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Effect of TIO_2/Talc powder Nanoparticles on the Rheology Performance of Base Calcium Grease

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Abstract

Recently, nanogrease attracts considerable interest for improving the rheological properties which used in many applications such as marine applications, and water pumps. the aim of this research is to study the effect of the addition of TiO_2 nanoparticles mixed with talc powder to calcium grease on properties such as viscosity, the relation between shear rate and shear stress, penetration and dropping point. For this purpose, the nanofluids were synthesized additive hybrid nanomaterials composed of 50 wt% TiO_2 and 50 wt% Talc powder added in five specific ratios (0.5%, 1%, 2%, 3%, and 4%wt.). The microstructure of nanoparticles and nanogrease were examined by Transmission Electron Microscope (TEM), and X-Ray Diffraction (XRD). The experimental work was investigated by a Brookfield programmable Rheometer. The results indicated that the modified calcium grease with the concentration (3 wt. %) is the optimal concentration and the dropping point increasing about (10.6%). Moreover, the rheological behaviors of the nanogrease shows that the grease with various concentrations of TiO_2 and talc powder demonstrates non-Newtonian behaviors and the results indicated that the shear stress and apparent viscosity increase with increasing volume concentration of TiO_2 and talc powder to (32%) and (30%) respectively.

Keywords: Nano Additives, Rheological behavior, Calcium grease

1. INTRODUCTION

Calcium greases are basic grease which provides high-anti rust capacity, inherent extreme pressure (EP) properties that stand out from the rest and high water resistance [1]. They have a mineral oil base and are used as general lubricants for automotive in chassis, ball joints, universal joints and wheel bearings, agricultural, construction, food, industry, mining, paper manufacturing and other industrial applications such as steel mills, continuous casters, conveyors, ball mills, crushers, off-shore and underwater applications [2, 3]. Therefore, there is a continuing need for the development of economic efficient lubricating calcium greases. To reduce friction and wear in engines, machines and other important devices involving sliding motion, many nanoparticles dispersed in the Calcium greases are being employed nowadays.

Nanoparticles based calcium greases are generally coined as nano-lubricants. Various nanoparticles like CaF_2, ZnO, CuO, $CaCO_3$, CNT, TiO_2, Fe, Cu, LaF_3, etc., are used to analyze the Rheology properties of the prepared nano-lubricant in the engines and machines [4–10]. With the improvement in frictional properties, these nano-lubricants also have increased thermal conductivity [11]. TiO_2 nanoparticles added to greases to improve the load carrying capacity and reduction in wear. Many research works are reported using TiO_2 nanoparticle as coating material and composite reinforcement to improve tribological and rheology, and it is found when mixed two nano particle the material properties in many case [12]; so in this research we mixed between TiO_2 nanoparticle and talc powder to make hyper nano additive to calcium greases. C. Selvam, et al. [13] study, the effective rheological behavior of ethylene glycol with single-walled carbon nanohorn inclusions. The viscosity of nanofluids increase with respect to nanohorn loading and decreases with respect to shear rate which indicates the non-Newtonian shear thinning behavior at higher nanohorn loading. ,Alaa Mohamed , et al., [14] found from the results demonstrated that grease behaves like a Newtonian viscoelastic material the apparent viscosity and dropping point increased by about 93 and 27 %. Bahaa M. Kamel, et al., [15] found that the rheological characteristics of the grease with a different volume fraction of GNS indicated a non-Newtonian behavior. Thermal conductivity of nanogreas also increases with an increase of GNS volume fraction. Moreover, the apparent viscosity, shear stress and dropping point increase by 59%, 52%, and 65%, respectively, with increasing GNS volume fraction.

Accordingly, the aim of this work is to investigate the microstructure of calcium grease after the dispersion of hyper mixed between TiO_2 nanoparticle and talc powder and the rheological behaviors of the nanofluids. It follows that dropping point of the nanofluids need to be evaluated.

2. EXPERIMENTAL METHODOLOGY

2.1 Materials

The commercially available calcium grease was used for fabrication of nanogrease. The main properties of the calcium grease were presented in table 1, Talc natural mineral made up of hydrous magnesium silicates, is mainly used to improve the mechanical properties, in this research used particle size 100 nm. The main properties of the Talc powder were presented in table 2.and nanoparticles of TiO_2 are being used as advanced filler to improve the mechanical properties of the grease. Table 3 shows the Properties of TiO_2 nanoparticles.

