EXPERIMENTAL STUDIES ON STABILITY OF MULTI WALLED CARBON NANOTUBE WITH DIFFERENT OIL BASED NANOFLUIDS

by

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In this experimental analysis, the stability of multi walled carbon nanotube based nanofluids with six different base fluids such as water, vegetable oil, engine oil, soap oil, brake oil, and suspension oil are studied. The nanofluids are prepared by the two-step method without the addition of surfactant and at two-volume concentrations. This stability analysis is performed by the UV-Vis spectrophotometer, measuring pH values, and photo capturing techniques. This analysis is carried out at three-time intervals such as at the time of preparation, 15 days after preparation, and 30 days after preparation. From the experimental analysis, the higher order of stability is found to be the multi walled carbon nanotube/water nanofluids, multi walled carbon nanotube/vegetable oil, multi walled carbon nanotube/engine oil, multi walled carbon nanotube/ soap oil, multi walled carbon nanotube/brake oil, and multi walled carbon nanotube/suspension oil-based nanofluids.

Key words: *nanofluids, stability, zeta potential, carbon nanotube, sedimentation*

Introduction

The suspended nanoparticles in base fluids are called Nanofluids. Nanofluids are proposed by many kinds of research that they yield a higher heat transfer rate than other fluids. However, the applicability of nanofluids is under hot debate. In order to improve the thermal performance of commercial heat transfer fluids, the nanomaterials with higher thermal conductivity are added. There are a lot of research works on the stability of multi walled carbon nanotube (MWCNT) based nanofluids. The poor stability of nanofluids leads to a negative impact on real-time applications. The smaller sized nanoparticles have the tendency to attract which leads to the fast setting. To reduce the attractive force and to improve the stability, surfactants are added by functionalization methods.

The nanofluids are different base fluids and these fluids are used in the various application. Choi [1] invented the nanoparticle mixed with the base fluid to use the heat transfer applications with nominal nm sized nanoparticles after that the fluid is called as nanofluids. Maxwell [2] invented the dispersing particles into fluids with theoretical correlation. Scale formation is called a fouling effect and the effect creates the inner surface of the heat exchanger curved coils [3-9]. Stability of various base fluids analysed with zeta potential analysis with the

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principle of electrophoretic [10]. Kim *et al.* [11] reported that without surfactant the nanofluids stable up to 30 days after the preparation of nanofluids. Ultra sonication is used to produce the waveforms and absorbance to calculate the stability of the nanoparticle settlements [12]. Ali *et al*. [13] reported that surface modification caused by nanofluids when the pH value only measures the surface changes and behaviors of the nanocoatings. Jana *et al*. [14] represented hybrid nanofluids, it is a combination of two or more nanoparticle mixed nanofluids. Stability is the major problems in the nanofluids due to the dispersion of nanoparticles into base fluids [15]. Kumar [16], Wang *et al.* [17], and Wei *et al.* [18] photograph method is the very easiest way to finding the nanoparticles sedimentation in periodic time intervals. Chemical test tubes are fixed with the stand with various base fluids and capture the images and compare the time intervals. The main drawback of the surfactant is destructing the nanoparticle with the increasing the saturation temperature, so this experiment conducted without surfactant of various base fluids [19, 20]. The sedimentation of nanofluids is observed by the functions of CNT in thermal oil [21-23]. All nanoparticles are settling down within 30 days due to poor stability [24-26]. Many investigators employed many stability investigation techniques and found UV-Vis spectrophotometer, measuring pH value and photo capturing techniques are the easy techniques for stability analysis [27-30]. The preparation, characterization, stability, and applications of nanofluids with various base materials and various base fluids have been investigated [31-34].

Figure 1. The MWCNT nanoparticles

Based on the literature review the investigation on the stability of MWCNT/suspension oil, MWCNT/soap oil, MWCNT/brake oil, and MWCNT/distilled water nanofluids is very limited. Therefore this experiment work employs MWCNT as base material and suspension oil, soap oil, brake oil, and distilled water nanofluids as a base fluid for preparing nanofluids and analyses the stability of prepared nanofluids. The MWCNT nanoparticles are shown on fig. 1.

Materials and methods

In this investigation MCWNT is taken as base nanomaterial. The MWNT has been purchased from Nanostructure and Amorphous Materials, Inc. Houston, Tex., USA. The dimensions of MCWNT are 50-80 nm, 5-15 nm inner diameter, length of 10-20 μm, 99.5% purity, Specific Surface Area is 32-40 m^2/g. The water, vegetable oil, engine oil, soap oil, brake oil, and suspension oil have been taken as babes fluids.

