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ORIGINAL ARTICLE

Titanium oxide nanoparticles as additives in engine oil

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Abstract This study examines the tribological behaviour of titanium oxide (TiO_2) nanoparticles as additives in mineral based multi-grade engine oil. All tests were performed under a variable load and concentration of nanoparticles in lubricating oil. The friction and wear experiments were performed using pin on disc tribotester. This study shows that mixing of TiO_2 nanoparticles in engine oil significantly reduces the friction and wear rate and hence improves the lubricating properties of engine oil. The dispersion analysis of TiO_2 nanoparticles in lubricating oil using UV spectrometer shows that TiO_2 nanoparticles possess good stability and solubility in the lubricant and improve the lubricating properties of the engine oil.

1. Introduction

One of the major losses occurring in the engine of an automobile is due to friction between its moving parts. This loss is significant and approximately 15% of the total loss of energy and has a direct impact on the efficiency and durability of the engine (Vadiraj et al., 2012). Different mechanical systems need a variety of functional lubricants to decrease the friction and wear of contacting surfaces as well as to significantly reduce the total energy consumed by mechanical systems. Lubricants play a major role in reducing the wear and friction between the two surfaces in contact with each other. In any type of machinery, when there is sliding between machine components, there develops a resistance called friction, to this movement. The relative motion quite often causes wear and tear of the components. Friction can be minimised by interposing a substance of low shear strength between the two moving surfaces. This phenomenon is known as lubrication and the interposed substance is called a lubricant. Hence, lubrication is fundamental to the operation of all engineering machines. Lubrication is necessary to minimise friction and wear. Many studies have focused on improving the lubrication performance of general lubricants. One approach is to incorporate particle additives into regular lubricants so that it can reduce

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the friction and wear of frictional surfaces. The main function of a lubricant is to keep two metal surfaces wet thus minimising friction and avoiding wear (Calhoun, 1960). Research studies have reported that the nanoparticles dispersed lubricants are found to have a significant effect on reducing the friction and wear rate. It is also observed that the friction and wear have a direct bearing on the shape, size and the concentration of the nanoparticles in the lubricating oil. Vadiraj et al. investigated the effect of nano boric acid and nano copper based engine and transmission oil additives in different volume ratios on friction and wear performance of cast iron and case carburised gear steel (Vadiraj et al., 2012). Wu et al. investigated the effect of additives CuO, TiO_2, and nano-diamond nanoparticles on the tribological properties of two different lubricating oils and observed that with CuO additive oils significantly exhibit good friction-reduction and anti-wear properties (Wu et al., 2007). Thottackkad et al. have studied the effect of Copper oxide nanoparticles as additives in the lubricating oil (Thottackkad et al., 2012). Hwang et al. investigated the effect of size and morphology of nanoparticles suspended in lubricating oils on the lubrication performance (Hwang et al., 2011). Zhang et al. also found in their study that Cu nanoparticles used as an oil additive can improve the anti-wear and friction-reduction performance of lubricating oil (Zhang et al., 2009). Choi et al. observed that the mixed nanofluids containing graphite and Ag nanoparticles showed enhanced load-carrying and anti-wear properties in the FZG gear rig test and also reduced the electric-power consumption by more than 3% compared to the base oil (Choi et al., 2011). Hsin et al. investigated the tribological properties of the two-phase lubricant oil and nanodiamond–polymer composite. Based on the results it is observed that nanodiamond–polymer composite possesses better antiwear, friction-reduction and load-carrying capacity than the nanodiamond additive (Hsin et al., 2011). Chu et al. experimentally investigated the anti-scuffing performance of nano-diamond-dispersed oil with various concentrations of diamond particles (Chu et al., 2010). It has been reported that the main mechanism of the friction reduction when nanoparticles were added can be attributed to the rolling/sliding effect (Chin-as-Castillo and Spikes, 2003). In order to further understand this, we will have to study what is tribology and how it plays a major role in saving materials from further wear and tear. In the present research work tribological properties of the lubricating oil were evaluated with the addition of TiO_2 nanoparticles using pin-on-disc tribotester under controlled conditions as per the ASTM standard G99 and the oil samples with dispersed TiO_2 nanoparticles were studied spectroscopically with the help of UV spectrometer.

2. Experimental

In this study titanium oxide nano particles of grain size 10–25 nm were used as additive and the lubricating oil was used. The apparent density and the bulk density of TiO_2 nanoparticles were 0.3 g/cm^3 and 0.20 g/cm^3 respectively. The TiO_2 nanoparticles used in this study were purchased from Supplier Nanoshel LLC, USA. Aluminium alloy (LM 25) was used (Al–Si 7 Mg) as pin material to be used on pin-on-disc tribotester. Servo 4T Synth 10 W-30 was used as lubricating oil.

A pin-on-disc type tribometer (DUCOM TR-20) was used to evaluate the tribological properties of the lubricant. This tribometer had a driven spindle and chuck for holding the revolving disc, a lever-arm device to hold the pin, and attachments to allow the pin specimen to be forced against the revolving disc specimen with a controlled load. The wear track on the disc is a circle, involving multiple wear passes on the same track. The system has a friction force measuring system (a load cell) that allows the coefficient of friction to be determined.

2.1. Fabrication of pin

The pins were fabricated from the aluminium alloy (LM 25) using manual labour techniques. The fabrication was done with the help of a cutting saw. The metal pieces were cut in triangular shapes and then cut metal piece were given a rough circular shape with the help of a hand grinder. The roughly circular aluminium pieces were then machined to standard (as per ASTM G99) size (10 mm diameter and 25 mm length) using lathe machine.

2.2. Preparation of nanolubricant

The nanoparticles are added to the lubricating oil at 0.3%wt, 0.4%wt, 0.5%wt. The required quantity of nanoparticles was accurately weighed using a precision electronic balance and mixed with the lubricating oil. A chemical shaker was used for mixing the nanoparticle additives in the lubricating oil. The time of agitation was fixed as 30 min based on the past experience in producing a stable suspension with sufficient time for sedimentation to begin. After the mixer is agitated for 30 min, the nanolubricant is obtained.

2.3. Pin-on-disc tests

Tribological behaviour of the lubricating oil was evaluated using a pin-on-disc tester, with and without the addition of nanoparticles. The nanoparticles added to the lubricating oil were titanium oxide, with an average size of 15–20 nm. Load, sliding speed and nanoparticle concentration were selected as parameters. To determine the optimum concentration of nanoparticles, experiments were performed at different concentrations (% by weight).

The range of test parameters for pin-on-disc used are as mentioned below:

- Load: 39.226 N, 49.033 N, 58.839 N.
- Sliding speed: 1.0 m/s.
- Nano-particle concentration (% weight): 0.3%, 0.4%, 0.5%.
- Sliding distance: 200 m.
- All the tests were carried out for a duration of 5 min.

The experiments were done as per the ASTM standard G99. Pins and disc were polished up to 600 grit size to make the surface flat and cleaned with acetone. Load was applied on pin by dead weight through pulley string arrangement. Lubricant was applied between the pin and disc in such a way that boundary lubrication condition occurs. Frictional force was read from the controller and electronic weighing balance (accuracy of 0.1 mg) was used to measure the weight loss