Stability and Thermal Conductivity Studies of MWCNTs Nanofluids

N.Pravin Diliban* [a] V Vigneshwaran [a]

[a] Department of Mechanical Engineering, SMK Fomra Institute of Technology, Chennai, TN, India.

Abstract

The results of the experimental research to enhance the thermal conductivity of the distilled water (DW) by dispersing Multiwall carbon nanotubes (MWCNT) have been presented in this article. Stability of the mixed fluid was improved by preparing a stable suspension of MWCNT in base fluid (water). The influence of parameters such as volume fraction of MWCNT added, sonication time, and type of surface modifier added and stability of Nano fluids were studied in detail. Solid volume fraction of MWCNTs were taken in 0.115%, 0.23% and 0.46%. Polysorbate 80 and CTAB 1 was used as surface modifiers, the results show that, the nanofluids which contained higher value of volume fractions show the higher value of thermal conductivity comparing to the base fluid (water), Polysorbate 80 show 0.71 W/mK and CTAB 1 show 0.714 W/mK And viscosity of the fluid show higher value to the nanofluid comparing to the base fluid and the nanofluid which consist CTAB 1 as surface modifier shows zeta potential value as 33, which was considered as most stable nanofluid sample. Thermal properties of the nanofluid where evaluated using KD 2 Pro thermal analyser and the results shows that the conductivity is higher for the sample with higher volume fraction and also shows that the conductivity of the sample with CTAB I is higher than the conductivity of the sample with Polysorbate 80 and without surface modifier. It clearly explicates that the addition of the surface modifiers will boost the stability of the sample and it will decrease the thermal properties of the sample.

Keywords: CTAB 1;Distilled Water (DW);Multiwall Carbon Nanotubes (MWCNT);Polysorbate 80;thermal conductivity; volume fraction; Zeta potential.

Available online at www.ijrp.org

International Journal of Research Publications

1. Introduction

Many industrial applications need ultra-high performance of coolant in the cooling system to reduce the produced heat. Therefore, need for high performance cooling and free cooling application. Nano fluids as a new coolant, innovative class of heat transfer fluids represent a rapidly emerging field where Nano science and thermal engineering co-exist.

Many conventional methods have been engineered to remove the heat as air cooling systems and liquid cooling systems (Subbiah, 2017).Air cooling system is not much efficient comparing to the liquid cooling system (Coles, Berkeley, Ellsworth, & Corporation, 2011). But, with the development of the high performance mechanical works, cooling capacity of the conventional liquid coolant also not much enough to perform to reduce the heat effectively (Leong, Saidur, Kazi, & Mamun, 2010). Therefore, the thermal conductivity properties of the coolant has to be changed. It can be done by adding nanoparticles to the conventional coolants, The coolants which are blended with nanomaterials are known as nanofluids, these nanofluids shows superior heat transfer performance reported that about 15-40% of heat transfer enhancement can be achieved by using various types of Nanofluids (W. Yu, D.M. France, S.U.S. Choi, 2007) .

Two-step method is the most widely used method for preparing Nanofluids and this is the most economic method to produce Nanofluids in large scale, because nano powder synthesis techniques have already been scaled up to industrial production levels (Li, Zhou, Tung, Schneider, & Xi, 2009) . Due to the high surface area and surface activity, nanoparticles have the tendency to aggregate(Ghadimi, Saidur, & Metselaar, 2011). Dry powders are produced by chemical or physical methods by using nanoparticles, nanofibers, nanotubes, or other nanomaterial. Then, the nano sized dry powder will be dispersed into a fluid and there are some methods have been practiced currently as: intensive magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenizing, and ball milling (Rafati, Hamidi, & Niaser, 2012).

The important technique to enhance the stability of nanoparticles in fluids is the use of surfactants (Yu & Xie, 2012). However, the functionality of the surfactants under high temperature is also a big concern, especially for high-temperature applications (Wang & Mujumdar, 2007). In this research work multiwall carbon nanotubes (MWCNTs) were used as the nanoparticles because of its structures are a better choice for phonon propagation in heat management system than SWCNT (Aliev, Lima, Silverman, & Baughman, 2010). MWCNT are polymers of pure carbon and can be reacted and manipulated using rich chemistry carbon. This provides opportunity to modify the structure and optimize solubility and dispersion, allowing innovative application in materials, electronics and mechanical in the field of heat transfer enhancement(Abhijit Roy1*, Sreejith C2, Abhishek Samanta1, Ragul G1, 2017).

