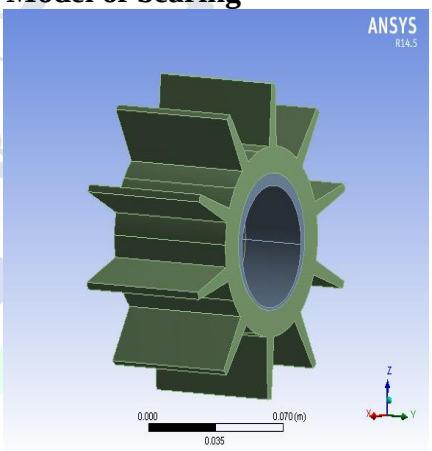

Figure No 01 – CAD Model of bearing

Boundry Conditions

ANSYS Launcher : 3D-DP , Multiphase: Off
Energy :On ,Viscous: Laminar
Radiation : Off , Heat Exchanger :Off
Species: Off , Acoustics: Off
Eularian Waveform: OFF

Velocity Inlet V=0.000652m/s
Gauge pressure = 5900 Pa
Pressure Outlet Gauge Pressure = 0 Pa ,
Mass flow Rate = 0.00005265 Kg/Sec

2. Coefficient of friction and Sommerfeld number –

A) Coefficient of friction -

Coefficient of friction is given by formula ,

$$f = 2\pi^2 *(\mu n/P)*(r/c)$$

Where,

f = Coefficient of Friction

μ = Dynamic Viscosity (mpa.s)

n = Speed in rps

r= radius of journal bearing (m)

c= clearance (m)

P= Load per unit area (N/m^2)

Table No. 03 – Coefficient of friction calculations

Bearing without fins		Bearing with Fins		Speed (rpm)
Initial Coefficient of Friction	Final Coefficient of Friction	Initial Coefficient of Friction	Final Coefficient of Friction	
0.061808	0.015069	0.079808	0.008991	1000
0.014513	0.007973	0.032513	0.000354	945
0.005224	0.004405	0.023224	-0.00369	925
-0.00338	0.002456	0.014617	-0.00521	910
-0.00671	0.001925	0.011294	-0.00654	910

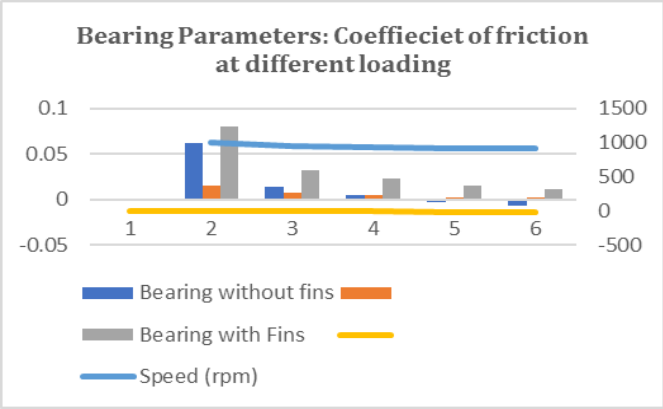

Chart -1: Bearing Parameters: Coefficient of friction at different loading

B) Sommerfeld number –

Sommerfeld number is given by equation,

S = (μn/ P)*(r/c)2

Where:

μ = Dynamic Viscosity (mpa.s)

n = Speed in rps

r = radius of journal bearing (m)

c = clearance (m)

P = Load per unit area (N/m2)

Table No. 04 - Sommerfeld number calculations

Speed rpm	Bearing without fins		Bearing with Fins	
	Initial Sommerfeld No	Final Sommerfeld No	Initial Sommerfeld No	Final Sommerfeld No
1000	0.064675	0.013646	0.073598	0.016335
945	0.021504	0.008099	0.031757	0.009351
925	0.013025	0.003575	0.022025	0.004756
910	0.0151	0.003037	0.018415	0.004369
910	0.0121	0.0025	0.012147	0.002155

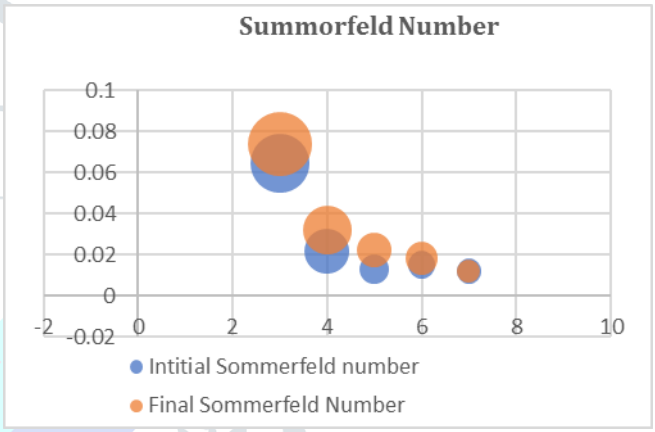

Chart -2: Bearing Parameters: Sommerfeld Number at different loading.

