Study of Plain and Textured Journal Bearings Using Computational Fluid Dynamics

Dinesh Shamrao Chaudhari[1], Dr.Vinay Kumar[2], Akashay Tajane[3] Dr.Vishal Sulakhe[4]

[1, 2,3,4]Department of Mechanical Engineering, SOET, Sandip University, Nashik , India-422213

Abstract:
Journal Bearing is used to bear the load and confine the rotation of the shaft. A loaded rotating journal (Shaft) is supported by a circular bushing (sleeve or bearing), the diameter of the bearing is slightly more than the diameter of the journal, to provide clearance so a proper supply of lubrication oil is possible, which can enhance the performance characteristics of journal bearing. Journal bearing are mostly used to carry the radial loads of shafts working in dry and lubrication conditions. Journal bearing is used in various applications like sugar mill bearing, cement industry and turbine etc. Journal bearings may prematurely fail because of misalignment, irregular surface, lack of lubrication, contamination, etc., which impacts the industry's production costs are also hazardous for human life. When a bearing is used under diverse oil conditions, the temperature of the bearing has been seen increase in the industry. Because of this, the theoretical analysis of plain and texture (diamond shape) brass, bronze, and gun metal journal bearings lubricated with SAE-40 oil has been done in present study using ansys CFD. The inner diameter of the bearing has been subjected to internal knurling. In terms of temperature rise, the outcomes of two bearings are compared. Performance of the textured bearing has improved in comparison to the plain bearing.

Keywords: Journal Bearing; Temperature; Lubrication; Surface Texture ; CFD analysis

1. Introduction:

Many types of bearings, such as ball and roller bearings, linear bearings, and mounted variants, can employ either plain or rolling element bearings. Bearings are mechanical assemblies with inner as well as outer rolling parts. For rotating or linear shaft applications, races are used. Ball bearings use spherical rolling elements for lower load applications while roller bearings use cylindrical rolling elements for larger weight-carrying requirements. Both supporting weight on the shaft and allowing the shaft to freely rotate are functions of the bearing. Journal bearings are often employed in a variety of applications and operating environments. A sugar mill bearing works under high load and low-speed conditions. Lubricating oil is contaminated with contaminants like bagasse, water, sugar cane juice, and dirt, and this contaminated oil flows into the journal bearing.

Kakade et al. [1] investigated the way a shaft behaves when it is contaminated with different substances, such as water, bagasse, and sugar cane juice when used in sugar mills. Dry and polluted environments enhanced the shaft's wear volume and friction coefficient.

Muzakkir et al. [2] analyzed the issue of journal-bearing failure in sugar mills. They noticed that phosphor bronze bearings have low friction and wear.

Rivas et al. [3] analyzed the bearings and shaft behavior in sugar mills. They discovered that the welding procedure is crucial for worn shafts; using asphaltic oil can reduce power consumption and coefficient of friction; SAE 67 offers a lower friction coefficient but higher wear loss when compared to SAE 64 under conditions of asphaltic oil and high-pressure grease lubricant.

Nagare and Kudal [4] suggested, In sugar mill bearings, grease lubrication is superior to oil lubrication in terms of performance.

Dadouche and Conlon [5] analyzed, the behavior of journal bearing's surface texture under contaminated oil situations. In comparison to highly texture bearing, the results indicated that lightly texture bearing worked well in contaminated oil.

Sharma et al. [6] examined the triangular textured journal bearing under various operating conditions and observed that a specific condition at the high-pressure region increases journal bearing performance.

Dumbre Omkar and Khillari Shubham [7] concluded that material like lead base Babbitt, and tin base brass shows good properties like less wear, and less corrosiveness So it is suitable material for journal bearing. It is also identified that wear rate increases when normal load and sliding velocity increase for both copper and aluminium. At ideal conditions, the wear rate of copper is lower than that of aluminium for the observed range of normal load and sliding velocity.

2. Theoretical Study (Analysis): In this Analysis two type of bearings, Plain knurled bearing and diamond knurled bearing has been taken. Material of bearing is Brass, Bronze and Gun Metal. For diamond knurling, diamond knurling (0.5 x 1mm pitch) is provided to internal diameter. Outer and Inner diameter of both type of bearing 40mm and 30mm respectively having length 40mm. Clearance between bearing and Journal is 0.03mm. Therefore Journal diameter is 29.7mm. During this analysis SAE 40 Oil are used. Following are thermo-physical properties of Oil.

SAE 40 Oil:

Specific Heat: 2KJ/Kg°k

Density: 872 kg/m^3

Viscosity (100°C): 14.5 cst = 14.5 mm^2/s

Thermal Conductivity: 0.135 W/mk

In this analysis Load 392N is applied on Journal which is running at 500 rpm, 600 rpm, 700 rpm & 800 rpm for 60min, 120min, 180min, and 240min respectively. During that speed measured the oil temperature between the journal and bearing after every 30 min. up to 240min. For this ANSYS Fluent 2018 R1 software is used.