Electrical conductivity (1000 higher than copper), mechanical strength (up to 10-100 times stronger than steel and lighter) and thermal conductivity (twice as high as diamond and) are the main properties of the MWCNTs and are used in many applications(Thostenson, Ren, & Chou, 2001) .Water has taken as base fluid, yet the stability is questionable and MWCNT would start to sediment after an ambient period of time, therefore, surface modifiers are added to the MWCNT/Water nanofluid (Bozorg, Fasano, Cardellini, Chiavazzo, & Asinari, 2016). Thermal conductivity property of the nanofluid depends up on the volume fraction of the particle and the thermal conductivity of the base fluid and nanoparticles and has been considered with the surface modifiers (Leong et al., 2010)**.** Thermal property analyser is used for thermal conductivity measurements(Singh & Kundan, 2013). This experimental research study was conducted to examine the heat transfer attributes of the coolant using water based MWCNT nanofluids as coolant. The thermal conductivity of nanofluid is compared with ordinary distilled water, and the effect of volume fraction, and viscosity of the coolant also examined, MWCNT were chosen due to the thermal conductivity characteristic of MWCNT and its mechanical property.

2. Nanofluid Preparation and Characterization.

Preparation of stable and suitable nanofluid with low or no agglomeration of nanoparticles is the first step in any nanofluid experiments. (Rafati et al., 2012)**.** The main aim of this project is to prepare Nanofluid with MWCNT nanoparticles and DW as base fluid for improving the heat transfer characteristics of the fluid. These analyses are performed by measuring all thermo physical properties like thermal conductivity, and viscosity at different volume fraction of the Nanofluids. For this work the MWCNT has purchased as nanomaterial powder. And it has been under gone following analysing process to identify the properties of the MWCNT.

2.1. Scanning electron microscope (SEM) image analyse

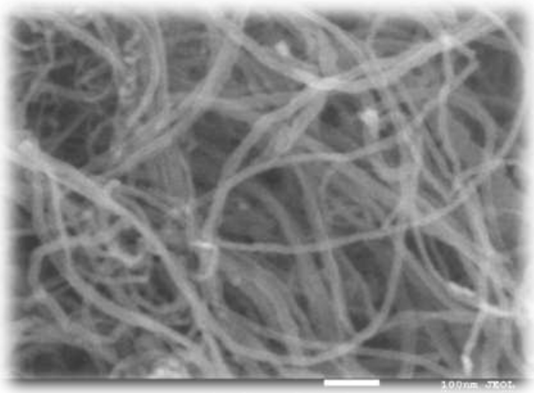

Figure 1.SEM Image of MWCNT

In order to analyse the diameter of the nanotubes SEM image analyse has been conducted, from the SEM image it clearly shows that the size of the nanoparticle is in 10-15nm range.

2.2 Energy Dispersive Analysis of X-Rays (EDAX)

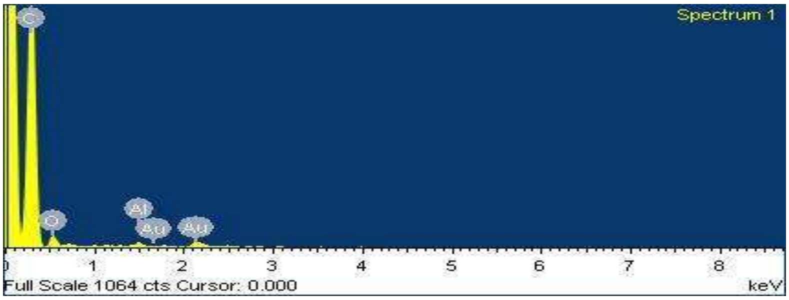

Figure 2.SEM Image of MWCNT

EDAX is known as Energy Dispersive Analysis of X-Rays which is used to find the chemical components present in the nanoparticle. Figure 2 is the EDAX analysis of MWCNT which will shows the carbon content present in the MWCNT nanoparticle.

