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To Study the Effect on the Viscoelastic Properties of a Mineral Base Engine Oil Additivated by Functionalized Multi Walled Carbon Nanotubes

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Abstract

The lubricants are most important component of any moving machinery system which helps to reduce the friction and thus overall wear and tear. **Objectives:** The important viscoelastic properties such as shear rate, shear stress, viscosity, Torque etc. of additivated mineral oil was investigated using a Rheometer and ultrasonic velocity measurements were conducted using nano fluid interferometer. **Method:** In the current experimental work, Multi Walled Carbon Nanotubes (MWCNT) were coated with stearic acid (carboxylic group) in order to investigate their viscoelastic properties as wear reduction additive for a mineral base engine oil (SAE 20W50). The functional MWCNTs were examined by FTIR technique, Scanning Electron Microscopy (SEM) and Field Emission Scanning Electron Microscopy (FESEM). The MWCNTs were then dispersed in a mineral oil by ultrasonication. **Findings:** The results show that by functionalization of MWCNTs, the viscoelastic properties of the base mineral oil improved as more stable bonds were created on metallic surface due to improved absorption qualities. It was also deduced that due to coating of MWCNTs with carboxylic group stearic acid, the stability of suspension is high and it does not coagulate even after few months. **Applications:** The improved additivated engine oil finds applications in almost all major automobile uses and to reduce the harmful effect on the environment.

Keywords: Carbon Nano-Tubes, Rheology, Viscoelasticity

1. Introduction

Lubrication plays a very important role in reducing wear and tear of mating surfaces. The lubrication systems used are normally of boundary type, mixed type, elastohydrodynamic and hydrodynamic type. In many cases of boundary and mixed type lubrication, high friction in the contact areas due to absence of lubricant causes high wear and other energy losses. Lubrication process maintains viscoelastic behaviour while ensuring smooth movement of one surface over another[1]. Lubricants ensure proper heat transfer due to high thermal conductivity and also reduce the phenomenon of friction and wear[2]. Most of the lubricants are liquids, which are available for commercial use as engine oils. The choice of lube oil is also very critical for improving the tool life. Thus to select a particular need based lube oil, it is imperative to study its viscoelastic and tribological properties[3]. Among the most studied properties of engine oils, one of the most important properties is its viscosity[4]. Viscosity is a parameter reliant on temperature and pressure fluctuation in the system. The continuous variation of viscosities over a range of temperatures and viscosities varying with rise and fall in working pressure are also important in lubricant rheology as well as for the life of machine elements in a running system. Basically the rise in working temperature reduces the viscosity of lubricating oil and increase in pressure causes viscosity to rise.

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Most of the commercial lubricants contain 90% base oil with additives about 10% to improve certain properties. Additives or friction modifiers wherever added result in reduced friction and wear, increased viscosity, improved viscosity index, resistance to corrosion and oxidation, aging or contamination and so forth. Friction modifiers are thus used many a times in such cases to improve lubrication properties and reducing energy losses. Various friction modifiers have been found to decrease the coefficient of friction in engine and gear oils to considerable effect which normally are of two types; organomolybdenum compounds and organic friction modifiers[5,6]. Among the latter, there are additives based on hydrocarbon chains which extend into the lubricants. With recent advances in nanoscience, the use of nanoparticles as effective friction modifiers has been widely appreciated[7].

Few researchers were able to achieve high dispersion of nanotubes of carbon by effective use of ionic liquids[8]. Also for some other findings, the suspension strength was enhanced by coating of nanotube walls of carbon with functional groups (O-H, C = O, COOH). Then, because of employing this process, functionalized CNTs with carboxyl group were unable to develop positive charge and instead developed negative charges and kept the dispersion of solution properly intact[9–12]. Further there is an increasing demand for better lubricants which reduce emissions and improve fuel efficiency because of which friction modifiers of new kind are being evolved and tested rapidly these days[13]. The current study is based on use of MWCNTs as friction modifiers in one engine oil (mineral base – grade 20W50).

In our research work we report various outcomes of the viscoelastic properties of MWCNTs in one mineral base engine oil. The objective of current research work is to study the consequence of using wall coated MWCNTs with carboxylic group stearic acid, on its viscoelastic properties, as well as on stability of the solution.

