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ANALYSIS AND OPTIMISATION OF LUBRICATION VISCOSITY ON THE BEARING OPERATIONS

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Abstract

One of the most important parts in an industrial machine is the bearings, as it supports the rotating shafts at required places while taking up its load. This eventually leads to friction and generates heat. Lubrication helps the performance of the bearing by reducing friction between the surfaces and removing heat. This paper investigates the effects of lubrication viscosity as an important part in the operating parameters of the bearings towards the heat generated and the vibration of bearing. The bearing which is located inside the spindle will be tested with the VG 32 and 46 lubrications at varying speeds and feed rates. The data collected by experiment, is replicated with the same type of bearing in the same spindle configuration but with different lubrication viscosities. The heat generated in correlation to the speed attained and the vibration will be measured and recorded to ensure optimal operation and to extend bearing life cycle. The outcome of the work found that the operating speed of the spindle has direct relation with the enveloped vibration of the bearing as it produces more load on the rotation of the bearing and the temperature. All the analysis proved that VG 32 lubrication produces lesser enveloped friction and operating temperature compared to VG 46 lubrication.

Keywords: Bearing, Lubrication, Speed, Vibration, Viscosity.

1. Introduction

This paper investigates the effects of lubrication viscosity in the operating parameters of bearings. It determines the heat generated and enveloped vibration level of the bearings. The lower the heat, the higher the lift cycle of the bearing [1]. When the vibration of the bearing is prominent it can't be used in precision equipment as small deviations can cause significant manufacturing defects which leads to the product being scrapped and the decrease in the quality of the manufactured product. When the viscosity is not within the specified viscosity range, the lubrication requirements will not be met, resulting in increased friction, wear and localized heat formations which reduces the life cycle of the bearing [2].

The experiment will be based on the effect of viscosity on the bearing performance determined by analysing the temperature profile of the bearings, measuring the enveloped vibrations caused by the bearings whilst concurrently increasing the operating speed. The experiment will also analyse the variations between the theoretical and experimental values of the bearings in operation. Since it is a non-destructive experimental design, the spindle would not be operated to the rated maximum speed, but instead the vibration at this speed will be estimated using a software simulations data.

This experimental investigation will also determine the effects of using the oil at a different viscosity either higher or lower than the recommended oil viscosity by the original equipment manufacturer (OEM) on the operating parameters of the bearing in terms of temperature and the enveloped vibration of the bearing. It will be determined by analysing the temperature profile of the bearings and measuring the enveloped vibrations caused by the bearings at different spindle speeds. We will also compare the variation in viscosity by calculating the frictional coefficient through a theoretical framework analysis.

2. Literature Review

2.1. Bearing performance parameters

The major factor that affects bearing performance is the rotating speed of the spindle or the machine it is installed in. As the dynamic loading and heat generation increases with the increasing speed it often leads to higher friction that declines bearing performance [3]. On the contrary, bearing performance parameters such as vibration and operating temperature effect the bearing's life cycle [4]. Both parameters must be kept at minimum to ensure that the bearing has a higher life cycle.

Vibration is the response to a dynamic force load. It is a fact that the increase in force will deteriorate the life cycle of bearings. An increase in vibration will result in an increase in excessive forces on the bearings. The radial vibration is affected by the structural failure [5]. With regards to our experiment, the usage of lubrication with an optimum viscosity tailored to the bearing can reduce this excessive force and elevate the bearing's life cycle [2]. As shown in Table 1, we can increase up it to 700 % if we manage to reduce the vibration to 50 %.

Vibration acceleration and enveloped acceleration differ from each other. Vibration acceleration is the overall vibration of the machine that can be measured in terms of displacement, velocity, or acceleration. It can be caused by the looseness, imbalance, and the misalignment of the spindle itself. Vibration acceleration is measured in mm/sec or root means square. Enveloped vibration is the effect of a certain vibration at a high frequency range. Defects in developing stages normally produce high frequency signals. Enveloped acceleration is better suited to problems like the bearing's initial stages of failure. Enveloped vibration is measured in the gE term. For a bearing to reach their calculated lifetime, the temperature conditions in the bearing must be maintained, to not exceed the operating temperature of the bearing. If the temperature differential between inner and outer bearing rings becomes too great, it will result in flaking.

In the experiment the suitable bearing lubrication will create a layer of film between the outer ring, the ball, and the inner ring [6]. This will eventually reduce contact friction and cause a reduction in the thermal effect produced by it [7]. Friction causes loss of power. An optimum bearing viscosity will ensure that a sufficient film of oil is deposited to reduce the friction between the metal-to-metal contact and therein reduce the overall power loss due to it [8].

Table 1. Impact of vibration reduction.

