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Effect of Surface Textures on the Performance of Journal Bearings with Contaminated Oil

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Abstract: ***The premature failure of journal bearings may be observed on account of lack of lubricating oil flow inside the bearing, misalignment on the shaft, surface irregularity on journal bearing and contamination blend with lubricating oil, etc., which may affect the production cost of the industry and also dangerous for human life. Sugar mill bearing is commonly known for operating with high load and low-speed conditions. The rise in temperature and wear of sugar mill bearing has been noticed in the sugar industry while working with contamination oil conditions. Hence the experimental investigation of the straight and spiral textured phosphorous bronze journal bearings lubricated with contamination oil has been conducted with a downsize of sugar mills. Dried and crushed bagasse of sugar cane is used as a contamination for entire experimental work. An internal knurling operation has been performed on the inner diameter of bearing through the lathe machine. The results of both textured bearings have been compared in the matter of temperature rise, change in internal diameter and wear loss with various contamination oil conditions. Improvement has been observed on the performance of straight textured bearing as compared to spiral textured bearing under contaminated lubricating oil conditions.***
Keywords: Journal bearing, surface texture, contamination (bagasse), wear, temperature rise.

I. INTRODUCTION

The shaft is loaded by gears, pulleys, rope, belt arrangement, etc., to maintain (bear) such loads and free rotation of shaft the bearing is required. Journal bearing is generally used, where various applications and operating conditions is needed. The failure of a journal bearing is occurred because of surface irregularity, misalignment, lack of lubrication and contamination, etc. The sugar mill bearing operates at low speed and high load. Contamination like bagasse, water, sugar cane juice, dirt is blended with lubricating oil and these contaminated oil flow inside the journal and bearing surfaces. Rivas et al. [1] investigated the behavior of bearing and shaft of sugar mills.

They found that the welding process is needed for the worn shaft to improve shaft life; coefficient of friction and power consumption may reduce using asphaltic oil; SAE 64 provides higher friction coefficient but less wear loss as compared to SAE 67 under high-pressure grease lubricant and asphaltic oil conditions. Muzakkir et al. [2] examined the problem like the failure of journal bearing in sugar mills. They observed that less friction and wear are encountered in the case of phosphor bronze bearing. Kakade et al. [3] investigated the behavior of shaft with different contamination like water, bagasse and sugar cane juice by the pin on disk machine. The coefficient of friction and material loss (wear) of the shaft was higher under dry and contaminated conditions. Nagare and Kudal [4] suggested that the use of grease lubrication, improve the performance characteristics of sugar mill bearing as compared to oil lubrication.

Some modification is required on the design of bearing like surface texture, which may improve the performance of bearing. Dadouche and Conlon [5] investigated the behavior of textured journal bearing with various contaminated oil condition. The result indicated that the performance of lightly texture bearing was better with contamination oil as compared to highly texture bearing. Gropper et al. [6] suggested that different surface texture shapes are needed for various applications. Sharma et al. [7] investigated the triangular textured journal bearing with different operating parameters and found that fixed-parameter improves the performance of journal bearing at the high-pressure region. Manser et al. [8] examined that T2 triangular texture shape enhances the load-carrying capacity of journal bearing.

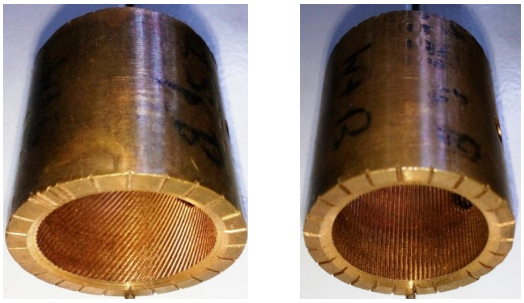
In this study, a case study is adopted from the sugar mill industry, to see and understand the behavior of textured phosphor bronze bearings with contamination (in term of bagasse) oil has been considered. The experiment has been performed on straight and spiral textured bearings with a downscale of sugar mills. The results of both textured bearings have been compared in the matter of temperature rise, change in internal diameter and wear loss with various contamination oil conditions. The performance of straight textured bearing has been improved while comparing with spiral bearing with contamination oil conditions.