2.3 Ultra violet spectroscopy

The purchased nanomaterials have been analysed by using the ultra violet spectroscopy, from the data gathered from UV Spectroscopy, it has been compared with the given reference UV spectroscopy graph

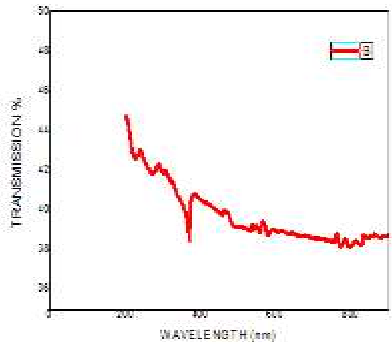

Figure 3.UV Image of MWCNT Sample

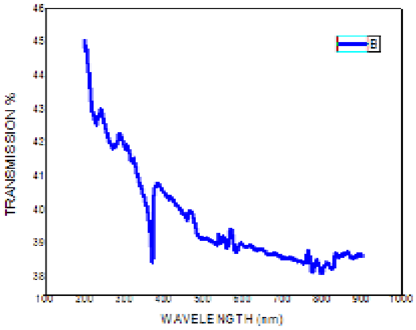

Figure 4UV Image of MWCNT Reference

From the Figure 3 and Figure 4 the peaks of the MWCNT Reference and the peaks of the MWCNT sample are the matching.

2.4 Nanoparticle Weight Calculation from Volume Fraction

Formula for the calculation of weight of the Nanoparticle from volume fraction.

$$W_{np} = \left(\frac{\emptyset}{100-\emptyset}\right) * \left(\frac{\rho_{np}}{\rho_{bf}}\right) * W_{bf} \qquad (1)$$

Where,

W_{np}	= Weight of the nanoparticle	(g)
W_{bf}	= Weight of the base fluid	(g)
$\emptyset$	= Volume Fraction	(%)
ρ_{np}	= Density of the nanoparticle	(kg/m^3)
ρ_{bf}	= Density of the base fluid	(kg/m^3)
Density of the nanoparticle (ρ_{np})	$=2.6\ g/cm^3$	
Density of the base fluid (ρ_{bf})	$= 995.6\ kg/m^3$	
For 100 ml base fluid;		
Volume of the base fluid (V)	$= 0.1 \times 10^{-3} m^3$	
Weight of the base fluid (W_{bf})	$= 995.6\ kg/m^3 \times 0.1 \times 10^{-3} m^3$	
	$=0.0995$ kg	

Table 1 Weight of MWCNT for different volume Fractions

Volume fraction ($\emptyset$)	Weight of MWCNT(gm.)
0.115 %	0.026
0.23 %	0.54
0.46 %	1.07

2.5 Preparation of Nanofluids

Two step method is one of the predominant method used for dispersion for metal oxide nanoparticles and MWCNT and SWCNT.MWCNT-Distilled Water based nanofluid prepared by two step method in which the dispersed nanoparticle is stirred using magnetic stirrer and ultra-sonicated. In this paper, the conventional two step method is employed for the preparation of the nanofluid. In this nanofluid is prepared by dispersing the MWCNT- Distilled Water with and without the adjunct of surface modifier Polysorbate-80 and CTAB I for the different volume fraction (Ø) 0.115%, 0.23% and 0.46%. In this process MWCNT is mingled with the Distilled Water by stirring it with the magnetic stirrer (Manufacturer: RemiElektrotechnik Ltd, India) for 30 minutes at ambient temperature accompanied by the dispersion of the Polysorbate-80 and CTAB I only for the samples with surface modifiers not for the samples without surface modifiers in order to avoid the agglomeration and settlement of the nanoparticles the blend is sonicated by using Probe type sonicator (Manufacturer: Leela Sonic, India) for 20 minutes. For varying volume fraction the nanofluids with and without surface modifier is prepared. The samples prepared by this method as good stability and the stability of the sample with Polysorbate-80 and CTAB I as surface modifiers is good then the samples without surface modifiers the stability of the samples are confirmed with sedimentation Photograph technique.

