



The Effect of Slot Size and Orientation on Temperature and Pressure Values for a Journal Bearing with Dimensions of L/D Ratio of 36 mm to 16 mm

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ABSTRACT

The effect of temperature and pressure on journal bearing performance was investigated to ascertain which of the bearings produced lowest lubricant temperature and highest pressure. 16 sliding bearings of Tin-base Babbitt with 89% Sn, 8%Pb and 3%Cu were locally produced in a foundry of 16 mm diameter and 36 mm length each, using B/D ratio > 1 for safe condition. They were grouped based on groove sizes of 0.0015, 0.002, and 0.0025 m and axial, radial and inclined (20, 40, 70°) orientations. The bearings were run one after the other for 5 mins with periodic oil lubrication at 40, 85, 125, 260 rpm. A thermocouple was used to measure temperature. The procedure was repeated for pressure with an oil pressure gauge used for measurement. Results showed that between 40 to 85 rpm, the sliding surfaces of the bearing and shaft were practically in direct contact and friction was highest (boundary lubrication). This explains the usual initial high temperature and little pressure comparatively values as obtained by measuring instruments. At speeds above 85 and 125 rpm, lower friction levels are achieved (mixed lubrication) and a thin film forms. Above 125 rpm, friction coefficient was minimum at the critical value of the duty parameter (dividing line between the mixed and hydrodynamic lubrication zones). This agrees with Stribeck curves for basic operation of hydrodynamic journal bearings. Also, the axial slot orientation at a depth of 0.002 m performed better for all speeds. The results confirm that proper groove size and orientation elongates actual bearing service life, thereby reducing mean down time and increase productivity.

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Introduction

Bearings are metallic objects with specially designed surface upon which another metal (journal) rolls. It is designed to reduce friction by supporting radial loads and used when load is light and motion is relatively continuous, such as in crank shaft [1]. A journal is a part of shaft that is in contacts with the bearing surface, hence the word journal bearing. The study of journal bearing in mechanical engineering is importance because of the functional role it plays in reduction of friction between wheels and shafts of machines and automobiles. When properly selected, assembled and mounted, they support, extend the service life of shafts, and wheels in the transmission of power and torque. Historically, [2] early bearings had wood or leather surfaces, lubricated with animal fat to reduce friction, but recent studies have shown that journal bearings made of alloys with inserted grooves /slots which contain oil during motion of Shaft or wheels enhance lubrication and reduce wear of contact surface by formation of oil film [3] These grooves are either introduced in a bearing axially, radially or at an angle [4]. The choice of type of groove depends on the direction of applied load, whether it is in one direction or varies considerably. Therefore one size of groove and orientation that will be suitable for one application may not be suitable for another. The most important factor that should be considered in groove size and orientation

should be service conditions; low coefficient of friction, low temperature increase and high pressure [5]. Once these factors are taken into consideration, wear of the bearing material will be highly minimized. Figure 1 shows some examples of various groove patterns used in the industry.

Recently, developments in the metallurgy of bearing materials combined with increased knowledge of lubrication processes make it possible to design and produce journal bearings with different groove sizes. In this research, 0.0015, 0.002, and 0.0025 m, considering the fact that our bearing's maximum thickness is 0.003 m. Slot orientations of axial, radial and inclined at angles of 20, 40 and 70° were chosen because not much work has been done using such orientations. Speeds of 40, 85, 125 and 260 rpm were used in experimenting because it was intended that the bearing will function between high and low speed operations. These researches were all carried out without considering the effect the surface of the bearing would produce, when they are plain or have grooves/slots on them. A lot of work has been done on bearing efficiency on the bases of their material composition, but not so many have worked on the effect of surface area with grooves introduced on them. Therefore, it makes it possible to investigate the effect of grooves on the performance evaluation of bearings, by measuring values of

pressure, temperature and coefficient of friction as used in this work. The focus of this study is to ascertain effect of slot size and orientation on values of temperature and pressure, of a journal bearing.

