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An Experimental Study of Tribological Behavior of Journal Bearing Material under Powder and GranularLubrication

Ashwini Haral[1], P. Kosabe[2]
[1, 2]*Department of Mechanical Engineering, JSPM's Jayawantrao Sawant College of Engineering*

Abstract: ***Proper lubrication of mechanical components is very important for the reliable efficiency and useful life. The working temperature of the components can affect the lubricating oil and can degrade the lubricating characteristics of oil. This paper presents the experimental investigation on tribological behaviour of journal bearing material. Two types of additives are used in lubricating oili.e., powder and granular types of additives. The investigation is carried out on pin-on-disc apparatus to determine the wear and coefficient of friction. The statistical analysis is performed using design of experiments and Taguchi robust design to determine the optimum parameters of lubricating additives. It is found that for constant speed of 400 rpm with 5% concentration with varying size the granular lubrication have lower values than powder lubrication for all load conditions***
Keywords: Lubrication, pin-on-disc, Taguchi, additives.

I. INTRODUCTION

This Study of mechanics of friction and the relationship between friction and wear back to the sixteenth century, almost immediately after the invention of Newton's law of motion. It was observed by several researchers that the variation of friction depends on interfacial conditions such as normal load, geometry, relative surface motion, sliding velocity, surface roughness of the rubbing surfaces, type of material, system rigidity, temperature, stick-slip, relative humidity, lubrication and vibration. Among these factors normal load and sliding velocity are the two major factors that play a significant role for the variation of friction. In the case of materials with surface films which are either deliberately applied or produced by reaction with the environment, the coefficient of friction may not.

II. RESEARCH BACKGROUND

F. Rahmani, R.K. Pandey et al. [1] have studied the performance of lubricating oil at high temperature range with high running speed and high load condition of machines. In this study they found that at high operating condition above 250^0C, lubricating oil normally starts degrading in the bearing. Finally they presented a review of using powder and granular lubricationfor journal bearing which are working with high speed with high load. In their study they concluded that powder and granular lubrication is only the way to work with high temperature rise situation.

Emmanuel Y.A. Wornyoh et al. [2] have reviewed the research related to dry particulates in sliding contacts. In their study they came to know that there are primarily two types of dry particulate lubricants that are studied granular and powder.. At low speeds i.e., low nominal shear rates, powder and granular lubricants may appear to take on similar velocity accommodation behaviour. However, one distinguishing phenomenological factor is their behaviours at the boundary, where powders usually adhere and coat surfaces, and granules usually slip, roll, and/or collide with surfaces.

Faisal Rahmani, Jayanta K. Dutt et al. [3] have explained the Performance behavior of elliptical-bore journal bearings lubricated with solid granular particulates. Finally they concluded that Dry particulates are potential media for providing granularlubrication in journal bearings operating in hot environments and at high temperatures. Granular particulates do not degrade thermally, even at considerably high temperatures. During running of the rotor, the circular bore of the bearing is modified to anelliptical shape due to wear, misalignment, and deformation under loaded conditions. Investigations were carried out to develop an understanding of the static and dynamic performance of powder-lubricated elliptical-bore journal bearings.

Dongya Zhang et al. [4] have investigated tribological performances under dry and starved lubrication conditions of the Babbitt alloy substrate (i) sprayed with PU composite coating and (ii) with bare surface To improve the tribological properties of Babbitt alloy used as journal bearing pad specifically under severe condition, Babbitt substrate was prayed with a coating of polyurethane (PU) polymer which had been suitably modified with PTFE particles.

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J. Paulo Davim [5] presents a study of the behaviour of the brass/steel pair in the presence of friction and wear. A plan of experiments, based on the techniques of Taguchi, was performed on a pin-on-disc machine. The objective was to establish a correlation between load, sliding velocity and temperature in contact with the wear and coefficient of friction. These correlations were obtained by multiple linear regression. Finally, conformation tests were performed to make a comparison between the foreseen results from the mentioned correlations and the experimental results.

Shyam Kumar Karna et al. [6] have optimized the process by applying the Taguchi method with orthogonal array robust design. Taguchi Parameter Design is a powerful and efficient method for optimizing the process, quality and performance output of manufacturing processes, thus a powerful tool for meeting this challenge. Off-line quality control is considered to be an effective approach to improve product quality at a relatively low cost. The Taguchi method is one of the conventional approaches for this purpose. Analysis of variance (ANOVA) is used to study the effect of process parameters on the machining process.**Y. Choi et al. [7]** they were investigated the friction coefficient for raw oil and nano-oil mixed with copper nano particleby using a disc-on-disc tribotester. The result shown that the average friction coefficient of raw oil and nano oil under a load of 3000N is decreased by 44 % and 39 % respectively.