3. Experimental Set Up

3.1 KD 2 Pro Thermal Analyser

Thermal transport property such as thermal conductivity and thermal resistivity of the nanofluid for room temperature (27^0C) which is reckoned using the KD 2 Pro thermal property analyser (Manufacturer: Decagon Devices) which will work on the postulates of transient line heat source method. KD 2 Pro analyser used for the measurement of thermal properties of the nanofluids. The instrument comprises of KS-1 sensor, 60mm single needle, ultra-low power microcontroller, cable –RS-32 which is connected to KD 2 pro. Working procedure is needle which is connected will be immersed into the vial tube containing the sample and the vial with sample is connected to sample holder of the water bath by which we can vary the temperature once we attain the required temperature the readings are taken and the pulse time 1 minute. The readings are taken for three trials and average value is taken to avoid the error.

3.2 Brookfield DVIII Ultra Programmable Rheometer

Brookfield DVIII ultra programmable rheometer (Manufacturer: Brookfield) is used to compute the rheological parameters such as viscosity of the fluid for varying temperature which is varied with the help of the water bath. Brookfield DVIII ultra programmable rheometer used to measure the viscosity of the MWCNT-Distilled Water based Nanofluid. The rheometer comprises of motor, calibrated spiral spring, shaft and spindle. The working principle is the spindle is connected to the drive motor through calibrated spring and the spindle is autocorrected before we take the reading. The spindle is immersed into the sample holder and the motor is switched on. Then the spindle which is immersed will start to rotate once the rpm is fixed by the rotation of the spindle rheometer will calculate the viscosity of the fluid.

4. Results and Discussions

In this chapter discuss all the results which get from the experiments like thermal conductivity measurement, viscosity measurement. Various experiments were performed during research work with the help of various apparatus and techniques as mentioned in previous chapter. The stability of the MWCNT-

Distilled Water is being discussed in this chapter.

4.1 Thermal Properties of Nanofluid

Thermal transport properties such as thermal conductivity, thermal conductivity ratio and thermal resistivity are discussed in this topic. Thermal conductivity of the MWCNT-Distilled Water based nanofluid were evaluated for. Figure 5 shows that when there is an increase in weight of nanomaterial there is increase in the value of the thermal conductivity and the result exactly suits with the property of the Distilled Water. And from the results obtained from KD 2 Pro for thermal conductivity it's been clear that CTAB I shows higher thermal conductivity property comparing to the other surfactants.

Similarly, the thermal resistivity is higher to the nanofluid which does not contain any surface modifier, because thermal resistivity is inversely proportional to thermal conductivity.

Table 2 Thermal Conductivity of Nanofluids

Weight(grams)	Without Surfactant (W/mK)	Polysorbate 80 (W/mK)	CTAB I (W/mK)
0.026	0.613	0.634	0.638
0.54	0.621	0.642	0.646
1.07	0.689	0.71	0.714

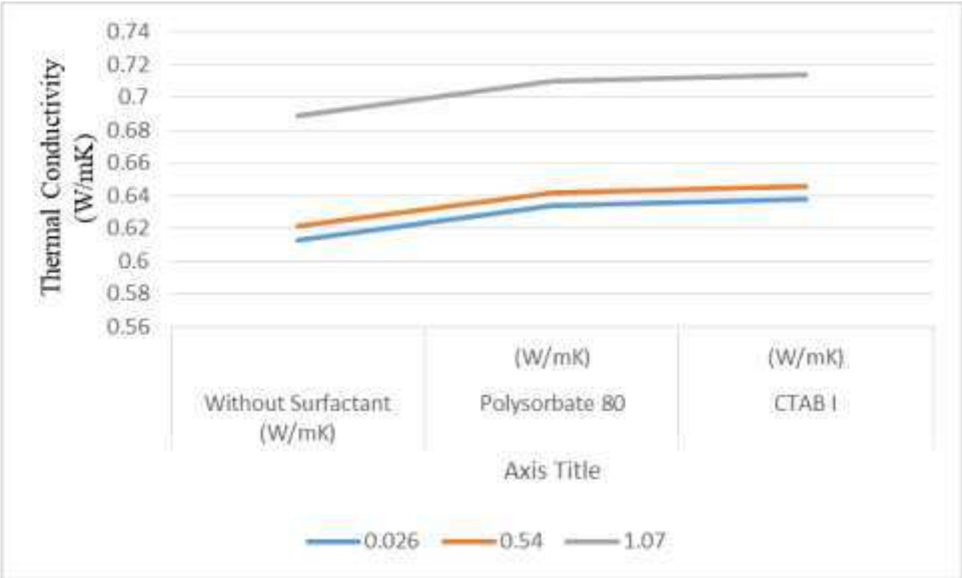

Figure 5 Thermal Conductivity of Nanofluids

Thermal conductivity ratio of the nanofluid is calculated using,

$$Kratio = \frac{Knf}{Kbf}$$

Where,
Kratio = Thermal conductivity ratio.
Knf= Thermal conductivity of nanofluid. (W/mK)
Kbf = Thermal Conductivity of Base fluid. (W/mK)
Figure 5 clearly explicates the thermal conductivity ratio of the nanofluid.