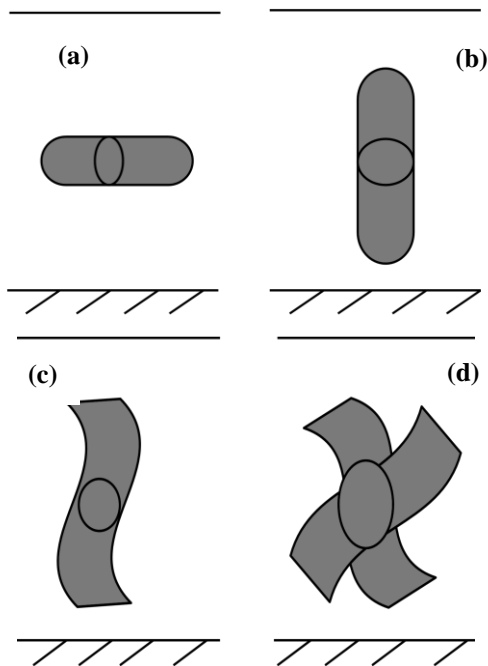


Fig. 1: Examples of various groove patterns as used in the industry- (a) Straight axial; (b) Radial slot; (c) Single loop and (d) Double loop

Material and Methods

Sixteen sliding bearings with the following compositions (Tin-base Babbitt with 89% Sn, 8% Pb and 3% Cu) locally produced in a foundry with dimensions of 16 mm diameter and 36 mm length each, using B/D ratio > 1 for safe condition were investigated. The bearings were grouped based on groove sizes of 0.0015, 0.002, and 0.0025 m and orientation (axially, radially and inclined at an angle of 20, 40, 70°. The bearings one after the other were fixed in a hub and a shaft inserted through them, one end fixed to the jaw of a Harrison 600 lathe machine and ran for 5 mins using SE-20 oil lubricant of 20 ml which was applied at intervals for various speed of 40, 85, 125, 260 rpm. After the period of five minutes, a thermocouple was clipped on the inner surface of the bearing which reads a temperature value immediately. The same was done for pressure but with an oil pressure gauge clamped at the base center hole of the bearing.

Results and Discussion

Operations of hydrodynamic lubrication was based on the fact that journals are allowed to run on bearing surfaces starting at a low speed, which result in high temperature and wear, because of high coefficient of friction. As speed increases, the journal and its load are being borne by the lubricant which at that point is under high pressure indicating that hydrodynamic lubrication has set in. Temperature value in accordance with the operations of hydrodynamic lubrication is better when at the start of operation its value is very high and then decreases as speed of operation increases. While the opposite is the case in terms of pressure value, where it was low at initial speed and increased as speed increases [6]. Based on this outlined principles, discussion was done considering Figures 1 to 6 with Table 1 and Figures 7 to 12 with Table 2 which were for temperature and pressure dependence on speed for all the bearings as used in the experiments respectively.

From Table 1, bearing with axial slot in relative comparison with other bearings produced the highest temperature value of 45°C at depth of 0.0015 m for speed of 125 rpm and a minimum temperature value of 25.7°C at a depth of 0.002 m for speed of 40rpm. Axial slot orientation at a depth 0.002 m produced the lowest temperature value cut across all speed carefully observed from Table 1. Others have their temperature values in-between the temperature range of 25.7°C and 45°C. This implies that maximally, performance is best at axial orientation with a depth of 0.002 m when lowest temperature is the only or major variable considered. This result is because metal to metal contact is highest at axial orientation with a depth of 0.0015 m and lowest at a depth of 0.002 m. It implies that if minimum temperature is the main factor to be considered in an operation with a bearing of dimension 36 mm long and 16 mm in diameter, then bearing with axial slot orientation at a depth of 0.002 m will be selected. These values 45 - 25.7°C at 0.0015 - 0.002 m form a temperature and depth range and are indicated as highest and lowest points. Statistically, when observed it would be deduced that all bearings give good temperature result which has its mean value at 31.0°.