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II. EXPERIMENTAL DETAILS

The experimental setup of journal bearing with downsizing has been designed and fabricated according to match the operating condition and environment of sugar mill bearing. The brass is commonly used as a bearing material for sugar mill bearing. In this analysis, EN8 and phosphorous bronze have been used as shaft and bearing materials, respectively. The size of the bagasse particle from sugar cane juice as a contaminant in oil is varied from 30 to 700 µm and measured with SEM machine. An internal knurling tool is attached to the lathe machine to perform an internal knurling operation on the inner diameter of bearing. Two textured bearings like straight (St) and spiral (Sp) have been used for entire experimental work. The external diameter, internal diameter and length of bearings are 40 mm, 30 mm and 40 mm, respectively. The diameter and rotational speed of the shaft are 30 mm and from 500 to 800 RPM, respectively. The length of bearing to the diameter of the journal (shaft) ratio is 1.333:1. The kinematic viscosity of SAE 40 engine (Gulf) oil is approximate 16.34 cSt @ 100 $^{\circ}$C . The total test run for two texture bearing is 40 hours (20 hours each) for 10 days. A capacity of 1.5 HP of AC electric motor with two pulleys and V-belt arrangement has been used to run (rotate) the shaft, which is subjected centrally with a constant load of 392.55 N. For varying speed of the shaft, a variable frequency drive (VFD) has been used. Wear analysis of the journal bearing is found by adding a deadweight load at the center of the span of the shaft. The shaft alignment has been maintained by double-row self-align deep grooved ball bearings (DGBB). The surface textured (spiral and straight knurled) bearings and test rig of journal bearing are shown in figures 1 and 2. The pitch diameter of 1 mm is the same for both straight and spiral knurled bearing. The pitch diameter of the 30º angle with the shaft axis is used for the spiral bearing.



(a) (b)

Fig. 1 Surface textured bearings (a) Spiral and (b) Straight

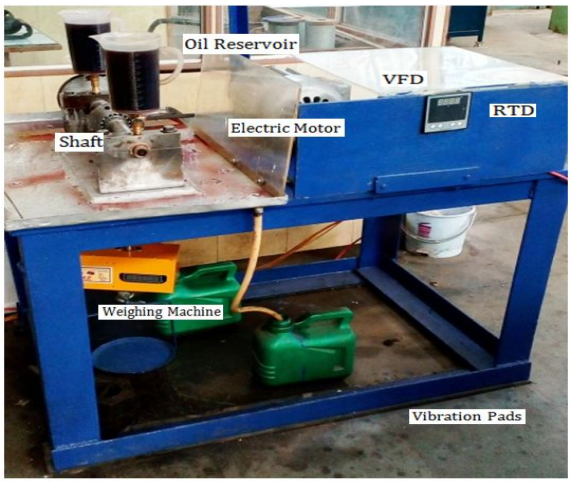


Fig. 2 Test rig of journal bearing

Two vibrations (rubber) pad of 6 mm thickness is required to keep at the bottom of the test rig, stabilize the vibration level of journal bearing. Two bearing housing is used to sustain the shaft and also restrict the movement of axial and rotation of bearings during the experimental work. The lubricating oil is flown inside the bearing through gravity. The internal diameter and temperature of all bearings have been measured by using coordinate measuring machine (CMM) with a least count of 0.005 mm and resistance thermometers (RTD) probe with a least count of ± 1 $^{\circ}$C , respectively.

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III. RESULTS AND DISCUSSION

Failure of the sugar mill bearing is mainly encountered because the temperature of the bearing increases continuously due to it is operated with contamination (like water, bagasse, sugarcane juice, dirt and occasionally a combination of two, three and all of them) lubricating oil conditions.