IMPACT OF VIBRATION REDUCTION ON BEARING LIFE (Assuming dynamic load is the major force component)		
% Reduction in vibration	% Increase in Bearing Life	
	Ball bearing	Other Rolling Element Bearing
5	17	19
10	37	42
15	63	72
20	95	110
25	137	161
30	192	228
40	363	449
50	700	908

3.Proposed Methodology

The performance of the bearings is affected by various factors such as the air pressure inside the spindle or machinery, the operating temperature of the machine and even the design of the spindle/machine itself. As these conditions are difficult to replicate in a laboratory situation, the bearing type and spindle will be kept constant throughout the experiment. It will be based on the effect of the viscosity on the bearing performance that will determined by analysing the temperature profiles of the bearings, measuring enveloped vibrations caused by the bearings with varying operating speeds.

For this, the temperatures and enveloped vibrations of the bearings will be recorded in correlation with spindle operating speed. The process is represented in Fig. 1 below. The spindle selected for the experiment was Mazak Nexus 210N with maximum operating speed of 12,000 rpm with 16HP.The recommended bearing for the spindle is NSK 70BNR10STY.The lubricant recommended for this operating speed and for the bearings is the Castrol VG 32. The lubrications used for experiment are Castrol Hyspin VG32 and VG46.

Petroff was first to explain the phenomenon of bearing friction. He assumed that the shaft is concentric with its bushing. Even though we seldom to make use of Petroff's method of analysis, it serves as an important equation as it defines groups of dimensionless parameters [9]. Even when the shaft is not concentric the coefficient of friction predicted by this law turns out to be reliable.

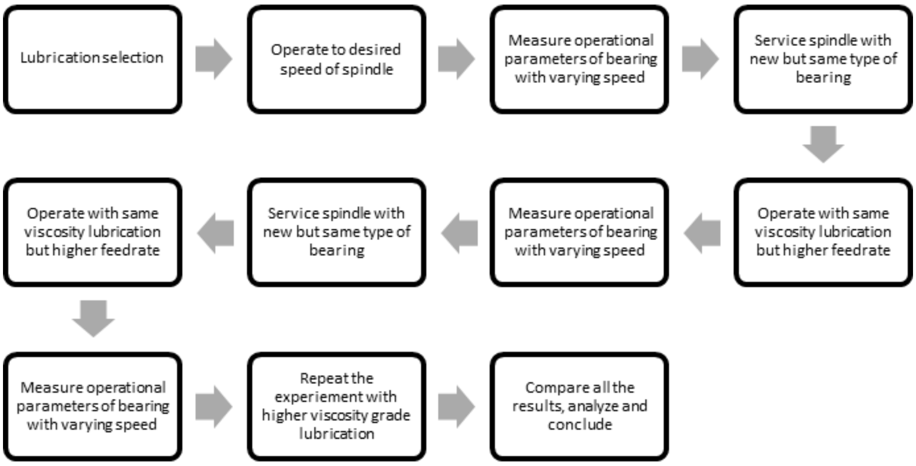

Fig. 1. Experiment process flow.

4. Results and Analysis

The results are categorized and analysed. The relationship between bearing temperatures and spindle speeds are examined in Figs. 2 and 3 below. Meanwhile, the relationship between enveloped vibrations and spindle speeds are characterized by Figs. 4 and 5 below. Both figures correlate the impact of the different lubrication on the parameters operating characteristics based on the front and rear end of the spindle shaft.

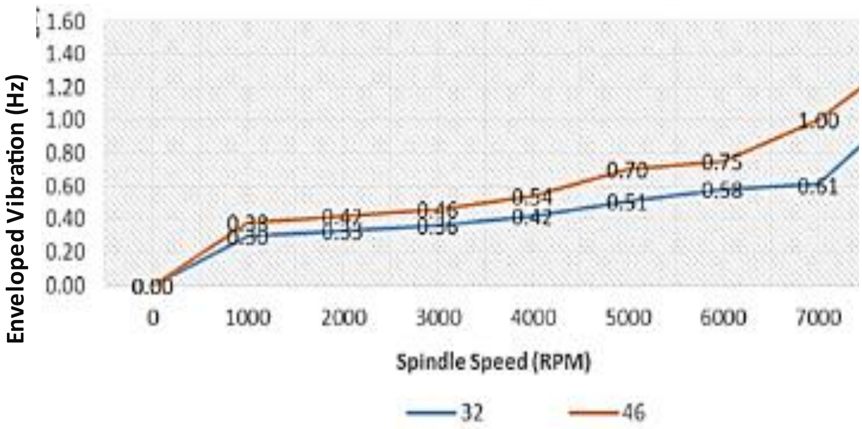

Fig. 2. Enveloped vibration to the spindle speed (front).

