Studies for Friction and Temperature Parameters in Thrust Ball Bearing Lubricated with Grease Containing MoS_2 Particles

V. Bhardwaj, V. K. Agarwal, R. K. Pandey

Abstract

The objective of this paper is to report the experimental comparisons of friction and temperature variations in thrust ball bearing (SKF51308) lubricated with fresh lithium grease and lithium grease containing MoS_2 particles. The friction force and temperature have been measured for the speeds varying in the range 2 to 5 m/s at two loads characterised in terms of Hertzian pressures P_H = 0.4 and 0.6 GPa. Using infrared (IR) camera, the temperature contours of bottom race of the test bearing have also been captured and compared for few sets of operating parameters. Based on the experimental findings reported herein, it has been observed that with increase in the rolling speed the coefficient of friction (friction force) and temperature both increases irrespective of the magnitude of load in absence and presence of MoS_2 particles in the grease. Moreover, it is also recorded that with increase in the load on the test bearing at a constant value of rolling speed, the temperature rise enhances and friction coefficient decreases. It is worth noting here that both the friction coefficient and temperature substantially reduce in the bearing in presence of MoS_2 particles in the lubricating grease.

Keywords: Thrust ball bearing, MoS_2 particles, Friction coefficient, Temperature contour, and Lithium grease.

1 Introduction

Industrial and domestic machines and appliances widely employ the grease lubricated rolling bearings to guide and support the loaded rotors. It happens due to the inherent operational simplicity of the bearing for long duration even greasing the bearing once. However, it is worth noting here that maintaining an effective lubricating film with grease in the rolling bearings is always a challenging task due to the poor conformity at the mating locations of rolling elements (roller and ball) and races. During functioning of the rolling bearings, the continuous movement of rollers/balls do not allow the lubricant (grease) to enter in the space existing between the moving consecutive rollers/balls at the track (on the races). Moreover in case of

Vivek Bhardwaj
Industrial Tribology, Machine Dynamic and Maintenance Engineering Centre (ITMMEC), I.I.T. Delhi, New Delhi, India, E-mail: vivekbhardwaj2100@gmail.com

V. K. Agarwal
Industrial Tribology, Machine Dynamic and Maintenance Engineering Centre (ITMMEC), I.I.T. Delhi, New Delhi, India, E-mail: vagarwal@itmmec.iitd.ac.in

R. K. Pandey
Department of Mechanical Engineering, I.I.T. Delhi, New Delhi, India,
E-mail: rajpandey@mech.iitd.ernet.in

elevated rolling speeds, the lubricant (grease) easily gets pushed aside from the track due to the centrifugal force acting on it and the possibility of its returning back on track happens to be poor due to the low fluidity of grease soap. It is essential to mention here that the soap (thickener) of grease forms 3-D entanglement network of fibres, which hold the base oil in it. Hence, without presence of grease in the vicinity of contacts in the rolling bearings, poor lubrication takes place. Therefore, lubricated contacts in ball bearing are normally subjected to parched/starved lubrication, which is reflected in terms of bearing's poor tribological behaviours and low inherent damping characteristics. Thus, it is worth researching for enhancing the tribological and dynamics performances of rolling bearings employing various concepts. Enhancing the performance behaviours of rolling bearings using the nano particles/powders is a promising research field. The lubricating particles (nano-materials/powders) once dragged and smeared on the surfaces of mating solids (i.e. rolling element, inner race, and outer race) at high pressure and above ambient temperature; it provides a thin stable layer of lubricating film, which is understood a reason behind the improvements in the tribological and dynamics performances of the rolling bearings even in the starved/parched lubricating conditions.