Thermal resistivity of the nanofluid were evaluated and result explicates that when there is an increase in thermal conductivity there is a decrease in thermal resistivity of the nanofluid and Figure 6 shows the thermal resistivity value of the nanofluid.

Table 3 Thermal Resistivity of Nanofluids

Weight (grams)	Without Surfactant (mK/W)	Polysorbate 80 (mK/W)	CTAB I (mK/W)
0.026	1.6313	1.5773	1.5673
0.54	1.6103	1.5576	1.5479
1.07	1.4514	1.4185	1.4005

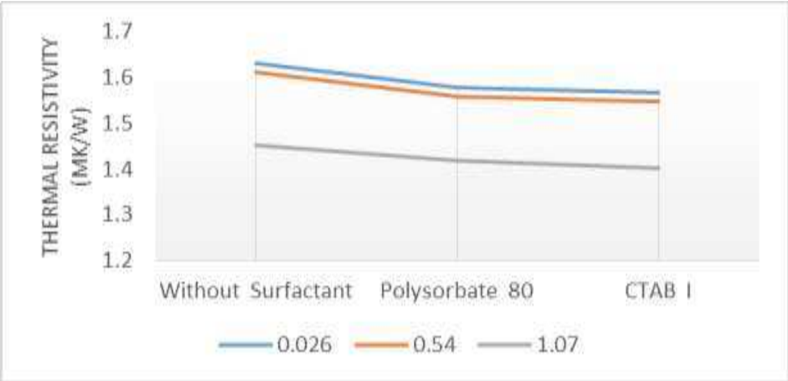

Figure 6 Thermal Resistivity of Nanofluids

4.2 Rheological Properties of Nanofluids

The rheological properties such as viscosity of the nanofluid was discussed in this topic. The viscosity was evaluated at room temperature (27^0 C) which explicates that with increase in weight there is increase in rheological properties from Figure 7 and the rheological property increases for CTAB I surface modifier, it's been clearly shown in the Figure 7. And Figure 7 shows the viscosity values of the nanofluid. From the Fig the graph is linear which clearly indicates that the prepared fluid is Newtonian fluid which will be more stable for and the dispersion rate is good.

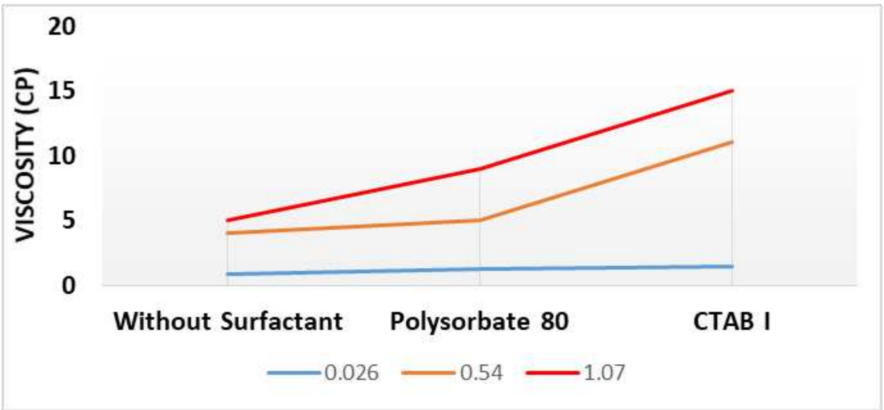

Figure 7 Viscosity of Nanofluids

Table 4 Viscosity of Nanofluids

Weight(grams)	Without Surfactant (cP)	Polysorbate 8 (cP)	CTAB I (cP)
0.026	1.4	1.2	0.8
0.54	11	5	4
1.07	5	9	15