Table1: main Properties of calcium grease used in this work.

Base oil	**Mineral oil**
Soap thickener	Calcium
Penetration (0.1 mm@25℃)	245
Dropping point, ℃	>100
Viscosity of base oil at 40℃ mm^2/s(cST)	96

Table 2: main Properties of talc powder

Chemical classification	Silicate
color	White
Specific gravity	2.7
Mohs hardness	1
Chemical composition	$Mg_3\,Si_4\,O_{10}\,(OH)_2$
Crystal system	monoclinic
fracture	Flat surfaces
uses	Used as filler and anti- stick coating in plastics, ceramic, paint, paper, roofing, rubber cosmetics

Table 3: main Properties of TiO_2 nanoparticles.

Property	**Value**
Assay	≥99.5% trace metals basis
Form	Nano particles
particle size	21 nm (TEM)
surface area	35-65 m^2/g (BET)
Density	4.26 g/mL at 25 °C(lit.)
Melting point	1850 °C

2.2. Syntheses of TiO_2 and Calcium Grease

For this study, the TiO_2 and talc powder (ratio 1:1) were added in four specific ratios (1%, 2%, 3%, and 4%wt.) to the lubricant base grease, which the properties of base grease and nanoparticles shows in Table (1, 2 and 3) respectively. Frist TiO_2 and talc powder was adding to N, N-dimethyl formamide (DMF) to prevent the agglomeration. After that the mixture at different concentration (1%, 2%, 3%, and 4%wt.) were added to calcium grease in the presence of chloroform and mixed well in a sonication bath for 20 min to ensure that the mixing dispersed well.

2.3 Materials Characterization

X-Ray Diffraction (XRD) was used to characterize the fabricated nanogrease. The sizes and shapes of the synthesized nanogrease were observed on a Transmission Electron Microscope (TEM). The viscosity of the nanogrease was measured by Brookfield programmable Rheometer DV-III ultra and the dropping point of nanogrease was measured by a Penetrometer.

2.4 Experimental

The Brookfield DV-III ultra-programmable rheometer measures fluids and semi fluid parameters of shear stress and apparent viscosity at given shear rates as shows in Fig 1a. The principle operation of DV-III Ultra is to drive a spindle (which is immersed into the test grease) through a calibrated spring and the viscosity of nanogrease measurement of the DV-III Ultra is determined by the rotational speed of the spindle [16]. In addition, the dropping point of lubricating grease is measured by penetrometer as shows in Fig. 1b. The test is done when the first drop of nano fluid falls from the cup. The dropping point is measured according to ASTM D566 [17]. The penetration of nanogrease was done according to ASTM D 217-20 [18] by penetrometer when allow the cone to penetrate the grease for 5 second then read the depth of penetration which shows in Fig 1b.

(a) (b)

Figure 1. a) The Brookfield DV-III ultra-programmable rheometer, and b) Penetrometer

3. Result and Discussion

3.1 Structural Characterization of TiO_2

Figure 2 (a), (b) shows the X-ray diffraction pattern of the TiO_2 and talc powder respectively, the result shows the pattern intense peak at 2θ = 25.9° corresponding to the (002) reflection. This peak indicating that the concentric cylindrical nature of graphene sheets nested together and the nanotubes are multi-walled in nature. In Fig. 2b, the pattern intense peak at 2θ = 9.71 and 28.89° indicating that the sample was pure enough which contained 59.2% SiO_2 and 30.97% MgO. In addition, Transmission Electron Microscopy (HRTEM) as shown in Fig. 3 show the nanogrease before and after dispersed carbon nanotubes and talc powder in calcium grease respectively. It's cleared from this figures that the dispersion of nano additive, more regular and homogeneous network structure, which confirm the rheological stability.

