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Preparation and Analysis of the Thermal properties of Engine oil Reinforced with Multi-walled Carbon Nanotubes

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Abstract. In the present study, the engine oil reinforced with multi-walled carbon nanotubes is used to improve the thermal characteristics of the SAE 20W40 engine oil. Multi-walled carbon nanotube (MWCNT) is used as the Nano particle and SAE 20W40 engine oil is chosen as the base fluid. Viscosity, flash point, fire point, pour point and thermal conductivity are the quality parameters effective in analysing the thermal performance of engine oil were also studied. Bath type Ultra sonication method is used for dispersing the Nano particle in the engine oil at two concentrations of 0.2 and 0.4 wt. % respectively. The experimental results reveal that the thermal properties of the engine oil with MWCNTs is enhanced significantly as compared to that of the base oil.

Keywords: Nanoparticle, Engine oil, Viscosity, Ultra sonication, MWCNT.

1. Introduction
Li et al. [1] made an experimental investigation to study the effect of Nano particle sizes on the thermal properties of Al₂O₃/DiW Nano fluids at different filler fractions. They have found that the thermal conductivity of Nano fluids is enhanced significantly due to the particle size (36nm) of Nano material at 35°C by varying the concentration up to 6.0 vol. %. He et al. [2] investigated the thermal conductivity characteristics of TiO₂-water Nano fluid of varying sizes of Nano particle at different filler fractions. They have used Nano particles with diameters of 95nm, 145nm and 210nm. They have found that the thermal conductivity is enhanced by 5% at different concentrations for the Nano particle size of 95nm. It is observed that the thermal conductivity is increased when the filler fraction increases. Nguyen et al. [3] have investigated the effect of particle size on viscosity characteristics of Al₂O₃ aqueous based Nano fluids. They have found that the effects of particle size on viscosity are more significant for high particles size concentration. Taha-Tijerina et al. [4] have investigated the effect of Nano structure properties on viscosity characteristics of Nano fluids. They have used h-BN-mineral oil and grapheme-mineral oil as Nano fluids. They have found that at low filler fraction (<0.10 wt. %) the viscosity of the Nano fluids decreases greatly with temperature. Choi et al. [5] have found that the thermal conductivity of MWCNTs/engine oil Nano fluid increased significantly by 160% at 1.0 vol. % filler fraction of nanotubes. Liu et al. [6] investigated the effect of filler fraction on the thermal conductivities of Nano fluids. They have used Nano fluids containing MWCNTs of 10-50nm
in diameter dispersed in ethylene glycol and synthetic engine oil. They have found that at 1.0 vol. % thermal conductivity enhancement is more for EG/MWCNT as compared to synthetic oil based Nano fluids. Hong et al. [7] have investigated the effect of concentration of Nano particle on the thermal properties of Nano fluids. They have prepared Nano fluids by mixing CNTs in Poly-olefin oils. They have found that the enhancement in thermal conductivity is increased as the filler fraction increases. Murshed et al. [8] have investigated the effect of Nano particle concentration on the thermal properties of Nano fluids. They have prepared Nano fluids by mixing CNTs in Poly-olefin oils. They have found that the enhancement in thermal conductivity is increased as the filler fraction increases. Hong et al. [9] have investigated the morphological characteristics of Nano fluids at varying concentrations of the Nano particle. They have used Ethylene glycol reinforced with Fe Nano particles as the Nano fluids. The size of the Nano particle used in this study is 10nm. They have found that the thermal conductivity is enhanced by 18% by using Nano fluid at a concentration of 0.55 vol. %. Beck et al. [10] have made an experimental study to investigate the effect of Nano particle size on the thermal conductivity of Nano fluids. They have used water based ceria (CeO$_2$) Nano fluids in their study, with particle sizes of 12nm and 74nm respectively. They have found that the effective thermal conductivity is increased with an increase of Nano particle size. From the literature survey it is clear that the inclusion of Nano particles in the preparation of Nano fluids has improved the thermal properties of the base fluids significantly. Therefore, the present work deals with the preparation of Nano fluids and the analysis of the thermal properties of the engine oil reinforced with multi-walled carbon nanotubes.

2. Experimental procedure
2.1. Materials used
Multi-walled carbon nanotubes is selected as the Nano material in this research work. Figure 1 shows the SEM image of the MWCNTs. The SEM image explains the Nano structures of the carbon nanotubes very clearly.

![Fig. 1. SEM image of MWCNTs.](image)

The SAE 20W40 engine oil is selected as the base oil. Figure 2 shows the details of the engine oil. The specifications of engine oil used are shown in Table 1. Bath type ultra sonicator is used for uniform mixing of carbon nanotubes with the engine oil.
Table 1. Specification of SAE 20W40 engine oil

| Characteristic Test       | Observation |
|---------------------------|-------------|
| Viscosity @ 100°C         | 14.36       |
| Viscosity @ 40°C          | 127.47      |
| Pour point (Deg. C)       | -10         |
| Flash Point (°C)          | 238         |
| Fire Point (°C)           | 244         |
| Thermal Conductivity @40°C | 0.142       |

2.2 Preparation of Nano lubricants

The Nano fluids were prepared by dispersing MWCNTs into the SAE20W40 oil base fluid in two different concentrations of 0.2 and 0.4 wt. % respectively. The mixture was then sonicated for 10min at 100% amplitude using a 130W, 20KHz ultrasonic processor (Nanotechnology research centre, Sathyabama University, Chennai) and it was followed by 20min stirring using a magnetic stirrer. The process was repeated until the total mixing time was 2 hours. The specification of MWCNT is presented in Table 2. The bath type ultra-sonication apparatus is shown in figure 3.