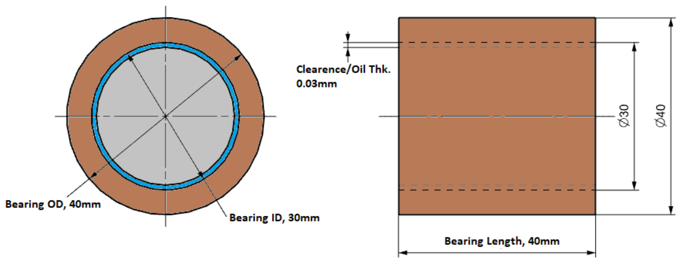


Fig.1. Journal Bearing

For CFD analysis oil film thickness 0.03 mm is used with different boundary conditions. In which outer side of oil film has stationary bearing wall side and inner side of oil film has rotating journal side.

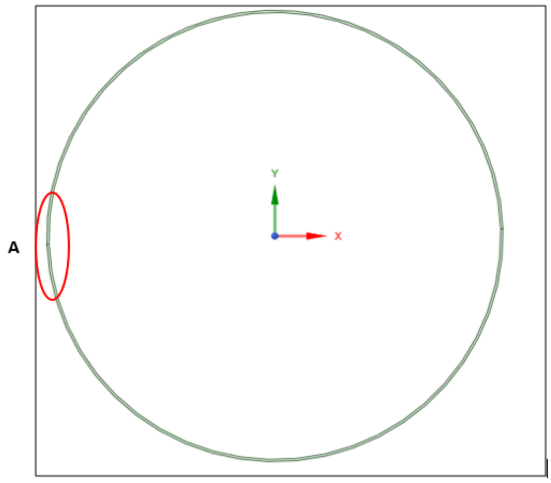


Fig.2. Oil film in bearing

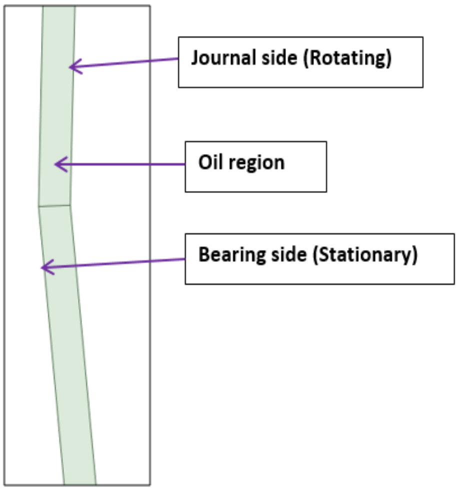


Fig.3. Detail of "A"

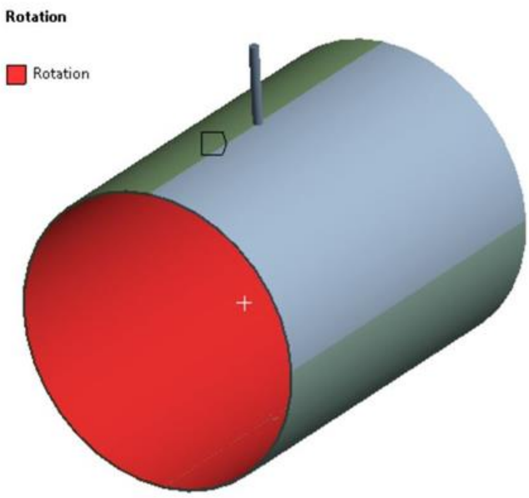


Fig.4. Oil film Rotating side

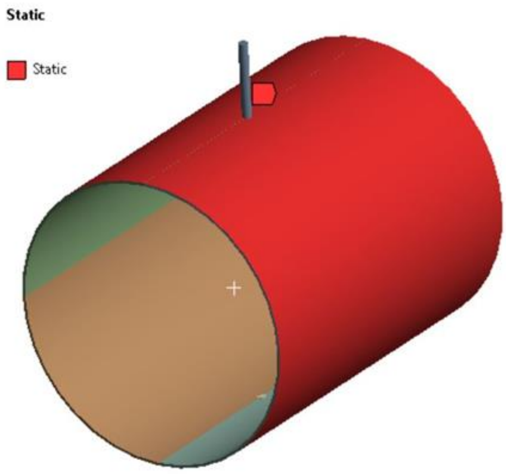


Fig.5. Oil film Stationary side

Meshing Overview:

For our analysis hexahedral mesh used with higher order element. Hexahedral mesh gives some freedom to approximate curves or bends in flat surfaces by varying the angles between quadrilateral faces along the mesh. Total Mesh Count : 2340 & Mesh Skewness : 0.4

Fig.6. Meshing

Boundary Conditions:

This analysis is Transient analysis & it has following boundary conditions:
Initial operating pressure =101325Pa (Atm. pressure)
Bearing load = 392N
Bearing surface area = 0.0037321839m2
Bearing pressure = 105032.34Pa
Hence operating pressure on Bearing = 101325 + 105032.34 = 206357.3Pa
Initial oil temperature = 26.85C
Side leakage is considered.
Ansys set up, Operating pressure and oil properties as shown in fig respectively.

