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Stability Analysis of Heat Transfer MWCNT with Different Base Fluids

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ABSTRACT

The technological development for industries faces the challenges in meeting out the cooling demand due to the existing coolants have reached their limitations. The nanofluids are the dispersion of the nanomaterials into base fluids have been developed to solve the problems associated with the existing coolants in the thermal systems. The stability of nanofluids is a crucial issue for both scientific research and practical applications to provide better cooling. In this investigation, seven Multi walled Carbon Nano Tube MWCNT nanofluids have been prepared by using two step method with Distilled water, Coolant oil, Engine oil, Gear oil, Vegetable oil, Coconut oil, and Grown oil as base fluids at the volume concentration of 0.1% and without adding any stabilizing agent. The UV-Vis spectrophotometers, measure of pH values, and photograph capturing techniques have been used for stability analysis in this investigation by keeping the nanofluids under static condition period of 30 days. It is found from the three stability analysis techniques that the stability of nanofluids are in the increasing order of MWCNT / Distilled water nanofluid, MWCNT / Coolant oil nanofluid, MWCNT / Coconut oil nanofluid, MWCNT / Vegetable oil nanofluid, MWCNT / Engine oil nanofluid, MWCNT /Gear oil nanofluid and MWCNT/Grown oil nanofluid. The MWCNT / Distilled water nanofluid has poor stability and MWCNT/Grown oil nanofluid has good stability.

Keywords: *Nanofluids*; Base fluids; Stability; MWCNT; Sonication.

1. 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 suspension is a crucial issue for both scientific research and practical applications to provide better cooling. To consider and evaluate stability of nanoparticles inside the base fluid, sedimentation velocity calculation of small spherical particles is found by using Stokes law. Stokes law "Eq. (1)" includes the effective parameters for stability of nanofluids.

$$v = \frac{2r^2}{9\mu}(\rho_p - \rho_f)g \tag{1}$$

Where, 'v' is the sedimentation velocity, 'r' the radius of particles, 'μ' is viscosity of liquid; 'ρ' is the density while 'p' and 'f' subscripts are the particles and liquid, respectively. Finally, 'g' is the gravity acceleration, which is the main reason of sedimentation. There are three forces acting on suspended particle such as buoyancy force, drag force and body force. Their balance makes the nanoparticle stable. Buoyancy and drag forces are acting upward and resisting against body force acting downwards resulting from gravitational attraction Hiemenz and Dekker (1986). Therefore, lower particle size, lower viscosity, lower temperature difference are the stability parameters. Addition of surfactant, pH control and Ultrasonic agitation (vibration) are the three common techniques for making stable nanofluids .Addition of surfactant and pH control is the two techniques to prevent clustering and agglomeration while ultrasonic vibration is applied to break down agglomeration. Zhu (2009), Wang (2009) and Pantzali *et al.* (2009) used all three techniques to improve the stability of nanofluid.

Surfactants can be defined as chemical compounds added to nano particles in order to lower surface tension of liquids and increase immersion of particles. Several literatures talk about adding surfactant to nano particles to avoid fast sedimentation, however, enough surfactant should be added to particle at any particular case. In researches, several types of surfactant had been utilized for different kinds of nanofluids. The most significant ones could be listed as a) Sodium dodecyl sulfate (SDS) Chandrasekar (2010), b) Salt and oleic acid ,c)Cetyltri methyl ammonium bromide (CTAB), Jiang (2003), d)Dodecyl trimethylammonium bromide (DTAB) and sodiumoctanoate (SOCT), Li (2008) ,e)Hexadecyltri methyl ammonium bromide(HCTAB),Yu *et al* (2010), f) Polyvinyl pyrrolidone (PVP), Pantzali *et al.* (2009), and g) Gum Arabic, Madni (2010). Xie (2003) showed the stability of carbon nanotubes / water nanofluids by taking simple acid treatment. This was caused by a hydrophobic-to-hydrophilic conversion of the surface nature due to the generation of a hydroxyl group. As the pH value of the solution departs from the Iso Electric Point (IEP) of particles the colloidal particles get more stable and ultimately modify the thermal conductivity of the fluid. The disadvantage of adding surfactant at the high temperatures as above than 60oC leads to damage the bonding between surfactant and nanoparticles. Ghadimi (2011), reviewed the stability of nanofluids, instruments and methods that can rank the relative stability of nanosuspension. The list includes UV–Vis spectrophotometer, zeta potential, sediment photograph capturing, TEM (Transmission Electron Microscopy) and SEM (Scanning Electron Microscopy),light scattering, three omega and sedimentation balance method.

In this investigation, the MWCNT nano fluids have been prepared with Distilled water, Coolant oil, Coconut oil , Vegetable oil , Engine oil, Gear oil , Grown oil as base fluids at the concentration of 0.1% . The MWCNT nanofluid have been prepared with two step method and the UV –Vis spectrometer, zeta potential analysis with pH values, and sediment photograph methods have been carried out to analyze the stability.

