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Surveying and Comparing Thermal Conductivity and Physical Properties of Oil Base NanoFluids Containing Carbon and Metal Oxide Nanotubes

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Abstract

In this research, nano materials with tubular structures are added to SAE 20W50 engine oil to study the rate of their effects on the properties of engine oil. Multi-walled carbon nanotubes (MWCNTs) and vanadium oxide nanotubes (VONTs) has been used as two different additive materials, one of them is carbonic and the other is metallic oxides and their effect on different parameters containing viscosity, thermal conductivity coefficient, flash point and pour point of engine oil as the quality properties of engine oil has been studied and compared. The samples of two concentrations 0.1 and 0.2 wt% with using planetary ball mill were made. The obtained results show that MWCNTs in all cases, which have been evaluated, had better functionality with respect to vanadium oxide nanotubes. In the 0.1 wt% concentration, flash point of MWCNTs/oil and VONTs/oil increased about 9.3% and 5.8% respectively. In addition, thermal conductivity of them increased 13.2% and 10.2% respectively.

1. Introduction

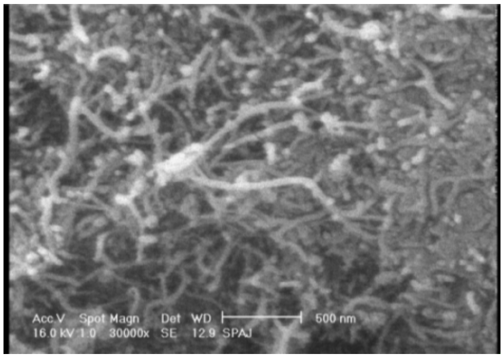
Nano materials have special properties such as quantum effect, little size effect, surface and interface effects, so they have especial potential for improving the materials properties in many fields [1]. Friction in mechanical systems is a main factor of energy losing [2], and improving the lubricant's properties is a major factor, which is very important for energy saving in the total energy input for a mechanical system [3]. Recently researchers are using different nano materials with spherical and tubular structures as additives in various fluids [4, 8]. MWCNTs are among the materials, which have been used in many of the research works as an additive in different base fluids, and have shown unique properties from themselves [9-13]. So far, the anti-wear and anti-friction properties of different nano lubricants had been studied by many researchers [14-19]. Also because of the weak heat conductivity properties of typical coolants such as water, ethylene glycol and engine oil and as a result of their functionality in heat conducting, there are many requests for heat transfer fluid with high efficiency in many industries for developing energy productivity of heat exchangers [20]. Therefore, the researchers have started to apply nano materials technology in the field of increasing heat transfer for producing homogenous and stable heat transferring fluids. Nano fluids are produced by dispersing nanoparticles inside the typical heat transfer fluid [21], and also heat transfer properties of fluids containing different nano structures had been studied by many researchers [20, 22-25]. In the present research, VONTs are used as a new additive in the engine oil. In order to preparation, the nano lubricants using planetary ball mill was determined as the most suitable method for dispersing nanotubes inside the base oil. Also carbon nanotubes were functionalized with dodecylamine for improving their stability in the base oil. The purpose of this work is comparing the functionality of VONTs as metallic oxide nanotubes with respect to MWCNTs for improving the engine oil's properties. Viscosity, pour point and flash point of nano lubricants and also thermal conductivity coefficient of them are selected as four quality parameters which are effective in the functionality of engine oil in different conditions, for the purpose of evaluating the functionality of nano lubricants.

2. Experimental procedure

2. 1. Materials

MWNTs and VONTs were synthesized by our group in R.I.P.I. The MWCNTs were synthesized with purity of 95 wt% during a CVD method over Co–Mo/MgO catalyst [26], and also the VONTs were fabricated under hydrothermal conditions. In a typical process, a certain amount of vanadium oxide powders was added to a solution of dodecylamine in ethanol. After stirring for about 12 h, about 20 ml deionized water dropwised to the above suspension and stirred for 4 h. Next, the mixture was transferred in to a hydrothermal autoclave and heated up to 200 °C for 8 days. Finally, the sample was rinsed several times with an ample amount of ethanol and n-hexane flowed and dried in an oven at 80 °C over night. Fig.1 and Fig.2 show the scanning electron microscope (SEM) and the transmission electron microscope (TEM) images of MWCNTs and VONTs respectively. The tubular and filamentous morphology of carbon nanotubes are shown very good in these images. Carbon nanotubes which are made, have an average diameter about 10-20 nanometer and an average length of 10 micrometers. Also vanadium oxide nanotubes have average diameter and length about 50-60 nanometers and 1 micrometer, respectively.