2. Experimental Work

The investigation mainly aim on using synthesised MWCNTs and then doing their characterization and functionalization using carboxyl group chemicals after decoration of MWCNTs, while the later phase focuses on viscoelastic analysis of a mineral base engine oil additivated with functional MWCNTs.

2.1 Materials

The required synthesised MWCNTs were supplied by Reinste Nano ventures, Gurgaon, Haryana, India as per the specifications shown below in Table 1.

The mineral base engine oil was purchased from lubricants suppliers in Chandigarh (Punjab), India. The samples as shown in Figure 1 were prepared as per experimental requirement.

Table 1. Specifications of MWCNTs used for experimentation

Property	Value
Purity	> 95wt%
Thickness	1.0-1.77 nm
Diameter	10-50 um:
Layers	1-5
SSA (Specific surface area)	360-450 m2/g
Appearance	black powder

Figure 1. Mineral base engine oil samples concentrated with 0, 0.1, 0.3 and 0.5 wt% of functionalized MWCNTs.

2.2 Characterization

There were different characterisation techniques employed to detect the presence of MWCNTs and to state their structure such as FTIR technique, Scanning Electron Microscopy (SEM) and Field Emission Scanning Electron Microscopy (FESEM) as shown in Figures 2 and 3.

The FTIR analysis depicted successful coating of carboxylic acid over Multi Walled Carbon Nanotubes which was deciphered by seeing spike in wavelength of particles through spectroscopy as shown in Figure 4.

The electron microscopy showed that that the functionalized MWCNTs resemble flakes of dendrite type structure. The presence of functionalized MWCNTs coated over the sample was detected through FTIR analysis which was done for both the cases i.e. before and after coating.

3. Results and Discussion

A mineral based engine oil JRT1 (20W50) with four samples of 0%, 0.1%, 0.3% and 0.5% concentration of functionalized MWCNTs were considered as samples as shown in Figure 1 The values of Viscosity, Shear Stress and Torque varying with the rise in temperature was recorded using Rheometer MCR302, SN000000, ID 80963516 from Anton Paar Gurgaon. Measuring system PP25/PE-SN25125 (d = 0.4 mm) with accessory TUI = P-PTD200-SN 81183777.

The setup is used to measure the shear stress (σ), viscosity (η) and torque (τ) for all four samples as a function of temperature in a range from 30^{0}C to 80^{0}C at constant shear rate (γ) of 10sec^{-1}. 20 data points were selected with