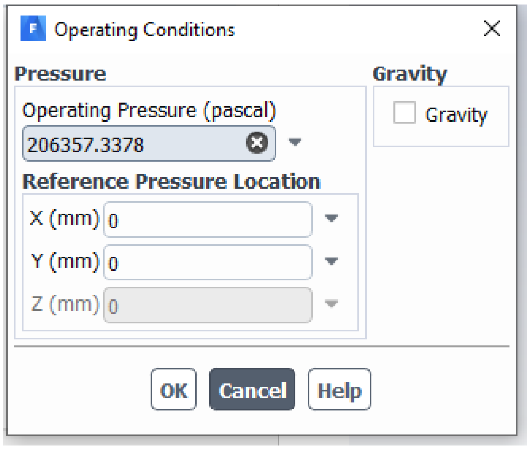


Fig.7. Operating Pressure

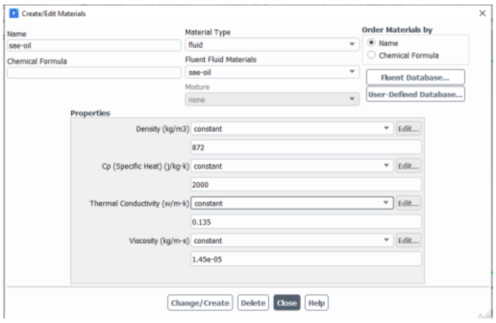


Fig.8. Oil Properties

In this analysis we used three materials for bearing 1) Brass 2) Bronze 3) Gun Metal.
Input data for ansys of respective material as shown in following figures.

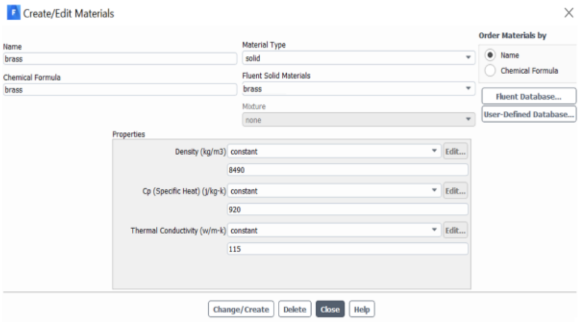


Fig.9. Brass Material

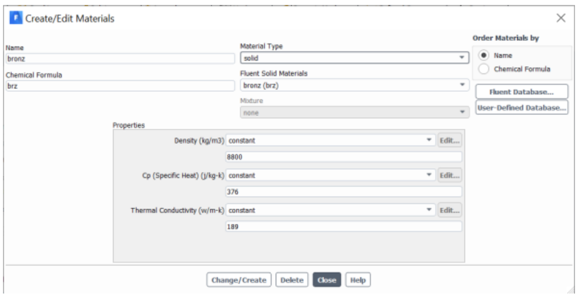


Fig.10. Bronze Material

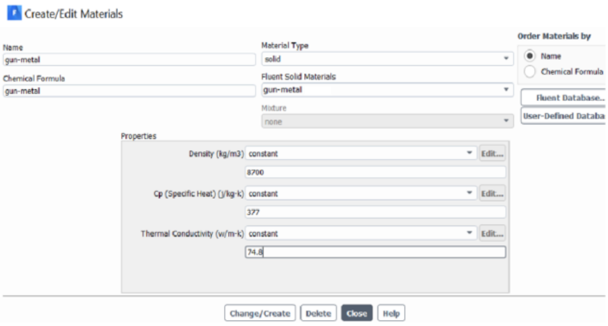


Fig.11.Gun Metal Material

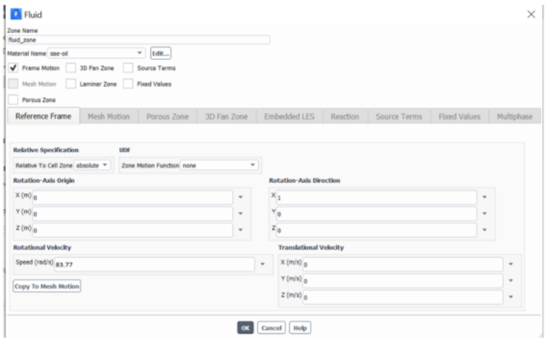


Fig.12. Fluid Zone

For inlet Boundary Conditions outer side of oil film has stationary bearing wall side and inner side of oil film has rotating journal side.

Rotational Wall free to rotate with rotational zone around X axis of rotation, roughness value and Roughness constant shows plain machined bearing surface. Ansys inputs as shown in below figure.

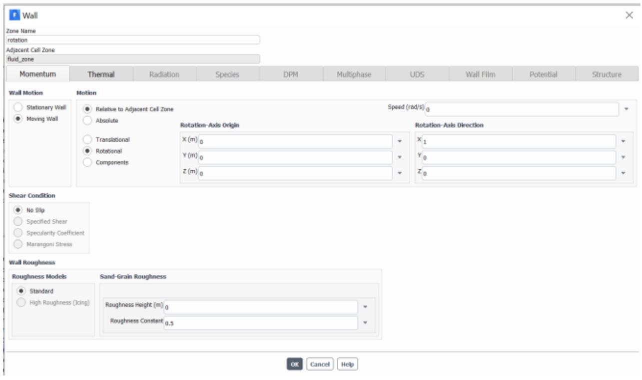


Fig.13. Inputs for plain bearing

For diamond knurling, diamond knurling (0.5 x 1mm pitch) is provided to internal diameter. So in ansys for knurled cases roughness height is considered 0.5mm and roughness constant is 0.5 as it will be well distributed knurled surface. As shown in below figure.