Also the SAE 20W50 engine oil (Behran-Pishtaz, Behran Oil Company, Iran) was used as a base fluid. Behran Pishtaz oil is distinguished engine oil, which has been made upon the highest world standards and is suitable for most of the today's light gasoline automobiles and heavy diesel vehicles. The specifications of used oil are shown in Table 1.



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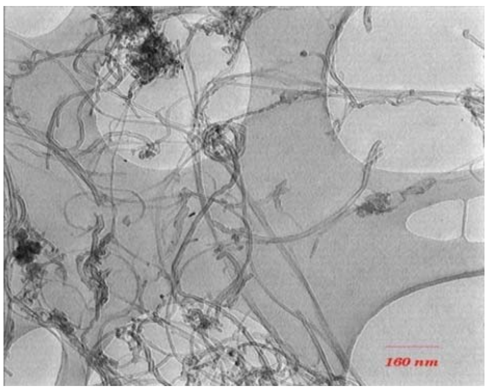

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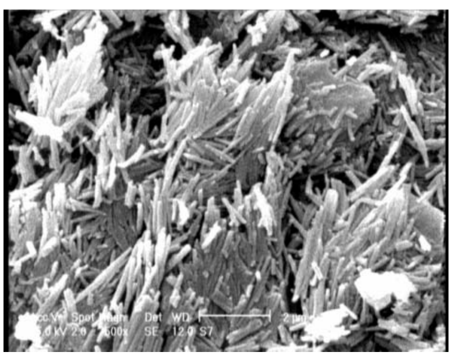
Fig. 1. SEM (a) and TEM (b), images of MWCNTs



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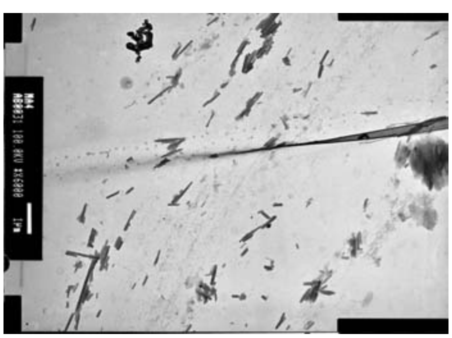


(b)

Fig. 2. SEM (a) and TEM (b), images of VONTs

Table 1. Specification of SAE20W50 engine oil

Viscosity at 40 °C (cSt)	172.11
Viscosity at 100 °C (cSt)	19.8
Density at 15 °C (Kg/m3)	889
Viscosity Index	133
Pour Point (°C)	-27
Flash Point (°C)	224

Bath ultrasonic (P120 Elmasonic, Germany) and probe ultrasonic (Syclon Ultrasonic Homogenizer/JY92-IIN, china) and planetary ball mill (PM100, Retche, Germany) were used for opening agglomerated carbon nanotubes from each other and dispersing them inside the base fluid and as a result, making the required nano fluid samples. In addition, we used the KD2-pro (Decagon devices, U.S.A) for measuring thermal conductivity of base oil and nano lubricants. Also transmission electron microscope (TEM, ZEISS EM 900), field emission scanning electron microscope (FESEM, Hitachi, model S-4160) were used for analyzing the properties of nanotubes.

2. 2. Preparation of nano lubricants

For preparation of nano lubricants, different methods such as planetary ball-mill, ultrasonic and functionalization were used for making a stable nano lubricant. Finally using planetary ball-mill was determined as the most suitable method for dispersing nano tubes inside the base oil. Also carbon nanotubes were functionalized with dodecylamine (dda) and by using planetary ball mill were dispersed inside the base oil. For amination MWCNTs 300 mg of carboxylated MWNTs were added to a solution of $SOCl_2$ and DMF (20:1) at 70 °C and stirred for 24 h. The MWNTs were filtered and washed with THF for several times and then dried in a vacuum oven at 50 °C. 200 mg of the resulted MWNTs were added to 1g of dodecylamine. The black suspension was sonicated in a bath ultrasonic for 2 h and then refluxed for 48 h. After that the sample was washed with sufficient amount of ethanol. Finally, the MWCNTs were dried at 65 °C overnight and then MWCNTs-dda was prepared.