2. MATERIALS AND METHODS

2.1 Details of MWCNT Nanostructures and Base Fluids

Table 1 Details of MWCNT

Property	Values
Outer diameter	50-80nm
inner diameter	5-15nm
True density	2.1 g/cm3
Bulk density	0.18 g/cm3
Length	10-20μm
Supplier	Nanostructured and Amorphous Materials, Inc. Houston, TEXAS, and USA.
Base fluids	Distilled water, Coolant oil, Coconut oil , Vegetable oil , Engine oil, Gear oil ,and Grown oil

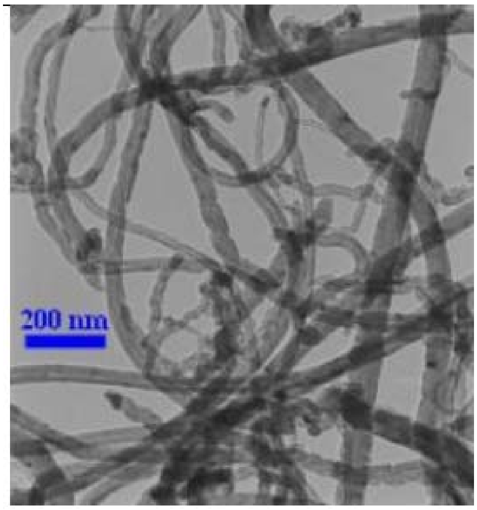


Fig. 1. SEM micrograph of MWCNT.

Fig. 2. Magnetic stirrer.

Fig. 3. Ultrasonic bath.

2.2 Synthesis of MWCNT Nanofluids

Preparation of Nano fluids is the first foot-step to the experimental studies of Nano fluids. The two primary methods to prepare Nano fluids are single-step preparation process and the two-step preparation process.. The one-step technique simultaneously makes and disperses the nanoparticles directly into a base fluid. This technique ensures stable dispersion and no agglomeration. In the two-step technique nanoparticles are produced by one of the physical or chemical synthesis techniques and proceed to

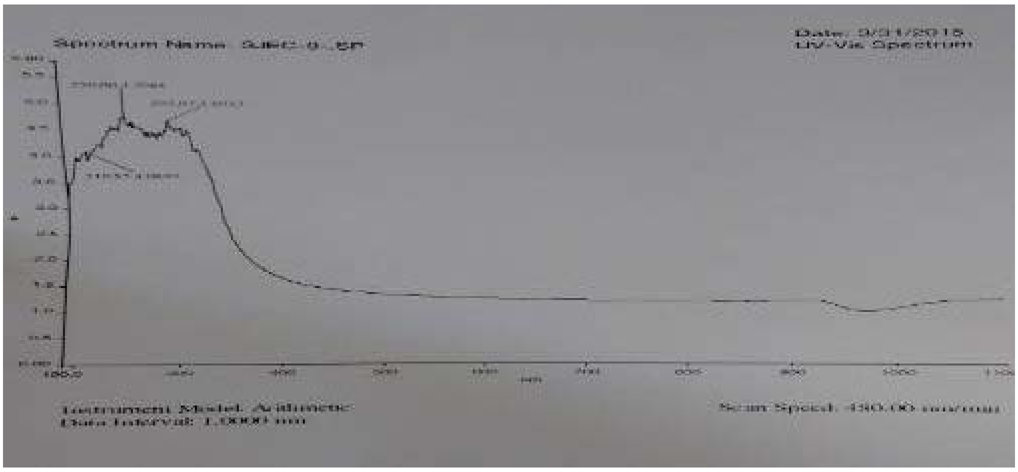


Fig.4. UV- visible spectroscopy of coconut oil based nanofluid.

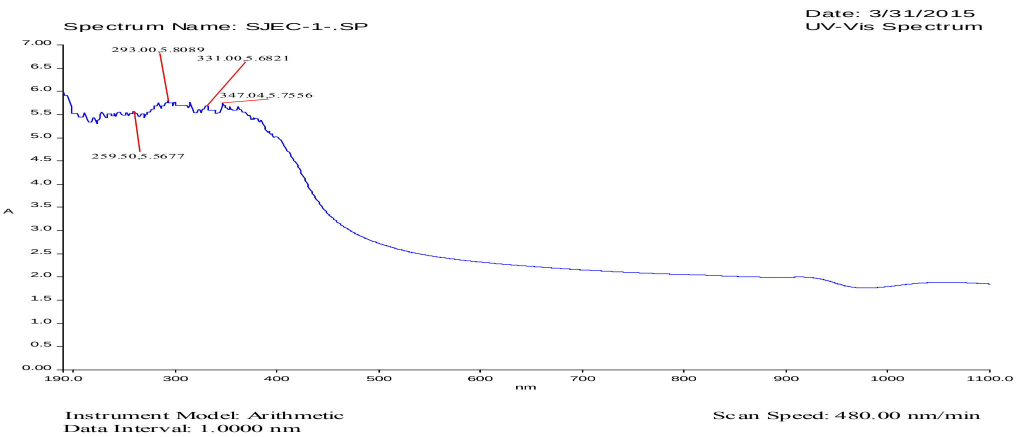


Fig. 5. UV- visible spectroscopy of engine oil based nanofluid.