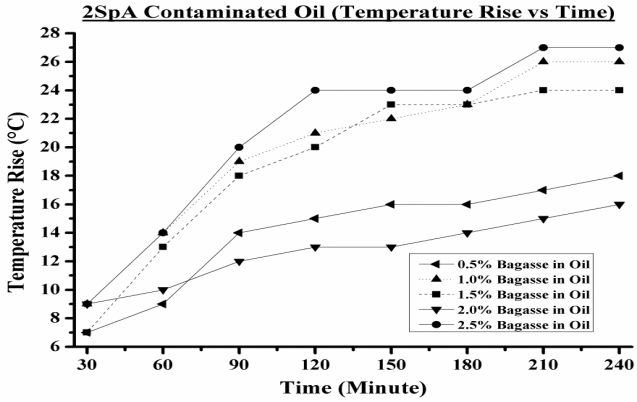


Fig. 3 Temperature of 2SpA bearing under various contaminated oil conditions

The temperature rise of 2SpA (spiral knurled) bearing with respect to time under various contamination (bagasse) oil conditions are shown in figure 3. The atmospheric temperature for each contamination oil condition was varied for the entire test run. The temperature of lubricating oil between the journal and bearing has been measured continuously after every 30 minutes of interval up to 240 minutes by RTD (resistance thermometer) PT 100 probe. The shaft is rotated at a speed of 500 RPM up to 60 minutes, 600 RPM for 60 to 120 minutes, 700 RPM for 120 to 180 minutes and 800 RPM for 180 to 240 minutes of the test run, respectively. The atmospheric temperature of 35 °C , 28 °C , 27 °C , 36 °C and 26 °C was measured at 0.5%, 1.0%, 1.5%, 2.0% and 2.5% of contaminated oil of the bearing, respectively. The maximum temperature rise of 27 °C and minimum temperature rise of 19 °C was recorded at 2.5% and 2.0% of the bearing, respectively. When contamination (sugar cane bagasse) is blended with operating oil, which may degrade the lubricating oil results affect the static characteristics of the journal bearing. The temperature rise of only 1 °C (approximate stable) has been observed at 0.5% and 2.0% of contaminated oil from 90 to 240 minutes of the test run, respectively. The temperature was close stable at 1.0% and 2.5% of contaminated oil from 120 to 180 minutes; it is increased 3 °C up to 240 minutes, respectively. The temperature rise of 2StB (straight knurled) bearing with respect to time under various contamination (bagasse) oil conditions are shown in figure 4. The atmospheric temperature of 37 °C , 29 °C , 40 °C , 30 °C and 38 °C was measured at 0.5%, 1.0%, 1.5%, 2.0% and 2.5% of contaminated oil of the bearing, respectively. The maximum temperature rise of 21 °C and minimum temperature rise of 10 °C was recorded at 1.0% and 1.5% of contaminated in lubricating oil of the bearing, respectively. The temperature rise has been found approximate similar at 0.5% and 2.0% of contaminated oil of the bearing. The temperature was increased up to 3 °C at 0.5%, 1.5% and 2.5% of contaminated oil of the bearing, from 90 to 240 minutes of test run.

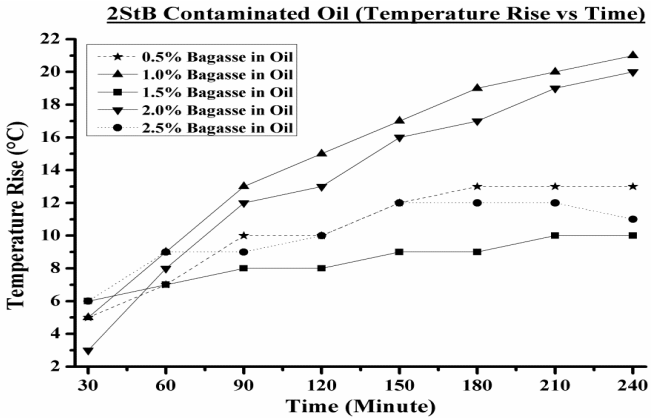


Fig. 4 Temperature of 2StB bearing under various contaminated oil conditions

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A. Comparisons of the Temperature of Textured bearings with Contamination Oil