2. 3. Measuring thermal conductivity

Thermal conductivity (K) of fluids is measured as their ability to conduct heat. For this purpose, we used KD2- pro equipment which is completely a portable field and laboratory apparatus for analyzing the thermal properties which uses the transient hot wire system for measuring thermal conductivity. Thermal conductivity of nano lubricants and base oil in 0.1 wt% concentration and at 20 °C temperature were measured.

2. 4. Measuring the viscosity, pour point and flash point

Kinematic viscosity, pour point and flash point of the base oil and nano lubricants, which were made at different concentrations, were measured on the basis standards of ASTM D-445, ASTM D-97 and ASTM D-92 respectively.

3. Result and Discussion

3. 1. Preparation of nano lubricants

At first, 0.1 wt% samples of engine oil containing VONTs and MWCNTs were made by using three methods, bath and probe ultrasonic [5, 6, 27] and planetary ball-mill. Surveying the samples, which were made show that using planetary ball-mill method, because of delivering higher energy for opening nanotubes from each other and dispersing them inside the engine oil, is more suitable than the two other methods. But carbon nanotubes because of being inert were not dispersed very well inside the oil and began to sedimentation early. Which for solving this problem, carbon nanotubes were functionalized by dodecylamine and again were dispersed inside the engine oil by planetary ball mill. For evaluating the stabilized condition of the samples containing VONTs and MWCNTs-dda, all of the samples were maintained inside the completely transparent glassy containers at fully stable condition for 720 hours. In this period the stability conditions of samples were visually inspected, and periodically registered. The observations, which had taken place, showed that in the samples, which were made by bath and probe ultrasonic, the nanotubes were not separated very well from each other and still they had agglomerated condition, and after a Short time, they began to precipitation. However, in the samples, which were made by planetary ball mill method, the nanotubes have better stable and uniform dispersion with respect to two previous samples, Fig.3. The functional specification of planetary ball mill is shown in Table 2.

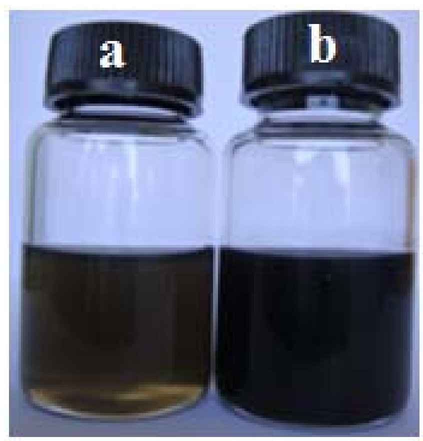


Fig. 3. Stability condition of nano lubricants base on VONTs (a) and MWCNTs (b) after 720 hours.

Table 2. Functional specification of ball mill.

Speed	300 rpm
Time	3 h
Weight of Balls	200 g
Weight of sample (fluid+ Nanotubes)	30 g

3. 2. Thermal conductivity coefficient

The results, which are related to measuring thermal conductivity coefficient of base lubricants containing VONTs and MWCNTs, are shown in Fig.4. As it is observed, adding VONTs and MWCNTs to engine oil causes more appreciable attention to oil's thermal conductivity coefficient. One of the reasons for this issue may be resulted from much higher thermal conductivity coefficient of carbon and metallic oxide nanotubes with respect to base engine oil without them. We must notice that in the case of different nano fluids, various parameters are effective on the produced changes in their properties, Including kind of base fluid and nanoparticles in suspension [6, 22], the rate of nanoparticles concentration and rate of dispersion of nanoparticles inside the base fluid.

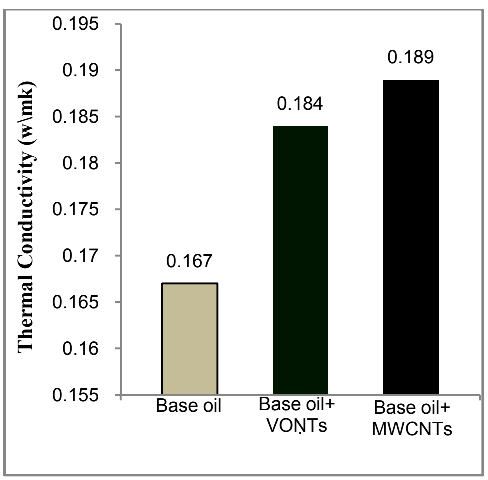
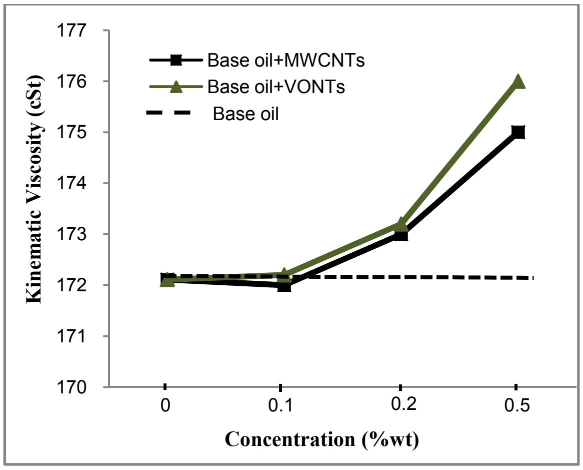


