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Experimental Investigations on Interaction Effect of Lubrication and Vibration in Bearings

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ABSTRACT

Bearings are amongst the frequently used components to be found in rotating machinery. Though inexpensive, their failure can interrupt the production in a plant causing unscheduled downtime and production losses. Many works are found in literature for bearings running under grease lubrication. There is no much importance given for bearings with liquid lubricants. This work intends to illustrate vibration behavior of roller bearings as a function of lubricant viscosity. Experimental tests were conducted in roller bearings, lubricated with mineral oil of three different viscosity grades (ISO 10, 32 and 68) under different loads and shaft speeds. The rms of vibration is determined through the processing and analysis of bearing radial vibration data. This is obtained for each of the conditions, during one hour test run for temperature stabilization. From root mean square (RMS) analysis of the vibration signals, it is identified that specific RMS change caused by the change in lubricant viscosity, which was related to change in oil film thickness. This study predicts that a ball bearing running with oil lubrication shows a better performance with high viscosity oil which reduces the average vibration level as well as increases in minimum oil flim thickness.

Keywords: Lubrication, Roller bearing, Vibration, Viscosity

1. INTRODUCTION

Bearings are one of the most widely used rotating machine element. In case of any problem behind it, it affects the overall performance of the machine. So it is necessary to keep the bearing cleanliness, adequate lubricant supply and selecting proper lubricant. Major works has been done for the detection of localized defects in bearings. But the lubrication induced bearing faults are very less. Around 50 - 80 % of bearing failure is due to (i) inadequate lubricant supply, (b) lack or excess of lubricant supply, (c) lubricant aging, (d) presence of solid or liquid contaminants in the lubricant. So it is necessary to correlate the bearing vibration with the lubrication. For adequate lubrication condition, the RMS value of vibration is less and vice versa. Not only the lubrication but also the following factors are also be considered. 1. Oil temperature 2. Bearing speed 3. Oil viscosity 4. External loading's.

The lubrication in a bearing occurs in three different regimes. They are full flim, mixed flim and boundary lubrication. The full flim lubrication is divided into elasto hydrodynamic lubrication and hydrodynamic lubrication. The prior one occurs at non conformal contacts at high pressure and later occurs at conformal contacts at low pressure. Measuring vibration of bearing leads to predict the failure of the bearings. The following journals have been studied to understand the behavior of vibration of bearings running with lubricants.

N. Tandon 1 investigates the effectiveness of vibration, stator current, acoustic emission and shock pulse measurements for detecting the existence of contaminants in grease (Silica and Ferric oxide particles). The vibration stator current, acoustic emission and shock pulse values are increasing when the particle size and level increasing. J.K. Halme 2 focuses on wear debris analysis and vibration measurements to monitor the running state of ball bearing. The test shows that changes in the bearing and lubrication can be monitored using various methods which can be used for monitoring a bearing condition at various stages of its service life. According to Maru 3 , the effect of lubricant contamination by solid particles and to determine the amount of vibration affected by contamination in the oil. The result shows that RMS values of the vibration changes at high frequency band with respect to changes in the oil lubricated roller bearings. Description of the vibration monitoring and analyzing techniques for finding defects in the anti friction bearings are from Kandagal 4 . The techniques such as time domain, frequency domain and spike energy analysis have been conducted to find the defects in the bearings.

The different vibration signals helps to identify the inner, outer race defects and roller defects in the bearings. Dowson equation [5], [7] have been used for finding the lubricant oil flim thickness between inner race and the ball of the bearing. Similarly the flim thickness between outer race and ball of the bearing has been calculated.

The present work intends to illustrate the effect of lubrication in a ball bearing vibration as a function of lubricant viscosity under different shaft speeds and different loading conditions. Also this paper intends to correlate the vibration and lubrication of the bearings.

2. METHODOLOGY

The test bearing is SKF 6206 ball bearing. The bearing is lubricated with mineral oil without additive of three different viscosities namely ISO 10, ISO 32, ISO 68 to obtain the vibration characteristics and different lubricant regimes of the bearings. The ball bearing is vertically loaded and is immersed partially in the oil container. The test bearing is placed at center of the two supported bearings. The load is applied on the bearing using spring balance attachment with the experimental setup. One hour test run has been employed to stabilize the lubricant oil properties.

