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Effect of Various Contamination Levels in Lubricating Oil on the Performance of Plain and Textured Journal Bearings

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Abstract:- The untimely failure of journal bearings may occur due to misalignment, surface irregularity, lack of lubrication, contamination, etc., which affects the production cost of the industry and also dangerous for human life. In general, sugar mill bearing operates under high load and low-speed conditions. The rise in temperature and material loss of sugar mill bearing has been noticed in the sugar industry when it is operated under contamination oil conditions. Hence the experimental investigation of plain and texture (diamond shape) phosphor bronze journal bearing lubricated with contamination oil has been conducted with a downscale of sugar mills. Dry and grind bagasse from sugar cane is used as a contamination condition. An internal knurling operation has been performed on the inner diameter of bearing through the lathe machine. The results of two bearings are compared as regards temperature rise, change in internal diameter and material loss under various contaminations oil conditions. Improvement has been observed on the performance of textured bearing as compared to the smooth bearing under contaminated lubricating oil conditions.

Keywords:- *Journal Bearing; Surface Texture; Contamination (Bagasse); Wear; Temperature Rise;*

I. INTRODUCTION

The purpose of the bearing is to support the load on the shaft and also provide the free rotation of the shaft. Journal bearing is generally used, where different applications and operating conditions is required. Sugar mill bearing operates at high load and low speed. Contamination like bagasse, water, sugar cane juice, dirt is blended with lubricating oil and this contaminated oil flow inside the journal bearing. Rivas et al. [1] examined the behavior of shaft and bearings of sugar mills. They found that the welding process is vital for worn shaft; power consumption and coefficient of friction may reduce using asphaltic oil; SAE 67 provides lower friction coefficient but more wear loss as compared to SAE 64 under asphaltic oil and high-pressure grease lubricant conditions. Muzakkir et al. [2] analyzed the problem like a failure of journal bearing in sugar mills. They observed that, low friction and wear in case of phosphor bronze bearing. Kakade et al. [3] investigated the behavior of shaft with different contamination like water, bagasse and sugar cane juice to match with sugar cane mills. The friction coefficient and wear volume of the shaft was increased with dry and contaminated conditions. Nagare and Kudal [4] suggested that the performance of grease lubrication was better as compared to oil lubrication in sugar mill bearing.

Some modifications to the design like surface texture inside the bearing improve the performance of bearings. Dadouche and Conlon [5] investigated the behavior of surface texture on journal bearing under contaminated lubricating oil conditions. The result showed that lightly texture bearing was performed well in contamination oil as compared to highly texture bearing. Gropper et al. [6] suggested that different surface texture is required for various applications. Sharma et al. [7] examined the triangular textured journal bearing with various operating parameters and found that a specified parameter at the high-pressure region improves the performance of journal bearing. Manser et al. [8] suggested that T2 triangular texture shape improves the load-carrying capacity of journal bearing.

In this present study, a case study is adopted from the sugar mill industry related to the performance of smooth and texture phosphor bronze bearing with contamination (in terms of bagasse) oil has been considered. The experiment has been performed on two bearings with a downscale sugar mill. The results of both bearings have been compared in respect of diametrical change, temperature rise, and wear loss. The performance of textured journal bearing has been improved while comparing to smooth bearing at contamination oil conditions.

II. EXPERIMENTAL DETAILS

A test rig of journal bearing with a downscale has been designed and manufactured to obtain the authentic consequence of sugar mill bearing. In this study, phosphorus bronze and EN8 have been used as bearing and shaft material, respectively. Generally, brass is used as a bearing material in the sugar mill bearing. The size of the bagasse particle as a contaminant in oil is used from 30 to 700 µm and measured with the SEM machine. A lathe machine with a knurling tool is used to perform an internal knurling operation on the inner face of bearing. Two different bearings like plain (P) and diamond (D) have been used for entire experimental work. The length, internal diameter and external diameter 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 runs for two bearings is 40 hours in 10 days. A capacity of 1.5 HP of AC electric motor with pulleys and V-belt arrangement is used to rotate the shaft with a constant load 392.55 N. For varying speed of the shaft, a variable frequency drive (VFD) has been used. The wear analysis of the journal bearing has been examined by using a deadweight load at the center of the span of the shaft. The shaft alignment is maintained by using Double-row self-align deep grooved ball bearings (DGBB). The diamond texture bearing and test rig of journal carrying are shown in figures 1 and 2. The pitch diameter is 1 mm, and their angle with the shaft axis is 30º for the texture bearing. It is crucial to keep two vibrations (rubber) pads with 6 mm thickness at the bottom of the test rig, to maintain the vibration level of the test rig. Two bearing housing is used to restrict the axial and rotation of bearings during the experimental work. Through gravity, the flow of lubricating oil inside the journal bearing. The temperature and internal diameter of all bearings have been measured by using resistance thermometers (RTD) probe with a least count of ± $1\,^{\circ}C$ and coordinate measuring machine (CMM) with a least count of 0.005 mm, respectively.