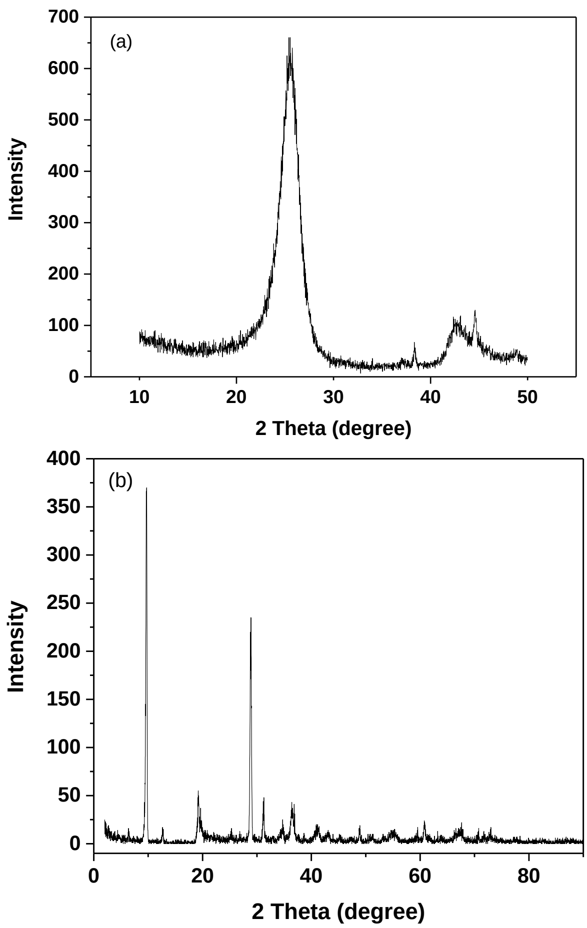
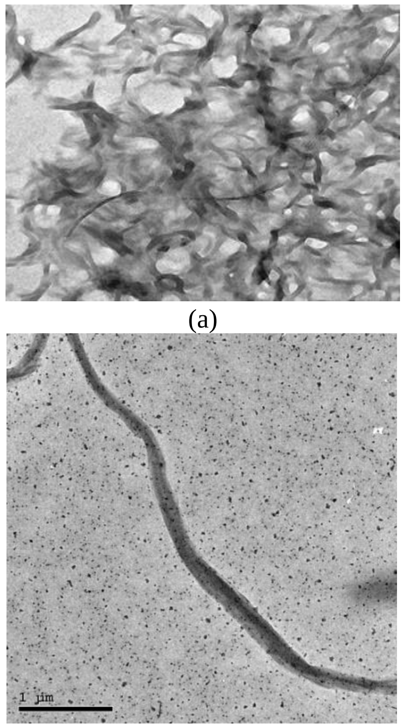


Figure 2. XRD pattern of (a) TiO_2 and (b) Talc powder



(a)

(b)

Figure 3. HRTEM image of (a) base grease and (b) grease with nano additives

3.2 Rheological Behavior of TiO_2/ Talc powder as an Additive

Figure 4 shows the shear rate as a function of shear stress at 30 °C for various volume concentrations of TiO_2/ Talc powder (0.5, 1, 2, 3 and 4 wt. %). It can be seen that the shear stress varied non-linearly with the shear rate for all volume concentrations, indicating the non-Newtonian behavior of nanofluids. The slope of the line increases with increase in volume concentration which indicates that the viscosity of the nanofluids increases with increase in volume concentration as reported in many articles .