An arrangement with the belt drive drives the power from the motor to the bearing shaft. The shaft speed can be adjusted with the help of v pulley arrangement. While conducting the tests, various input parameters such as speed, load and the viscosity of the lubricant oil has been varied and the results are summarized. An accelerometer is fixed on the test bearing to measure the radial vibration data of the bearing. The RMS value is amplified and filtered with low band pass filter at 10 kHz frequency. Then the signal is acquired using Data acquisition system with the sampling rate of 10 kHz. Each signal is having 10, 000 data with the time period of 15 seconds run time. Thus the acceleration RMS value of the bearing has been acquired.

To ensure the changes in bearing vibration as a function of oil viscosity, RMS value has been measured for each 10 mins. The experiments are conducted for three radial load 50 kg, 80 kg and 120 kg as 500 N, 800 N and 1200 N with the shaft speed of 10 Hz. Then the procedure has been repeated for three oil viscosities and 18 Hz and 30 Hz shaft speeds. At this moment, the viscosity of the oil has been kept constant. Then these experiments were conducted for every lubrication condition just by changing the oil in the container. Then these tests are conducted for several times to check their repeatability of results.

3. RESULTS AND DISCUSSION

RMS vibration level of the bearing can be influenced by the following factors.

1. The load acting on the bearing,
2. Speed of the bearing and
3. The lubricating oil viscosity which is employed to minimize the level of vibration.

3.1 Causes of Shaft Speed

As the speed increases, the vibration amplitude also increases. As the speed decreases, the vibration level also decreases. This factor is having direct relation with the vibration level of the bearing.

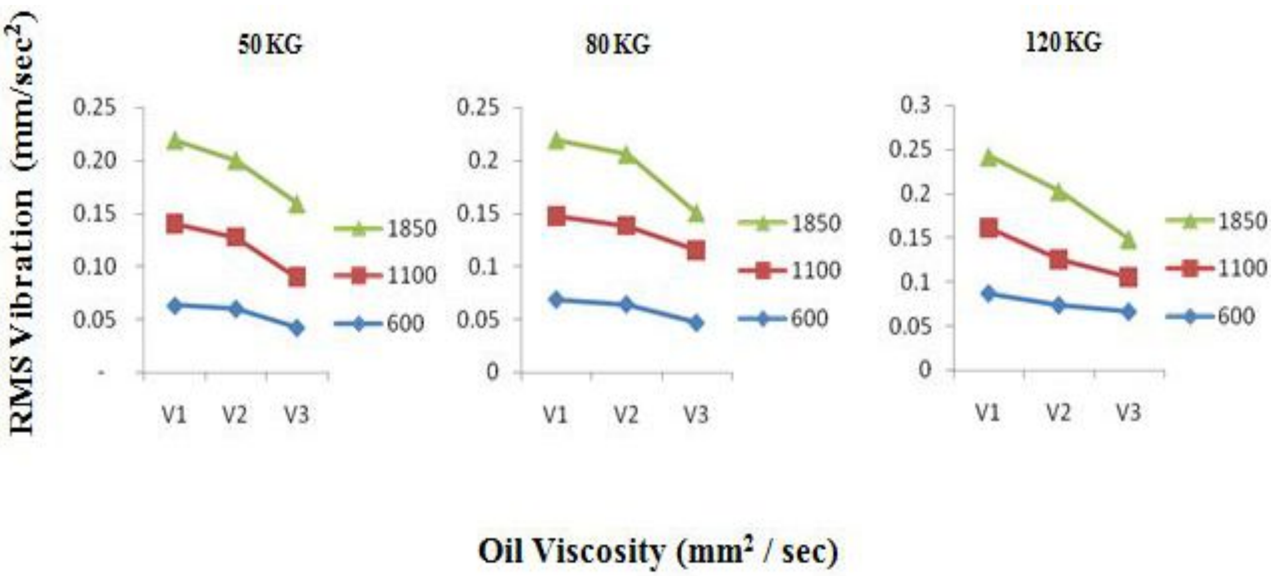

Figure 1 Effect of Shaft speed

3.2 Causes of Load Acting on the Bearing

The load acting on the bearing is increased regularly. The load acting on the bearing is 490 N, 780 N, and 1200N respectively which are the maximum of (10 %) of dynamic load carrying capacity of the bearing.

When the load acting on the bearing increases, consequently the RMS level also increases. When the load on the bearing decreases, the RMS level also decreases. This factor is also having direct relation with the vibration level of the bearing.