Fig. 1. Surface texture bearing of diamond shape.

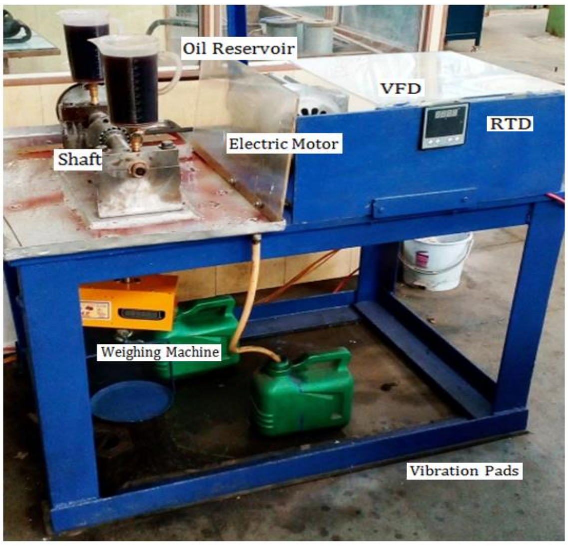

Fig. 2. Test rig of journal bearing.

III. RESULTS AND DISCUSSION

Contamination like bagasse, sugar cane juice, water, dirt and sometimes the combinations of two, three and all of them, whenever they are mixed with operating lubricating oil inside the sugar mill bearing, influence their tribological performance. Hence an experimental investigation has been performed on two different bearings like plain and texture with contaminant oil conditions.

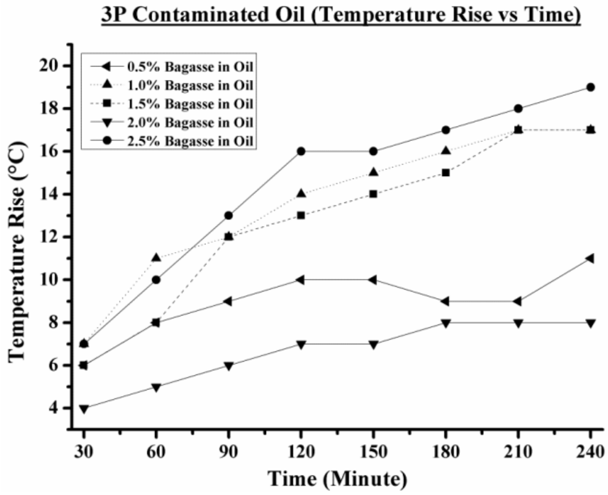

Fig. 3. Temperature of 3P bearing with contaminated oil conditions.

The experimental results of 3P (plain knurled) bearing with contaminated (bagasse) oil between temperature rise and time are shown in figure 3. The atmospheric temperature for each contamination condition was not considered constant throughout the test run. The temperature of lubricating oil inside the bearing was measured continuously after every 30 minutes of interval up to 240 minutes by RTD (resistance thermometer) PT 100 probe. From 0 to 60, 60 to 120, 120 to 180 and 180 to 240 minutes of the test run, the shaft was rotated at 500, 600, 700 and 800 RPM, respectively. The atmospheric temperature of $35\,^{\circ}C$, $28\,^{\circ}C$, $27\,^{\circ}C$, $36\,^{\circ}C$ and $26\,^{\circ}C$ were 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 $19\,^{\circ}C$ and minimum temperature rise of $8\,^{\circ}C$ have been observed at 2.5% and 2.0% of the bearing, respectively. The degradation and reduction in viscosity of lubricating oil are apparent due to contamination (bagasse) is presented in oil during the test run, which can also influence the performance characteristics of the journal bearing. The temperature was increased from 0.5% to 1.5% of contaminated oil afterword it decreased up to 2.0% of contaminated oil of the bearing. This minimum temperature could be possible due to the only flow of lubricating oil inside the bearing instead of contaminant oil because contaminants get stuck at the bottom of the beaker, so continue stirring manually with a hand blender is very important to observe better experimental results. Approximate temperature rises were encountered at 1.0% and 1.5% of contaminated oil of the bearing.