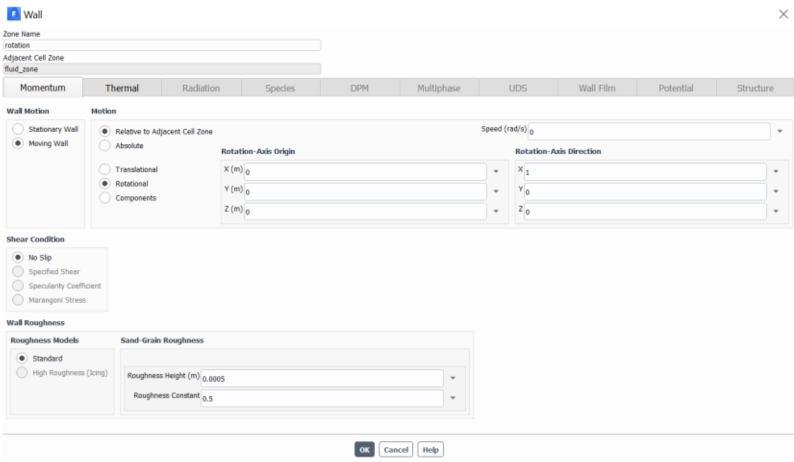


Fig.14. Inputs for knurled bearing

3. Results

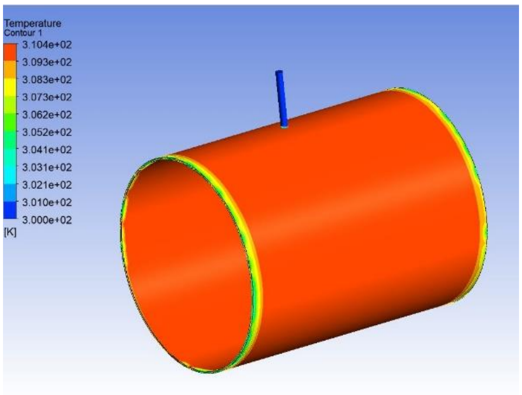
A: Brass Bearing

Case :1 - Without Knurling (Plain)

Initial oil temperature = 26.85 °C

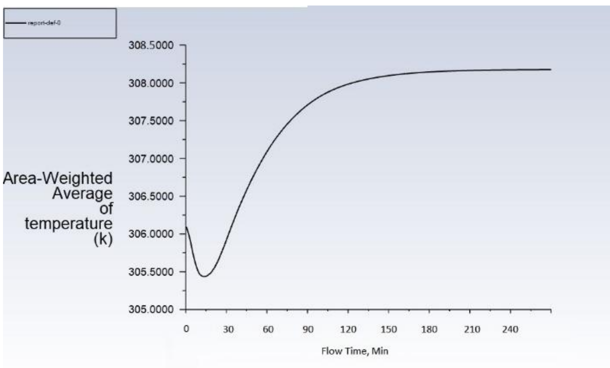
oil temperature at 240 min (800rpm) = 37.25 °C

Increase oil temperature = 37.25- 26.85 = 10.4 °C



37.25 degrees centigrade maximum

Fig.15.Temperature Contour



35.1 degrees centigrade average

Fig.16.Average Temperature Graph

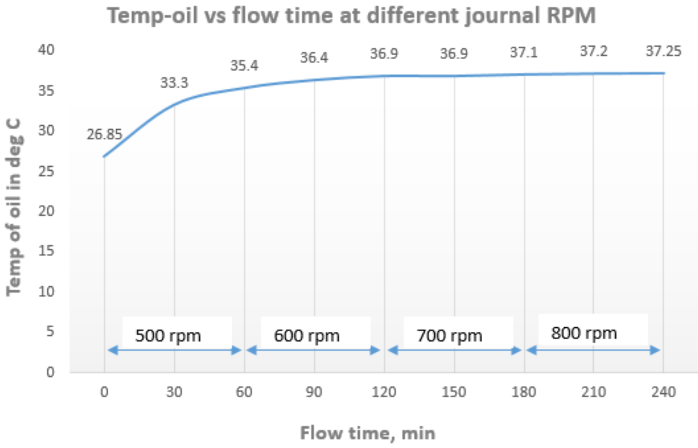


Fig.17. Oil Temperature – Flow Time at Different RPM for plain brass bearing

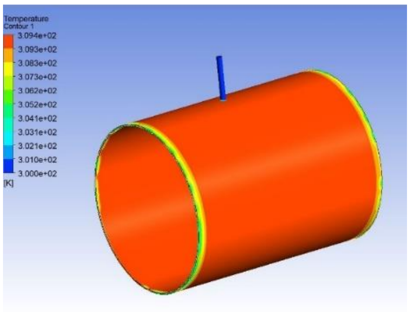
The analysis results of plain brass bearing oil temperature rise and time as shown in above fig.15, fig.16 & fig.17 The maximum temperature 33.3°C, 35.4°C, 36.4°C, 36.9°C, 36.9°C, 37.1°C, 37.2°C & 37.25°C observed at 30min, 60min, 90min, 120min, 150min, 180min, 210min & 240min respectively with defined rpm. As per graph the temperature rise suddenly for first 60min then it's become in stable condition.