Table 2. Specifications of the multi-walled carbon nanotube

| MWCNT                | Description               |
|----------------------|---------------------------|
| Available Form       | Black Powder              |
| Diameter             | Av. Outer Dia : 20nm      |
| Length               | Av 20 micrometer          |
| Nanotubes Purity     | >98%                      |
| Metal Particles      | <1%                       |
| Amorphous Carbon     | <1%                       |
| Specific Surface Area| 220 m2/g                  |
| Bulk Density         | 0.20g/cm3                 |

Figure 2. SAE 20W40 Engine oil
Figure 3. Bath type Ultra sonication apparatus

2.3 Testing the characteristics of lubricant with carbon nanotube

The properties of Nano fluids are tested in Delta laboratory, Chennai, India. The thermal conductivity of the base oil and Nano lubricants of all samples was measured on the basis standard of DM&AL/256 at a temperature of 40°C. The thermal properties of the engine oil with and without CNTs are calculated on the basis of established standards ASTM D 445, ASTM D 92 and ASTM D 97 respectively. The properties of Nano fluids is shown in Table 3.

Table 3. Properties of Nano fluids

| Thermal properties          | Observation | Sample 1 (0.2 wt. %) | Sample 2 (0.4 wt. %) |
|-----------------------------|-------------|----------------------|----------------------|
| Viscosity @ 100°C           |             | 15.21                | 15.99                |
| Viscosity @ 40°C            |             | 133.85               | 145.17               |
| Pour point (Deg. C)         |             | -12                  | -16                  |
| Flash Point (°C)            |             | 243                  | 253                  |
| Fire Point (°C)             |             | 251                  | 267                  |
| Thermal Conductivity @40°C  |             | 0.151                | 0.157                |
3. Results and Discussions

3.1 Thermal Conductivity

![Thermal Conductivity Chart]

Fig. 4. Thermal conductivity of Nano-lubricants and base lubricant.

The results of thermal conductivity measurements of base lubricants containing MWCNTs are shown in Figure 4. The experimental results reveal that the thermal conductivity of Nano-lubricants is enhanced significantly as compared to the base oil. This is mainly due to the higher thermal conductivity of the MWCNTs with respect to engine oil. The thermal conductivity is enhanced by 6.3% and 10.5% at 0.2 and 0.4 wt. % concentrations of Nano lubricants with respect to the engine oil respectively.

3.2 Viscosity

![Viscosity Chart]

Fig. 5. Kinematic viscosity at 100°C.
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The kinematic viscosities of Nano lubricants at 40°C and 100°C were measured at 0.2 and 0.4 wt. % respectively. The results of viscosity measurements of engine oil containing MWCNTs are shown in Figure 5 and Figure 6. The experimental results indicate that the viscosity of all the samples is reduced by increasing the temperature. Also it is observed that the amount of viscosity had an increasing trend with increasing the concentration of carbon nanotubes.

3.3 Pour point, Flash point and Fire point

The oil’s pour point is the temperature at which the rate of flow will stop. The changes in pour point of engine oil with and without CNTs at two different concentrations are shown in Figure 7. The results indicate that the pour point of all the samples has improved with increasing the concentration of carbon nanotubes. Flash point is the temperature of the oil at which its vapour will ignite. The comparison of engine oil with and without CNTs at varying concentrations in terms of flash point is shown in Figure 8. The results indicate that the flash point of all the samples has an increasing trend with increasing the concentration of carbon nanotubes. The changes in the fire point values of Nano lubricants at varying concentrations is shown in Figure 9. The results reveal that the fire point of all the samples showing an increasing trend with increasing the concentration of carbon nanotubes. It was observed that flash point and fire point of Nano-lubricants had their best amounts at 0.4 wt. % concentration.
■ Base Oil
■ Base Oil + MWCNTs

**Fig. 7.** Pour point of lubricants.

**Fig. 8.** Flash point of lubricants.

**Fig. 9.** Fire point of lubricants.
4. Conclusion
In this research work, the effects of adding MWCNTs in engine oil at two different concentrations was analysed. The results reveal that the concentration of MWCNTs in the engine oil had a significant improvement in the thermal properties of the base oil. The flash point and fire point of Nano lubricants is enhanced by about 6.3% and 9.4% respectively at the concentration of 0.4 wt. %. The results indicate that the heat harvesting capability of Nano lubricant is increased. It is concluded that the addition of Nano particle plays a vital role in enhancing the thermal performance of the engine oil.

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