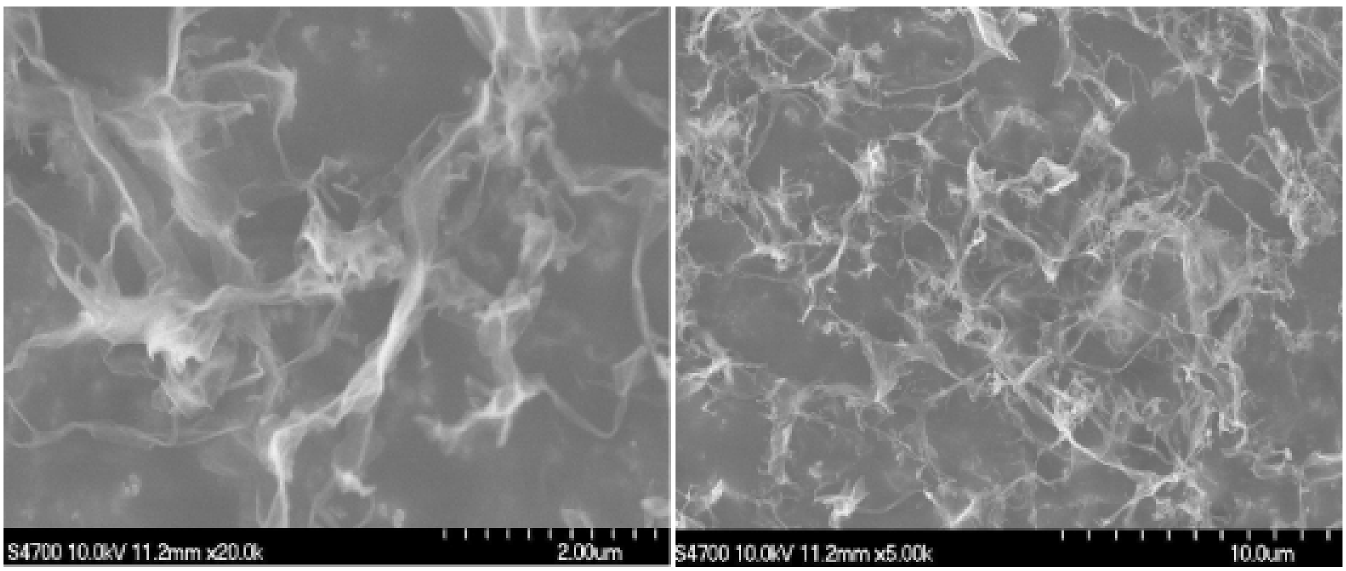
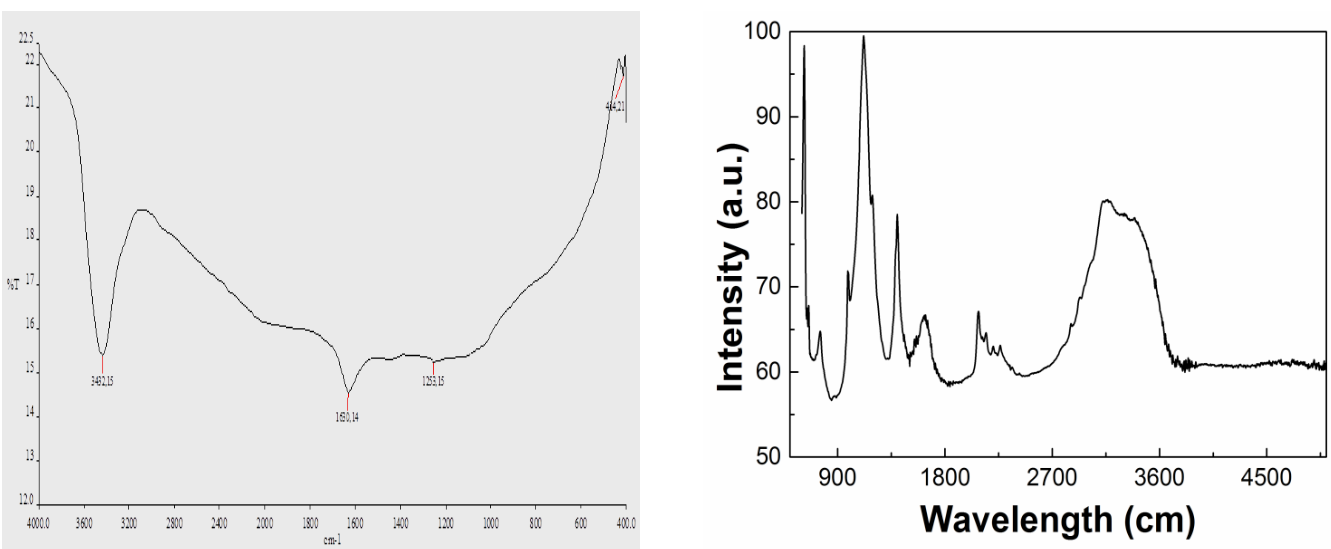


Figure 2. Scanning Electron Microscopy (SEM) images of pure MWCNTs – Courtesy Reinste Nano Ventures, Delhi, India.



3(a) Before functionalization of MWCNTs.

3(b) After functionalization of MWCNTs.

Figure 3. FTIR images showing nature of MWCNTs before and after being functionalized with stearic acid (carboxylic group).