Table 1: Dependence of Temperature (°C) on Speed for all the Bearings

| SPEED (rpm) | 40 | 85 | 125 | 260 |
|------------------------------|-------|-------|-------|-------|
| NON-SPLIT | 37.50 | 38.00 | 38.50 | 39.20 |
| AXIAL SLOT AT | | | | |
| 0.015(m) | 40.10 | 43.30 | 45.00 | 38.00 |
| 0.020(m) | 25.70 | 26.00 | 28.30 | 29.70 |
| 0.025(m) | 27.80 | 28.00 | 29.30 | 29.80 |
| RADIAL SLOT AT | | | | |
| 0.015(m) | 28.30 | 27.90 | 29.40 | 30.10 |
| 0.020(m) | 30.70 | 30.10 | 30.00 | 34.50 |
| 0.025(m) | 30.00 | 30.30 | 30.50 | 32.00 |
| 20° INCLINED SLOTS AT | | | | |
| 0.015(m) | 30.50 | 29.50 | 26.50 | 34.50 |
| 0.020(m) | 30.50 | 30.80 | 30.30 | 31.70 |
| 0.025(m) | 31.80 | 35.40 | 33.20 | 38.20 |
| 40° INCLINED SLOTS AT | | | | |
| 0.015(m) | 31.90 | 31.70 | 33.20 | 32.60 |
| 0.020(m) | 30.80 | 30.30 | 28.70 | 28.00 |
| 0.025(m) | 30.80 | 31.50 | 30.00 | 29.20 |
| 70° INCLINED SLOT AT | | | | |
| 0.015(m) | 29.20 | 28.10 | 30.90 | 30.40 |
| 0.020(m) | 38.30 | 38.20 | 38.40 | 38.20 |
| 0.025(m) | 37.80 | 38.20 | 35.00 | 29.30 |