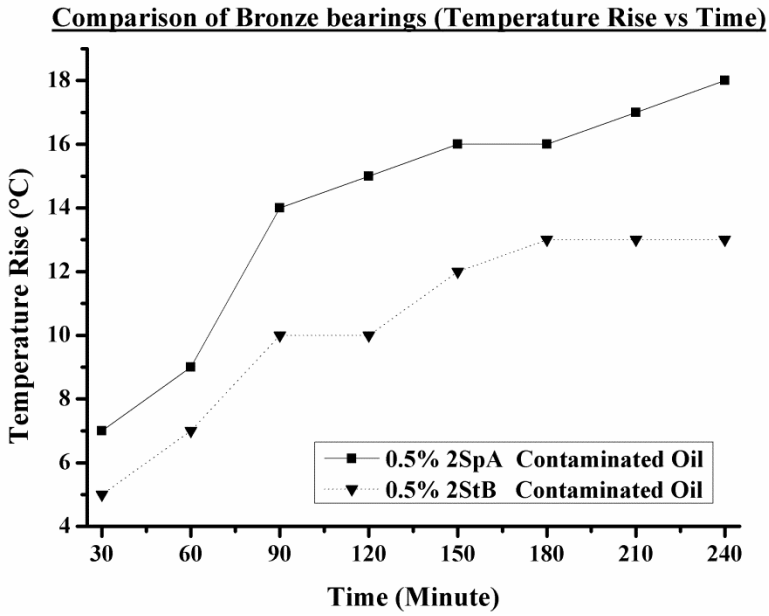


Fig. 5 Temperature of Phosphorous bronze bearings at 0.5% of contaminated oil

Comparison of the temperature of 2SpA and 2StB phosphor bearings as regards time under 0.5% of contaminated oil is shown in figure 5. Higher the temperature rise of 2SpA bearing has been noticed when comparing with 2StB bearings at 0.5% of contaminated oil. The temperature rise increases continuously up to 240 minutes of the test run in case of 2SpA bearing at 0.5% of contaminated oil. Only 3 °C of the temperature rise were marked on 2StB bearing between 90 to 240 minutes of test run.

Comparison of the temperature of 2SpA and 2StB phosphor bearings with respect to time under 1.0% of contaminated oil is shown in figure 6. Higher the temperature rise of 2SpA bearing has been noticed when comparing with 2StB bearings with at 1.0% of contaminated oil. The temperature rise increases continuously up to 240 minutes of the test run in the case of 2SpA and 2StB bearing of 1.0% of contaminated oil.