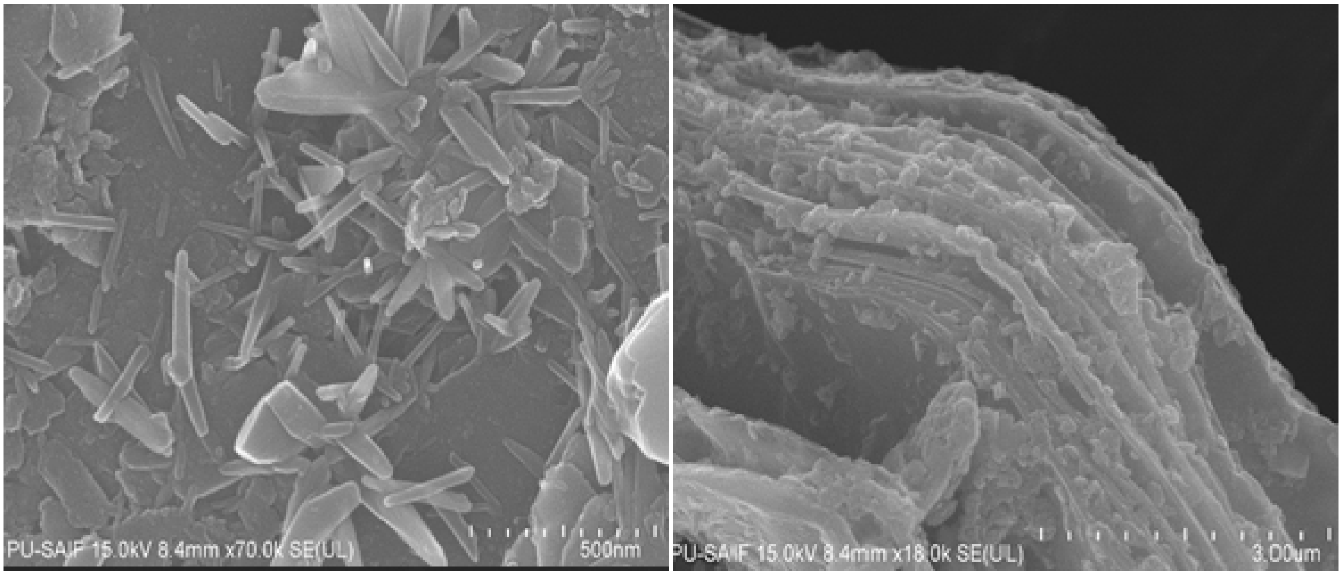


Figure 4. Field Emission Scanning Electron Microscopy (FESEM) images of pure MWCNTs.

measuring duration of 720 seconds. Shear stress, viscosity, and shear rate are related to the following relation $\sigma = \eta\gamma$. The measured values of shear stress, viscosity, and torque with temperature are reported in Figures 5 and 6.

The following are the detailed measured values graphs for variation of viscosity, Shear stress and torque for non CNT added sample and samples with 0.1, 0.3 and 0.5% concentration respectively of the additives for a time period of 720 seconds over a temperature range of 30-80 degree C as shown in Figures 7-9.

The above shown graphs and the following graphs depict the nature of working fluid clearly over a particular range of temperature and helps to predict the behaviour of fluid under actual working conditions.

Prior utilization in viscoelastic investigation, base oil sample and samples with 0.1, 0.3 and 0.5 wt.% functional MWCNTs were distributed by process of ultrasonication in one engine oil base fluid and were studied. The solubility and steadiness of the solution was established when particles did not coagulate.