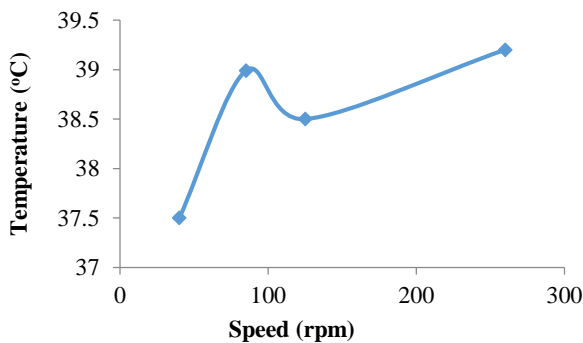


Fig. 1: Temperature curve for non-split bearing

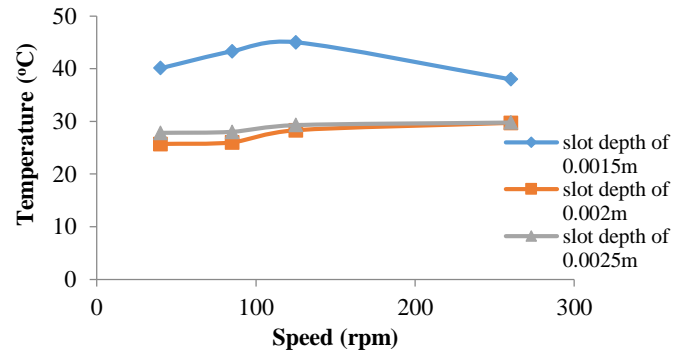


Fig. 2: Temperature curve for axial slot bearing

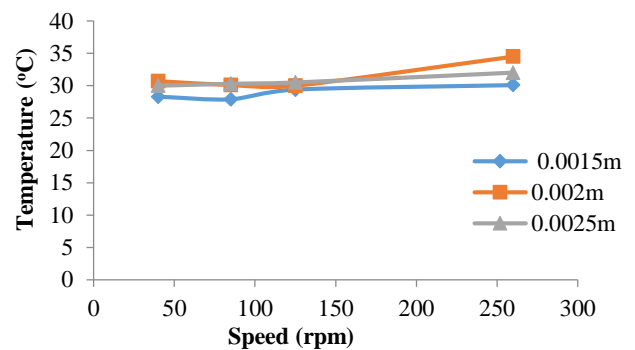


Fig. 3: Temperature curve for radial slot bearing

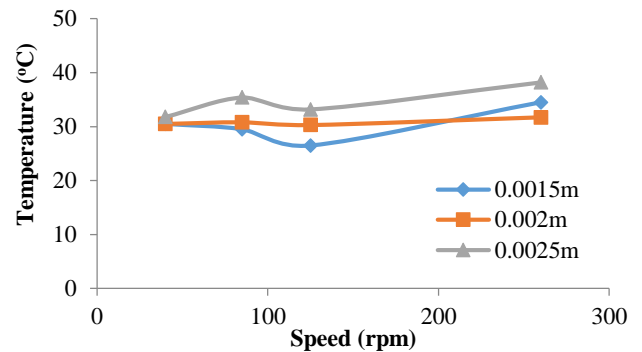


Fig. 4: Temperature curve for 20° inclined slot bearing

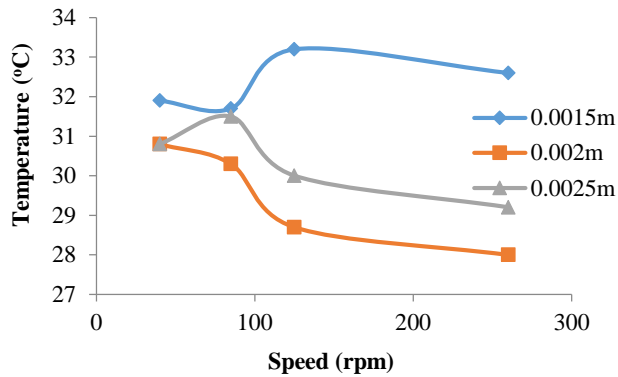


Fig. 5: Temperature curve for 40° inclined slot bearing

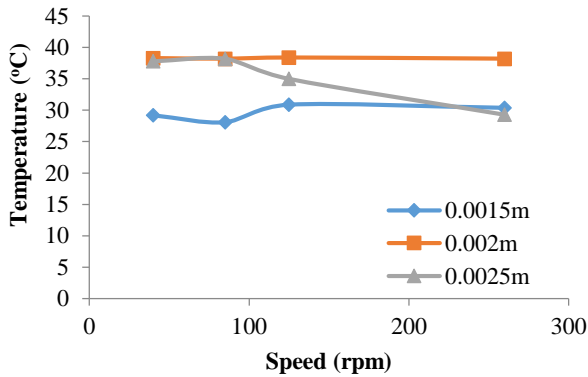


Fig. 6: Temperature curve for 70° inclined slot bearing

From Table 2 and Figures 7 to 12, peak pressure value of 2.7 N/m² was recorded on a bearing with slot inclined at 70° and at a depth of 0.002 m, while minimum pressure value of 0.00 N/m² was recorded at non split bearing and axial slot bearing at a speed of 40 rpm for all depths. Temperature values when compared, one temperature value at one depth against another temperature value at another depth, all at one particular orientation, along their various columns are best at low values for temperature and high values for pressure. When values as such are obtained, it means hydrodynamic lubrication is beginning to set in and will be used as a standard in investigating which of the bearings performed better than the others.