disperse them into a base fluid. In this investigation nanofluids were prepared by using Multi walled Carbon Nano Tube (MWCNT) with Distilled water, Coolant oil, Engine oil, Gear oil, Vegetable oil, Coconut oil, and Grown oil as base fluids at the volume concentration of 0.1% and without adding any stabilizing agent. Two-step preparation process was used to prepare above nanofluids. In this study required amount of base fluid was first poured into 500-ml glass beakers and mixed with MWCNT of 0.1 wt. % concentration and the suspensions were dispersed using a magnetic stirrer. The homogeneous solutions were obtained after magnetic stirring as shown in Fig.2.

The magnetic stirrer employs a rotating magnetic field which stirs the magnetic pellet immersed in a fluid thus allowing it to spin very quickly which in turn enabling the even dispersion of the particles and ultrasonic vibrator (Toshiba, India) generating ultrasonic pulses of 100W at 36 ± 3 kHz also ensures dispersion of particles in the fluid.

Sonication is a process in which sound waves are used to agitate particles in solution. Such disruptions can be used to mix solutions, speed the dissolution of a solid into a liquid (like sugar into water), and remove dissolved gas from liquids. To get a uniform dispersion and stable suspension which determine the final properties of nanofluids, the nanofluids are kept under ultrasonic bath (Fig.3) continuously for 1 hour.

3. RESULTS AND DISCUSSIONS

3.1 Stability Inspection with UV –Vis Spectrophotometer

The UV-Vis spectrophotometer, measure of pH values, and sedimentation techniques has been used for stability analysis in this investigation by keeping the nanofluids under static condition period of 30 days. Sedimentation method is the most elementary method for evaluation of Nano fluids. An external force field is applied to start the sedimentation of nanoparticles in the Nano fluids. The weight of sediment or the volume of sediment indicates the stability of Nano fluids. Nano fluids are generally considered to be stable if the concentration of the supernatant particles remains constant with time. Sedimentation method was used to measure the stability of graphite

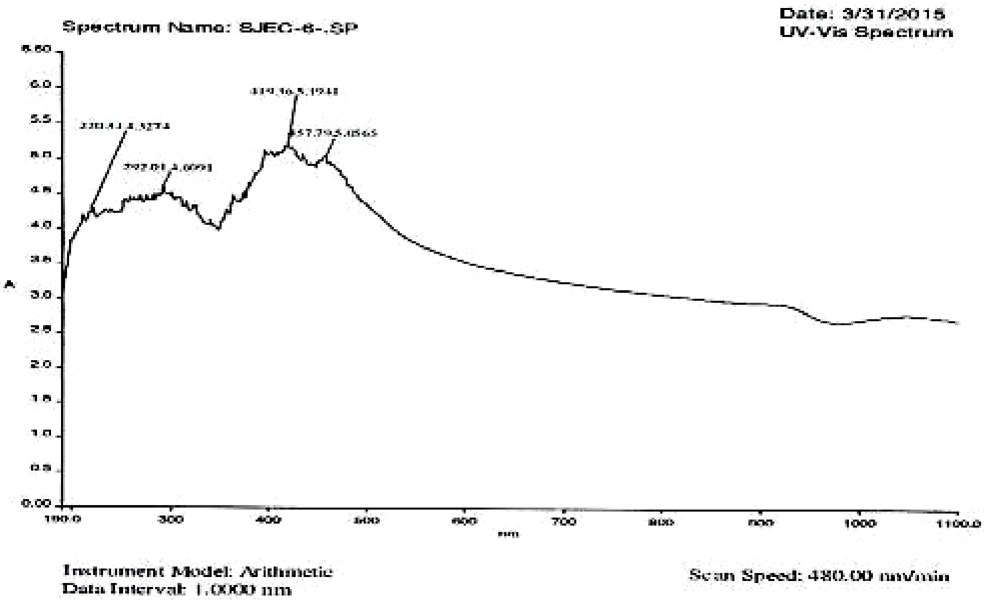


Fig. 6. UV- visible spectroscopy of gear oil based nanofluid.