The experimental results of 2DA (diamond knurled) bearing with contaminated (bagasse) oil between temperature rise and time 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 20 °C and minimum temperature rise of 11 °C have been noticed at 1.0% or 2.0% and 1.5% or 2.5% of contaminated oil of the bearing, respectively. From figure 4, the temperature of the bearing from 0.5% to 2.5% of contamination oil conditions were observed decreases and increases alternatively. Nearly similar temperature rise has been seen between 0.5%, 1.5% and 2.5% of contamination oil.

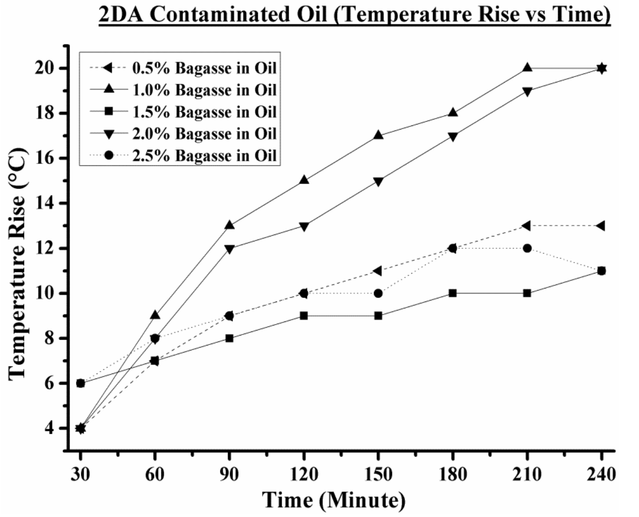

Fig. 4. Temperature of 2DA bearing with contaminated oil conditions.

A. Comparison of the temperature of 3P (plain) and 2DA (diamond knurled) bearings with different contamination oil conditions

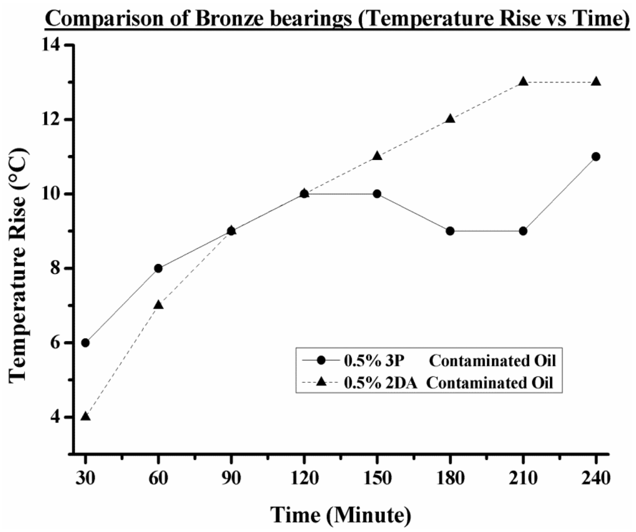

Fig. 5. Temperature of bronze bearings at 0.5% of contaminated oil.

A comparison of phosphorous bronze bearings at 0.5% of contaminated oil in between temperature rise and time is shown in figure 5. The temperature rise at 0.5% of contaminated oil of 2DA bearing is higher than the 3P bearing. An approximate result of the temperature rise of bronze bearings has been noticed up to 150 minutes; subsequently, their differences are from 3 to 4 °C up to 240 minutes. The temperature of 2DA bearing is continuously increased up to 240 minutes. The temperature of the 3P bearing is stable from 90 to 210 minutes afterword it increases up to 240 minutes of test run. Only 2 °C of the temperature difference between 2DA and 3P bearings have been seen after 4 hours of the test run, from figure 5.