Fig. 4. Thermal conductivity of nano lubricants and base lubricant

Upon of the obtained results, adding VONTs and MWCNTs-dda to SAE 20W 50 engine oil, base on the method which has been done in this research, causes increase of 10.2% and 13.2% in oil's thermal conductivity coefficient respectively. So multi walled carbon nano tubes had more ability than vanadium oxide nanotubes for improving thermal conductivity coefficient of engine oil. By paying attention to this fact that one of the functions of engine oil is cooling the engine and transferring the produced heat resulted from combustion and friction between the parts to outside environment. So using nanotubes structures can be considered as a way for improving thermal conductivity properties of engine oil.

3. 3. Viscosity

Viscosity is one of the most important parameters, which play a basic role in the process of lubricating [16]. The rate of nanotubes concentration and temperature are the two most important and effective parameters on the viscosity of nano lubricants. So for the surveying the rate of the effect of nanotubes concentration and temperature on viscosity of engine oil, nano lubricants containing VONTs and MWCNTs at three different concentrations, 0.1, 0.2 and 0.5 wt% were made and their viscosity at two temperatures 40 and 100 degree centigrade were measured. Viscosity of nano lubricants as a function of concentration of nano additives is shown in Fig.5. Upon the usual trend, with increasing of temperatures the viscosity of all the samples decreased. On the other hand with paying attention to the graphs, it can be concluded that increasing the concentration of nanotubes in each of the two nano lubricants causes an increase in viscosity, although the changes of viscosity is relatively little. The highest rate of increase in viscosity is 2.2%, related to the sample that contains VONTs with 0.5 wt% concentration at 40° C temperature. As it is observed, generally the changes in viscosity of nano lubricants containing MWCNTs are lower than the nano lubricants, which contain VONTs.



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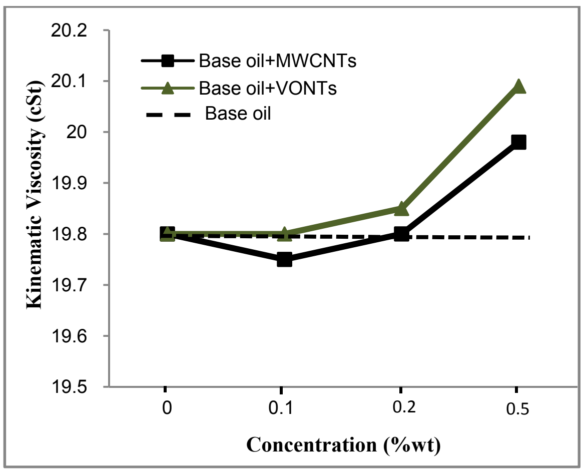


(b)

Fig. 5. Kinematic viscosity of lubricants at 40 °C (a) and at 100 °C (b)

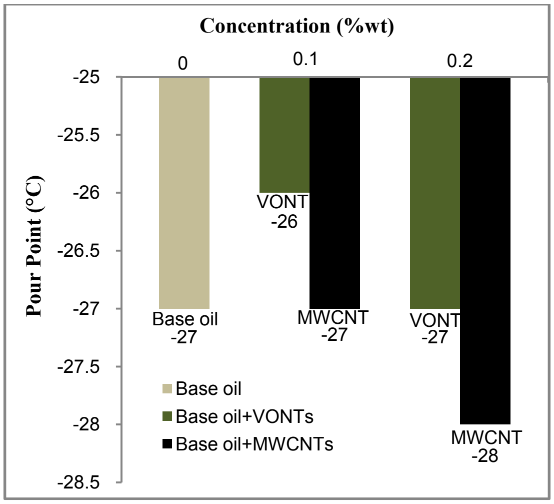
The interesting point, which is related to viscosity of nano lubricants with 0.1 wt% concentration, is that in both of temperatures 40°C and 100°C they had no appreciable changes or a little reduced with respect to the viscosity of oil without nano additives. When nanotubes are added to the oil, they are placed between the oil layers and lead to ease of fluid layers movement on each other. As a result, the viscosity will decrease slightly. As concentration increases, nanotubes are agglomerate and create larger and asymmetric particles, which prevent movement of oil layers on each other, so viscosity will increase.