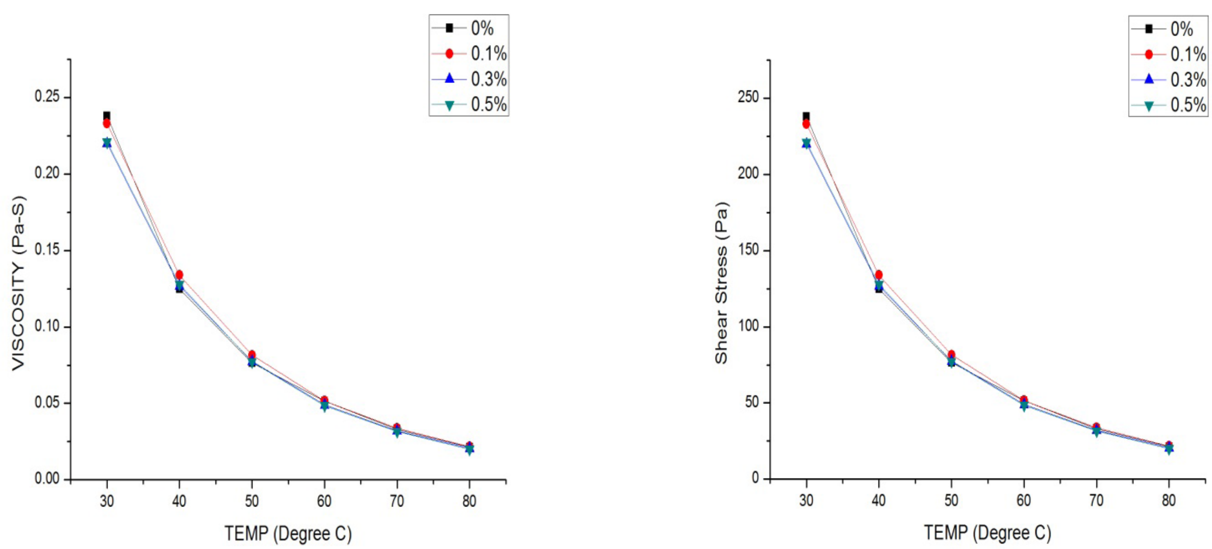


Figure 5. Variation of viscosity and shear stress with temperature.

Multi walled functionalized CNTs were tried as probable additive for one mineral base engine oil for improving its wear resistance properties. In order to improve the dispersibility of carbon nanotubes and the stability of the suspension, the walls of MWCNTs were coated with stearic acid (carboxylic group). It was deduced that their diffusion in engine oil is advantageous since it reduces the friction and wear when equated to the outcomes perceived for non additivated base oil. We effectively enhanced the stability of suspension by using MWCNTs as friction modifier additives. MWCNTs are helping to the decrease of the friction, being possible antiwear additives for mineral base engine oils.

4. Conclusions

The conclusions can be drawn as follows:

- The samples with additives show remarkable difference in all the parameters tested over temperature range of 30^0C- 80^0C for 720 seconds duration.
- The samples showed consistency in terms of percentage variation for dynamic viscosity, shear stress and torque.
- For 0.1% additives dynamic viscosity, shear stress and torque increase by about 2% after running time of 720 seconds and attaining general engine oil running temperature of 80^0C.
- For 0.3% and 0.5% additives dynamic viscosity, shear stress and torque decrease by about 4% and 7% respectively after running time of 720 seconds and attaining general engine oil running temperature of 80^0C.

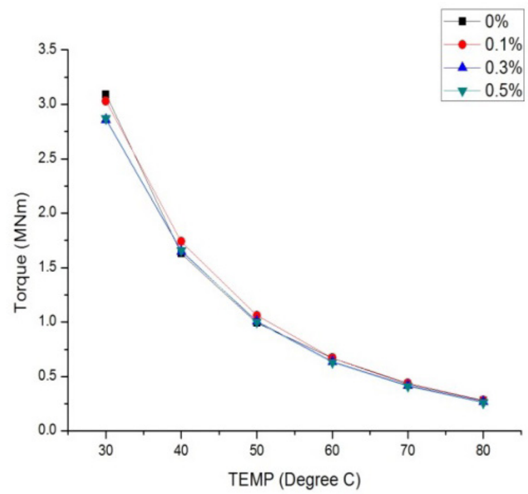


Figure 6. Variation of torque with temperature.

