Behaviour Analysis of Hydrodynamic Bearing usedin Wire Rod Block Mill

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***Abstract*--Any machinery's ability to produce effectively depends on the bearings that support the journal that transmits power and performs useful work. Knowing about a sliding contact bearing's behaviour and necessary operating conditions is crucial because it lacks a rolling element, which might make it easier for specialists to maintain industrial machinery. This article primarily focuses on the fundamental concepts and criteria for the operating environment, which become crucial when a very thin layer of lubricant of the order of 1000 parts per thousand of the journal diameter is needed. Along with having a basic understanding of sliding contact bearings, it's important to learn more about the components and potential reasons for failure of these kinds of bearings. This study also includes an experiment in which the authors discover that a tiny hole in the journal face along its axis extends the bearing's life by preventing metal-to-metal contact during journal starting and stopping and, as a result, lowers the bearing's operating temperature.**

***Index Terms*--hydrodynamic bearing,sliding contact bearing ,wire rod block mill ,white metal bearing .**

NOMENCLATURE

Z – Absolute viscosity
N – Rotation per minute
p – Working pressure
c – Diametral clearance
d – Bearing diameter
k – Leakage correction factor
μ – Coefficient of viscosity
W – Load on bearing
V – Journal velocity
C – Heat dissipation constant
Tb–Bearing temperature
Ta – Ambient temperature
To – Temperature of oil
VG – Viscosity grade
μ - Micron

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I. INTRODUCTION

FOR being a mechanism a machine it is very important toa mechanism to provide a useful work output in a constraint motion. For this to happen a relative motion between different link is very important. relative motion which of lower pair type that is surface contact bearing is used to carry heavy fluctuation and high speed. Antifriction type bearing is capable of taking load and RPM both but the load capacity and jerks are restricted to its radial clearance level that may be of the order of 150 – 200 μ that also with limited time interval and will create lot of vibration and temperature but a friction type of bearing having no rolling element is capable to accommodate the deflection of shafts of the order of 200 – 250 μ that even with regular usage and is capable of taking shock loads also.

One of the bearings used is of sliding contact type that we called as hydrodynamic bearing where the journal rotates with very small clearance of the order of 1/1000 th of the journal diameter [1]. As the clearance is very small the running conditions becomes very critical which totally depends on the material [2], viscosity of oil, journal RPM etc. As this bearing works with very small radial clearance, it becomes very necessary for us to study its behavior with different condition of this bearing and to find the ways that how can we increase its life span through different processes.

The prime mover movement and accuracy is also of great importance as the load applied to the bearing fluctuates at high RPM the oil pressure also gets fluctuates while fluctuating when oil reaches at lower pressure which is lower than atmospheric pressure it starts to getting boiled and produces bubble [2], the bubbles again travel from a low-pressure zone to high pressure zone and from high pressure zone to low pressure zone while travelling with such variation at high pressure zone it gets collapsed and produces high pressure this high pressure sometimes erodes the material and cavitation forms. Impact pressure from such collapse can degrade the bearing material. Cavitation erosion is more likely to occur on tri-metal bearings with soft lead-based overlays. Therefore, cavitation-related failures can be avoided by replacing tri-metal bearings with

babbitt overlay with bi-metal bearings or high-strength tri-metal bearings .

Hydrodynamic bearing is a mechanical element used to bear high load it also has good damping properties which makes it suitable for the applications where a high rpm as well as load is needed. A mechanical component that can handle heavy loads due to the wedge-shaped geometry created during the relative motion between the journal and bearing surface is known as a hydrodynamic journal bearing. Due to its great load carrying capacity and effective dampening characteristics, hydrodynamic journal bearing is frequently employed. The primary issue with hydrodynamic bearing is fluid film failure when it is in use. The journal and bearing surface may come into contact with one another on account of this. Higher loads on the bearing cause a reduction in film thickness and a rise in bearing temperature as a result of the fluid film's rising temperature. Both load capacity estimations (static performance) and dynamic analysis rely on the pressure distribution [4]-[5]. Overheating of the surfaces is caused by wear and friction caused by this. Thus the power misfortune increments. A hydrodynamic journal bearing's performance characteristics were predicted using the FSI method in this study. Pressure distribution along the journal surface has been predicted using three-dimensional studies [6].