In this research work, the two-step technique is used to prepare nanofluids at 0.2% and 0.6% volume concentration. The required amount of MWCNT is calculated for two different volume concentrations of nanofluids. The surfactant is not used in this analysis for preparing nanofluids. The MWCNT is dispersed into the required amount of water and it is processed with a magnetic stirrer for one hour and then it is processed with ultra-sonication for three hours for reducing the agglomeration and to break the entangling of MWCNT. The same procedure is followed for preparing other samples for the volume concentrations of 0.2% and 0.6%. Magnetic stirrer for mixing of nanoparticles. Magnetic stirrer has the specification of at 36±3 kHz, REMI made and which generates pulses of 1000 W.

An ultra-sonication CITIZEN made 110 watts with probe-type disruptor is used to disperse the nanotubes which give better dispersion than the bath-type ultra-sonication within a short duration. It takes three hours with 75% power & 25% pulse. Ultra sonication running three hours of preparing MWCNT nanofluids. Bath type ultra-sonication is used to disperse nanotubes in various base fluids. The sample image of the MWCNT nanofluids with suspension oil at 0.2 % volume concentration is given in fig. 2. From fig. 2, it is seen that MWCNT are uniformly scatted in the base fluids and found no considerable aggregation as the average diameter of the aggregation is considerable. Therefore it is ensured that the nanofluids prepared just after preparation are highly stable.

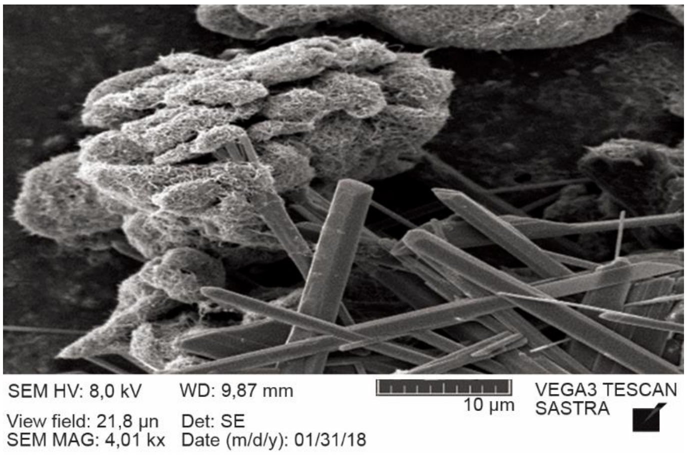

Figure 2. The SEM image of MWCNT/suspension oil at 0.2% nanofluids

Stability analysis techniques

Stability is considered as an important factor in applying nanofluids in a real-time situation. Due to the smaller size of nanoparticles, it causes enhanced interactive force which leads to agglomeration. The unstable nanoparticle will cause a reduction in thermal performances. There are several techniques available to find the stability of nanofluids. In this investigation, UV-Vis spectrometer, measuring pH value and photo capturing techniques are employed.

Results and discussion

UV–Vis spectrometer

The UV-Vis spectrometer is used for the analysis. Lambda 35 is used to measure the values and nanofluids results obtained. From fig. 3 it is clear that the samples prepared are highly stable at the time of preparation. The observation is made based on the volume concentration that the 0.2% suspension oil-based nanofluids show higher stability than the 0.6% suspension oil-based nanofluids. The 0.2% distilled water-based nanofluids show more stable than the 0.6% distilled water-based nanofluids. It is observed from the UV-spectrometer values of suspension oil-based nanofluids show better stability after 30 days. Found the other samples did not show considerable results and which are neglected for the analysis.

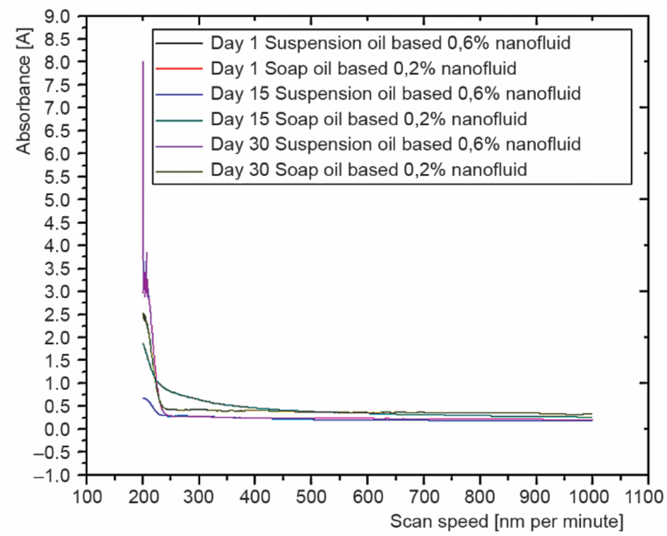

Figure 3. The UV-Vis spectrometer values
(*for colour image see journal web site*)

Measuring pH value method

Measuring pH values in Systronic-309 make, glass electrode type instrument is used for the analysis. Evaluating the stability of nanofluids with measuring pH vale method is associated with the determination of zeta potential values of the sample. This means that there is no tendency of entangling the CNT due to zero value electrostatic attractive force. It is also observed that zeta potential values determined are not so closer to the isoelectric points than the suspension oil. The pH values of the samples are correlated with the zeta potential values and found that the zeta potential values of suspension oil-based nanofluids are away from the isoelectric point and distilled water-based nanofluids are closer to the isoelectric point. Therefore the suspension oil maintains stability and the distilled water-based nanofluids losses its stability to some extent at the time of 15 days from the date of preparation.