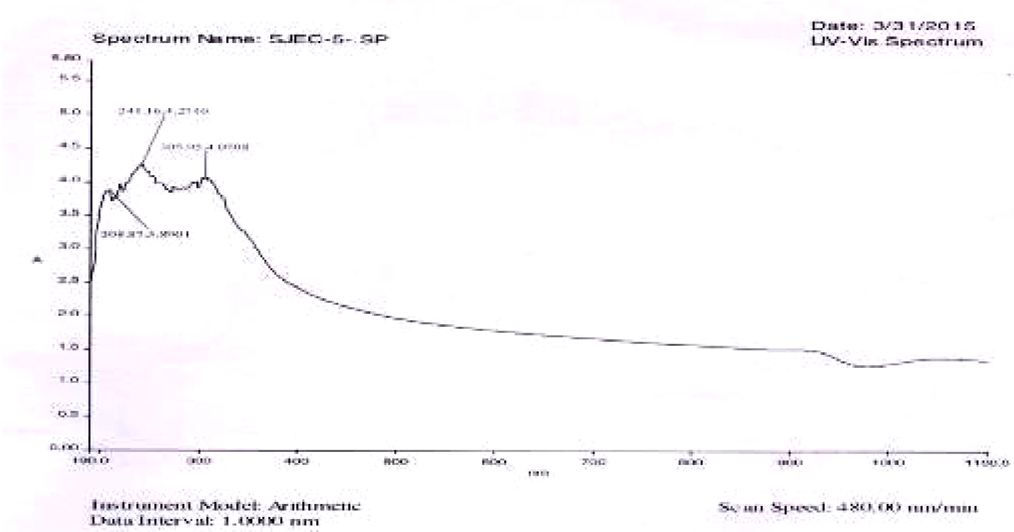


Fig.7. UV- visible spectroscopy of vegetable oil based nanofluid.

suspension. Use of camera has proven to be a suitable aid to capture sedimentation photographs for observing the stability of Nano fluids. The sedimentation was recorded using photographs of samples after several days of preparation. Spectral analysis via UV- Vis spectrophotometer is another useful way to evaluate stability of Nano fluids. The UV-spectroscopy gives quantitative results corresponding to concentration of Nano fluids.

The UV Visible Spectroscopy of nanofluids Ultra Violet– Visible spectrophotometer (UV–Vis) measurements have been used to quantitatively characterize the stability of nanoparticles dispersed in base fluids. The UV–Vis spectrophotometer exploits the fact that the intensity of the light becomes different by absorption and scattering of light passing through a fluid. Jiang (2003) were the first who proposed nanofluid sedimentation estimation by using UV– Vis spectrophotometer. Further, this method was used by Hwang (2007), and Lee (2009) have used the same method. In this investigation, the UV-Vis. spectrophotometer, Lambda 35 model, Perkin Elemer make, absorption range of 190 nm to 1100nm was used to study the stability of nanofluid. The inspection range is from 230nm to 600nm.

The MWCNT nanofluids with different base fluids have been characterized with sample of just after preparation and after 30 days. The UV- visible spectroscopes of sample after 30 days are given in Figs.4-10.