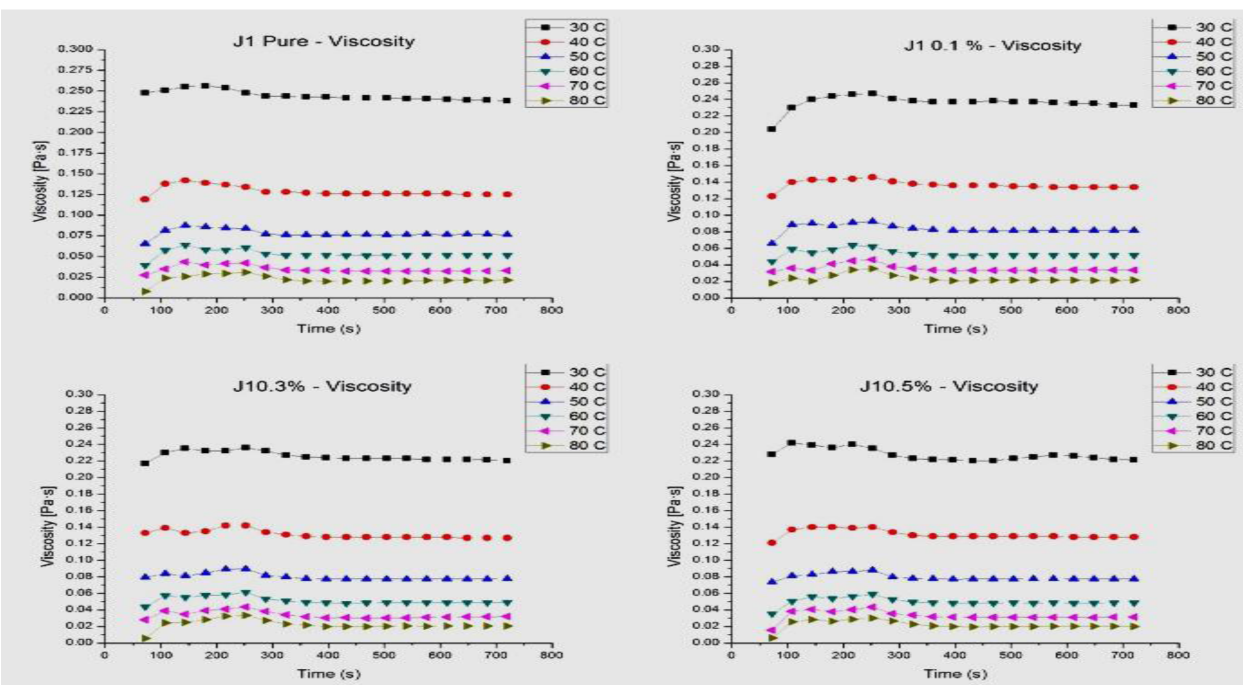


Figure 7. Showing the variation of dynamic viscosity for 0%, 0.1%, 0.3% and 0.5% MWCNTs concentration sample with time over a temperature range of 300C - 800C.

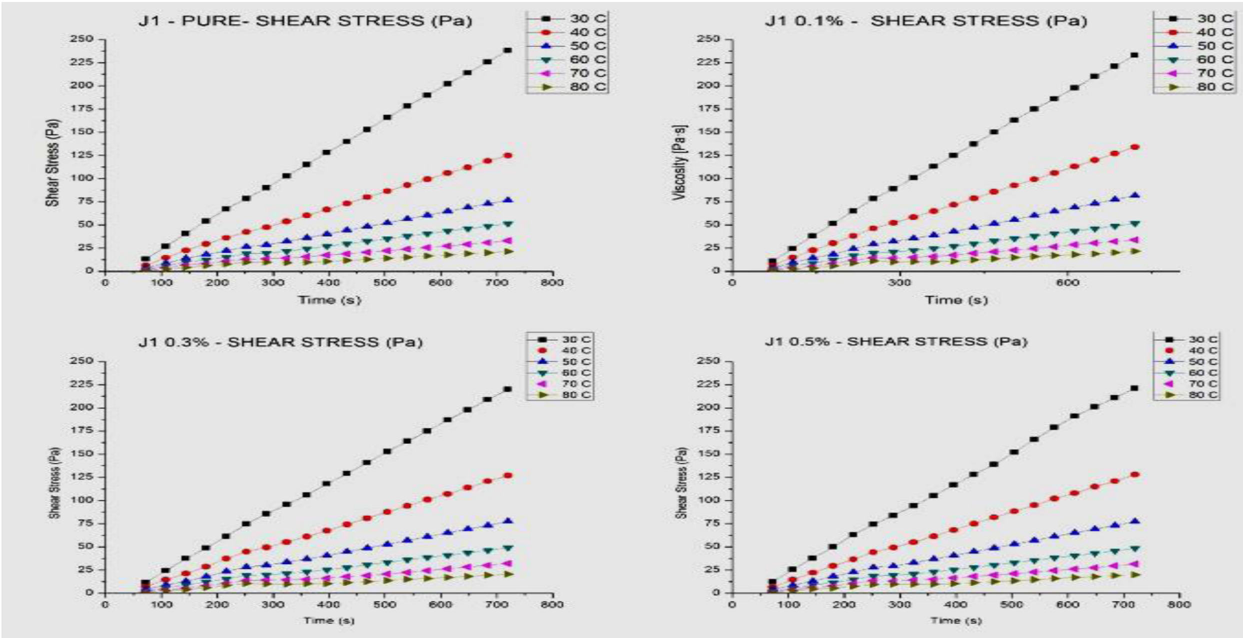


Figure 8. Showing the variation of shear stress for 0%, 0.1%, 0.3% and 0.5% MWCNTs concentration sample with time over a temperature range of 300C - 800C.