There exists vast scope for improving the tribo-dynamics of rolling bearings using different types of lubricating nano/micro size powders. A literature review is being presented herein for reporting the findings of published papers in the field. Effects of MoS_2 particles and nanotubes on the tribological performance behaviours of conformal and non-conformal contacts have been explored by several researchers namely Lin et al. [1], Raadnui et al. [2], Mesgarnejad and Khonsari [3], Kalin et al. [4], Lahouij et al. [5], Furlan et al. [6], Marquart et al. [7], and Kogovsek et al.[8]. Five different stages (running-in period, healthy working period, transition-I, transition-II, and developing failure stage) of lubrication mechanisms in MoS_2 coated thrust ball bearings operating over extended time have been identified [3]. Using a ball-on-disc configuration, the tribological properties of MoS_2 nanotubes blended lubricating oil have been experimentally evaluated under the boundary lubrication regime at the Hertzian contact pressure of 1GPa and sliding velocity of 0.005 m/s [4]. The findings have been compared to reference base oil and it has been found that in presence of MoS_2 nanotubes the friction reduced two times and the wear as much as 5-9 times lowers. Role of lubricating properties of MoS_2 nanoparticles (perfectly crystallised and poorly crystallised) at the interface of steel surfaces is investigated using the reciprocating pin-on-flat configuration [5]. Good lubricating properties with poorly crystallised MoS_2 particles have been reported. It is concluded that this has happened due to the high ability to exfoliate and to form rapidly a tribo-film made of h-MoS_2 sheets on the surfaces compared to the perfectly crystallised particles.

For gaining a deeper understanding on the thermal stability of MoS_2 particles employed in the lubrication [6] and enhancing the lifetime of MoS_2 lubricated ball bearings [7], experimental studies have carried out in the years 2012 and 2013, respectively. It has been reported that MoS_2 starts decomposing above temperature rise of 650^0C, which results in the formation of sulphides responsible for loss of the tribological behaviours [6]. The effect PAO oil containing the MoS_2 nanotubes on the friction behaviour of steel/steel contact (ball-on-disc configuration) has been tested in all the lubrication regimes considering the surface roughness and the running-in conditions [8]. About 40-65% reductions in the friction has been reported in the presence nanotubes in the lubricating oil as compared to the base oil. It is noticed that majority of industrial and domestic machines employ ball bearings to guide and support the rotors efficiently [9], which consumes significant energy to overcome the friction. Moreover for longer life of heavily loaded non-conformal contacts in the rolling bearings, the existence of high temperature and high value of friction coefficient is not desirable [11, 12]. It is also reported and worth giving thought that one third of all the energy used in the industrialized nations goes to overcome the friction. High friction often results in high wear and about 30% of the productions in industries go to replace the worn out of the products [10]. In view of information reported in the literature pertaining to the nuisance of friction, it is essential to conduct the intensive research for reducing the friction coefficient and temperature in the ball bearings to reach sustainability with low energy consumption.

The objective of this paper is to present findings of an experimental study, which has been conducted for reducing the friction and temperature in thrust ball bearing (SKF 51308) lubricated with grease containing MoS_2 particles.

2 Experimental details

2.1 Details of test bearing

Experiments have been conducted on test bearing (SKF 51308: thrust ball bearing) that is photographically shown in Fig.1. Top and bottom races of test bearing placed in the fixtures have also been shown in Fig.1. Moreover, this figure also provides a schematic illustration of mounting and loading the races of test bearing on the test rig. Sets of test bearings from same batch of production were procured from the suppliers for performing the experiments. Races and balls of test bearings were tested for the material composition, micro hardness, and surface roughness.

Fig.1 Photographic view of test bearing (SKF- 51308) and schematic representation of bearing mounting and loading on the test rig

The chemical composition of the ball and bearing races are listed in the Table 1. The micro-hardness and average surface roughness (R_a) at the races were measured and found 700 HV and 0.08 µm, respectively.

Table 1: Chemical composition (wt %) of the test bearing components

Component	C	Si	Mn	Cr	S	P	Fe
Ball	1.0	0.286	0.344	1.430	0.006	0.014	96.72
Bearing inner race	0.98	0.201	0.354	1.490	0.008	0.010	96.85
Bearing outer race	0.98	0.201	0.354	1.490	0.008	0.010	96.85