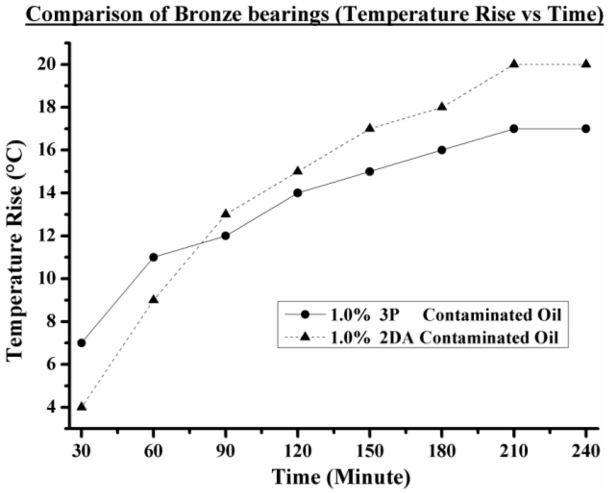

Fig. 6. Temperature of bronze bearings at 1.0% of contaminated oil.

A comparison of bronze bearings with 1.0% of contaminated oil in between temperature rise and time is shown in figure 6. The temperature rise of 3P bearing is lower as compared to 2DA bearing. The temperature of both bearings is continuously increased up to 240 minutes. The differences in temperature of 3P and 2DA bearings are from 1 to 3 °C up to 240 minutes. The temperature of the 3P bearing is not much affected while operating with less contaminant oil conditions, like 0.5% and 1.0%.

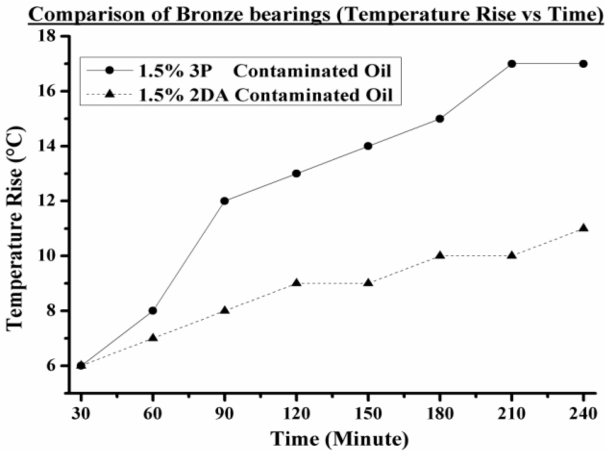

Fig. 7. Temperature of bronze bearings at 1.5% of contaminated oil.

Comparison of both bronze bearings with 1.5% of contaminated oil in between temperature rise and time is shown in figure 7. The temperature rise of 3P bearing is higher as compared to 2DA bearing because it operates under a high percentage contamination oil condition (1.5%). The temperature of the 3P bearing is continuously increased up to 240 minutes. The temperature differences of 3P and 2DA bearings are from 4 to 7 °C up to 240 minutes. The temperature of 2DA bearing has been found stable from 120 to 240 of the test run.

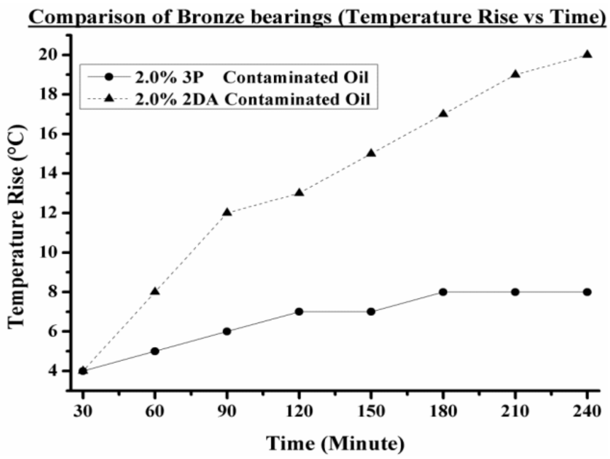

Fig. 8. Temperature of bronze bearings at 2.0% of contaminated oil.

Comparison of both bronze bearings with 2.0% of contaminated oil in between temperature rise and time is shown in figure 8. The temperature rise of 3P bearing is lower as compared to 2DA bearing because of the only flow of lubricating oil inside the bearing instead of contamination oil. The temperature of 2DA bearing is continuously increased up to 240 minutes. The temperature differences of 3P and 2DA bearings are from 3 to 12 °C up to 240 minutes. The temperature of the 3P bearing is increased up to 120 minutes, subsequently it stable or constant up to 240 minutes of test run.