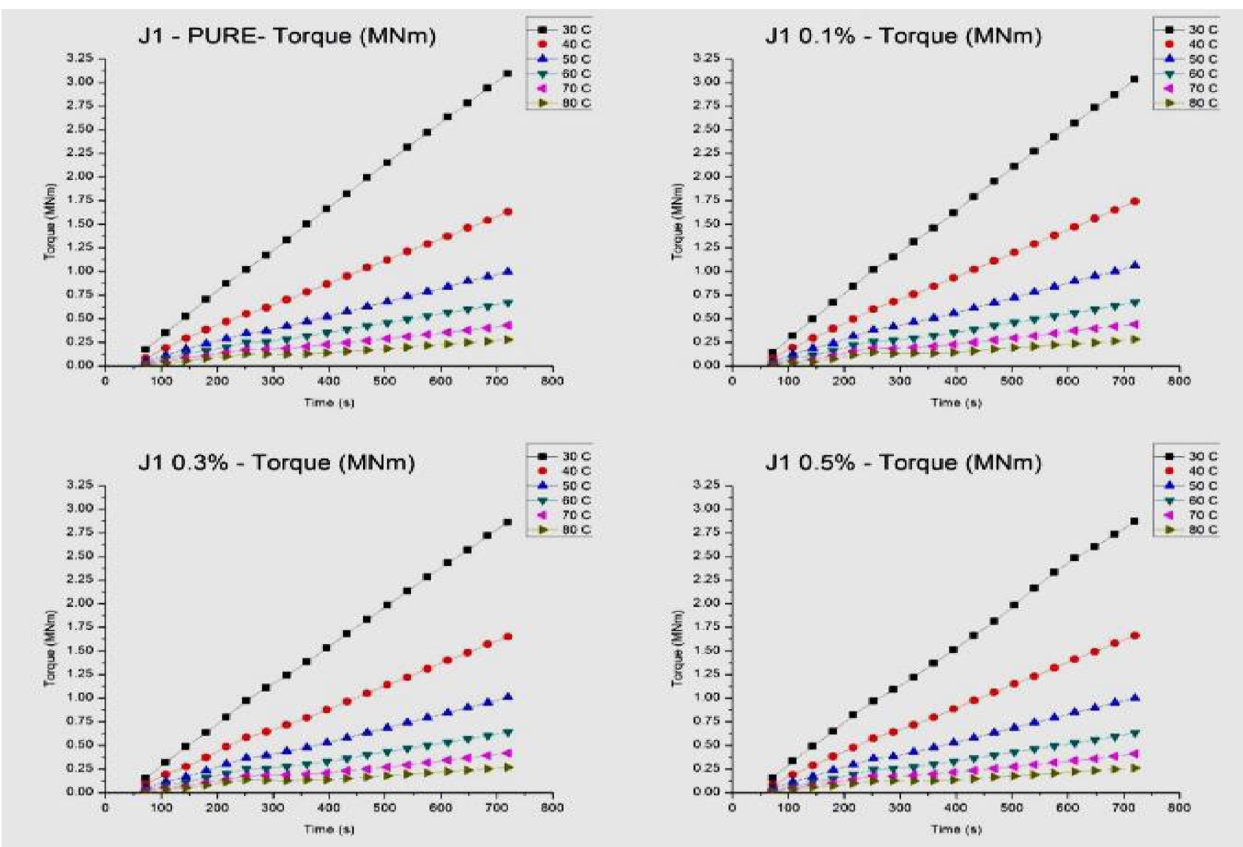


Figure 9. Showing the variation of torque for 0%, 0.1%, 0.3% and 0.5% MWCNTs concentration sample with time over a temperature range of 300C - 800C.

- JRT1 show relatively lower variation of dynamic viscosity with temperature, thus depicting consistent behavior with temperature variations.
- Dynamic viscosity decreases with temperature for all the samples showing second degree polynomial variation.

It was found through this study that the use of Multi Walled Carbon Nanotubes based friction modifiers or wear reducing additives make the engine oil more efficient in terms of improvement in various viscoelastic properties.

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