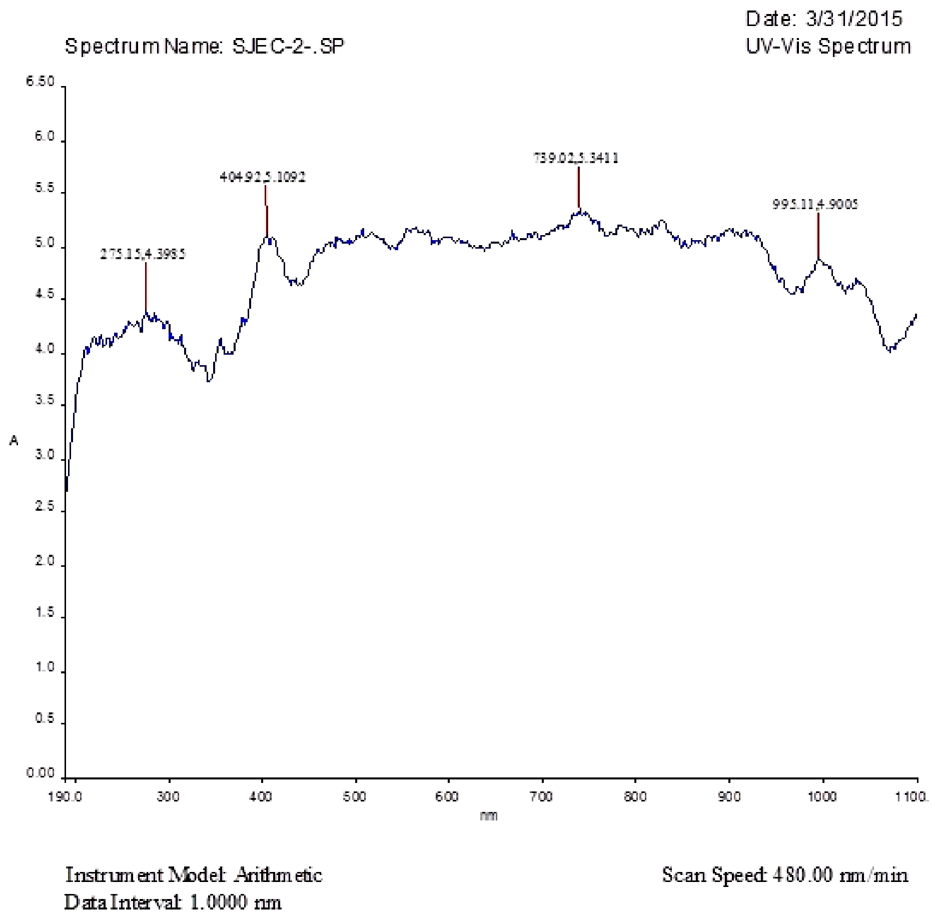
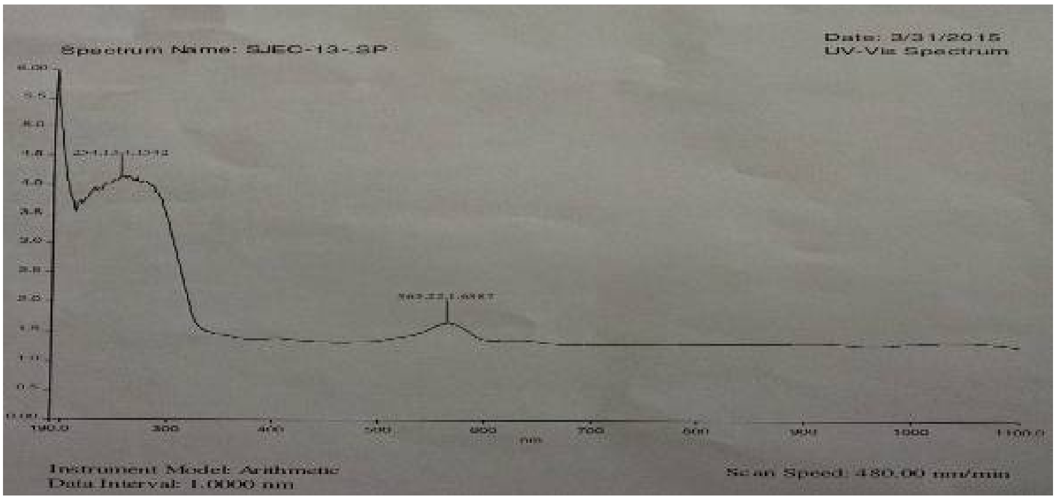


Fig.8. UV- visible spectroscopy of grown oil based nanofluid.

From the above graphs, it is inferred that the stability of nanofluids is increasing in order Distilled water, Coolant oil, Coconut oil, Vegetable oil , Engine oil, Gear oil ,and Grown oil. The analysis clearly shows that MWCNT/Grown oil nanofluid has the highest stability among all other nanofluids which have been considered in this work.

3.2 Stability Inspection by Measuring pH Value

When dispersing MWCNT nanoparticles into any base fluid, the particle surface can acquire an electric charge by absorbing or desorbing at the particle/liquid interface, especially when the base fluid is a polar medium like distilled water Hunter (2004). This absorbing and desorbing mechanism form two layers that surround the particle surface. The inner region is the Stern layer, where the ions are strongly attached to the particle surface. The diffuse layer, which is the outer layer, contains ions that are not firmly bound. The potential at this electrical double layer (EDL) boundary is known as the zeta potential (ζ). The magnitude of ζ represents the strength of the electrostatic energy barrier between particles. A greater ζ increases the inter particle repulsion in a nanofluid of similar nanoparticles. Hence, less aggregation will occur and the nanofluids will be more stable. The ζ and the thickness of the EDL are strongly dependent on the pH value. Once the pH value exceeds a certain limit, the ions cause significant shrinkage of the EDL, and the nanofluid is no longer be stable Hunter (2004). Xie (2008), (2002) and Lee *et al.* (2009) measured the thermal conductivity of nanofluids with water, ethylene glycol, and pump oil as base fluid. They have reported significant decrease in thermal conductivity enhancement with increasing pH values. They have related the Iso-Electric Point (IEP) of MWCNT nanoparticles and pH value which causes mobility of nanoparticles. The (IEP) is the point at which there is no either positive or negative electrical charge of particles at certain pH value. Wang (2009) suggested the pH value affects the thermal conductivity and stability of nanofluids. Zeta potential and associated suspension stability are: 0 mV - little or no stability, 15Mv- some stability but settling lightly, 30mV-moderate stability, 45mV-good stability, and 60mVvery good stability. Generally, a suspension with a measured zeta-potential above 30 mV (absolute value) is considered to have good stability. Therefore, measuring the pH value corresponding to the IEP is one of the most common methods among the researchers to determine the stability. Therefore, it is essential to