Table No. 05 Initial Experimental and CFD Values Of Coefficient Of Friction And Sommerfeld Number

Load	Initial Coefficient Of Friction For Bearing With Fin		Initial Sommerfeld Number For Bearing With Fin	
	Experimental Values	CFD Values	Experimental Values	CFD Values
1	0.08181	0.08473	0.074672	0.0773422
2	0.03451	0.04418	0.0315036	0.0403246
3	0.02522	0.02838	0.0230249	0.025903
4	0.01662	0.02127	0.0151684	0.0194156
5	0.01329	0.01329	0.0121347	0.0121347

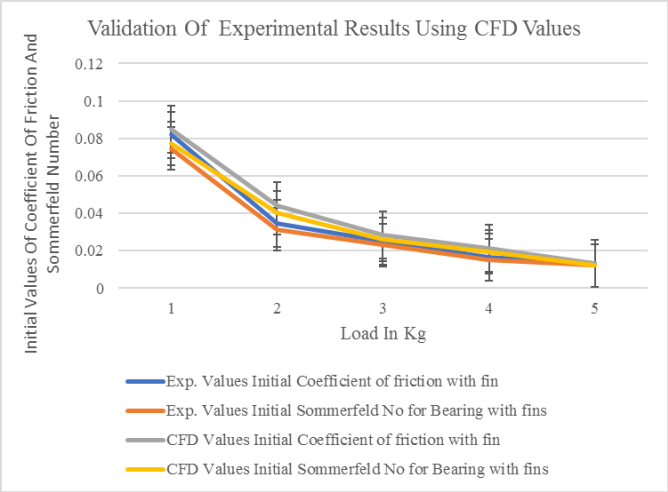

Chart No.03 – Validation of Experimental results with CFD Values

Table No. 06 Final Experimental And CFD Values Of Coefficient Of Friction And Sommerfeld Number

Load	Final Coefficient of Friction For Bearing With Fin		Final Sommerfeld Number For Bearing With Fin	
	Experimental Values	CFD Values	Experimental Values	CFD Values
1	0.01899	0.01987	0.017335	0.0181354
2	0.01035	0.01049	0.009451	0.009577
3	0.00631	0.00658	0.005756	0.0060029
4	0.00479	0.00495	0.004369	0.004520185
5	0.00346	0.00362	0.003155	0.003301

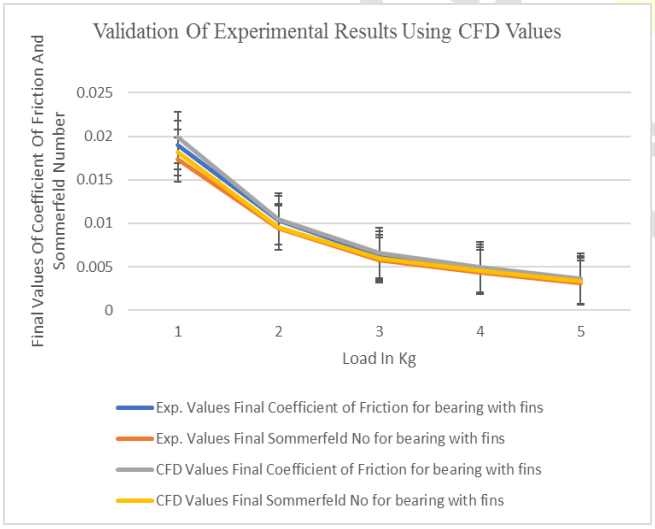

Chart No 04 : Validation Of Final Experimental Values Using CFD Values

3. CONCLUSIONS

Determining the hydrodynamic journal bearing's coefficient of friction and Sommerfeld number is the project's goal. To do that, we chose a bearing and conducted trials for both bearings with and without external fins. It is discovered that the viscosity of oil decreases with increasing temperature when load is applied to a bearing (without fin), while viscosity increases when load is given to a bearing (with fin) when temperature is lowered.

The coefficient of friction decreases to a specific value when the load on the bearing increases, as can be seen in the plot of the coefficient of friction vs load. This suggests that the coefficient of friction is the limit zone when constructing bearings.

The Sommerfeld number also regulates the bearing design and is dependent on operating parameters such as lubricant viscosity, speed, and temperature, as can be seen from the plot of Sommerfeld number vs. load. The Sommerfeld number value decreases with an increase in load.

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