So finally it can be concluded that MWCNTs and VONTs in the case that they are add to SAE 20W50 engine oil with lower concentration had no appreciable effect on the rate of oil's viscosity.

3. 4. Pour point and flash point

The oil's pour point is the boundary point of temperature, which at this point the oil can not flow either. In this research, surveying the produced changes for pour point by the effect of adding VONTs and MWCNTs to engine oil had been done. The trends of changes in pour point as a function of nanotubes concentration are shown in Fig.6(a). As it is seen, adding vanadium oxide nanotubes to engine oil not only causes an improvement in its pour point but also at 0.1 wt% concentration the pour point has decreased at a rate of 3.7%. But in sample which contains MWCNTs, pour point at 0.1 wt% concentration had no change and at 0.2 %wt concentration it has improved at a rate of 3.7%.

It can be said that the flash point of oil is in fact the determinant for higher temperature limits of functionality for that oil. Because flash point is the lowest temperature at which oil's vapor that are in contact with air are exposed to an ignition, takes fire at a moment and then rapidly extinguishes. The trends of changes of flash point as a function of nanotubes concentration are shown in Fig.6(b). Adding nanotubes to engine oil causes an increase in its flash point until an appreciable amount, such that only at 0.1 wt% concentration the amount of flash point of nano lubricants containing VONTs and MWCNTs has increased about 5.8% and 9.3% respectively.



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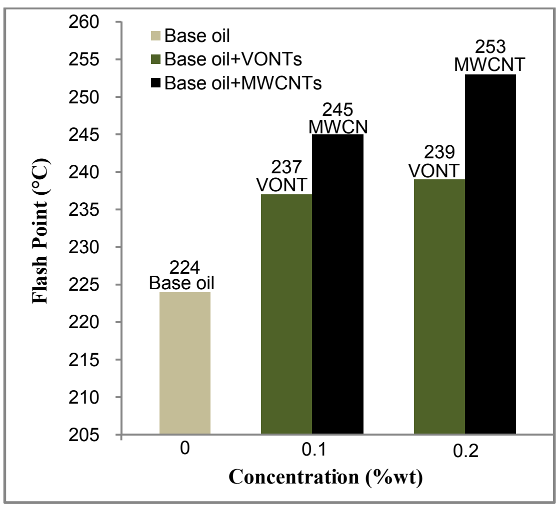

(b)

Fig. 6. Pour point (a) and flash point (b) of nano lubricants

Also by increasing nanotubes concentration, the amount of flash point also has increased. It can be concluded that increasing of thermal conductivity through adding of nanotubes, is attributed to increasing of oil resistance against ignition. Upon the obtained results, MWCNTs with respect VONTs had a better functionality for improving flash point of SAE 20W50 engine oil. The most amount of increase in flash point is 13% related to oil/MWCNTs sample with 0.5 wt% concentration.

4. Conclusion

In this research other effects of different nano materials with tubular structure on the properties of SAE 20W50 engine oil was reviewed. Vanadium oxide nanotubes (VONTs) and Multi-walled carbon nanotubes (MWCNTs) as two carbonic and metallic oxide materials are dispersed at different concentrations inside the base oil using planetary ball mill and carbon nanotubes for better stability were functionalized by dodecylamine.

Surveying the results shown that flash point and thermal conductivity coefficient by the effect of adding nanotubes, improved at a considerable rate but pour point and viscosity in lower concentration (0.1 wt%), had no appreciable changes. In the 0.1 %wt concentration, flash point of MWCNTs/oil and VONTs/oil increased about 9.3% and 5.8% respectively. Also thermal conductivity of them increased 13.2% and 10.2% respectively. Totally, comparing the obtained results from surveying the effects of VONTs and MWCNTs on the properties of engine oil shown that, MWCNTs had better functionality for improving the properties of SAE 20W50 engine oil than VONTs.

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