The starting and end torque produced in the bearing is a main problem rise due to the non-availability of proper and rich hydrodynamic layer of lubricant. To reduce this problem through an experiment [3] we find that a journal with a fine hole of about 1mm in diameter is capable of sucking the oil of proper viscosity and produces a thin layer of oil in the starting and end position so that the torque carrying capacity and temperature distribution in the bearing gets enhanced ultimately the life of the bearing which is totally beneficial for any industries.

The painful parameter of the running condition of this bearing is temperature and vibration which becomes very severe when deviate from the basic running parameter that is radial clearance, basic running requirement, bearing material, bearing housing condition, bearing press application, way of heat dissipation, viscosity of lubricant oil, journal condition, lubricant contamination etc. Here in the study, we tried to study this bearing by studying several journals and articles from different sources that how could we increase its life span so that our industry can take maximum advantage of their expenditure and to save and increase the overall effectiveness.

For the study of this bearing, we used different parameter like temperature, vibrations, the temperature pick up point is about 50mm from the bearing assembly point while the vibration pick up point is about 120mm from the bearing point. resistance temperature detector (RTD) and vibration meter (VB -8205) is used for a month and readings are noted for its study. these readings will help us to understand the behavior of bearing under different temperature of oil we used here VACUOLINE 525 (VG 100) i.e 100 cst at 40°C the film of the oil is said to be in 60°C to maintain a continuous flow and proper thickness inside clearance.

The bearing's minimum oil film thickness and critical thickness for proper operation are the issues this type of bearing faces. The strain at which the oil film separates so metal to metal contact starts, is known as basic tension or the base working strain of the bearing. In light of the fact that focusing on the bearing material and its various properties is crucial to the production of plain bearings, the authors will also endeavor to acquire knowledge of the bearing material and its various properties for improved bearing performance.

Fig. 1. Hydrodynamic bearing

II. METHODOLOGY

In steel plants where wire rods of different cross sections are to be manufactured, usually a high-speed machinery called wire rod block mill is employed wherein tension to the ongoing wire to reduce its cross section and to produce it in mass amount are provided. Depending upon speed requirement and machine manufacturer, these machines can be worked at the speed of 100 m/s. Here in this present paper, the authors consider machine speed of 57 m/s and radial clearance 0.2 mm Fig.2. The lubricant used in the above machine is of viscosity grade 100 and maintained between the temperatures of 30°c to 35°c . Different measurement devices are used to take temperature and vibration readings later on using those data and time frequency a graph plot has been created which is found important to study their behavior . there are some standards given by the manufacturer which works as an refrence.

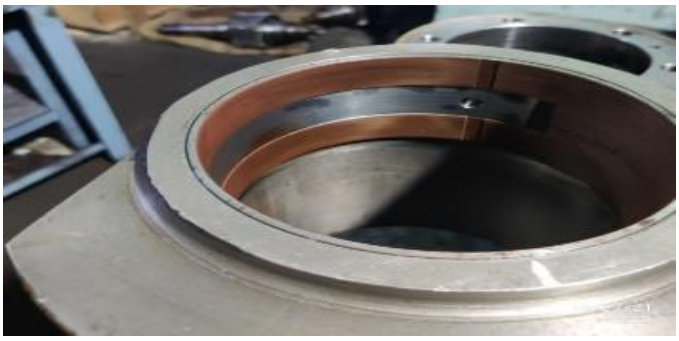

Fig. 2.Hydrodynamic bearing in Wire rod block mill

III. DATA COLLECTION

Data collection is a vital method to complete research where its behaviour can be seen and a conclusion can be drawn about how a bearing behaves with the variation of other parameter such as temperature and vibration. Readings of temperature through a resistance temperature detector (RTD) are recorded where the pickup point is 50 mm far from the bearing and different vibration readings in mm/s. A vibration meter (VB – 820 5) is used for every day reading and found that the readings are varying from 1 mm/s to 3 mm/s and temperature varies from 40 °C to 60 °C.

The effect of hole on a journal of journal bearing arrangement is observed. When a journal with a hole of 1mm and a journal without hole are compared, the performance of the journal with hole is observed to be better in terms of a temperature rise, load capacity, pressure distribution, wear and tear etc. An oil source of SAE 30 is used to lubricate the bearing and found that when shaft starts to rotate say in 600 rpm it starts to suck the oil present behind it due to centrifugal force and enhances the property and life of journal bearing due to the hole present in it. The hole present in it provides a good thick oil film which reduces the metal-to-metal contact in starting and at the end of the process due to the formation of oil film wedge action.