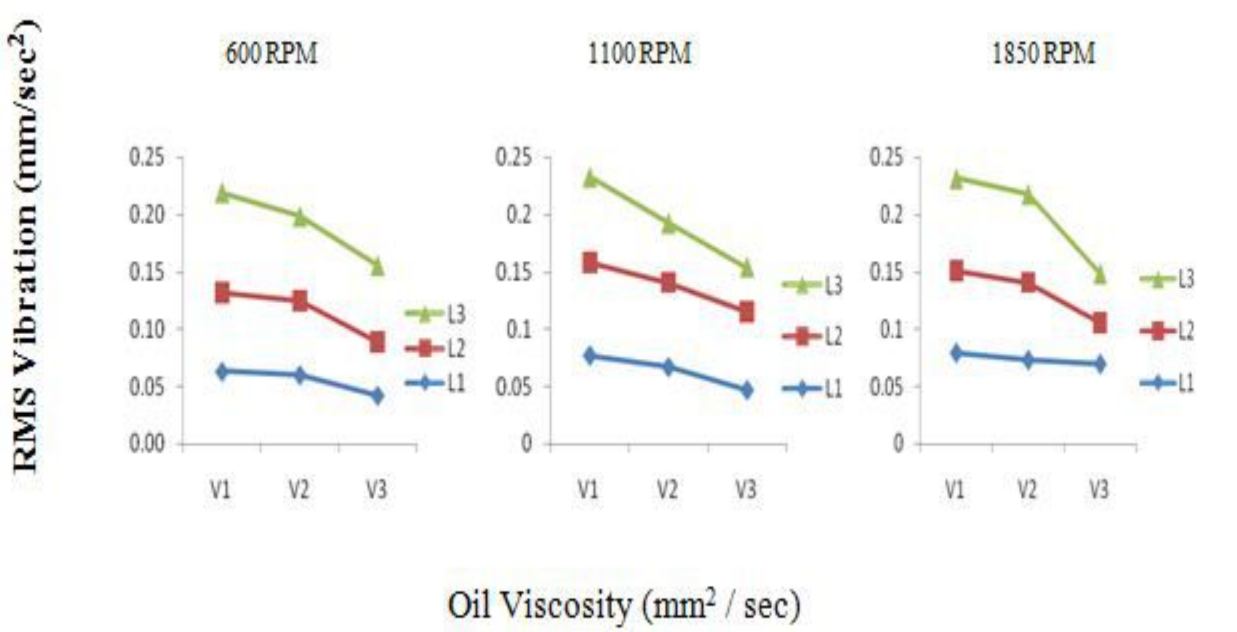

Figure 3 Effect of Load acting on the bearing

3.3 Causes of Lubricant Viscosity

The vibration amplitude can be reduced when the viscosity of lubricant oil increases. At this region, the asperity contacts will be minimized. Also the lubricant absorbs the vibration level of the bearing to some extent. At lower viscosity grade oils, there may be possibility of occurring asperity contacts which increases the vibration level.

From the above result, it is confined that the RMS value can be minimized by operating the bearing at higher viscosity grade levels. Due to this action, the life of the bearing seems to be extended.