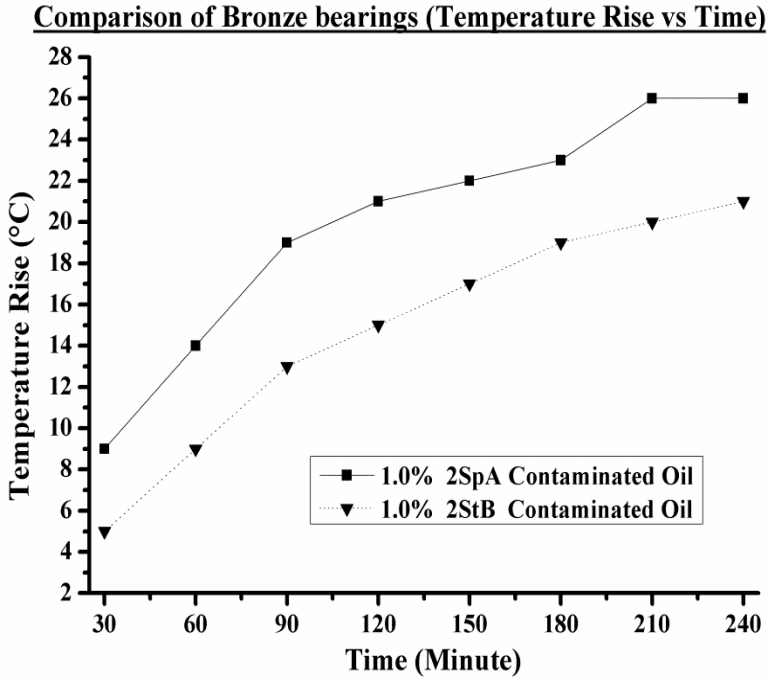


Fig. 6 Temperature of Phosphorous bronze bearings at 1.0% of contaminated oil

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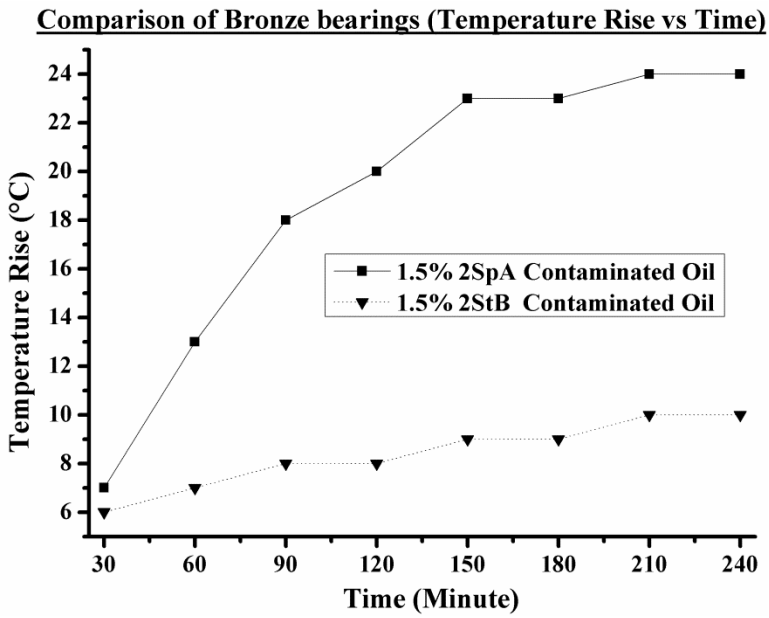


Fig. 7 Temperature of Phosphorous bronze bearings at 1.5% of contaminated oil

Comparison of the temperature of 2SpA and 2StB phosphor bearings with respect to time under 1.5% of contaminated oil is shown in figure 7. Higher the temperature rise of 2SpA bearing has been noticed when comparing with 2StB bearings with at 1.5% of contaminated oil. The temperature rise increases continuously up to 240 minutes of the test run in case of 2SpA bearing at 1.5% of contaminated oil. Only 4 °C of the temperature rise was marked on the 2StB bearing between 30 to 240 minutes of test run.

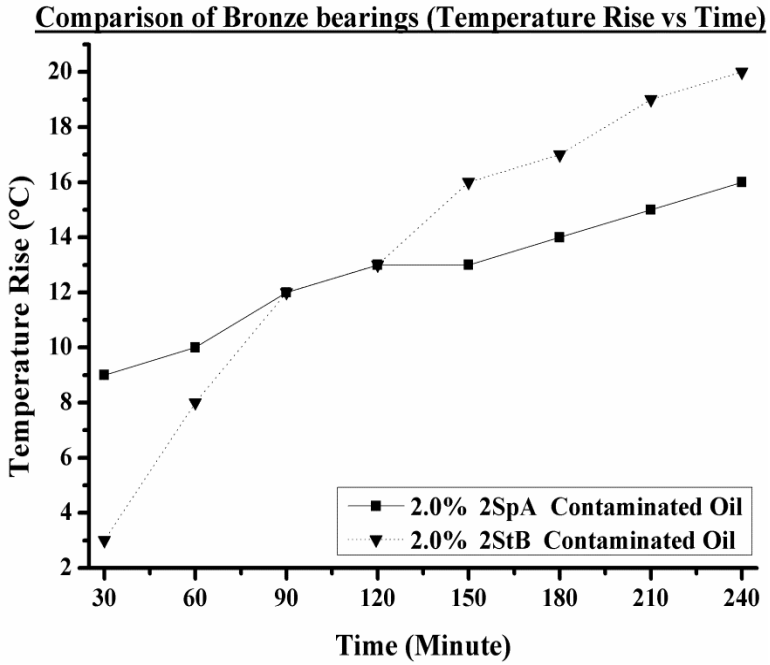


Fig. 8 Temperature of Phosphorous bronze bearings at 2.0% of contaminated oil

Comparison of the temperature of 2SpA and 2StB phosphor bearings with respect to time under 2.0% of contaminated oil is shown in figure 8. Higher the temperature rise of 2StB bearing has been noticed when comparing with 2SpA bearings with at 2.0% of contaminated oil. The temperature rise increases continuously up to 240 minutes of the test run in case of the 2SpA and 2StB bearing at 2.0% of contaminated oil.