Table 2: Dependence of Pressure on Speed for the Bearings

| SPEED (rpm) | 40 | 85 | 125 | 260 |
|------------------------------|------|------|------|------|
| NON-SPLIT | 0.00 | 0.20 | 0.35 | 0.75 |
| AXIAL SLOT AT | | | | |
| 0.015(m) | 0.00 | 0.25 | 0.46 | 0.52 |
| 0.020(m) | 0.00 | 0.12 | 0.34 | 0.50 |
| 0.025(m) | 0.00 | 0.21 | 0.37 | 0.49 |
| RADIAL SLOT AT | | | | |
| 0.015(m) | 0.12 | 0.19 | 0.23 | 0.41 |
| 0.020(m) | 0.24 | 0.28 | 0.31 | 0.34 |
| 0.025(m) | 0.18 | 0.19 | 0.23 | 0.35 |
| 20° INCLINED SLOTS AT | | | | |
| 0.015(m) | 0.10 | 0.15 | 0.17 | 0.21 |
| 0.020(m) | 0.12 | 0.25 | 0.37 | 0.67 |
| 0.025(m) | 0.05 | 0.07 | 0.09 | 0.14 |
| 40° INCLINED SLOTS AT | | | | |
| 0.015(m) | 0.04 | 0.12 | 0.17 | 0.23 |
| 0.020(m) | 0.05 | 0.18 | 0.37 | 0.27 |
| 0.025(m) | 0.08 | 0.12 | 0.09 | 1.90 |
| 70° INCLINED SLOT AT | | | | |
| 0.015(m) | 0.90 | 1.80 | 2.10 | 2.40 |
| 0.020(m) | 0.80 | 1.50 | 1.90 | 2.70 |
| 0.025(m) | 0.40 | 1.20 | 2.00 | 2.50 |

