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ORIGINAL ARTICLE

Morphology investigation of worn bearing surfaces using SiO_2 nanolubrication system

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Abstract The new technology that uses nanoparticles as additive of lubricant has become an attractive study recently. The performance of nano-SiO_2 which acts as the nanoparticle in the lubrication system is investigated. Tests were conducted at nanolubrication mixing ratio of 0.0, 0.1, 0.2, 0.5, 0.55, 0.6, and 0.8 wt.% of SiO_2 with plain bearings using a 2,750 rpm high-speed rotating motor. For each mixing ration, the frictional temperature and weight loss of plain bearings were recorded and compared. During the surface morphology, the worn bearing surfaces are investigated by scanning electron microscopy. The surface element analysis was also employed to get more morphology investigation by using energy dispersive x-ray spectrometer as well as element mapping. The results showed that tribology performance of nanolubricant is at optimum by using 0.5 wt.% mixing ratio.

Keywords Nanolubricant · SiO_2 · Wear · Bearing · Morphology analysis · Scanning electron microscopy

1 Introduction

The applications of bearing become more important after the industrial revolution in eighteenth century. The requirement of accuracy and durability of bearings also becomes more and more crucial, since heavy duty machines and railroad cars are available. Today, not only the cost concern, the design of bearing continues to progress with advanced materials and new geometries enabled by computer-aided design. Computer-aided manufacturing, such as computer numerical-controlled machining, has drastically improved the accuracy of mass-produced bearings. The technology of bearings is a widely used tribo-element. It involved frictional contacting, lubrication, surface study, and especially tribology. Bearings can be classified as providing sliding or rolling contact. Rolling bearings have balls or rollers to minimize rubbing, and lubricant has also been used. A sliding bearing typically uses lubricant to reduce friction between the sliding surfaces. The fluid lubricant forms a film between the sliding surfaces so that there is no contact between the solid components. Sliding bearing is commonly used in industry and robot implementation. Sliding bearings have conformal contact with sliding surfaces where lubricant is usually used. Lubrication can be defined as the control of wear and friction between two relative motion surfaces. The formation of a very thin film between the surfaces is the key reason for lower friction and wear effect. Lubrication has always implied the use of lubricating oil, usually formulated by blending appropriate quality of lube base with additives. Recently, studies on the additives of lubricants by using nanoparticles have attracted the attentions of many researches. Polytetrafluoroethylene, graphite, and molybdenum disulphide are the common particles used in commercial. Besides these materials, current researches are interested in the effects of additives where the performance of inorganic composites and ceramics as additive is to be further determined. Furthermore, less pollution results when using nanolubricant in machining due to low consumption of lubrication oil. The detailed analysis and implementation of nanoparticles suspended lubrication in the machining process with a proper parameter setup are mandatory to ensure its efficiency.

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Table 1 Physical properties of Aldrich nano-SiO_2 particles

Properties	Aldrich nano-SiO_2
Structure	Amorphous
Melting point	Approx 1600 °C
Density	2.2 g/ml
Thermal conductivity at 300 K	0.014 W/cm-K
Average diameter	5–15 nm

Table 2 Physical characteristics of FUCHS Ecocut HSG 905 lubricant

Properties	FUCHS Ecocut HSG 905
Density at 15 °C	0.826 g/ml
Viscosity at 20 °C	8.0 mm^2/s
Viscosity at 40 °C	4.6 mm^2/s
Flash point	130 °C
Evaporation loss	90 %

One of the nanoparticles, silicone dioxide (SiO2) is well known as hard materials and can be easily found in the market with affordable prices. They can be found within the size range of 5–100 nm. The SiO2 is used as additives of nanolubricant in this present research, and the performances are investigated. The physical properties of SiO2 are tabled as Table 1. The SiO2 is used as additives of nanolubricant in this present research and the performances are investigated. Nanolubricant is prepared by blending of nanoparticles and ordinary mineral oil. Sarhan et al. [1] prepared the nanolubricant by adding SiO2 (0.2 wt.%) with an average size of 5–15 nm into the ECOCUT SSN 322 neat mineral oil with 40.2 cSt at 40 °C from FUCHS and followed by sonification (240 W, 40 kHz, 500 W) for 48 h in order to suspend the particles homogeneously in the mixture. Sarhan et al. [1] reported that the cutting force and power has been reduced considerably using a nanoparticle lubricant, as such lubricant works as billions of rolling elements in the tool chip interface. Correct application of lubricants has been proven to greatly reduce friction which results in reduced power consumption. According to Lee et al. [2], 0.1 vol.% of graphite particles (average size is 55 nm and specific gravity is 2.26), 0.5 vol.% of dispersant (alkyl-aryl-sulfonate), and commercial mineral oil (Supergear EP220, SK, Korea) were mixed by using an ultrasonic homogenizer at ambient temperature. The surfaces of the nanoparticles are modified by the dispersant, and the dispersant helps to suspend the particles in the as-prepared nanolubricant. The nanolubricant is more stable by adding with dispersant. This is mainly attributed to the repulsive force provided by the dispersant between the surfaces of nanoparticles inside the nanolubricant. The tribology performances of nanolubricants are studied recently. The nanoparticles are acting as rolling element also reported in few researches [3, 4]. Wu et al. [3] compared the performance of CuO, TiO2, and nano-diamond used as additives in lubricating oils. The oils, especially CuO, exhibit good friction reduction and anti-wear behavior. It also reported that the sphere-like nanoparticles may result in rolling effect between the rubbing surfaces and reduced the friction coefficient. This effect makes the original pure sliding friction changes become a mixed friction of sliding and rolling, so the friction coefficient can be decreased obviously and remain constant.

The changes mentioned above can be considered as direct effect of nanoparticles on lubrication enhancement. Apart from it, some of the authors also reported the secondary effect of the presence of nanoparticles on the surface effect. On the other hand, nanoparticles embedded effect is observed by several reports [5, 6]. Those reports show how the nanoparticles are embedded on the friction surfaces or fill surface grooves. In addition, the deposition of nanoparticles on rubbing surfaces can contribute to higher applied load, longer duration time, and lower operating temperature [7]. Few surface investigation tools have been used to check the

Fig. 1 Plain bearings (GEZ40ET-2RS LS) with 40-mm bore diameter