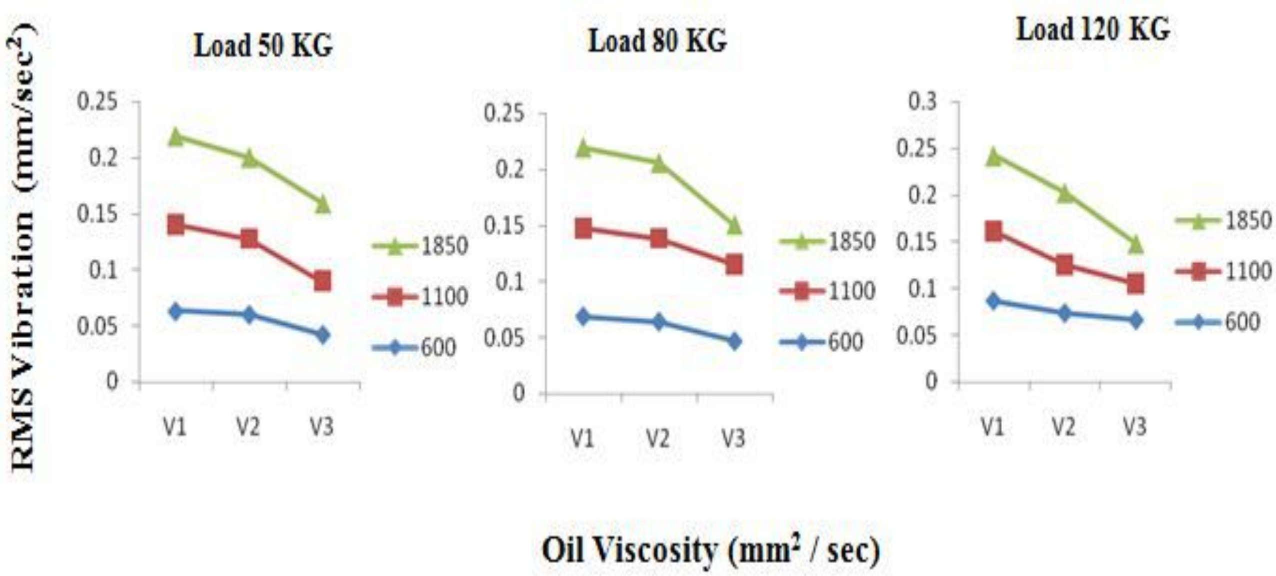

Figure 4 Effect of Lubricant Viscosity

3.4 Analysis of Minimum Oil Flim Thickness

The above obtained differences in RMS value is due to the variation of oil viscosity. Then the minimum oil flim thickness is compared with the viscosity on the oil at every lubricating condition. The following figure shows the variation of minimum oil flim thickness as a function of several loading and shaft speeds. The oil flim thickness between inner, outer and the ball are shown to correlate the vibration behavior of the bearing. The minimum oil flim thickness at each and every lubrication condition can be calculated using Dowson equation [5].

A periodic increase in the oil flim thickness can be obtained over the variation of several shaft speed and loads. Moreover, it will be confined that the flim thickness can be small when the viscosity grade of the oil is very less. The flim thickness drop shows that the direct metallic surface contact occurs between the mating parts so the RMS vibration is large. When the flim thickness and the viscosity of the lubricant is small, consequently the vibration level is higher than ever.

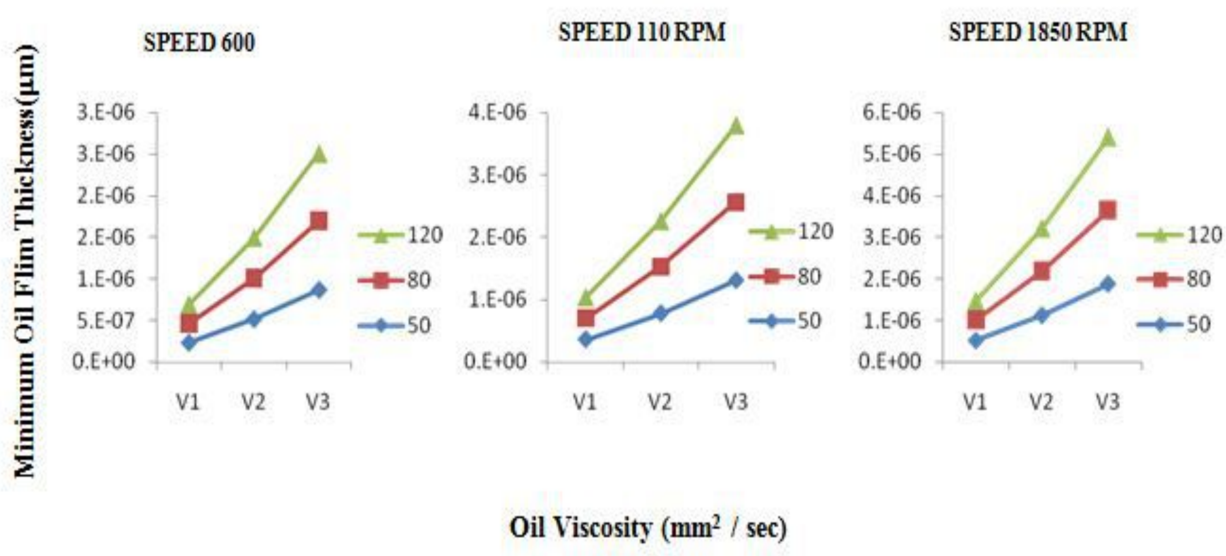

Figure 5 Effect on Minimum Oil Flim Thickness

3.5 Analysis of Lubrication Factor ( )

The obtained RMS value can be correlated with the mode of lubricant regime occurring in each kind of lubrication condition. The bearing lubrication regime will be calculated with the help of lubrication factor ( ). The following formula gives the relation between the lubrication factor ( ) and minimum oil flim thickness (h_{min}) values.

$$\lambda = \frac{h_{\min}}{\sqrt{R_{q1}^2 + R_{q2}^2}}, \quad (1)$$

R_{q1}, R_{q2} are the surface roughness values of two mating parts.

When 1 means the lubrication regime is boundary between the two mating parts. When 3 means the lubrication regime is full flim or elasto hydro dynamic between them. When 1 3 means the lubrication regime is mixed flim or partial elasto hydro dynamic lubrication regime between the two mating parts.

