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Stability Analysis on MWCNT/Water Nanofluids with and without Surfactant

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Abstract

Much research works are being carried out in applications of nanofluids at different engineering fields as they have improved thermal conductivity. However, the effective applications of nanofluids have limitations such as poor stability, sedimentation, erosive wear and potential health risk. In heat transfer application point of view, stability of nanoparticles plays a major function in enhancing heat transfer. In this experimental investigation, the stability of Multi-walled Carbon Nano Tube (MWCNT)/water nanofluids with surfactant and without surfactant has been carried out by keeping the nanofluids at static condition and at constant temperature at different time interval. The nanofluids were prepared by means of the use of Multi-walled Carbon Nano Tube (MWCNT) as base materials and distilled water as base fluids at 0.1%, 0.3%, 0.5% and 0.7% volume concentration with 0.02% and 0.05% sodium dodecyl butane sulfonate (SDBS) as surfactant and without the surfactant two-step method is used to put together the nanofluids underneath attention. The stability analysis of prepared nanofluids are studied with the UV-Vis. spectrophotometer, measure of zeta potential value , and photograph capturing techniques by keeping the nanofluids under static condition for The MWCNT nanofluids have been characterized with the sample of just after preparation after 30 days of preparation and after 60 days. It is studied that the nanofluids with surfactant showed better stability than the nanofluids without surfactant. Found that the nanofluids at 0.7% volume concentration with surfactant showed good stability with negligible visual sedimentation even after 60 days than the nanofluids without surfactant. Therefore the MWCNT/water nanofluids are the potential heat transfer fluids to apply in heat transfer field. Copyright © VBRI Press.

Keywords: Applications, carbon nano tube, nanofluid, properties, stability.

Introduction

Though the nanofluids exhibit good thermal conductivity and they do not long last for real time applications due to settling of particles. Therefore, the stability of the nanofluid is a crucial trouble for both scientific research and practical applications to provide better cooling applications. Nanofluid, which is a new class of cooling medium, was introduced by Choi *et al.* in 1995 [**1**]. These contemporary fluids show enhanced thermal conductivity which is very promising for industrial applications [**2-4**]. Homogeneous dispersion and stability of nanofluids are matters of concern among scientists and industries [**5-7**]. Therefore, various stabilization methods such as ultrasonication, pH control, and adding surfactant had been considered independently in preparation of nanofluids. Previously, the methods to inspect stability were limited to sedimentation, photo capturing technique, TEM (transmission electron microscopy), SEM (scanning electron microscopy), however, in 2003, a new method for stability measurement by UV-Vis Spectrophotometer changed into added by Jiang *et al.* [**8**]. In this technique, the supernatant concentration of a CNT suspension was measured quantitatively versus the sedimentation time. Although this method was at first only applicable to ceramic suspensions, Jiang *et al.* (2003) proved the validity of this technique in nanofluid stability measurements as well [**8**]. Since there is limited attention to nanofluid stability and optimizing preparation method by UV-Vis spectrophotometer and all the discrepancy regarding to nanofluid thermal and electrical conductivity results are due to the lack of standardization in preparation method, stability inspection is considered as a critical necessity to conduct some experiments. In this paper, based on the preliminary studies and reviewed literature [**12, 13**] the effect of pH values [**10-12**) and SDS (sodium dodecyl sulphate) surfactant concentration loading from one-tenth to twice the amount of nanoparticle concentration (ranging 0.01-0.2 wt. %) has been monitored on the stability measurement of 0.1 wt. % Titania (TiO2) [**9**] nanofluid. The absorbance measurements using UV-Vis spectrophotometer were taken as the stability responses in the periods of one day, two days, one week (168 hrs) and one month (720 hrs) after preparation. Surfactants may be defined as chemicals added to nanoparticles so as to surface tension of liquids and growth immersion of particles. Several literatures communicate approximately including surfactant to nanoparticles to avoid rapid sedimentation; however, sufficient surfactant should be brought to particle at any precise case. In researches, several sorts of surfactant have been utilized for different types of nanofluids. The most extensive ones can be indexed as a) Sodium dodecyl sulfate (SDS).Chandrasekhar *et al.* [**14**], (b) Salt and oleic acid, (c) Cetyltri methyl ammonium bromide (CTAB), Jiang [**15**], (d) Dodecyle trimethylammonium bromide (DTAB) and sodiumoctanoate (SOCT), Li *et al.* [**16**], (e) Hexadecyltri methyl ammonium bromide (HCTAB), Yu *et al.* [**17**], (f) Polyvinyl pyrrolidone`1q (PVP), Pantzali *et al.* [**18**], and (g) Gum Arabic, Madni *et al.* [19]. Xie *et al.* [**20**] showed the stability of carbon nanotubes/water nanofluids by using easy acid treatment. This turned into because of a hydrophobic-to-hydrophilic conversion of the surface nature because of the technology of a hydroxyl group. As the pH cost of the answer departs from the Iso Electric Point (IEP) of particles the colloidal particles get more stable and ultimately regulate the thermal conductivity of the fluid. The disadvantage of adding surfactant at the high temperatures as above than 60ºC leads to damage the bonding among surfactant and nanoparticles. Ghadimi [**21**], reviewed the stability of nanofluids, units and strategies that can rank the relative stability of nanosuspension. Muruganandam *et al.* [**22-23**] found that the 0.3% volume concentration of nanofluid indicates good stability even after 45 days of preparation when compared with 0.1 and 0.5% Volume concentration.

