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Abstract

Ball bearings are widely employed in industrial and domestic machines for supporting and guiding the rotors energy efficiently. A ball bearing involves many rolling/sliding concentrated contacts formed between the balls/races and balls/cage. Such concentrated contacts function under wide range of operating parameters (load, speed, material properties, surface finish, geometrical conformity etc.) and in many situations even in the harsh environments (i.e. at elevated temperature, dusty environment, contaminated lubricant and starved lubrication). Currently, worldwide research is going on to improve the tribodynamic performance behaviors of ball bearings. For this purpose, great efforts are being made to improve the performances of contacted contacts found in ball bearings. Recently, textures at the interface of mating surfaces and use of micro/nano materials in lubricants (nano lubricants) have emerged as viable technologies, which are being employed for improving the performance behaviors of concentrated contacts. Surface textures involve well-defined patterning of nano/micro sizes of dimples, grooves, and other geometries, on the surfaces of mating solids. The beneficial effects of surface textures and nano lubricants in improving the performance behaviors of generic concentrated contacts are being established and reported. However, there is dearth of experimental and theoretical studies for improving the tribodynamic performances of ball bearings using the textures.

The primary objective of this research work is to explore and improve the tribological and dynamic performance behaviors of rolling/sliding point contacts and ball bearings using textures and micro/nano materials. The additional objective of this research is to propose formulas for design of concentrated point contacts operating under fully flooded and starved conditions at light loads and high speeds and accordingly predicting the frictional torque, minimum film thickness, temperature rise, and stiffness in ball bearings.

In many mechanical systems such as gyroscopes, textile machinery, vacuum cleaners etc., the oil/grease lubricated ball bearings are used to support and guide the high speed (rpm varying in range of 10k to 100k) rotors under lightly loaded conditions. In this situation, the understanding of variation of performance behaviors in terms of operating parameters is important from design/operational perspectives. Thus, numerical explorations have been made for understanding the roles of fully flooded and starved lubrications on the performance behaviors of lightly loaded concentrated contacts operating at high speeds. The thermohydrodynamic lubrication (THL) analysis of the lightly loaded circular contacts have been reported at combinations of operating parameters [rolling speed \( (\omega) = 5 - 40 \text{ m/s}, \text{ loads (} p_{lf} = 0.1 - 0.2 \text{ GPa}, \text{ and slip factors (} S = 0.0-2.0)] \), incorporating the lubricant starvation. Based on the numerical investigations, the design expressions for predicting the performance parameters (minimum film thickness, traction coefficient, film temperature rise, and stiffness coefficient) in terms of operating parameters have been developed using the non-linear regression analysis.

The tribo-dynamic performances of medium loaded \( (p_{lf}=0.4-0.6 \text{ GPa}) \) ball bearings have been explored employing the textured races (comprising the dimpled surface and grooved surface separately) and micro/nano materials (MoS\(_2\), hBN and WS\(_2\)) blended greases. Experiments were conducted on thrust ball bearings (SKF-51308) for the measurement of frictional torque, temperature rise, and vibrations. The soap structures of fresh and used greases were examined using Transmission Electron Microscope (TEM). However after the experiments, the surfaces of races and balls were investigated using Scanning Electron Microscope (SEM) and Energy Dispersive X-ray (EDAX). Substantial decrease in frictional torque (up to 33% reduction) and vibration amplitude (up to 50% reduction) have been observed with textured ball bearing (texture comprise of micro dimples only) lubricated with MoS\(_2\) blended grease in comparison to grease lubricated conventional ball bearing. However, grease lubricated textured ball bearing (texture comprise of circumferential micro grooves only) have yielded about 27% and 22% reductions in frictional torque and vibration amplitude, respectively. In case of oil lubricated textured (having circumferential grooves) ball bearing, the frictional torque and vibration amplitude reduced better as compared to grease lubricated cases.