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Effects of TiO_2 nanoparticles and oleic acid surfactant on the rheological behavior of engine lubricant oil

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ABSTRACT

In this work, we have studied the effect of titanium (IV) oxide (TiO_2) nanoparticles dispersed in an engine lubricant oil on its rheological behavior. In order to prepare this nanofluid, mechanical stirrer and ultrasonic bath were used. The nanoparticles were characterized using SEM, TEM and dynamic light scanning. The rheological behavior of the system was studied by a parallel plate rheometer. Then, oleic acid, as surfactant, was used to stabilize suspensions. Also, the effect of the surfactant on the rheological behavior was studied. Three different models for rheological behavior, namely Power law, Cross and Carreau models, were considered. The Carreau model provides the best prediction of the rheological behavior for this system.

1. Introduction

Nanoparticles have been used as lubricant oil additives in recent years [1–4]. Between various inorganic nanoparticles which are used as lubricant oil additives, TiO_2 nano particles have shown so important effects to improve the tribological properties [5].

Addition of solid particles to engine lubricant oil can reduce friction [6]. Among of studies, it has been reported that the addition of particles to the lubricant oil is effective in reducing wear and friction. The friction and anti-wear behaviors are dependent on the characteristics of nanoparticles, such as size, shape and concentration [7].

Liu and co-workers carried out studies on a wide range of different colloid solid nanoparticles using a four-ball tribotaster [8]. Their results show that the deposition of tribochemical reaction products, which are produced by nanoparticles during the friction process, causes an anti-wear boundary film, and decreases shearing stress [7].

Sudeep et al. reported that friction coefficient is reduced when 0.25 wt% of nano sized TiO_2 which has uniform anatase phase, is dispersed in lubricant oil [6]. 0.25 wt% addition of TiO_2 to the base oil has shown stable friction. In our study, agglomeration of the TiO_2 nanoparticles has been decreased by addition of the oleic acid as a surfactant. The TiO_2 coated nanoparticles with this surfactant, makes the nano fluid stable. Computer modeling and laboratory experimental investigations have shown two types of heterogeneous structures consisting of, particles and bulk drop-like aggregates.

Since the system is so complicated and most of the reports are based on the theories and calculations and there are few experimental reports in this field, many unanswered questions still remains for research [9].

In pervious works, the effects of various shear rates on the viscosity and shear stress of magnetite fluid [10], cellulose nanocrystals [11], silica nanoparticles in polyethylene glycol [12] and ceramic particles [13] have been investigated [14].

On the other hand, experimental data for rheological properties of adhesive [15], magnetite fluid [16] and nano coolant [17] was compared with the conventional model.

The rheological properties of TiO_2 suspensions play an important role in the applications and industrial process. The most important parameter which is used for describing the rheological properties of suspensions, is still viscosity [18].

Motahar et al. [19] reported thermal conductivity and rheological properties of n-octadecane with dispersed TiO_2 nanoparticles which were experimentally investigated. The rheological behavior of the n-octadecane/TiO_2 samples indicated that dispersions with low nanoparticle mass fractions demonstrate Newtonian behavior, and for the

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Table 1
Properties of the engine lubricant oil.

SAE	Kinematic viscosity	Viscosity index (VI)	Density	Pour point	Flash point
10W40	25.19/40c 15/100c	150	0.870 g/cm^3	-30 °C	210 °C

higher mass factions the shear-thinning behavior was observed. By increasing mass fraction of TiO_2 nanoparticles, rheological data demonstrates transition from Newtonian to non-Newtonian behavior.

In the present study, we have investigated the rheological properties of TiO_2, in form of anatase, dispersed in an engine oil, and we have discussed the effects of concentration, surfactant and shear rate on the viscosity. The interaction of nanoparticles and aggregation have also been evaluated. Finally, experimental data has been compared with conventional models results.

2. Materials and experiments

2.1. Materials

Titanium (IV) oxide (TiO_2) nanoparticles with average size of 10-25 nm from US Research Nano Co. were prepared. It is anatase form with >99% purity.

A base oil (mineral oil without any additives) was used as lubricant, which is a crude oil refinery by-product. The properties of the base oil are reported in Table 1.

In order to obtain good dispersion of TiO_2 in the aforementioned base oil, the surface of TiO_2 nanoflakes was coated and modified by oleic acid (OA) which was supplied by Merck Co.

2.2. Experiments

2.2.1. Preparation of the samples

To prepare the samples, in the first step TiO_2 nanopowder in different weight fractions (0.1, 0.5 and 1%wt) were mixed with SAE10 engine oil. TiO_2 nanoparticles were dispersed in oil with both mechanical stirrer and ultrasonic bath, to break down aggregated nanoparticles and disperse them in oil as uniform suspension. The bath temperature was set at 50 °C for 20 minutes with the frequency 50–60 Hz. After that for preparation of the sample of nano TiO_2, the mechanical stirrer was used at 1200 rpm for 15 minutes. Finally, stable suspension was prepared.

Mahbubul et al [20] studied the effect of ultra-sonication period on particle dispersion and rheological properties of Al_2O_3–water. They found that the viscosity values of the nanofluids is decreased with increasing ultra-sonication period.

In the first experiments, in order to study the effect of the additives alone, no surfactant or dispersant agent was added. For the other samples, TiO_2 nanopowders in (0.1, 0.5 and 1 wt%) were mixed with the base fluid (10% oleic acid and 90% engine oil). The problem was at the time of stability. So when Oleic acid was added as a surfactant, the time of stability was more than the time considered in Fig. 1(a) TiO_2 + engine oil. Oleic acid acts as surfactant for coating nanoparticles. The uniform dispersions of TiO_2 are shown in Fig. 1.

Fig. 1. Dispersion of nanoparticles (a) TiO_2 + engine oil (b) TiO_2 + engine oil + surfactant.

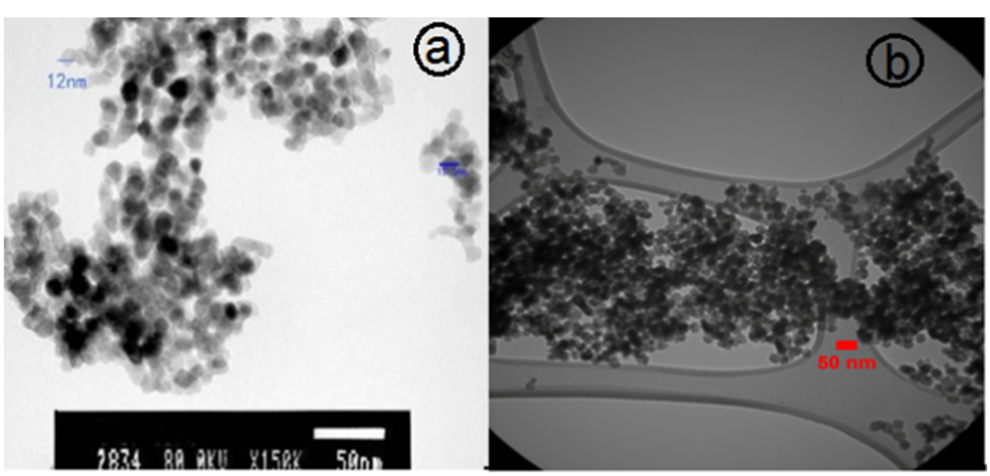

Fig. 2. (a) SEM image of TiO_2, (b) TEM image of TiO_2.