Studied that there is no much report on stability analysis of MWCNT nano fluids with surfactant and without surfactant. In particular, the study of nanofluids with higher percentage of surfactant is very limited. Therefore this work studies the stability of MWCNT/ water nano fluids with surfactant and without the surfactant addition. The objectives of this work are to optimize the stability based on three methods like UV-Vis spectrophotometer, Zeta potential value, and Photograph technique.

Materials and methods

Details of MWCNT nanostructures

The information of MWCNT are given through the supplier as stated in **Table 1**. The SEM photo shows that the MWCNTs are dry situations in the **Fig. 1**. **Fig. 1** shows that the MWCNTs have observable agglomeration and decent dispersion at the time of preparation of nanofluids.

Table 1. Specification of MWCNT.

Outer diameter	50-80nm
Inner diameter	5-15nm
True density	2.1 g/cm^3
Bulk density	0.18 g/cm^3
Length	10-20μm
Supplier	Nanostructured & Amorphous Materials, Inc. Houston, TEXAS, and USA.

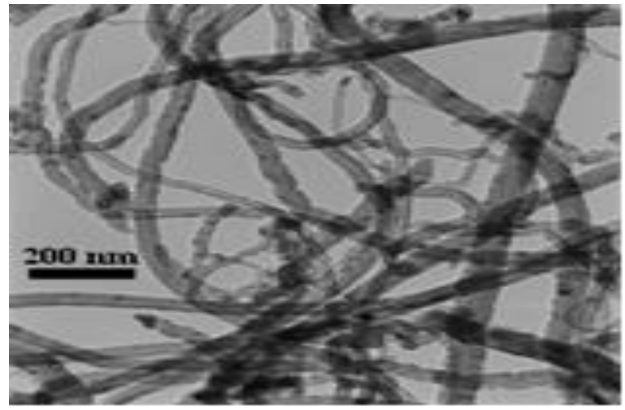

Fig. 1. SEM image of MWCNT.

Preparation of MWCNT/Water nanofluid

Preparation of nano fluids is the first foot-step to the experimental research of nano fluids. The number one techniques to put together nano fluids are: single-step approach and the two-step approach [**24**]. The one-step technique concurrently makes and disperses the nanoparticles without delay into a base fluid. This approach guarantees stable dispersion and no agglomeration. In the two-step technique nanoparticles are produced by way of one of the physical or chemical synthesis techniques and proceed to disperse them into a base fluid. In this research nanofluids were prepared by way of the use of Multi walled Carbon Nano Tube (MWCNT) with Distilled water, as base fluids on the CNT nanofluids with the concentrations of 0.1%, 0.3%, 0.5% and 0.7%vol. The preparation was done without surfactant and with surfactant at 0.2% and 0.5% concentration of Sodium dodecyl butane sulfonate (SDBS) as stabilizing agent [**25**] and the details as shown **Table 2**. In this investigation, the widely used method, the two-step approach turned into used to prepare the nanofluids. In this observe required amount of base fluid turned into first poured into 1 liter glass beaker and the MWCNT of 0.1, 0.3, 0.5 and 0.7% vol. Concentration had been loaded separately and the suspensions have been dispersed by using the use of a magnetic stirrer [**26**]. The magnetic stirrer employs a rotating magnetic subject which stirs the magnetic stirrer immersed in a fluid for this reason allowing it to spin in no time which in turn permitting the even dispersion of the debris. The magnetic stirrer as shown in **Fig. 2** were used to prepare the nanofluids for 15 minutes as the first phase.