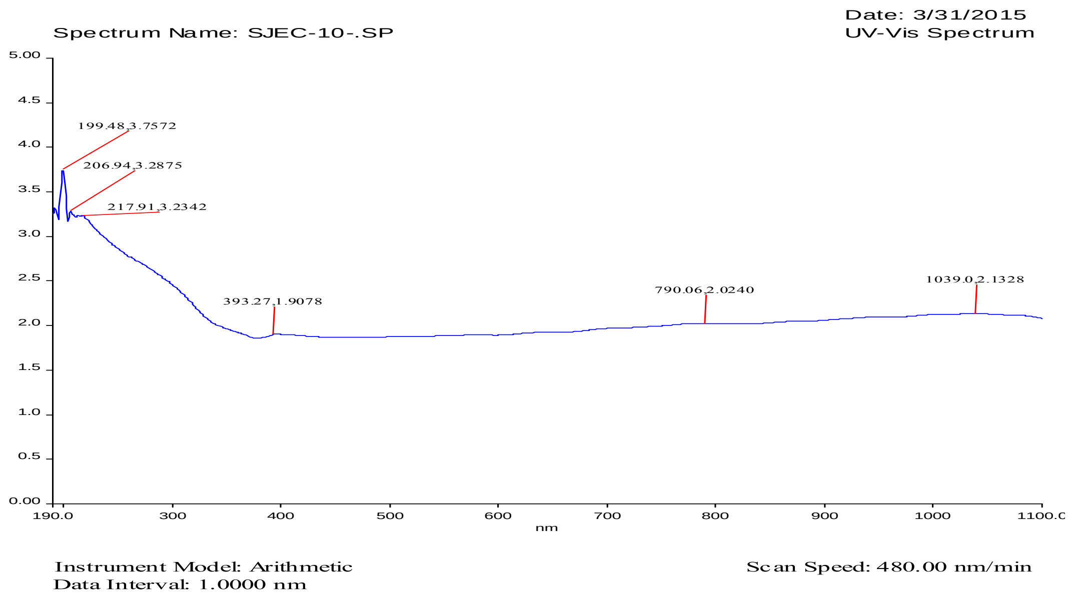


Fig. 10. UV- visible spectroscopy of water based nanofluid.

Fig. 11. pH measurement of fluids.

measure the pH value of nanofluid to ensure the optimum value for attaining the maximum thermal conductivity and stability before applying nanofluid in any thermal systems.

In this investigation, .the pH(Hydrogen potential) meter (Deep vision,0.01 accuracy, in the range of 1-14, working temperature range 0 – 100o C was used to measure the pH value of MWCNT/water nanofluid. The pH meter was calibrated by using a single point calibration technique, with a standard buffer solution of pH 7.00.

The pH value of the conventional and nanofluids were measured using pH meter (Fig.11) and reported in the Table.6.In the measurement of pH value for both conventional and Nano fluids shows its acidic nature by its value in pH scale.

Table 2 pH Values of MWCNT Nanofluids

S.NO	MWCNT Fluids with	pH values just after preparation	pH values after 30 days
1	Coconut oil	5.49	4.72
2	Engine oil	11.3	9.2
3	Gear oil	4.43	1.53
4	Vegetable oil	7.3	4.61
5	Grown oil	6.6	5.7
6	Coolant oil	8.53	8.38
7	water	7	6.85

From Table.2, it is found that the MWCNT / Distilled water nanofluid has poor stability and MWCNT/Grown oil nanofluid has good stability after 30 days of static condition. This is because the pH value of MWCNT/distilled water nanofluids is away from the pH value correspond to the Iso electric point of MWCNT nanofluid and the MWCNT/Grown oil nanofluids pH corresponding to the Iso electric point is nearly close to the value.

3.3 Stability Inspection with Photograph Capturing Technique

The photographs of test tubes with nanofluid were taken by using Sony digital camera of 16.1 Mega Pixel, W Series, 5x Optical Zoom Cyber-shot (Black).Sedimentation is the tendency for particles in suspension to settle out of the fluid in which they are entrained, and come to rest against a barrier. This is due to their motion through the fluid in response to the forces acting on them: these forces can be due to gravity, centrifugal acceleration or electromagnetism. The sedimentation of Nanofluids, after sonication were recorded using digital camera and shown in the Fig.12. The sedimentation photograph after 15 days and 30 days were shown in Fig.13 and Fig.14 respectively. In distilled water based nanofluid the MWCNT setteled down at the bottom after 30 days as shown in Fig.14.