Case-2 : With Knurling

Initial oil temperature = 26.85 °C

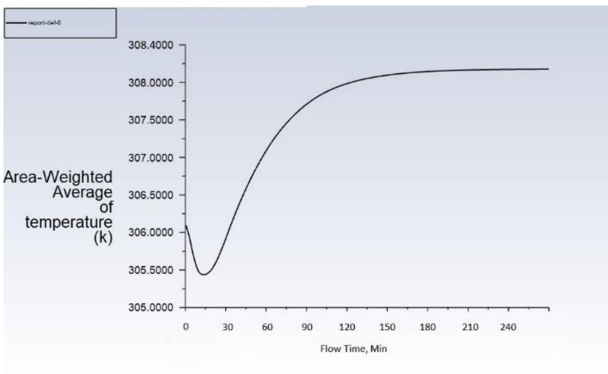
oil temperature at 240 min (800rpm) = 36.25 °C

Increase oil temperature = 36.25 - 26.85 = 9.4 °C



36.25 degrees centigrade Maximum

Fig.18.Temperature Contour



35.05 degree centigrade average

Fig.19.Average Temperature Graph

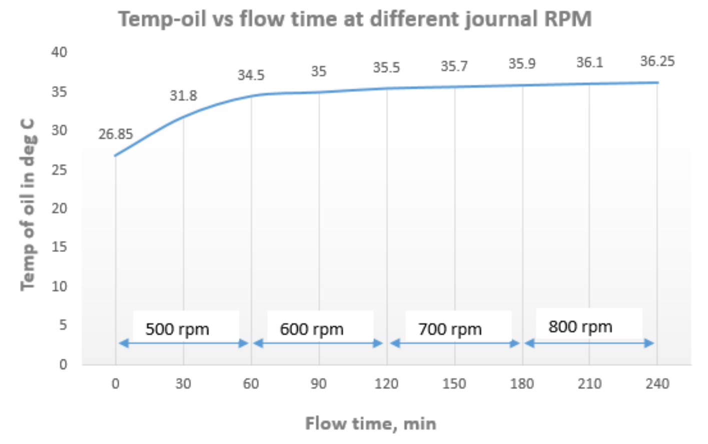


Fig.20. Oil Temperature – Flow Time at Different RPM for knurled brass bearing

In case of knurled brass bearing oil temperature rise and time as shown in above fig.18, fig.19 & fig.20 The maximum temperature 31.8°C, 34.5°C, 35°C, 35.5°C, 35.7°C, 35.9°C, 36.1°C & 36.25°C observed at 30min, 60min, 90min, 120min, 150min, 180min, 210min & 240min respectively. From graph, temperature rise suddenly for first 60min then it's become in stable condition. From above two cases it is observed that, increase in oil temperature of knurled bearing is less than the increase in oil temperature of plain brass bearing by 1°C.

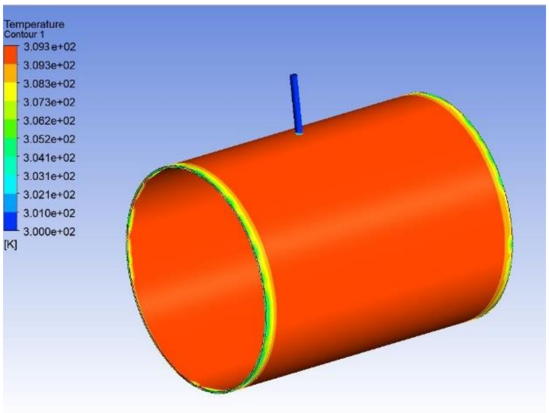
B: Bronze Bearing

Case :1 - Without Knurling (Plain)

Initial oil temperature = 26.85 °C

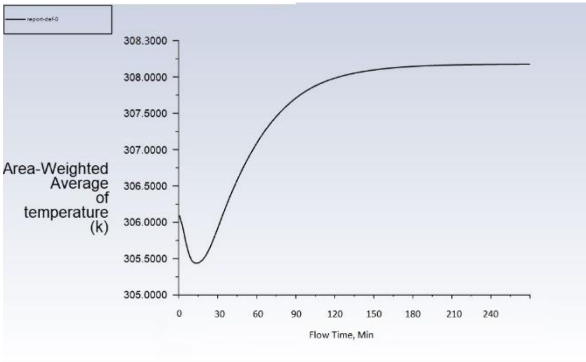
Oil temperature at 240 min (800rpm) = 36.15 °C