The authors continuously recorded the running data of the bearings like temperature of the bearing vibration of the bearing and change in viscosity of the bearing . For collecting such impotant data several equipment were used like PLC controlled temperature screen and vibration pick up device . Along with the data collection a experiment is also done on the bearing and where we simply made a small hole beside the journal of say 1mm from where we continuously feeded the lubricating oil . Here we found that a centrifuge action is happening inside the journal bearing as a result of which the wear level and running temperature gets reduced in very good extent which is a very good result . A lower wear and running temperature will lead to a better bearing life as lower temperature will lead to lower frictional loss and lower torque generation by the journal rotation .

IV. DISCUSSION

The authors use manual visage viscosity meter which shows the viscosity of oil in centistokes at 40 °C where the scale range is 5 centistokes to 460 centistoke at 40 °C. The oil used is having standard viscosity grade of 100 centistoke at 40 °C; the observations gives the value of viscosity of oil at different elevated temperature. Overall, the film does not break until the oil temperature reaches 60 °C, so maintained the oil temperature at 30 – 35 °C.

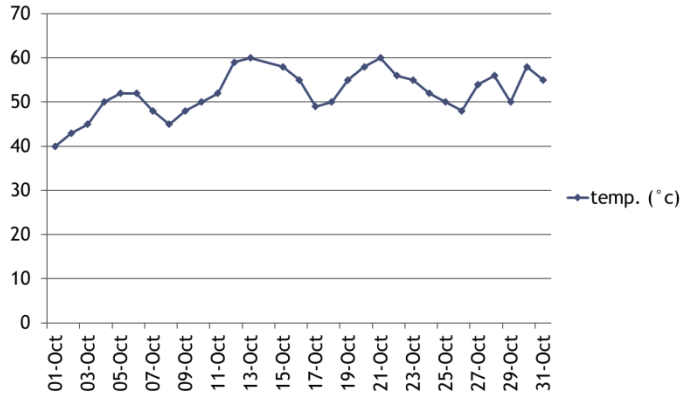

Fig. 3.Temperature variation over a month period

During the analysis of this bearing, bearing of dimensions were 124 mm in inner diameter and 130 mm in outer diameter with the diametral clearance of 0.3 mm that is 300 µ in the set up. The speed of the said journal was about 6000 rpm which was developed by a prime mover of 1800 kw. The pick-up point temperature reading was about 40 - 50 mm from the bearing surface. The lubricant used here was of VG 89 and the flow was about 110 lpm. The temperature of the applications was measured quickly and accurately using a resistance temperature detector (RTD). These devices can be constructed using various material such as platinum, nickel, copper, nickel – iron. There were totally 24 bearings used in that machine running at a time but for the experimental purpose we focused on only one bearing and found different temperature readings in the entire month. The variation from 40°C to 60°C was recorded through a digital display (PLC controlled). The maximum limit set by the manufacturer is 85°C beyond which the machine will get shut down. Proper and continuous watch on the bearing is necessary to avert failure of the system.

During this entire process, the temperature of the lubricant was maintained at about 32 to 35°C through a plate type heat exchanger and the media used to cool the lubricant oil is water which is then supplied to direct contact type cooling tower where it's temperature gets reduced by force draught operation done by 96" draught fan made up of alluminium alloy and also some timesfibre reinforced plastic .

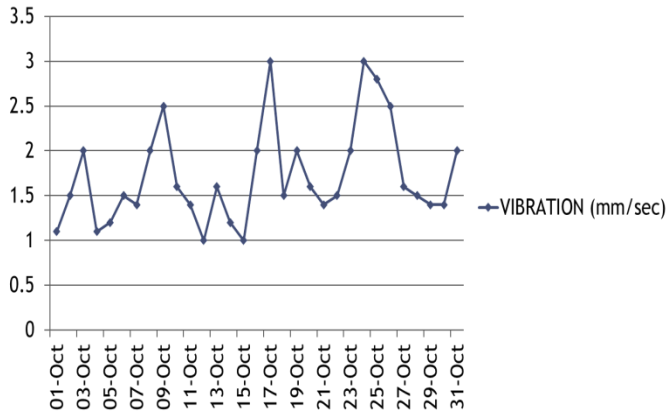

Fig. 4. Variation of vibration over a month period

The vibration readings of the same bearing were noted. The pick-up point was about 120 mm from the bearing surface. the machine under observation can discharge materials at the rate of 55 mps. It is obvious that the bearing will show the higher values of vibration and temperature readings in the load condition in comparison to the machine in unload condition. The sensory device used here was VIBRATION METER VB-8205 and as per the original manufacturer's norms, acceptable range of vibration reading is 1 – 4 mm/ s in the load condition. The readings noted in the entire month varies from 1 mm/s to 3 mm/s; but the readings above 3 mm/s are point of concern and to reduce such vibration a proper maintenance is required in regular interval.