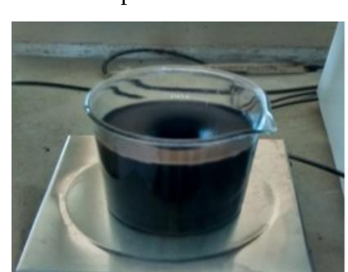

Fig. 2. Magnetic stirrer.

Table 2. Concentration of carbon nanotube and surfactant.

Sample without Surfactant	Sample with surfactant	
	0.02%of SDBS	**0.05% of SDBS**
0.1% of MWCNT + Distilled water	0.1% of MWCNT + Distilled water	0.1% of MWCNT + Distilled water
0.3% of MWCNT + Distilled water	0.3% of MWCNT + Distilled water	0.3% of MWCNT + Distilled water
0.5% of MWCNT + Distilled water	0.5% of MWCNT + Distilled water	0.5% of MWCNT + Distilled water
0.7% of MWCNT + Distilled water	0.7% of MWCNT + Distilled water	0.7% of MWCNT + Distilled water

Fig. 3. Ultrasonic bath.

Sonication is a method in which sound waves are used to agitate particles in solution. Such disruptions can be used to mix answers, pace the dissolution of a stable into a liquid (like sugar into water), and take away dissolved fuel from drinks [**27**]. After magnetic stirring, the Ultrasonic vibrators become used to get a uniform dispersion and solid suspension which determine the very last of nanofluids. The photo of the Ultrasonic vibrator is proven in **Fig. 3**. The Ultrasonic vibrator (VURO, India) generating ultrasonic pulses of 40W at 36 ± 3 kHz turned into programmed for four hours to ensure the uniform dispersion of MWCNT particles inside the base fluid.

Stability inspection with UV-vis Spectrophoto meter

The UV – Visible spectrophotometer (UV–Vis) measurements were used to quantitatively symbolize the stableness of nanoparticles dispersed in base fluids by means of many researchers. The UV–Vis spectrophotometer exploits the reality that the intensity of the mild turns into extraordinary by means of absorption and scattering of light passing through a fluid. Jiang *et al.* [**28**] have been the first who proposed nanofluid sedimentation estimation through the use of UV–Vis spectrophotometer. Further, this method changed into used by Hwang *et al.* [**29**], and Lee *et al.* [**30**] have used the same technique. In this investigation, the UV-Vis. Spectrophotometer, as shown in **Fig. 4**, Lambda 35 model, Perkin Elemer make, absorption variety of one hundred ninety nm to 1100nm become used to observe the stability of nanofluid. The inspection variety is from 230nm to 600nm.

Fig. 4. UV-Vis. Spectrophotometer.

Zeta potential value

Zeta potential is a measure of the effective electric charge on the nanoparticle surface Hwang *et al.* [**29**], and Lee *et al.* [**30**]. The magnitude of the zeta potential presents information about particle balance, with particle with better significance zeta potentials displaying increased balance due to a bigger electrostatic repulsion between the particles. The zeta potential of nanofluids depends on concentration of nanoparticles and surfactant, temperature, pH value and nanofluids and sonification method [**31**]. In this investigation, the pH and temperature are fixed.

The electric powered ability on the boundary of the double layer is called the Zeta potential of the particles and has values that generally variety from +100 mV to -100 mV. Nanoparticles with Zeta Potential values more than +25 mV or less than -25 mV generally have excessive levels of stability. Dispersions with a low zeta potential value will eventually aggregate due to Van Der Waal inter-particle attractions Hwang *et al.* [**29**], and Lee *et al.* [**30**]. In this investigation, the Zeta potential value of the nanofluid prepared was found by using Zeta potential Analysis (SZ 100 model, accuracy 0.02, in the range of 0.3nm – 8.0µm).

Photograph capturing technique

This technique measures the visual sedimentation of the nanoparticles at the bottom of the vessel Hwang *et al.* [**29**], and Lee *et al.* [**30**]. In this investigation, the photographs had been taken by the usage of Sony digital camera of 16.1MegaPixel, WSeries, 5x Optical Zoom Cyber-shot (Black).