Comparison of both bronze bearings with 2.5% of contaminated oil in between temperature rise and time is shown in figure 9. The temperature rise of 3P bearing is higher as compared to 2DA bearing. The temperature of the 3P bearing is continuously increased up to 240 minutes. The temperature differences of 3P and 2DA bearings are from 1 to 8 °C up to 240 minutes. The temperature of 2DA bearing is increased only 5 °C up to 240 minutes of test run. The temperature of 2DA bearing is increased up to 120 minutes; subsequently, it close to stable up to 240 minutes of test run. The performance of 2DA bearing is far better than 3P bearing when operating at high contamination oil.

B. Wear and diameter analysis of fabricated bearings

Material loss and diameter change of phosphor bronze bearings are given in tables 1 and 2. Wear of the bearings has been measured by weighing machine for four decimal places with 0.005 gm of least count. Wear (material loss) can be calculated by the differences of the initial weight of bearing before experiment and final weight of bearing after finishing the test. Reduction in weight (material loss) of 3P bearing is more as compared to 2DA bearing. The inside diameter of bearing before and after experiments are simply measured by CMM (coordinate measuring machine) with 0.005 mm of least count. The clearances have been found more in texture (diamond knurled) bearing rather than 3P (plain) bearing. Reduction in weight and increase in diameter of the bearings are less than 0.3 gm and 0.4 mm, respectively. So it is clear that when texture bearing operates under extreme contamination (bagasse), oil conditions give better results as compared to the plain bearing.

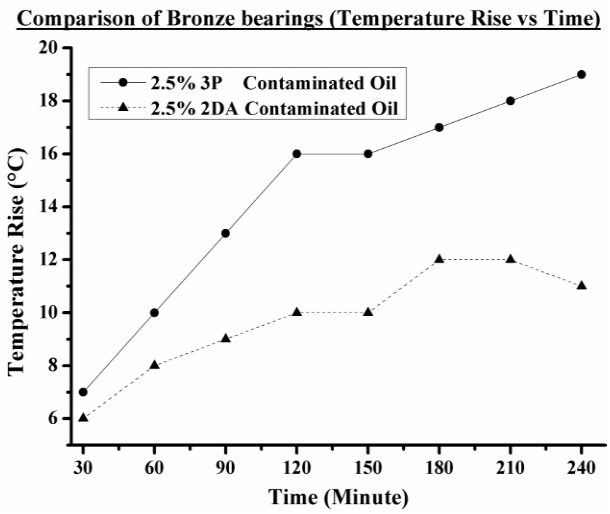

Fig. 9. Temperature of bronze bearings at 2.5% of contaminated oil.

Bearing no.	Bearing name	Weight before experiment (gm)	Weight after experiment (gm)	Reduction in weight (gm)	Percentage reduction in weight	Duration of the test (h)
1	3P	190.6934	190.4636	0.2298	0.120	20
2	2DA	181.1778	180.9948	0.1830	0.101	20

Table 1:- Finding of wear of fabricated bearings:

Bearing no.	Bearing name	Diameter before experiment (mm)	Diameter after experiment (mm)	Increase in diameter (mm)	Percentage increase in diameter	Duration of the Test (h)
1	3P	30.094	30.120	0.026	0.086	20
2	2DA	30.097	30.133	0.036	0.120	20

Table 2. Finding of bearing diameter:

IV. CONCLUSION

The performance of phosphorus bronze bearings with contaminant lubricating oil condition has been studied and analyzed, through experimentally. Based on the results, the conclusion can be pointed out: The maximum temperature rise of 2DA and 3P bearings are approximately identical but differ in minimum temperature. The temperature rise was observed less at 0.5% 1.0% and 2.0% of contaminated oil of 3P bearing as compared to 2DA bearing. At 2.0% of contaminated oil of 3P bearing was found less because there is a possibility to the only flow of lubricating oil inside the bearing instead of bagasse contamination oil, such situation alters the desired result of the bearing hence the continuous stirring is much needed inside the beaker through the hand blender. The 3P bearing gives better performance than texture bearing when it operates with low contaminated lubricating oil (1.0%). The temperature rise was found higher at 1.5% and 2.5% of contaminated oil of 3P bearing as compared to 2DA bearing. The 2DA bearing gives better performance than 3P bearing, when it operates with high contaminated lubricating oil (up to 2.5% and above also). Wear of 3P bearing is more as compared to 2DA bearing. The diameter clearances have been found more in texture (diamond knurled) bearing rather than 3P (plain) bearing. So it is quite clear from the above discussions that the 2DA bearing gives better tribological performance under highly contaminated oil conditions as compared to the 3P bearing.

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