Increase oil temperature = 36.15- 26.85 = 9.3 °C



36.15 degrees centigrade maximum

Fig.21.Temperature Contour



35.1 degrees centigrade average

Fig.22.Average Temperature Graph

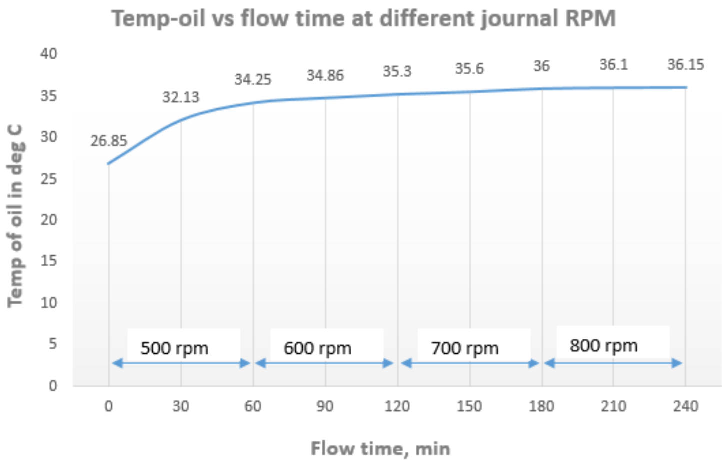


Fig.23. Oil Temperature – Flow Time at Different RPM for plain bronze bearing

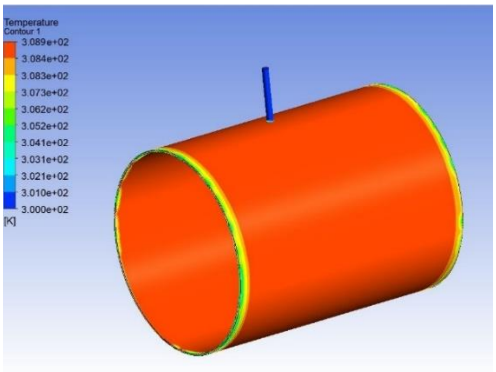
For plain bronze bearing oil temperature rise and time as shown in above fig.21, fig.22 & fig.23 The maximum temperature 32.13°C, 34.25°C, 35.86°C, 35.3°C, 35.6°C, 36°C, 36.1°C& 36.15°C observed at 30min, 60min, 90min, 120min, 150min, 180min, 210min & 240min respectively with defined rpm.

Case :2 - With Knurling

Initial oil temperature = 26.85 °C

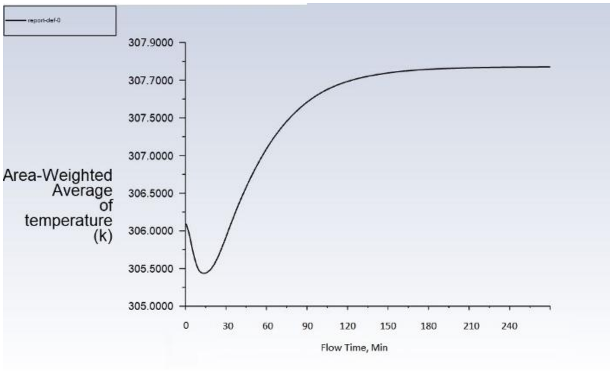
oil temperature at 240 min (800rpm) = 35.75 °C

Increase oil temperature = 35.75- 26.85 = 8.9°C



35.75 degrees centigrade maximum

Fig.24.Temperature Contour



34.65 degrees centigrade average

Fig.25.Average Temperature Graph

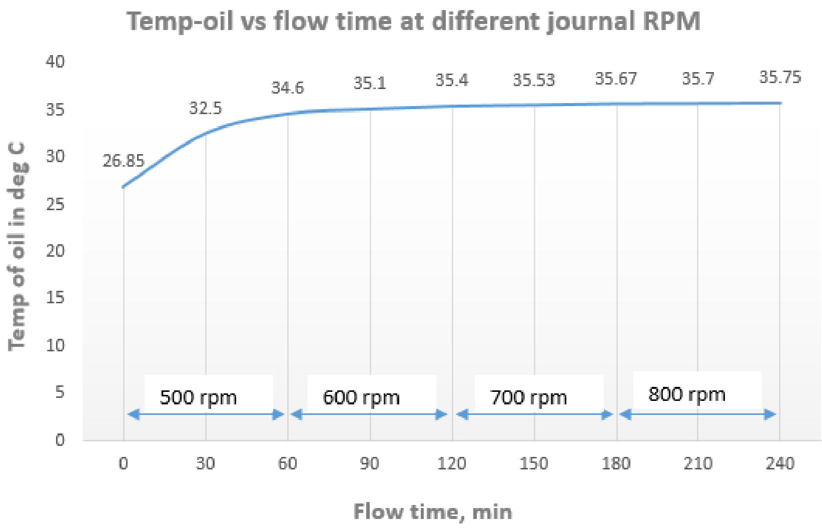


Fig.26. Oil Temperature – Flow Time at Different RPM for knurled bronze bearing

For knurled bronze bearing oil temperature rise and time as shown in above fig.24, fig.25 & fig.26 The maximum temperature 32.5°C, 34.6°C, 35.1°C, 35.4°C, 35.53°C, 35.67°C, 35.7°C & 35.75°C observed at 30min, 60min, 90min, 120min, 150min, 180min, 210min & 240min respectively. From graph, temperature rise suddenly for first 60min then it's become in stable condition. From above two cases it is observed that, increase in oil temperature of knurled bearing is less than the increase in oil temperature of plain brass bearing.