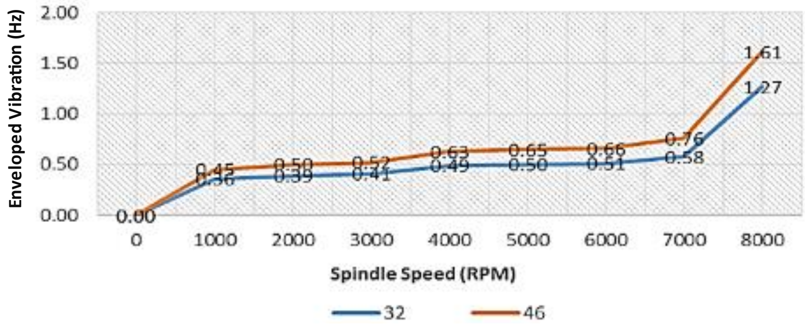

Fig. 3. Enveloped vibration to the spindle speed (rear).

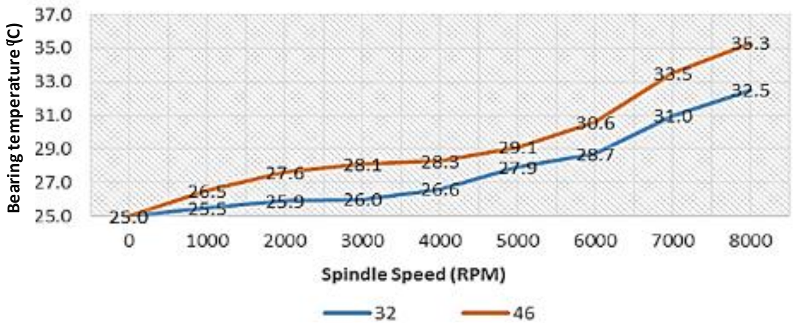

Fig. 4. Bearing temperature to spindle speed (front).

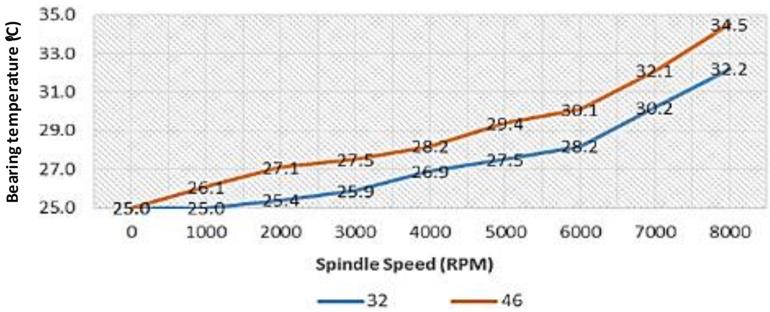

Fig. 5. Bearing temperature to spindle speed (rear).

The operating speed of the spindle has a direct relation with the enveloped vibrations of the bearing as it produces more load on the rotation of the bearings. All the analysis illustrates that the VG 32 lubrication produces lesser enveloped friction and a lower operating temperature compared to VG 46 lubrication. At lower feed rates, insufficient lubrication causes the bearing to have a dry run. Insufficient lubrication also causes the bearing to have an inconsistent lubrication layer between the moving surfaces of the bearing. At higher feed rates, an excessive amount of lubrication does not only result in a disproportionate lubrication layer between moving surfaces of the bearing, but it also causes high strain on the bearing. The friction between the bearing and the lubrication is due to the restrictive nature of lubricant free flow due to the overly viscous layer which causes an incomplete dispersion where not all the moving parts have a layer of lubrication between them to suppress friction. As a result of the high viscosity of the VG 46, high drag and high friction are witnessed. It creates a higher enveloped acceleration and operates at a higher operating temperature compared to VG 32. It is also proven theoretically that VG 46 has a higher coefficient of friction compared to VG 32 lubrication using Petroff's equation, thereby validating the experimental results.

5. Limitation

The limitation that has been recorded during this project implementation was the limited range of lubricant material used. To overcome this issue, several different lubricants of different material base could be chosen, and the experiment could be replicated. The usage of a thermal camera to generate thermal contours and profiles would engender more accurate results and could be an avenue for future work.

6. Conclusion

As conclusion, the bearings must be supplied with optimum oil viscosity as recommended by the manufacturer. As calculated the recommended viscosity provides a 30 percent reduction in overall friction. We can also conclude that a higher viscosity lubrication will results in a higher enveloped vibration and operating temperature. Moreover, it is imperative that the lubrication feed rate must be optimal so that it does not affect the operating parameters of the bearings. Observing the results obtained, we can achieve a 7 percent reduction in enveloped vibration. The enveloped vibration and operating temperature need to adhere strictly to the operating conditions of the bearing as prescribed by the machine manufacturer. Any deviations will reduce the life cycle of the bearings resulting in repair and service of the machinery which will be cost prohibitive. The objective of the paper was achieved as it is proven that usage of the optimum viscosity will result in the optimum operating parameters of bearing whilst increasing it lifecycle.

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