The observation is made based on the volume concentration that the 0.2% suspension oil-based nanofluids show higher stability than the 0.6% suspension oil-based nanofluids. The 0.2% distilled water-based nanofluids show more stable than the 0.6% distilled water-based nanofluids. It is observed from the zeta potential values of suspension oil-based nanofluids are closer to the isoelectric point. The pH values measured are shown in tab. 1.

Table 1. The pH values of MWCNT nanofluids

Base fluids	pH value day 1	pH value day 15	pH value day 30
Distilled water	7	6.85	6.69
Vegetable oil	7.3	4.61	1.92
Engine oil	5.49	4.72	3.95
Soap oil (SA8)	6.19	5.09	3.99
Brake oil	7.26	4.61	1.96
Suspension oil	6.36*	6.04*	5.92*

Photo capturing technique

In the photo capturing method using Nokia Coolpix 10× high-resolution camera is used to take the photographs in periodic time intervals. The images of the samples have been captured and the 0.2% nanofluids gives the remarkable results and given in fig. 4. The images of the samples have been captured and the 0.6% nanofluids gives the remarkable results and given in fig. 5.

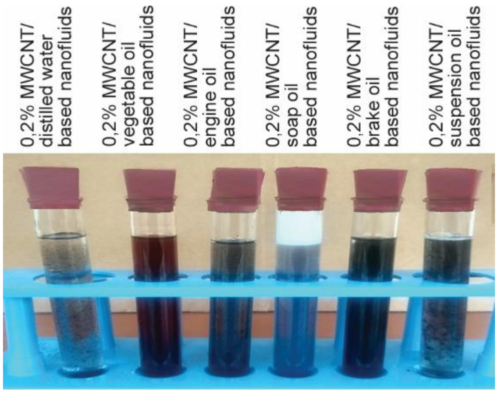

Figure 4. Image of 0.2% nanofluids (after 30 days of preparation)

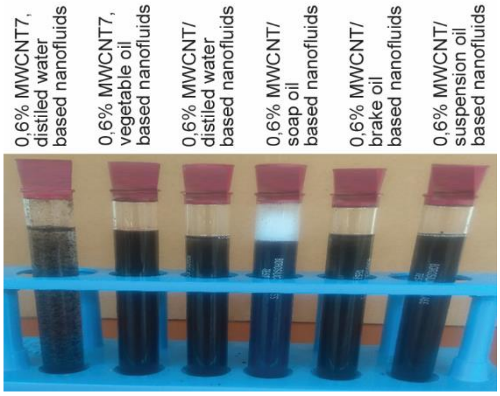

Figure 5. Image of 0.6% nanofluids (after 30 days of preparation)

From figs. 4 and 5, it is apparent that the suspension oil-based nanofluids show a very lower level of sedimentation even after 30 days of preparation. Similarly, distilled water nanofluids show a higher level of sedimentation at the bottom, while comparing to other samples. It is clear from the above stability evaluation methods. The suspension oil-based nanofluids are highly stable even after 30 days of preparation and distilled water-based nanofluids is poorly stable 30 days after preparation. The order of higher stability of the nanofluids under consideration of this investigation is suspension oil, soap oil, brake oil, and distilled water nanofluids. The observation is made based on the volume concentration that the 0.2% suspension oil-based nanofluids show higher stability than the 0.6% suspension oil-based nanofluids. The 0.2% distilled water-based nanofluids show more stable than the 0.6% distilled water-based nanofluids.

The interpretation for the highly stable nanofluids and poorly stable nanofluids is associated with the electrostatic attractive force and repulsive force between the CNT in the base fluid. The reason for the high stability of suspension oil is that the higher viscosity of suspension oil than other nanofluids. The viscous force retains the suspended nanotube for a long time. Whereas, the distilled water base nanofluids easily allows the CNT entangling for aggregation and resulting in the sedimentation. The reason for the highly stable of lower volume concentration is that there is no tendency of forming more attractive force and agglomeration of a CNT. As there is no heavy mass of agglomerated CNT, higher stability is achieved naturally.

Conclusion

In this investigation, the stability of MWCNT with different base fluid has been carried out at three-time intervals. The investigation employed the UV-Vis spectrophotometer, the measure of pH values and manual photograph techniques to study the sedimentation of the nanofluids at 0.2% and 0.6%. It is concluded that the 0.2% volume concentration suspension oil-based nanofluids provide better stability when compared with other nanofluids at the 30^{th} days of preparation. The water-based nanofluids show poor stability on the 30^{th} days of preparation. However the suspension oil-based nanofluids at 0.6% lost its stability after 30^{th} days of preparation.

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