2.2 Description of test rig and measurement of friction and temperature

Photographic views of the experimental test rig employed in the study are shown in Fig. 2. Fixtures (for mounting the races of bearing) were fabricated for holding the bearing races. The bearing races fitted fixtures can be seen in Fig. 1. Photographic views of mounting and loading the test bearing on the test rig is illustrated in Fig. 3. In the experiments, the lower race was driven by a motor while keeping the upper race stationary. Frictional torque is measured using a strain gauge type S- shape load cell, which can be seen in Figs. 2 and 3. Loading is done by attaching the weights on one end of the lever, which gets amplified six times on the test bearing. Well before the start of the experiments, the load cell was calibrated using the standard dead weights. Moreover, for assessing the temperature distributions in the test bearing at different operating parameters, thermal images of lower race (rotating race) of bearing were captured using an Infrared (IR) camera (FLIR P-640 model).

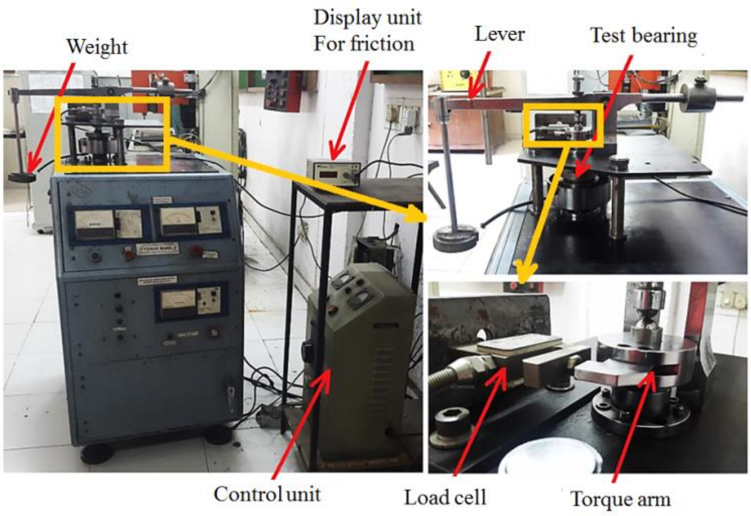

Fig. 2 Photographic view of experimental test rig

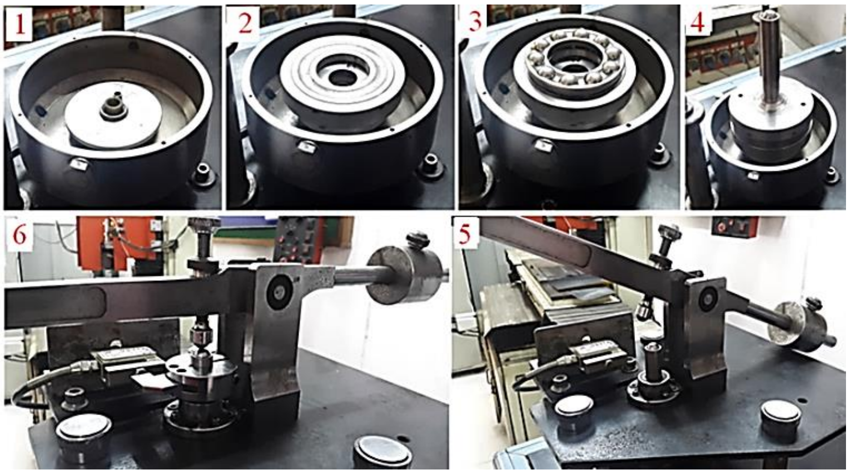

Fig. 3 Photographic views showing steps of mounting and loading of test bearing

2.3 Preparation of grease containing MoS_2 particles

Commercial lithium grease was employed for lubricating the test bearing in the experiments. Two grams of MoS_2 powders, having the shape and size (2-5 µm) as shown in image obtained by Scanning Electron Microscopy (SEM) in Fig.4, was added to 50 grams of fresh lithium grease [13]. For having homogeneous distribution of MoS_2 particles in the grease, mixing was done using stirrer for duration of 20 minutes. Thereafter, to check the homogeneous distribution of MoS_2 particles in the grease, sample is prepared as per mentioned procedure [14] for conducting the Tunnelling Electron Microscopy (TEM). The TEM images of fresh grease and grease containing MoS_2 particles are shown in Fig.5. From this figure, it can be seen that the MoS_2 particles are trapped in between the soap fibres of the grease. Moreover, this figure also indicates that no deterioration has happened to the grease fibres during the mixing of MoS_2 particles through stirring.