From the readings, it is confined that when speed and load increases the values of minimum oil flim thickness increases correspondingly the lubrication factor also increases. When the viscosity grade is small (i.e. ISO 10), the minimum oil flim thickness and lubrication factor is also small and the lubrication will be boundary lubrication 50 kg, 80 kg and 120 kg for 600 RPM and it will be partial or mixed flim lubrication when the load and speed of the bearing increases.

When the viscosity grade increases (i.e. ISO 32), the flim thickness and lubrication factor also increases up to some conditions leads to mixed or partial flim lubrication regime occurs than full flim lubrication.

When the viscosity grade is very high (i.e. ISO 68), the flim thickness and lubrication factor also increases and the lubrication regime occurs only as full flim lubrication condition. This is also known as Elasto hydrodynamic lubrication condition.

From the above results, it is clear that when lubricant viscosity is high correspondingly the oil flim thickness and the lubrication regime are also high. So that it is possible to reduce the direct asperity contact between two mating parts which establishes full flim lubrication condition .

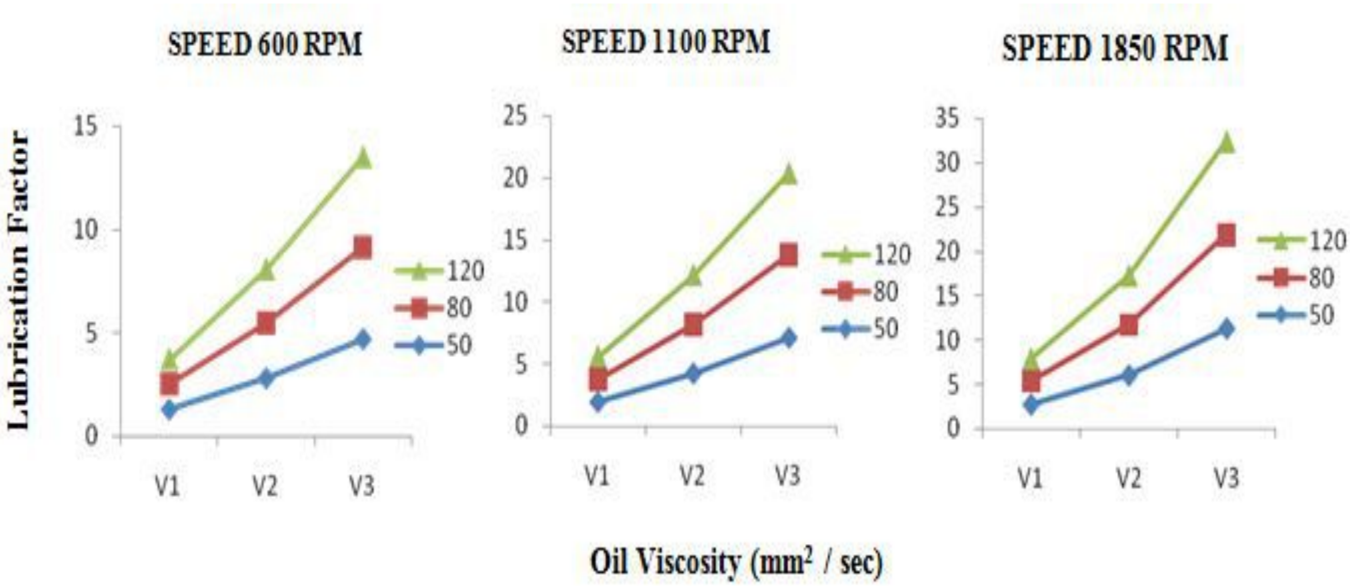

Figure 6 Effect on Lubrication Factor

4. CONCLUSIONS

The ball bearing was tested under different shaft speed and different loading conditions to understand the vibration characteristics under several oil grades. The RMS response of the bearing was enumerated as a function of lubricant viscosity. The minimum oil flim thickness and the lubrication factor give the type lubrication regime of the bearing.

From the above results, it concludes by as follows.

i. The RMS response of the bearing increases as the speed and load acting on the bearing increases and vice versa.
ii. The RMS level decreases when the viscosity of the lubricating oil decreases and vice versa.
iii. When the viscosity of the lubricating oil decreases, the minimum oil flim thickness between the inner, outer race and the ball decreases where it is possible to occur boundary lubrication regime.
iv. When the viscosity of the lubricating oil increases, the minimum oil flim thickness between inner, outer and ball increases where partial or full flim lubrication occurs with respect to the lubrication factor value.

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