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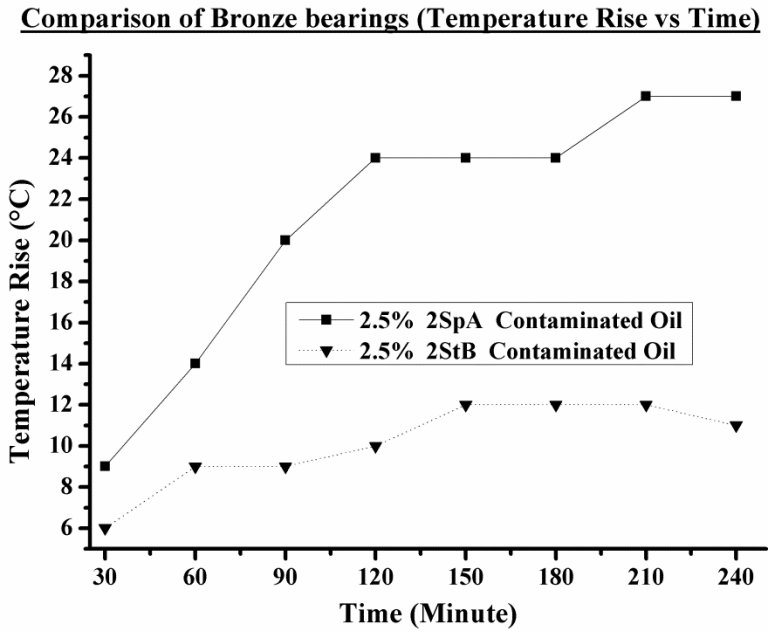


Fig. 9 Temperature of Phosphorous bronze bearings at 2.5% of contaminated oil

Comparison of the temperature of 2SpA and 2StB phosphor bearings with respect to time under 2.5% of contaminated oil is shown in figure 9. Higher the temperature rise of 2SpA bearing has been noticed when comparing with 2StB bearings with at 2.5% of contaminated oil. The temperature rise increases continuously up to 240 minutes of the test run in case of 2SpA bearing at 2.5% of contaminated oil. Only 3 °C of the temperature rise were marked on 2StB bearing between 60 to 240 minutes of test run.

B. Analysis of material loss and diameter change

The calculation of manufactured bearing and its diameter are presented in table I and II. Material loss and increase in internal diameter affect the performance characteristics of journal bearing. The weight before and after experiments of 2SpA and 2StB bearings is measured by weighing machine with four decimal places, and their differences are called the reduction in weight (wear). More wear (material loss) is noticed in the case of 2SpA bearing when comparing with 2StB bearing. The percentage reductions in the weight of 2SpA and 2StB bearings are 0.058 and 0.045, respectively. Each bearing operates for 20 hours of the test run. The internal diameter of bearings before and after the experiment is measured by coordinate measuring machine (CMM) with the least count of 0.005 mm accuracy. The inner diameter of bearing increases, so the bearing clearances, which reduces the load-carrying capacity of the bearing. The increase in the internal diameter of 2SpA bearing is more as compared to 2StB bearing. The material loss and gain in the inner diameter of textured bearings are less than 0.2gm and 0.02mm, respectively.

From the above analysis, the performance characteristics of 2StB (straight) texture bearing is found better as compared to 2SpA (spiral) texture bearing when its operate with contaminated lubricating oil, so it provides an idea to the design engineer to select such bearing (as a sugar mill bearing) to improve the performance of sugar industry.

Table I Wear calculation of manufactured bearings:

Bearing no.	Bearing name	Weight before experiment (gm)	Weight after experiment (gm)	Reduction in weight (gm)	Percentage reduction in weight	Duration of the test (hours)
1	2SpA	183.9803	183.8735	0.1068	0.058	20
2	2StB	181.1490	181.0679	0.0811	0.045	20

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Table II Calculation of bearing diameter:

Bearing no.	Bearing name	Diameter before experiment (mm)	Diameter after experiment (mm)	Increase in diameter (mm)	Percentage increase in diameter	Duration of the test (hours)
1	2SpA	30.089	30.101	0.012	0.040	20
2	2StB	30.108	30.117	0.009	0.030	20

IV. CONCLUSION

The study and analysis of straight and spiral texture phosphorus bronze bearings with various contaminations lubricating oil have been performed through experimentally. The conclusion of such analysis can be drawn below:

The maximum and minimum temperature of 2SpA bearing has been observed higher as compared to 2StB bearing. Higher temperature rise were found on 2SpA bearing at 0.5%, 1.0%, 1.5% and 2.5% of contaminated oil as compared to 2StB bearing. At 2.0% of contaminated oil, the lower temperature rise was found on 2SpA bearing as compared to 2StB bearing. The wear and increase in the internal diameter of textured bearings were less than 0.2gm and 0.02mm, respectively. The wear (material loss) and increase in internal diameter are noticed more in the case of 2SpA bearing while comparing with 2StB bearing. The performance characteristics of 2StB (straight) texture bearing is found better as compared to 2SpA (spiral) texture bearing when its operate with contamination lubricating oil, so it gives an idea to the design engineer to select such bearing (as a sugar mill bearing) to improve the performance of the sugar industry.