Results and discussion

UV-vis Spectrophoto meter technique

Fig. 5a – **Fig. 5i** shows the UV spectrometer readings for 0.1, 0.3, 0.5, and 0.7 MWCNT volume concentration of without, 0.2% and 0.5% SDBS surfactant. From **Fig. 5a** to **Fig. 5i**, it is clear that the nanofluids of all volume concentration just after preparation are highly stable with surfactant and without surfactant. This might be the reason of ultrosonification. Observed that the stableness of nanofluids increases with growing volume concentration. Therefore the 0.7% nanofluids has higher stability than other nanofluids with 0.5% surfactant even after 60 days of preparation. It is discovered that the stability will increase with growing volume concentration of surfactant. This is due to the more surfactant leads to form good coating. These coatings weaken the electro static repulsion [**31**]. The addition of more surfactant tends to create the effective attraction of MWCNTs [**31**]. In this investigation, the 0.5% surfactant for 0.7% volume concentration MWCNT nanofluids did not show any agglomeration as the the absorbance range is longer than the other nanofluids.

From the **Table 3**, it is clear that the MWCNT nanofluids without surfactant results higher zeta potential after 30 and 60 days of preparation of nanofluids. It shows that the nanofluids without surfactant are not stable for 60 days lasting. This is due to the effective wander walls force of attraction between the MWCNTs. It is observed that the nanofluids with surfactant show good stability even after 60 days of preparation. It may be noted that the all MWCNT nanofluids just after preparation showed good stability. The zeta potential value increases day by days. However, the zeta potential values are within the range of highly stable such as -35.5mV. Comparing all the nanofluids under consideration, the 0.7% Vol. concentration MWCNT nanofluids show good stability at the 0.5% surfactant. This is due to the effect of more surfactant which converts the hydro phobic MWCNT Into hydrophic nature. The more surfactant reduces the surface tension between the MWCNTs and water particles *et al.* [**31, 32**]. The 0.5% surfactant has the ability to form efficient coating. This coating increases the repulsive force and counter balance the Vander walls attraction.

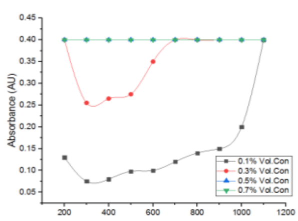

Fig. 5a. Without surfactant Just after preparation.

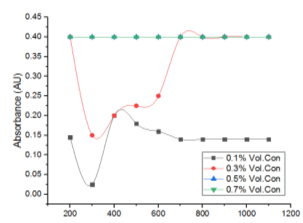

Fig. 5b. With 0.02% surfactant Just after preparation.

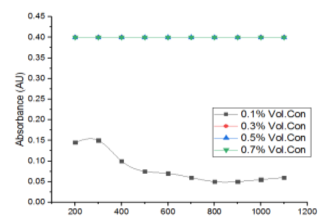

Fig. 5c. With 0.05% surfactant Just after preparation.

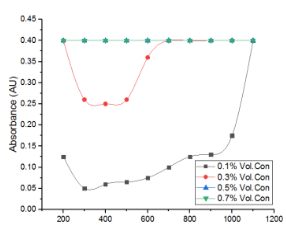

Fig. 5d. Without surfactant 30 days after preparation.

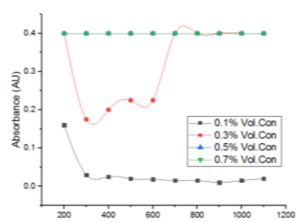

Fig. 5e. With 0.02% surfactant 30 days after preparation.

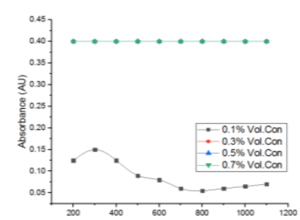

Fig. 5f. With 0.05% surfactant 30 after preparation.

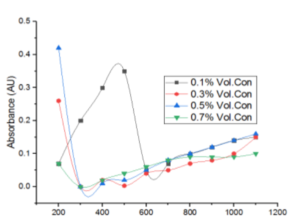

Fig. 5g. Without surfactant 60 days after preparation.

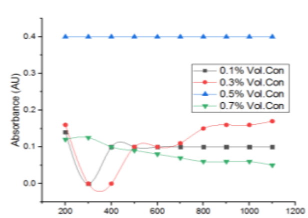

Fig. 5h. With 0.02% surfactant 60 days after preparation.