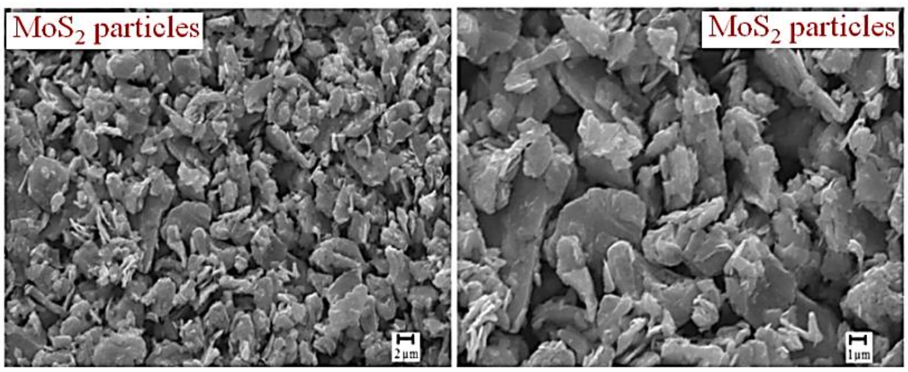

Fig.4 SEM micrograph of MoS_2 particles

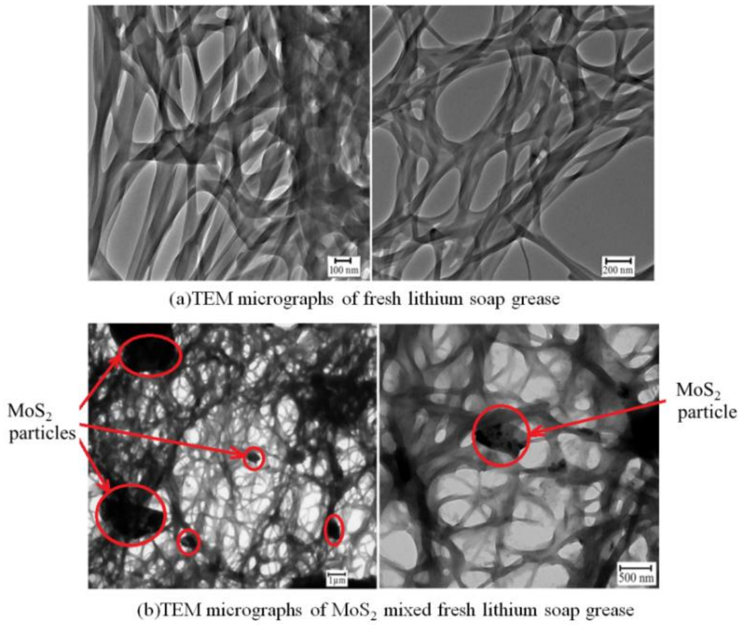

Fig.5 TEM images of fresh grease and the grease containing the particles of MoS_2

2.4 Procedure of experiments

All the experiments were conducted at the ambient environmental conditions. Test bearing races were cleaned with acetone. Therefore, on each races one gram grease was uniformly spread before the start of the experiment. Each experiment was conducted for the duration of thirty minutes. The speed varying in the range 2.35-4.71 m/s under the two loads characterized by Hertzian pressures 0.4 and 0.6 GPa has been used to perform the experiments. Friction force and temperature distribution were recorded at the end of each test.