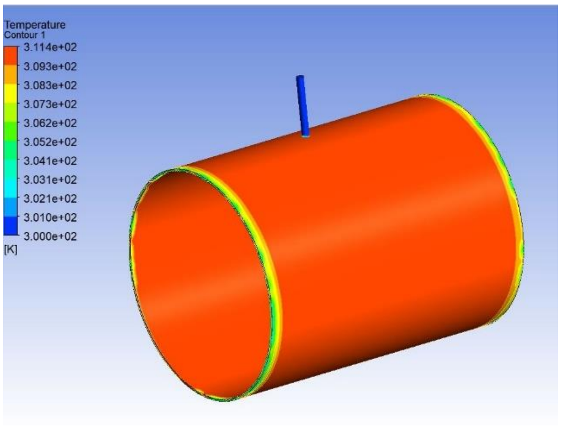
C: Gun Metal Bearing

Case :1 - Without Knurling (Plain)

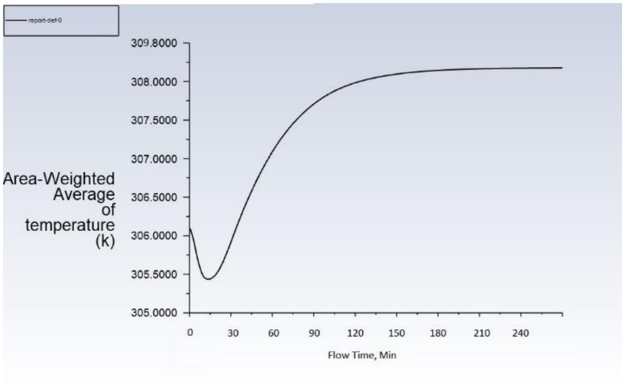
Initial oil temperature = 26.85 °C

oil temperature at 240 min (800rpm) = 38.25 °C

Increase oil temperature = 38.25- 26.85 = 11.4 °C



38.25 degrees centigrade maximum
Fig.27.Temperature Contour



36.65 degrees centigrade average
Fig.28.Average Temperature Graph

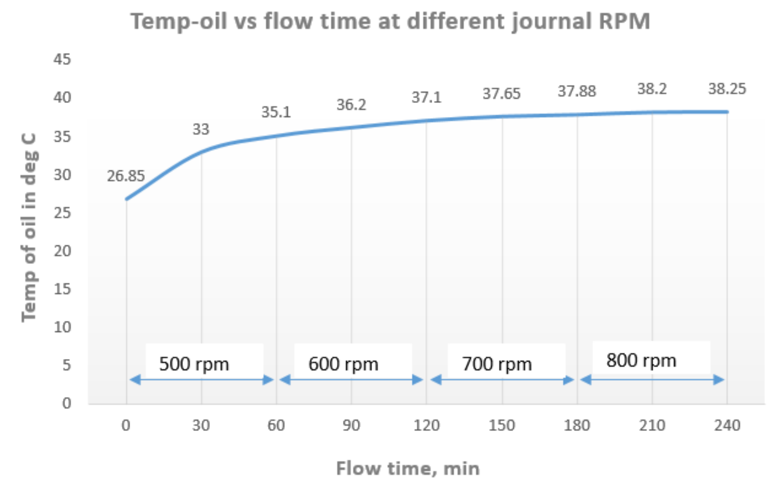


Fig.29. Oil Temperature – Flow Time at Different RPM for plain gun metal bearing

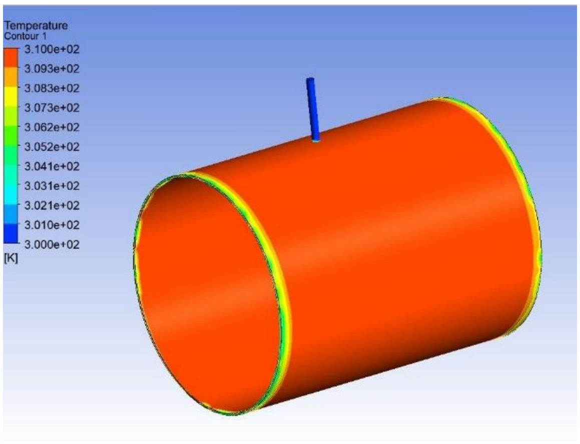
Analysis results of plain gun metal bearing oil temperature rise and time as shown in above fig.27, fig.28 & fig.29 The maximum temperature 33°C, 35.1°C, 36.1°C, 37.1°C, 37.65°C, 37.88°C, 38.2°C & 38.25°C observed at 30min, 60min, 90min, 120min, 150min, 180min, 210min & 240min respectively with defined rpm.