III. ANEXPERIMENTAL WORK

A. Selection Of Material Pair Of Journal And Bearing

A pair of material i.e. material of journal and bearing is selected. Journal is a part of shaft which rotates insight the bearing. One surface must be made harder than the other. The hard surface then controls the interaction and the softer one conforms. Since the softer surface is therefore more susceptible to damage, it is usually chosen to be the most easily replaced and cheapest component.

Table 1: Guide to the relative performance of bearing materials

Bearing Alloy	**Load capacity and Fatigue**	**Maximum operating temperature**	**Conformability and embeddability**	**Resistance to seizure**	**Hardness and wear resistance**
Tin bronze	High	High	Moderate	Moderate	High
Phosphor bronze	Very High	High	Poor	Moderate	Very High
Leaded bronze	high	High	Good	Good	High
Copper lead	Moderate	High	Very Good	Very Good	Moderate
Aluminium bronze	Very High	Very High	Poor	Moderate	Very High
Gunmetal	Moderate	High	Good	Moderate	High
Brass	Moderate	Moderate	Poor	Moderate	High
Copper beryllium	Very High	Very High	Poor	Good	Very High
Tin based whitemetal	Moderate	Moderate	Excellent	Excellent	Low
Lead based whitemetal	Moderate	Moderate	Excellent	Excellent	Low
Aluminium low tin	High	High	Good	Good	Moderate
Aluminium high tin	Moderate High	High	Good	Good	Moderate

Table 1 lists the broad range of copper alloy materials, indicating their relative properties which need to be considered for bearing applications. Also included for comparison is whitemetal and aluminium based materials that are commonly used for bearings. It can be seen from Table 1 that copper alloy materials cover a wide range of properties.

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B. Selection Of Dry Lubricant Or Solid Particulate As Additives

Various materials that protect interacting surfaces after the fluid film is lost have been either discovered or created. These materials may be applied to a surface in the form of an additive to a fluid lubricant, or in a pure form, and may also be added or alloyed into the surface when the component is being manufactured. The more common types of materials include the following.

1) Molybdenum disulfide (MoS2) also known as moly
2) Polytetrafluoroethylene (PTFE) also known as Teflon
3) Graphite
4) Boron nitride
5) Talc
6) Calcium fluoride
7) Cerium fluoride
8) Tungsten disulphide (WS2)

Graphite and molybdenum disulphide (MoS2) are the predominant materials used as solid lubricant. In the form of dry powderthese materials are effective lubricant additives due to their lamellar structure. Graphite is structurally composed of planes of polycyclic carbon atoms that are hexagonal in orientation. The distance of carbon atoms between planes is longer and therefore the bonding is weaker.

Table 2: Dry Lubricant Selection Criteria

	Graphite	**MoS2**	**WS2**
Temperature limit	450^{0}C	400^{0}C	600^{0}C
Load carrying capacity	Medium	High	High
availability	Easy	difficult	difficult
cost	negligible	High	High

C. Experimental Test Setup



Fig. 1 Pin on Disc wear tester

Tribometer is an instrument that measure friction, wear and coefficient of friction i.e tribology properties between two surfaces in contact. It has an arrangement for varying load, running speed and track diameter to measure the change in tribological properties of materials. In pin on disc tribometer pin is made up of soft material and the disc is made up of hard material such as MS or CI. pin is stationary part and it is holded by pin holder and disc is rotating part. Pin is in direct contact with the rotatingdisc. The coefficient of friction between pins and disc and wear rate of pin is directly shown by digital meter.

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Following are the final oil compositions ready for experimentation.

1) Graphite powder of size 0.1 to 10 microns1) 1% i.e. 8.6 gram
2) 5% i.e. 43 gram 3) 10% i.e. 86 gram

2) Graphite Granules of size 150 to 500 microns.4) 1) 1% i.e. 8.6 gram
5) 5% i.e. 43 gram 6) 10% i.e. 86 gram

IV. RESULTS AND DISCUSSION

Results of ANOVA for Coefficient of Friction and wear rate shows that, load and speed are the most significant factors and track diameter is least affecting factor for changing the COF and Wear of a journal bearing material pair. So considering onlytwo input factors i.e. load and speed various graph for two size and three concentrations of graphite are drawn using the resultsobtained from experiments.