3 Results and discussion

3.1 Friction coefficient and temperature rise

Friction coefficient and temperature rise variations with rolling/sliding speeds (varying in the range 2.35- 4.71 m/s) at two loads characterised in terms of Hertzian pressure 0.4 GPa and 0.6 GPa have been shown in Fig. 6 using fresh grease and grease containing MoS_2 particles as lubricating mediums. From this figure, the magnitudes of friction coefficient reveal that the test bearing has operated in the elastohydrodynamic lubrication regime. Friction coefficient increases at the constant load with increase in the rolling/sliding speed. It happens due to the enhanced shearing of the lubricating medium. Moreover, friction coefficient decreases with increase in load. It is understood that at high load film thickness reduces. This leads to the shearing of less quantity of lubricating grease, thus, resulting in the reduction of friction coefficient. For all the operating parameters employed in the investigation, the friction coefficient comes out lesser with the lubricating grease containing the MoS_2 particles as compared to fresh lubricating grease. Better smearing of the MoS_2 particles on the bearing races yield a stable solid lubricating film formation, which reduces both the friction coefficient and temperature rise significantly at the elevated operating condition.

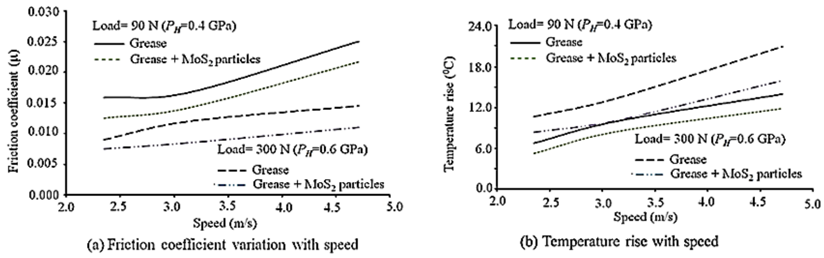

Fig.6 Variation of friction coefficient and temperature rise with rolling/sliding speeds at different operating parameters

3.2 Temperature contours in lower race of bearing

The temperature contours in the lower race of bearing have been plotted in Figs. 7 and 8 for the different operating parameters. From the temperature contours, it can be concluded that the maximum temperature location is not at the contacting track of ball and race. It can be noticed in Figs. 7 and 8 that the locations of the maximum temperature is lying in the grease, which has been pushed aside to track during the operation of the bearing due to the continuous motion of balls. For all cases of the operating conditions, the temperature rise with the MoS_2 particles added grease is low as compared to fresh grease. It is worth noting that MoS_2 additives are more effective at elevated operating conditions (P_H =0.6GPa, speed =4.71 m/s) in reducing the temperature rise.

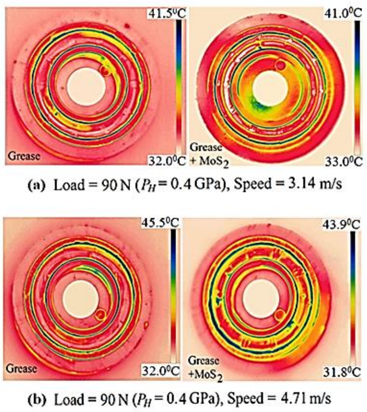

Fig.7 Temperature contours at P_H=0.4 GPa

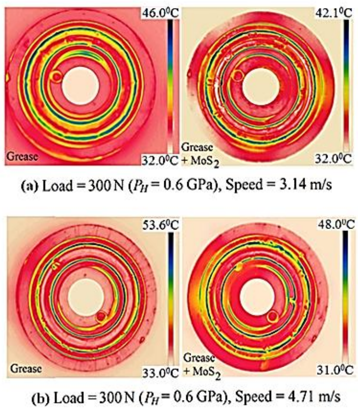

Fig.8 Temperature contours at P_H=0.6 GPa

4 Conclusions

Based on the experimental studies reported herein, the following conclusions have been drawn:

- Friction coefficient significantly reduced when the grease containing the MoS_2 particles is employed for lubrication of test bearing. About 20% reduction in the friction coefficient is observed compared to fresh grease irrespective of the loads applied at all the rolling speeds.
- Vital temperature reduction is observed at higher load (P_H=0.6 GPa) in comparison to lower load (P_H=0.4 GPa).
- About 6^0C temperature reduction is recorded at the high speed (4.71 m/s) and load (P_H=0.6 GPa) with grease having MoS_2 particles.
- At elevated operating conditions, grease containing MoS_2 particles yields better results in terms of reduced friction and temperature.

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