Case :2 - With Knurling

Initial oil temperature = 26.85 °C

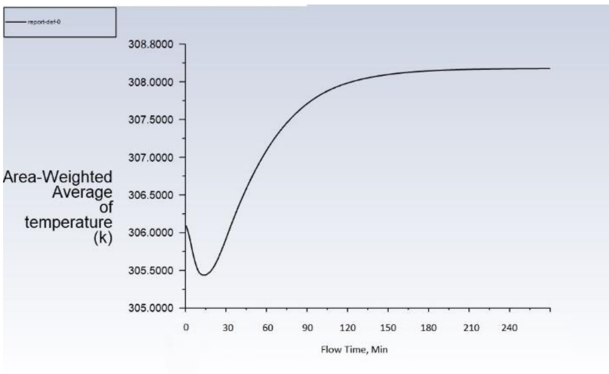
oil temperature at 240 min (800rpm) = 36.85 °C

Increase oil temperature = 36.85- 26.85 = 10 °C



36.85 degrees centigrade maximum

Fig.30.Temperature Contour



35.65 degrees centigrade average

Fig.31.Average Temperature Graph

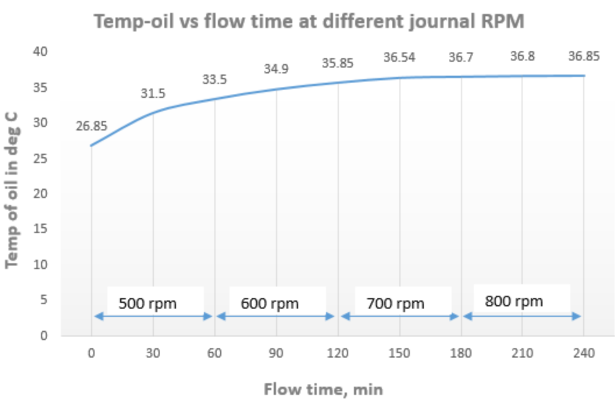


Fig.32. Oil Temperature – Flow Time at Different RPM for knurled gun metal bearing

For knurled gun metal bearing oil temperature rise and time as shown in above fig.30, fig.31 & fig.32 The maximum temperature 31.5°C, 33.5°C, 34.9°C, 35.85°C, 36.54°C, 36.67°C, 36.8°C & 36.85°C observed at 30min, 60min, 90min, 120min, 150min, 180min, 210min & 240min respectively. From graph, temperature rise suddenly for first 60min then it's become in stable condition. From above two cases it is observed that, increase in oil temperature of knurled bearing is less than the increase in oil temperature of plain brass bearing.

4. Conclusion:

The theoretical performance of Brass, Bronze & Gun Metal bearings with SAE-40 lubricating oil has been studied and analysed, through CFD. Based on the results, the conclusion can be pointed out: The maximum temperature rise for all three plain bearings i.e. Brass, Bronze, and Gun Metal are 10.4°C, 9.3°C, and 11.4°C respectively. Similarly, the maximum temperature rise for all three texture (knurled) bearings i.e. Brass, Bronze, and Gun Metal are 9.4°C, 8.9°C, and 10°C respectively. So from the above results, we can say that increase in the oil temperature of the knurled bearing is less than the increase in the oil temperature of the bearing.

Because of knurling (textured) journal bearing the oil surface area is slightly more than the plain journal bearing so it is efficient for heat transfer. At the same time due to the shape of diamond knurling having depth 0.5mm with 1mm pitch, some amount of oil gets remains in that knurled patch so that it is also useful to reduce the temperature.

In texture (diamond knurled) bearings rather than (plain) bearings, the diameter clearances have been seen more frequently. The knurled bearing provides better tribological performance than the plain bearing, as is evident from the above description.

References:

1. A.B. Kakade, S.P. Ingole, D.V. Bhatt, and J.V. Menghani, "Tribological behavior of sugar mill roller shaft in laboratory simulated conditions," Wear, vol. 302, pp. 1568–72, 2013.
2. S.M. Muzakkir, H. Hirani, G.D. Thakre, and M.R. Tyagi, "Tribological failure analysis of journal bearings used in sugar mills," Eng. Fail. Anal., vol. 18, pp. 2093–103, 2011.
3. J.S. Rivas, J.J. Coronado, and A.L. Gómez, "Tribological aspects for the shafts and bearings of sugar cane mills," Wear, vol. 261, pp. 779–84, 2006.
4. P.N. Nagare, and H.N. Kudal, "Tribological Failure Analysis and Suitability of Grease Lubrication for Sugarcane Crushing Mill Journal Bearings," J. Fail. Anal. Prev., vol. 18, pp. 1311–19, 2018.
5. A. Dadouche, and M.J. Conlon, "Operational performance of textured journal bearings lubricated with a contaminated fluid," Tribol. Int., vol. 93, pp. 377–89, 2016.
6. S. Sharma, G. Jamwal, and R.K. Awasthi, "Enhancement of steady state performance of hydrodynamic journal bearing using chevron-shaped surface texture," Proc Inst Mech Eng Part J J Eng Tribol, vol. 233, pp. 1833–43, 2019.
7. Dumbre Omkar, Khillari Shubham(2016) A REVIEW PAPER ON STUDY OF WEAR ANALYSIS OF BEARING MATERIAL.