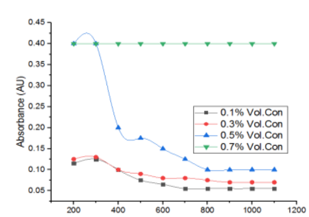

Fig. 5i. With 0.05% surfactant 60 after preparation.

Table 3. Zeta potential value.

Particulars	Just after preparation				30 days after preparation				60 days after preparation			
MWCNT/water Nanofluids at various volume concentrations	0.1%	0.3%	0.5%	0.7%	0.1%	0.3%	0.5%	0.7%	0.1%	0.3%	0.5%	0.7%
Zeta Potential Values without surfactant	-22.9 (mV)	-41.1 (mV)	-51.7 (mV)	-62.2 (mV)	-32.4 (mV)	-45.2 (mV)	-58.4 (mV)	-65.7 (mV)	-50.9 (mV)	-58.7 (mV)	-70.7 (mV)	-77.7 (mV)
Zeta Potential Values with 0.02% surfactant	-21.1 (mV)	-24.3 (mV)	-48.5 (mV)	54-6 (mV)	-22.5 (mV)	-35.4 (mV)	-47.7 (mV)	-55.8 (mV)	-40.9 (mV)	-48.7 (mV)	-60.5 (mV)	-62.3 (mV)
Zeta Potential Values with 0.05% surfactant	-20.9 (mV)	-22.1 (mV)	-44.7 (mV)	-52.2 (mV)	-20.1 (mV)	-35.5 (mV)	-44.4 (mV)	-50.8 (mV)	-30.1 (mV)	-32.8 (mV)	-34.5 (mV)	35.5 (mV)

Photograph capturing technique

Sedimentation is the tendency for particles in suspension to settle out of the fluid in which they are entrained, and are available to relaxation in opposition to a barrier. This is due to their movement through the fluid in reaction to the forces performing on them: these forces can be because of gravity, centrifugal acceleration or electromagnetism. The sedimentation of Nanofluids, after Sonication were recorded using virtual camera and shown inside the **Fig. 6a** to **Fig. 6i**. The sedimentation photograph Just preparation, 30 days after preparation and 60 days after preparation were shown in **Fig. 6e** to **Fig. 6f** and **Fig. 6g** to **Fig. 6i** respectively. In distilled water based nanofluid the MWCNT settled down at the bottom after 60 days as shown in **Fig. 6f**. It is seen from the Fig… that the 0.7 % concentration with 05% surfactant shows less sedimentation even after 60 days of preparation. Also observed that the other nanofluids result the visible sedimentation at the beaker. This is due to the agglomeration of MWCNT because of strong wander walls attractive force.

Fig. 6a. Without surfactant Just after preparation.

Fig. 6b. With 0.02% surfactant Just after preparation.

Fig. 6c. With 0.05% surfactant Just after preparation.

Fig. 6d. Without surfactant 30 days after preparation.

Fig. 6e. With 0.02% surfactant 30 days after preparation.

Fig. 6f. With 0.05% surfactant 30 after preparation.

Fig. 6g. Without surfactant 60 days after preparation.

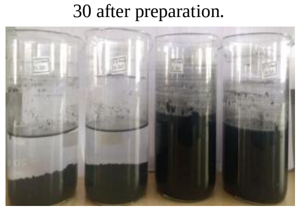

Fig. 6h. With 0.02% surfactant 60 days after preparation.

Fig. 6i. With 0.05% surfactant 60 after preparation.

Conclusions

In this investigation the CNT/water nanofluid have been prepared at 0.1%, 0.3%, 05%, and 0.7% 0.02% and 0.05% sodium dodecyl butane sulfonate (SDBS) as dispersant agent by using two step method. The stability of prepared CNT nanofluid is analyzed with surfactant and without surfactant. The three stability techniques like UV-Vis. spectrophotometer, measure of zeta potential value, and photograph capturing have been used. It is found that that higher the percentage of surfactant leads to better stability of nanofluids. Studied that the 0.7% volume concentration with 0.05% surfactant show good stability and it lasts even after 60 days. This is due to the effect of greater surfactant which increases the repulsive force between them and converts hydrophobic into hydrophilic nature fluids. Therefore 0.7% MWCNT/Water Nanofluid with 0.05% surfactant is the good choice for applications of nanofluids as coolant.

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