5. Conclusion

In this present work, the distilled water is mixed with nanoparticle which can also be called as Nanofluid is prepared successfully with and without Polysorbate-80 and CTAB I as surface modifier for volume fraction 0.115%, 0.23%and 0.46%. By using the Sedimentation Photograph Technique, the stability of the samples is analysed and shows that the nanofluid with CTAB I is more stable than the nanofluid without CTAB I. Thermal properties of the nanofluid where evaluated using KD 2 Pro thermal analyser and the results shows that the conductivity is higher for the sample with higher volume fraction and also shows that the conductivity of the sample with CTAB I is higher than the conductivity of the sample with Polysorbate 80 and without surface modifier. It clearly explicates that the addition of the surface modifiers will boost the stability of the sample and it will decrease the thermal properties of the sample by 17.5%

References

Abhijit Roy1*, Sreejith C2, Abhishek Samanta1, Ragul G1, I. G. (2017). Effect of Multi-Walled Carbon Nanotubes on Automotive and Aerospace. International Journal of Emerging Trends in Science and Technology, 89, 5105–5113.

Aliev, A. E., Lima, M. H., Silverman, E. M., & Baughman, R. H. (2010). Thermal conductivity of multi-walled carbon nanotube sheets: Radiation losses and quenching of phonon modes. Nanotechnology, 21(3). https://doi.org/10.1088/0957-4484/21/3/035709

Bozorg, M., Fasano, M., Cardellini, A., Chiavazzo, E., & Asinari, P. (2016). A review on the heat and mass transfer phenomena in nano fl uid coolants with special focus on automotive applications. Renewable and Sustainable Energy Reviews, 60, 1615–1633. https://doi.org/10.1016/j.rser.2016.03.027

Coles, H., Berkeley, L., Ellsworth, M., & Corporation, I. B. M. (2011). *“ Hot ” for Warm Water Cooling*.

Ghadimi, A., Saidur, R., & Metselaar, H. S. C. (2011). A review of nanofluid stability properties and characterization in stationary conditions. International Journal of Heat and Mass Transfer, 54(17–18), 4051–4068. https://doi.org/10.1016/j.ijheatmasstransfer.2011.04.014

Leong, K. Y., Saidur, R., Kazi, S. N., & Mamun, A. H. (2010). Performance investigation of an automotive car radiator operated with nanofluid-based coolants (nanofluid as a coolant in a radiator). Applied Thermal Engineering, 30(17–18), 2685–2692. https://doi.org/10.1016/j.applthermaleng.2010.07.019

Li, Y., Zhou, J., Tung, S., Schneider, E., & Xi, S. (2009). A review on development of nanofluid preparation and characterization. Powder Technology, 196(2), 89–101. https://doi.org/10.1016/j.powtec.2009.07.025

Rafati, M., Hamidi, A. A., & Niaser, M. S. (2012). Application of nano fl uids in computer cooling systems (heat transfer performance of nano fl uids), 46, 9–14. https://doi.org/10.1016/j.applthermaleng.2012.03.028

Singh, M., & Kundan, L. (2013). Experimental Study on Thermal Conductivity and Viscosity of Al 2 O 3 - Nanotransformer Oil, (3), 125–130.

Subbiah, P. (2017). Study of Cooling System in I . C . Engine Improving Performance with Reduction of Cost. Indian Journal of Science and Technology, 9(1), 1–8. https://doi.org/10.17485/ijst/2016/v9i1/85781

Thostenson, E. T., Ren, Z., & Chou, T. (2001). Advances in the science and technology of carbon nanotubes and their composites: a review Erik. Composites Science and T, 61(61 (2001) 1899–1912), 1899–1912. https://doi.org/10.1016/S0266-3538(01)00094-X

W. Yu, D.M. France, S.U.S. Choi, and J. L. R. (2007). Review and Assessment of Nanofluid Technology for Transportation and Other Applications.

Wang, X., & Mujumdar, A. S. (2007). Heat transfer characteristics of nanofluids : a review, 46, 1–19. https://doi.org/10.1016/j.ijthermalsci.2006.06.010

Yu, W., & Xie, H. (2012). *A Review on Nanofluids : Preparation , Stability Mechanisms , and Applications* (Vol. 2012). https://doi.org/10.1155/2012/435873