1) Graphs Of Varying Size Of Graphite At Constant Speed In Rpm

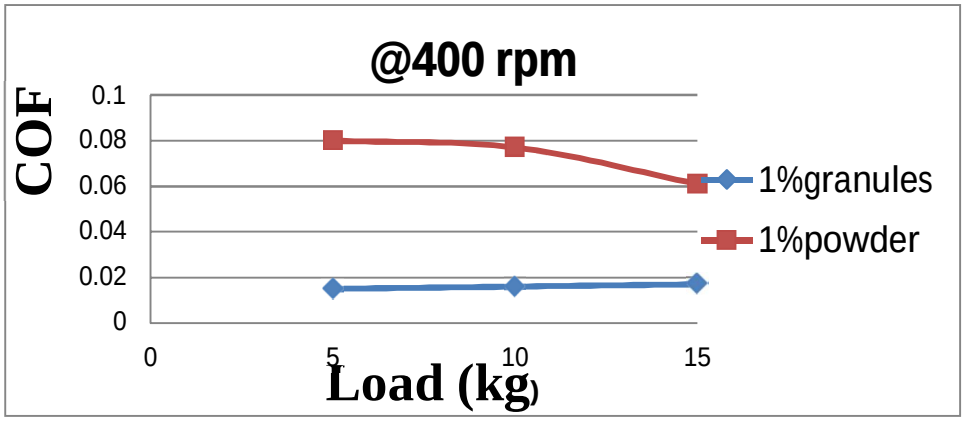


Fig. 2 1% Granules and 1% Powder at 400 rpm with increasing load

For constant speed of 400 rpm with 1 % concentration with varing size the granular lubrication have lower values than powder lubrication for all lload conditions. With increasing load, COF decreases for powder and increases for Granules with very small values.

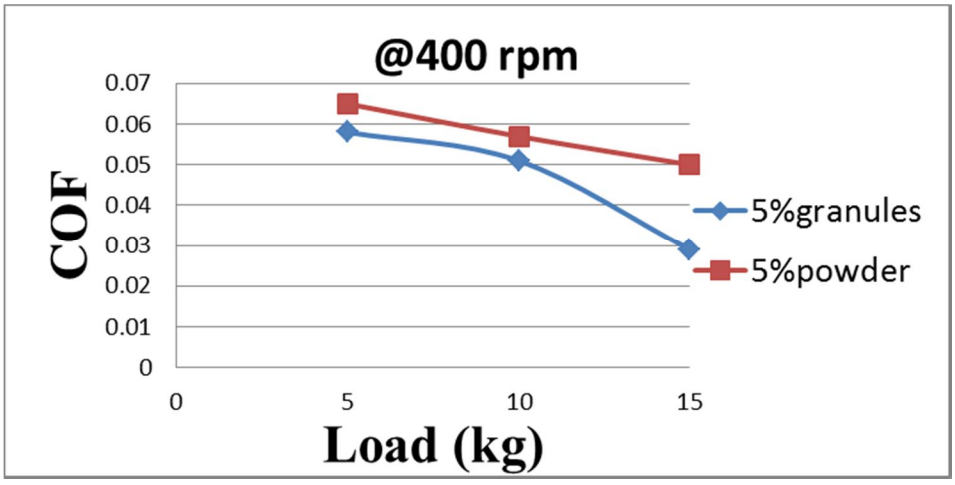


Fig. 3 5% Granules and 5% Powder at 400 rpm with increasing load

For constant speed of 400 rpm with 5% concentration with varying size the granular lubrication have lower values than powder lubrication for all load conditions. With increasing load, COF decreases for powder as well as for granular lubrication with very small values.

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2) Graphs of Varying Concentration of graphite Granules at Constant Load

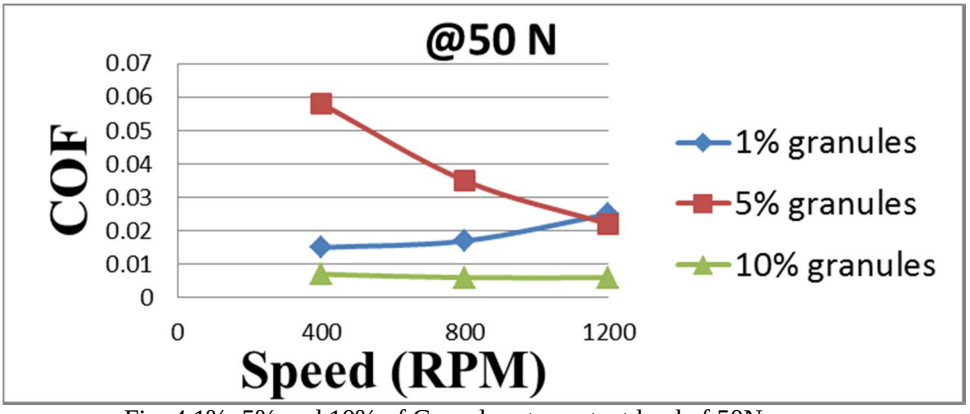


Fig. 4 1%, 5% and 10% of Granules at constant load of 50N

With increasing concentration of graphite granules from 1% to 10% at constant load of 50N, 100N and 150N with increasing speed the COF first increases for 5% concentration ant then decreases to lower value for 10%.