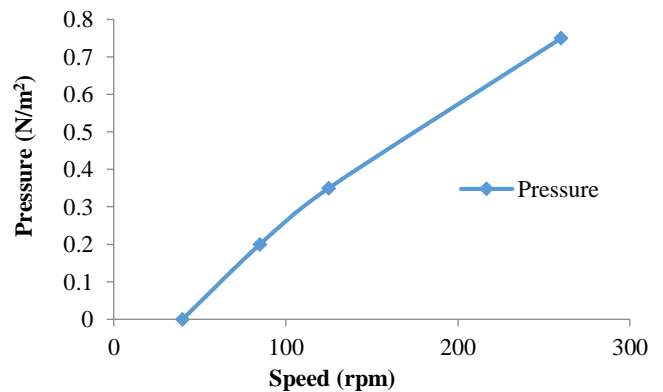


Fig. 7: Pressure curve for non-split bearing

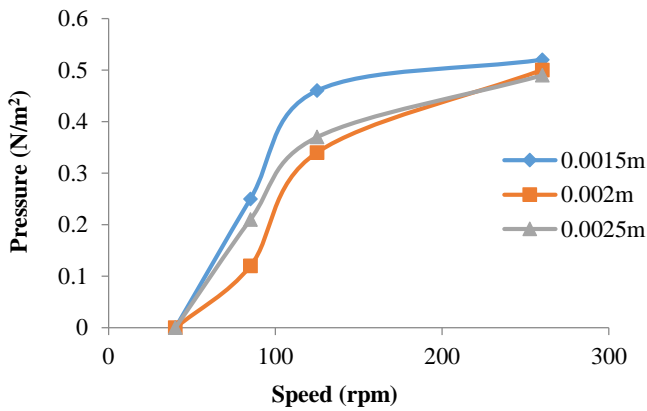


Fig. 8: Pressure curve for axial slot bearing

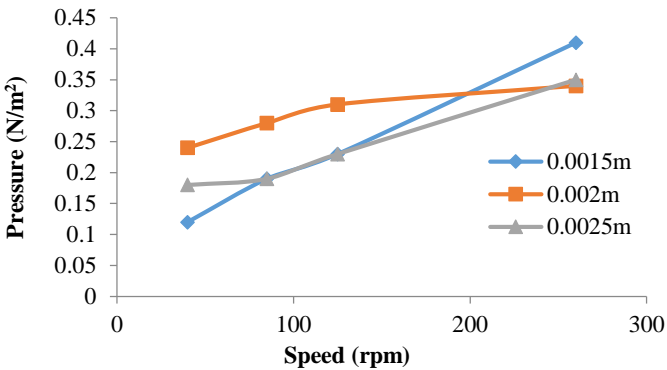


Fig. 9: Pressure curve for axial slot bearing

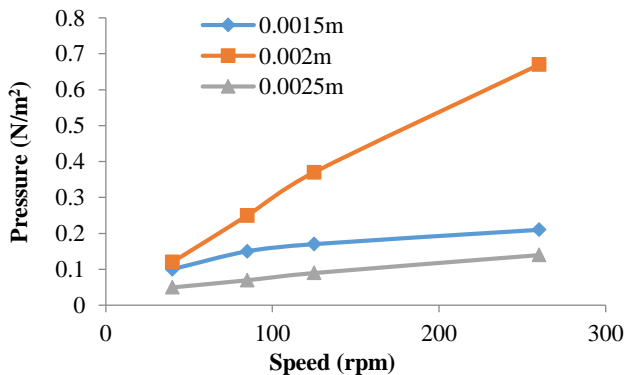


Fig. 10: Pressure curve for 20° inclined slot bearing

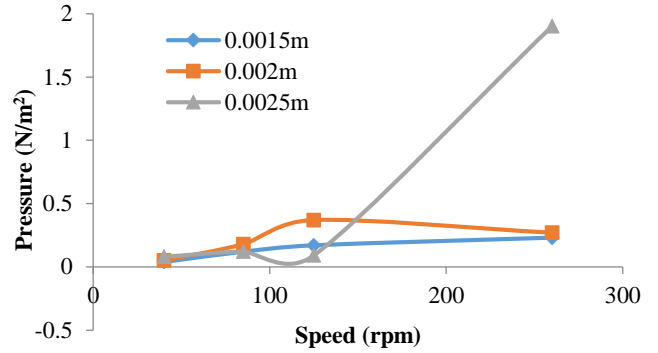


Fig. 11: Pressure curve for 40° inclined slot bearing

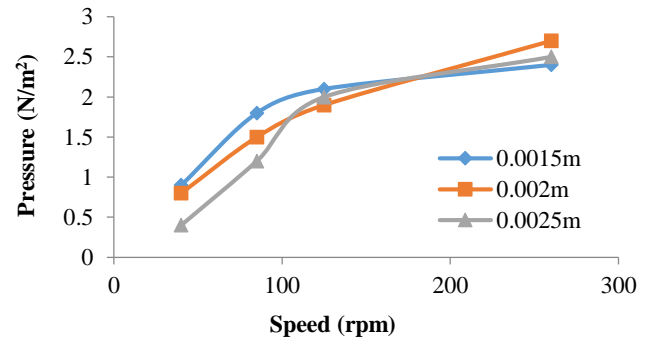


Fig. 12: Pressure curve for 70° inclined slot bearing

Conclusion

Result of effect of slot size and orientation on temperature and pressure values for a journal bearing with dimensions of L/D ratio of 36 mm to 16 mm has shown that bearings with axial slots performed better at depth of 0.002 m for all speed.

References

- [1] Czichos, H. (1978). Tribology series 1: A system approach to science and technology of friction lubrication and wear, Elsevier Scientific publishing company, Amsterdam, Oxford-New York.
- [2] Avraham, H., Bernard, F. and Hanuman, R. (1993). "Modeling and simulation of elastic and friction forces in lubricated bearings for precise motion control. New Jersey institute of Technology, New York, NJ, USA.
- [3] Clevite, C. and Victor, R. (2002). Engineering bearing failure analysis. Dana Corporation. iopscience.iop.org/1742-6596/36
- [4] Bukovnik, S., Nicole, D., Valdas, C., Wilfried, J. B. and Bernhard, L. (2006). Analysis of diverse simulation models for



Amine et al, The Effect of Slot Size and Orientation on Temperature and Pressure for a Journal Bearing with Dimensions of L/D Ratio of 36 mm to 16 mm, TAJET 2(1), August 2021: 7-12.

- combustion engine journal bearings and the influence of oil condition.
- [5] Bushan, B. (1999). Principles and application of tribology .John Willey and Sons Inc., New York.
- [6] Calayag, T.S. (2009). The practicality of using the zinc aluminum alloys for friction-type bearings, Proc. of the 25th Annual Conferences of Metallurgists, pp. 305-313.