The authors use vibration meter model naming VB – 8205 to check the vibration of the plain bearing on daily basis for a month and found that the vibration readings varies from 1.2 mm/s to 3 mm/s. Generally, it is considered the vibration range below 1 mm/s as safe readings .

Fig. 5.PLC showing running temperature data .

A PLC operated temperature showing display continuously works for condition-based monitoring of the machine. OEM has provided some standards for running temperature like 60°C is acceptable limit of bearing temperature. The machine gets tripped when the temperature of the bearing crosses 75°C. there are total 24 bearing readings which are continuously shown in this display in regular sequence. As there are total 24 number of bearings running at a time, so it becomes very necessary for the user to identify the bearing which is showing more temperature. The above said work can be easily done using this channel as it totally contains 24 channels i.e., 4 bearing in each stand.

The set of equations:

Coefficient of friction (μ) = $\frac{33}{10^8}(\frac{ZN}{p})(\frac{d}{c})$ + k

Heat generated (Q_g) = μ.W.V(N-m/s or J/s or watts)

Heat dissipated (Q_d) = C.A (tb – ta) (J/s or W)

Heat transmitted (Q_t) = Q_t = m.S.t (J/s or watts)

Amount of artificial cooling required =

Heat generated – Heat dissipated = Qg – Qd

V. CONCLUSION

Based on the above experiments with vibration meter or viscosity meter it can be concluded that with the viscosity of oil the changes with temperature and this gives different vibration readings. the oil used here is of viscosity grade VG 100 and the minimum oil film thickness, that is MOFT, is considered to 4^{th} part of diametral clearance in the running condition and usually industrieswhere this type of bearing is used, maintain radial clearance of 25 micron per cm of journal diameter.

This is additionally be inferred that the disappointment of bearing materials not just relies upon the bearing materials, their legitimate determination it is enormously impacted by the functioning states of the heading. In this study, the most common reasons engine bearings fail and how to fix them are discussed. When selecting a bearing material, careful consideration must be given to balancing the bearings' properties with those of the application for which they are intended.

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VII. REFERENCES

[1] P.Tiwari and V. Kumar (2012, September), Analysis of Hydrodynamic Journal Bearing: A Review, ISSN: 2278-0181, Vol. 1 Issue 7, pp. 07.
[2] S. B. Chikalthankar, V. M. Nandedkar, P. V. Jawale (2014, February), Comparative Study of Bearing Materials and Failure of Plain Bearings, ISSN: 2278-0181, Vol. 3 Issue 2, pp.01 – 05.
[3] H.Patidar, Prof. D.K.Pasi (2016, April), Experimental Investigation of Effect of Holes on Journal Surface on Bearing Performance, ISSN: 2278-0181, Vol. 5 Issue 04, pp. 01– 05.
[4] M. nigade, Dr. s.b, zope, experimental analysis of hydrodynamic journal bearing, ISSN: 2278-0181, Conference Proceedings, NTASU - 2020, pp. 01– 03.

[5] A. K. Meybodi, A. Assempourand and S. Farahani (2011), A general methodology for bearing design in non-symmetric T-shaped sections in extrusion process, Journal of Materials Processing Technology,vol.212: pp.249 - 261.
[6] A. Z. Szeri (2010), Composite-film hydrodynamic bearings, International Journal of Engineering Science,vol.48,pp.1622-1632.

VIII. BIOGRAPHIES

ChandanChattoraj received his degrees, viz. B.E., M.Tech. andPh.D from Regional Engineering College Durgapur (National Institute of Technology Durgapur), West Bengal, India in the domain of Mechanical Engineering. He was awarded with University Gold Medal.

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Amit kumar was born in tatanager city in Jharkhand on 16 jan1994 . He did his masters from Dr. Bidhan Chandra Roy college of engineering and graduated from Netaji Subhas Institute Of Technology , Patna Bihar in mechanical engineering.

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Mr. kumar has presented his research work in Forum Of Scientists Engineers And Technology (FOSET) and gets recognized there also . Along with this he also shows his intrest to attend the related workshops and seminars frequently. Along with application and running condition he is equally focused on erection and commissioning works in different steel plants .