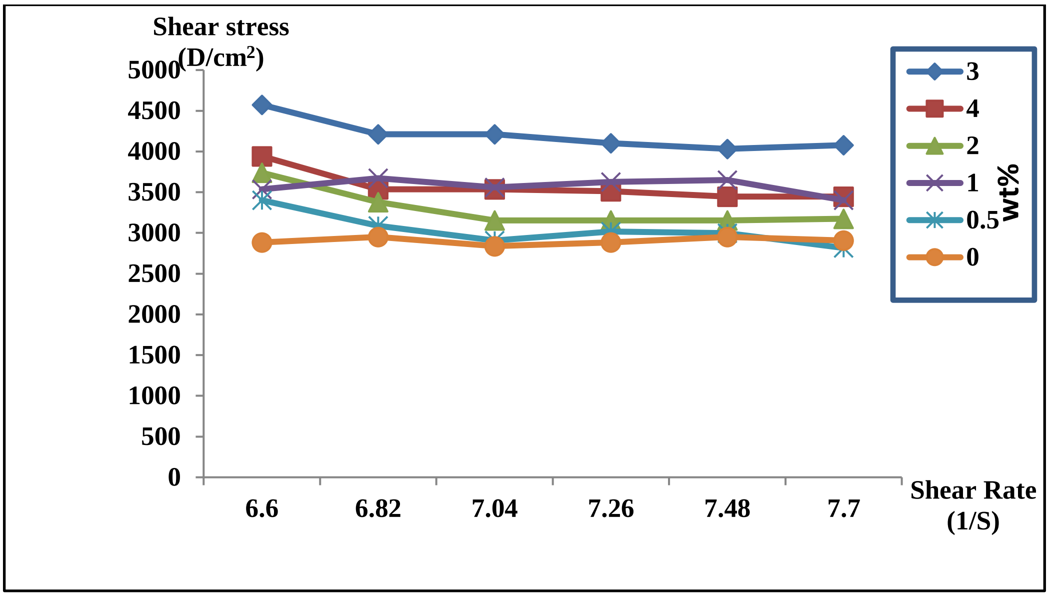


Figure 4 Shear stress versus Shear rate for base grease at different wt% of TiO_2 /Talc powder at 30 °C.

Figure 5 shows the viscosity as a function of shear rate for nano fluids at 30 °c. This result indicates that the viscosity of nano fluids depends strongly on the volume fraction of TiO_2/ Talc powder. The viscosity enhancement ratios of nano fluids as a function of a solid volume fraction. It can be seen that the shear stress and apparent viscosity of the calcium grease containing 3 wt. % TiO_2/ Talc powder are much higher than of pure calcium grease at all shear rates. At this concentration point, the shear stress and apparent viscosity are increased by 32% and 30 %, respectively. The shear stress of base grease and the grease containing TiO_2/ Talc powder. become larger with the increase of shear rate and with the increase of the percentage of TiO_2/ Talc powder. additives on calcium grease[19]. Finally, the shear stress and apparent viscosity containing 3 wt. % TiO_2/ Talc powder. are much higher and more stable than that of pure calcium grease, although 4wt.% showed higher values than 3wt. % but the change is somewhat insignificant, and therefore it may economically have recommended to use the 3wt. %.