V. ACKNOWLEDGMENT

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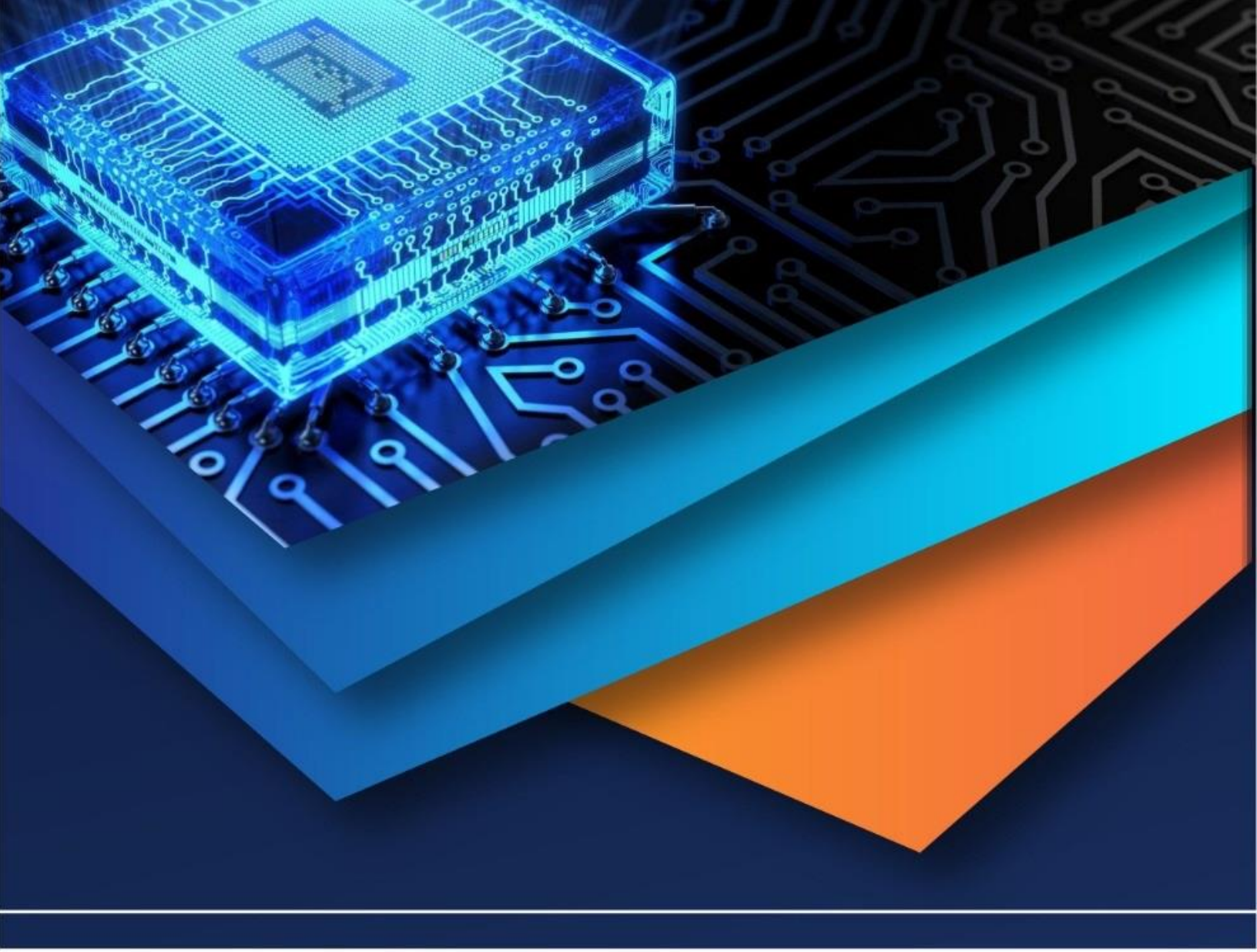
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