V. CONCLUSION

A. Copper alloy and aluminum alloy are most commonly used as crankshaft and connecting rod bearing material of high speed and heavy duty diesel engines. So copper alloy is selected as a bearing material for preparation of pins.

B. Powder and Granules have been used successfully for lubrication of hydrodynamic journal bearing in hostile environment.

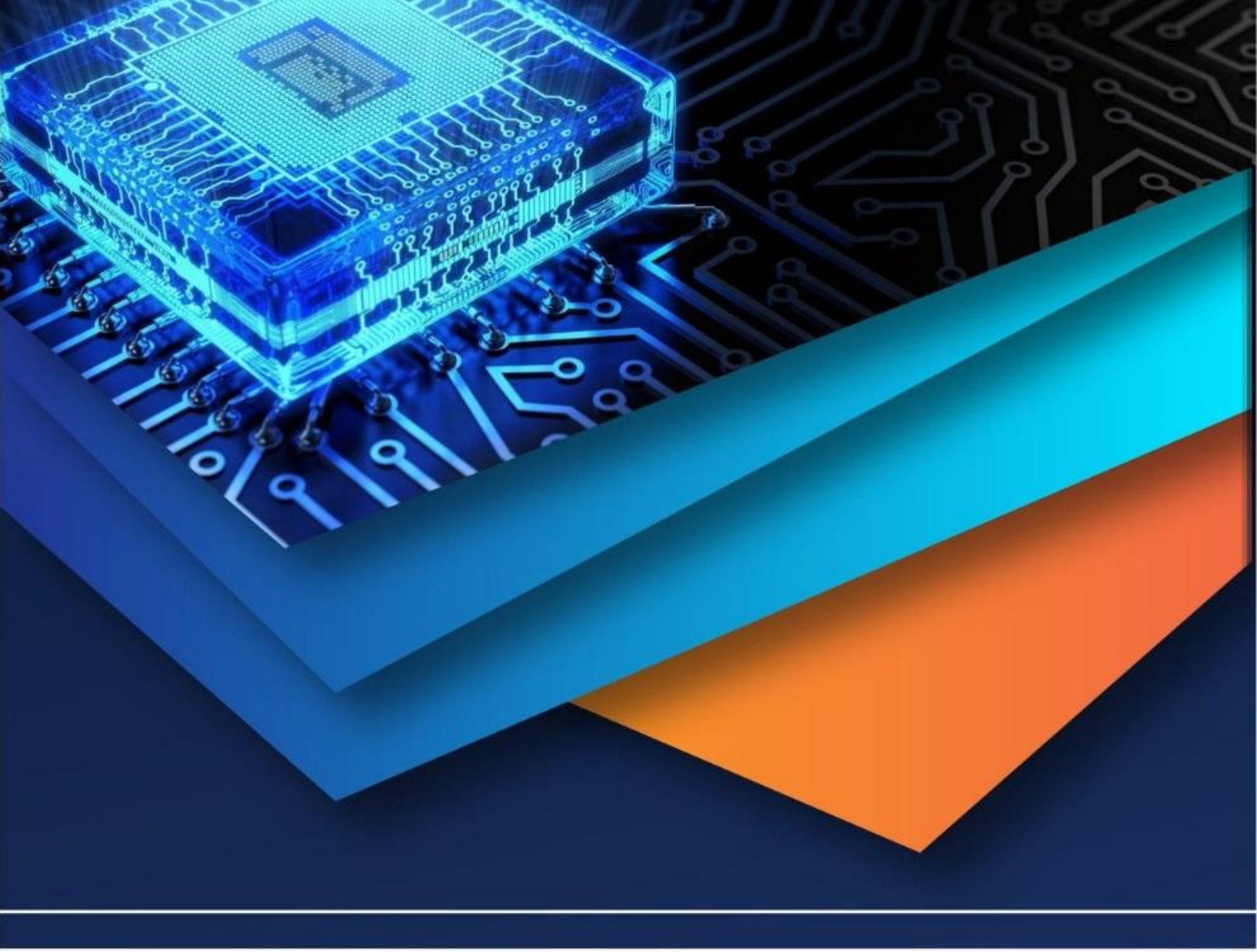
C. Graphite, MoS_2 and WS_2 have the better lubricating properties among all dry lubricants so graphite is selected as additives in lubrication.

D. Taguchi Technique is used by various researchers for DOE. For 3 factors and 3 levels L9 Orthogonal Array (OA) is selected which gives all possible combination of experiments and reduce time and cost of experiments.

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