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From Figs. 12-14, it is found that the MWCNT / Distilled water nanofluid has poor stability and MWCNT/Grown oil nanofluid has good stability after 30 days of static condition.

4. CONCLUSIONS

In this experimental investigation, the 0.1% concentration MWCNT nanofluids have been prepared with Distilled water, Coolant oil, Coconut oil, Vegetable oil , Engine oil, Gear oil ,and Grown oil. as the base fluids and with the two step methods to study the stability of MWCNT nanofluids. The prepared nanofluids were characterized by UV –Vis Spectrophotometer, Zeta potential analysis with pH values, and Photograph capturing techniques for analyzing the stability of nanofluids. The samples are put under static condition. It is found from the three stability analysis techniques that the stability of nanofluids are in the increasing order of MWCNT / Distilled water nanofluid, MWCNT / Coolant oil nanofluid, MWCNT / Coconut oil nanofluid, MWCNT / Vegetable oil nanofluid, MWCNT / Engine oil nanofluid, MWCNT /Gear oil nanofluid and MWCNT/Grown oil nanofluid. The MWCNT / Distilled water nanofluid has poor stability and MWCNT/Grown oil nanofluid has good stability.

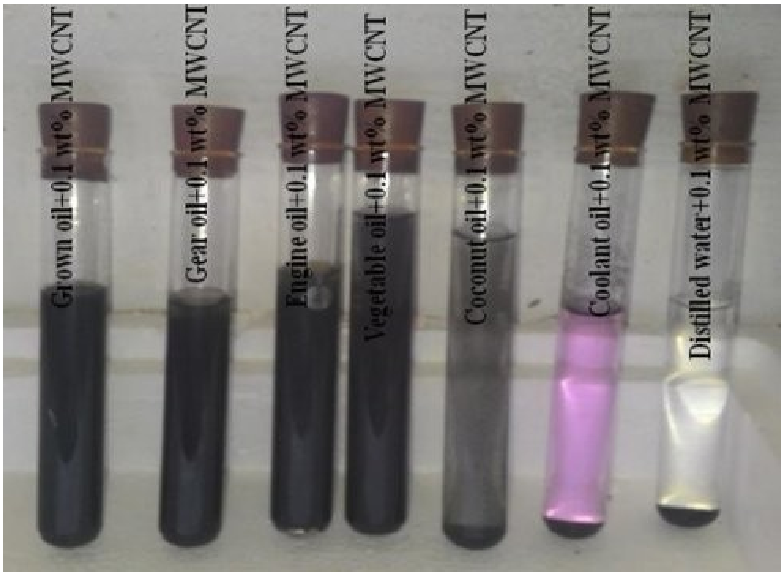

Fig. 12. Sedimentation samples of nanofluids just after sonication.

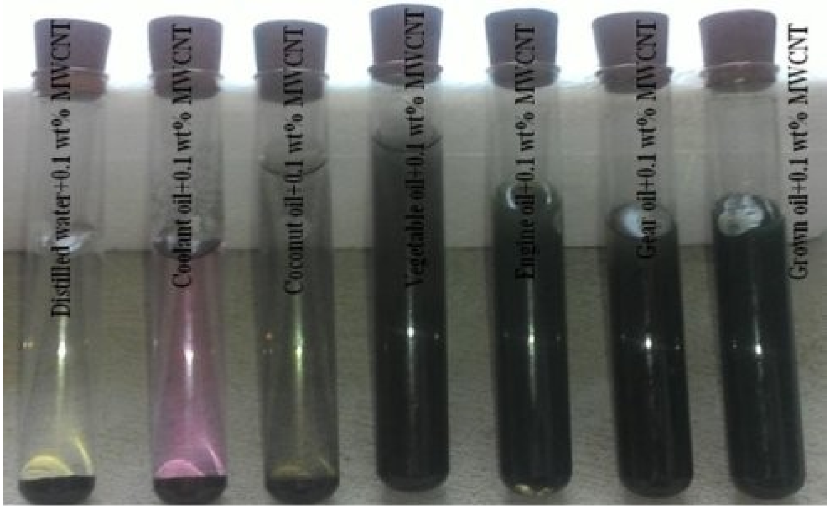

Fig. 13. Sedimentation samples of nanofluids after 15 days.

