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Evaluation of rheological behavior of 10W40 lubricant containing hybrid nano-material by measuring dynamic viscosity

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Abstract

In the present paper, the dynamic viscosity of 10W40 lubricant containing hybrid nano-materials has been examined. Hybrid nano-materials were composed of 90% of silica (SiO_2) with 20–30 nm mean particle size and 10% of multi-walled carbon nanotubes (MWCNTs) with inner diameter of 2–6 nm and outer diameter of 5–20 nm. Nano-lubricant samples were prepared by two-step method with solid volume fractions of 0.05%, 0.1%, 0.25%, 0.5%, 0.75% and 1%. Dynamic viscosity of the samples was measured at temperatures between 5 and 55 °C and at shear rates of 666.5 s^{-1} up to 11,997 s^{-1}. Experimental results indicated that the nano-lubricant had non-Newtonian behavior at all temperatures, while 10w40 oil was non-Newtonian only at high temperatures. With the use of the curve fitting technique of experimental data, power law and consistency indexes were obtained; furthermore, these coefficients were assessed by shear stress and viscosity diagram.

Introduction

A fluid containing solid particles with a smaller size than 100 nm is called nanofluid. Nanofluid is one of the revolutionary developments of fluid and thermal science. These fluid

various applications, e.g. heating and refrigeration, automotive, industrial converters, lubrication, nuclear power, electronics, etc. [1], [2]. The main advantage of nanofluids is their larger thermal conductivity which is a result of nanoparticles presence and their Brownian motion [3], [4]. Identification of thermo-physical characteristics of nanofluids is effectively essential for using them properly. Many studies have been conducted on identifying nanofluids characteristics. These studies have revealed that these characteristics are influenced by various factors, including temperature, nanofluid concentration and diameter of nanoparticles. Studies on thermal conductivity properties indicate that increasing in temperature and concentration of nanofluids or decrease of nanoparticles diameter result in increment of nanofluid thermal conductivity [5], [6], [7], [8], [9]. Viscosity is another characteristic that has been studied in many papers. According to these studies, increment of temperature and nanoparticles size or decreasing of nanofluid concentration causes viscosity of nanofluid to decrease [10], [11], [12], [13], [14], [15], [16]. Modeling of these properties has been discussed in some papers. The effect of temperature and concentration on thermal conductivity and viscosity was observed in studies in which neural network was utilized for approximation of nanofluids thermal conductivity and viscosity behavior [17], [18], [19]. New equations have been presented in some of these studies for predicting viscosity and thermal conductivity. Table 1 shows some of these equations.

Another characteristic of nanofluids which has not been noticed properly is their rheological behavior. This characteristic is in accordance with any deformation of flow or the shape of a matter which is caused by an external force [22], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42]. A summary of the studies conducted on this subject is shown in Table 2. The occurred deformation may cause viscosity to either increase or decrease which are called shear thickening and shear thinning respectively. There is a specific type of fluids which is called Bingham fluid. For these fluids viscosity varies linearly with the initial force.

In the present paper our main objective is to discuss the rheological behavior of SiO_2-MWCNTs (90%:10%)/10W40 hybrid nano-lubricant and determination of temperature and concentration effects on this nanofluid. This paper is unique since the rheological behavior of this specific nanofluid had not been studied before, so the effects of the studied factors were totally unknown.

Section snippets

Material

In this study, SiO_2 nanoparticles with the average particle size of 20–30 nm and multi-walled carbon nanotubes (MWCNTs) with inner diameter of 2–6 nm and outer diameter of 5–20 nm were used as nano-additives. X-ray powder diffraction (XRD) was utilized in order to verify the sizes of the nanoparticles and its results are depicted in Fig. 1.

Physicochemical properties of SiO_2 nanoparticles and MWCNTs are shown in Table 3, Table 4 respectively.

The base fluid during this study was 10W40 engine oil and ...

The effects of concentration and temperature on viscosity

The effect of temperature and concentration on viscosity of the hybrid nano-lubricant at a constant shear rate is depicted in Fig. 4. It can be observed that increment of temperature resulted in viscosity reduction. This phenomenon was expected because in higher temperatures, the connection between the particles, which prevents the movement of the fluid layers on each other, becomes weaker. In fact, the increase in temperature reduces the van der Waals forces between the particles. It can also...

Conclusion

In this study SiO_2 nanoparticles of 20–30 nm and multi-walled carbon nanotubes with inner diameter of 2–6 nm and outer diameter of 5–20 nm were dispersed in 10W40 engine oil with proportion of 90% and 10% respectively, resulting in SiO_2-MWCNTs (90%:10%)/10W40 hybrid nano-lubricant. Viscosity data of the nano-lubricant were measured for 0.05%, 0.1%, 0.25%, 0.5%, 0.75% and 1% volume fractions and at temperature ranges of 5–55 °C and shear rates of 666.5 s^{-1} up to 11,997 s^{-1}.

Studying the extracted data...

Acknowledgement

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