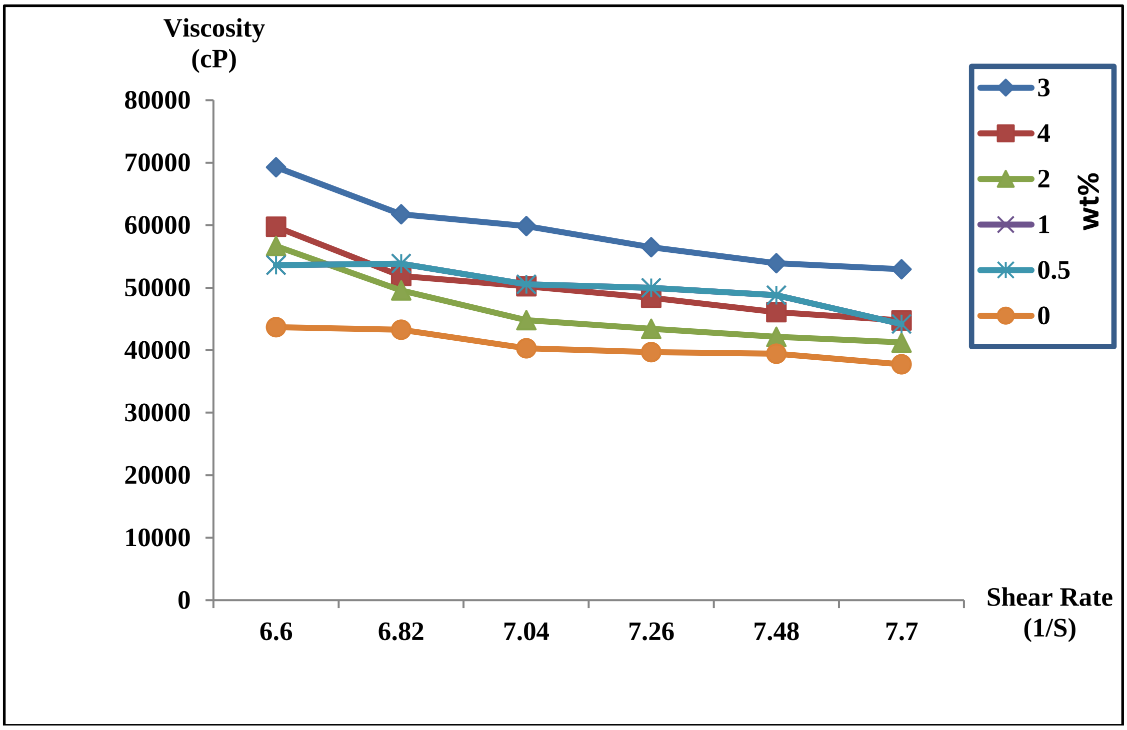


Figure 5. Apparent viscosity versus Shear rate for base grease at different wt% of TiO_2 / Talc powder at 30 °C.

3.3 Effect of TiO_2/ Talc powder additives in Dropping Point.

Figure 6 represents dropping point as a function of TiO_2/ Talc powder concentration in calcium grease. The results show that the drop point temperature of calcium grease change from 92°c in blank to become (92, 94, 96,99,102,103°c) respectively with the different concentration of TiO_2/ Talc powder. The result wasn't the expected results despite the increase of additive in calcium, because of soap fiber length that holds the structure of the grease . The results indicated that the dropping point increase with the increase of TiO_2/ Talc powder concentration to 10.6%.

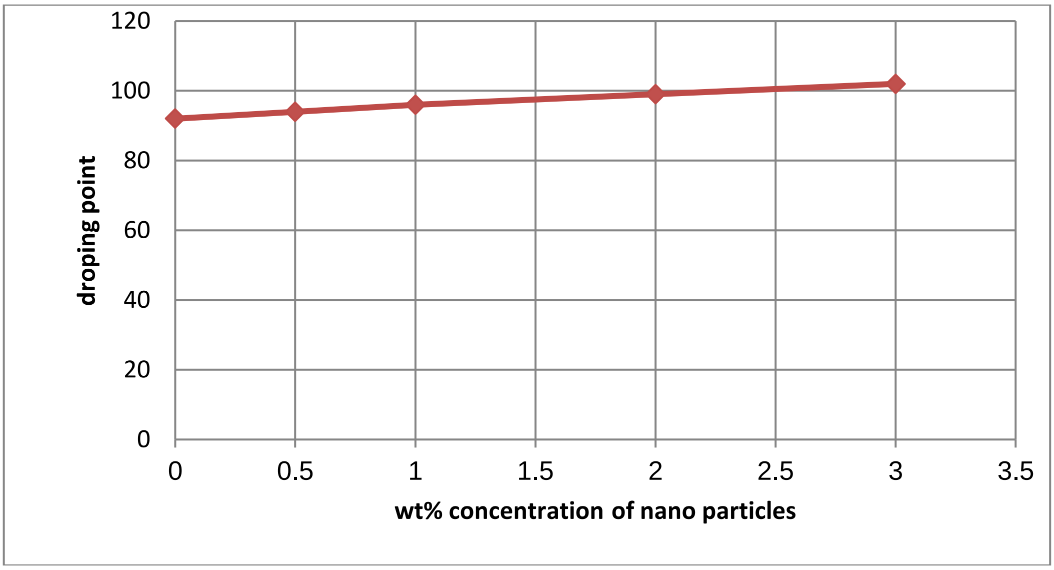


Figure. 6 Effect of TiO_2/ Talc powder additive on dropping test

4. CONCLUSIONS

In this work, an experimental study on the rheological behavior of calcium grease was performed. The effects of hybrid nanomaterials composed of (50 wt% TiO_2) and (50 wt% talc powder) added in four specific ratios (1%, 2%, 3%, and 4%wt.) to the lubricant base grease were examined. A new correlation was proposed to predict the consistency of nanoparticle lubricant in terms of temperature and solid volume fraction. Measurements showed that the grease with various concentrations of hybrid nanoparticles demonstrates non Newtonian behaviors and the results indicated that the shear stress, and apparent viscosity increase with increasing the concentration to (32%) and (30%) respectively. The dropping point increased about (10.6%). Finally, the various concentrations of TiO_2/ talc powder to the calcium grease doesn't have any significant improvement on grease because thickener gives grease its characteristic consistency, not the additives.

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