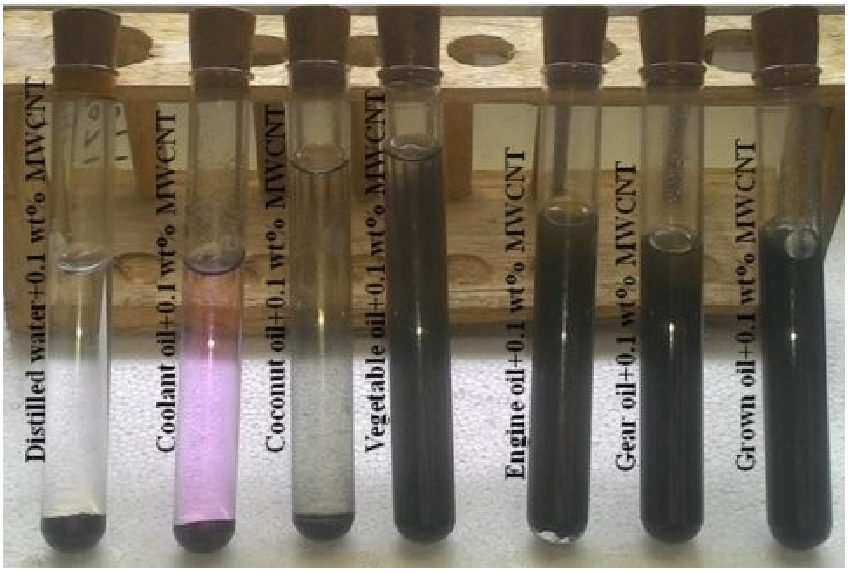

Fig. 14. Sedimentation samples of nanofluids after 30 days.

REFERENCE

Chandrasekar, M., S. Sureshand and A. Chandra Bose (2010). Experimental investigations and theoretical determination of thermal conductivity and viscosity of Al2O3/ water nanofluid, *Exp. Thermal. Fluid Science 34(2), 210–216.*

Ghadimi, R., H. S. Saidur and C. Metselaar (2011). A review of nanofluid stability properties and characterization in stationary conditions, *International Journal of Heat and Mass Transfer 54, 4051–4068.*

Hiemenz, P. C. and M. Dekker (1986). Principles of colloid and surface chemistry, *Second ed., Dekker, New York*,.

Hunter, R. J. (2004). Foundation of Colloid Science, *Oxford University Press.*

Hwang, Y., J. K. Lee, C. H. Lee, Y. M. Jung, S. I. Cheong, C. G. Lee, B. C. Ku and S. P. Jang (2007). Stability and thermal conductivity characteristics of nanofluids, *Thermo chim. Acta 455(1-2), 70–74.*

Jiang, L., L. Gao and J. Sun (2003). Production of aqueous colloidal dispersions of carbon nanotubes, *Journal of Colloid Interface Science 260(1), 89–94.*

Lee, K., Y. Hwang, S. Cheong, L. Kwon, S. Kim and J. Lee (2009). Performance evaluation of nano- lubricants of fullerene nanoparticles in refrigeration mineral oil, *Current Applied Physics 9(2), 128–131.*

Li, X. F., D. S. Zhu, X. J. Wang, N. Wang, J. W. Gaoand and H. Li (2008). Thermal conductivity enhancement dependent pH and chemical surfactant for Cu–H2O nanofluids, *Thermo chim. 469(1–2), 98–103.*

Madni, C. Y. Hwang, S. D. Park, Y. H. Choa and H. T. Kim (2010). Mixed surfactant system for stable suspension of multi walled carbon nanotubes, Colloids Surface A: *Physicochemical Engineering. Aspects 358(1–3), 101–107.*

Pantzali, M. N., A. A. Mouza and S. V. Paras (2009). Investigating the efficacy of nanofluids as coolants in plate heat exchangers (PHE), *Chemical Engineering Sciences. 64(14), 3290–3300.*

Wang, X. J., D. S. Zhu and S. Yang (2009). Investigation of pH and SDBS on enhancement of thermal conductivity in nanofluids, *Chemical Physics Letters 470, 107–111.*

Xie, H., H. Lee, W. Youn and M. Choi (2003). Nanofluids containing multi walled carbon nanotubes and their enhanced thermal conductivities, *Journal of Applied Physics 94(8), 4967–4971.*

Xie, H., J. Wang, T. Xi and Y. Liu (2002). Thermal conductivity of suspensions containing nanosized SiC particles, *International Journal of Thermo physics 23(2), 571-580.*

Xie, H., L. Chen and Q. Wu (2008). Measurements of the viscosity of suspensions (nanofluids) containing nanosized Al2O3 particles, *High Temperatures – High Pressures 37, 127–135.*

Yu, W., H. Xie, L. Chen and Y. Li (2010). Enhancement of thermal conductivity of kerosene-based Fe3O4 nanofluids prepared via phase-transfer method, Colloids Surface A, *Physicochemical Engineering. Aspects, D.M. 355, 109–113.*

Zhu, D. S., X. F. Li, N. Wang, X. J. Wang, J. W. Gao and H. Li (2009). Dispersion behaviour and thermal conductivity characteristics of Al2O3 –H2O nanofluids, *Current Applied Physics 9, 131– 133.*