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A Review on the Influential Parameters on Thermal conductivity of Nanofluids

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ABSTRACT
The recent advances in technology especially in the field of materials have shown remarkable enhancement of the properties of the materials. The field of nanotechnology has increased its significance due to wide range of applications of nanomaterials. CNT's are a type of nanomaterials., which are used based on their great tensile strength and electrical conductivity. The use of CNT's in conducting fluids has given a new concept of nanofluids. Nanofluids are engineered colloidal suspensions in a base fluid. The nanoparticles used in these nanofluids are typically made of Metals, Oxides, Carbides or CNT's. The base fluid used experimented are Water (H_2O), Ethylene Glycol, TKO – 19 Ultra (Mineral Oil), Synthetic (α - olefin). All the base fluids are suspended with different kinds of suspension particles and thermal conductivity enhancement of the fluids has been studied from various papers and observed maximum enhancement of thermal conductivity of the following review paper.

***Keywords* –** Carbon nano tubes, Nano fluids, Engine oil, Ethylene Glycol, Thermal conductivity.

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I. INTRODUCTION

Carbon nanotubes are tubes made out of carbon with diameters of 10^{-9} m order. These are known for their remarkable tensile strength, electrical conductivity. They also exhibit good thermal conductivity. This is due to their nanostructure and bond strength between atoms. In addition to this CNT's can. Chemically modified to obtain various properties. These properties are found valuable in many areas of technology like electronics, optics, composite materials, etc., these were first discovered by Sumio Iijima in the year 1991 in NEC laboratories in Japan. CNT's are the molecular carbon fibers that consist of tiny graphite cylinder which is closed at both with caps, which consist of six pentagonal rings [1].

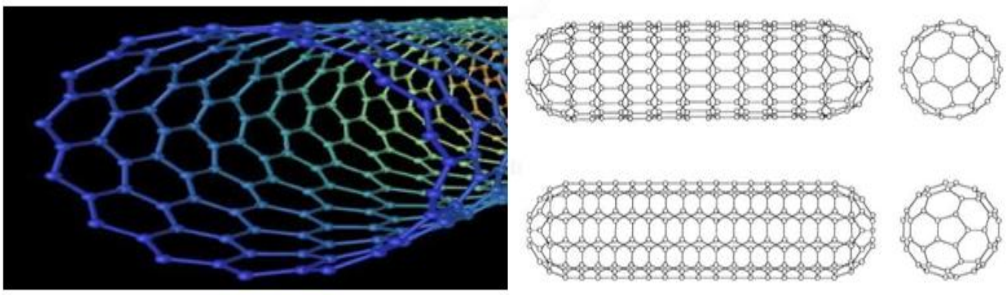

Figure 1. Single walled CNT 3D View

Generally, CNT's have extraordinary flexible and elastic and have high aspect ratio. They also have a lower thermal expansion coefficient. Generally, CNT's are fist found using the Arc Discharge technique. But there are other ways to produce CNT's those are Laser ablation, Plasma torch, Chemical Vapour Deposition (CVD), Super – growth CVD, Liquid electrolysis method. CNT's are broadly classified into two types, they are Single-walled Carbon nanotubes (SWCNT's) and Multi walled carbon nanotubes (MWCNT's) as shown in Fig.1.

1.1 SWNCT's

SWCNT's are cylinders formed with one layer (wall) of carbon molecules. The diameters of the SWCNT's are determined by synthesis temperature. SWCNT's are used an additive in base fluids to form nanofluids. Polymers are used to increase their strength and a catalyst for better control reactions. They also used electromagnetic shielding. These are also used as super capacitors.

1.2 MWCNT's

MWCNT's on the other hand differ from SWCNT's by the number of cylinder walls they have. MWCNT's form multiple concentric walls of increasing walls of increasing diameter in consequential order as shown in Fig. 2. These have similar applications SWCNT's but with more capacity or more output than SWCNT.

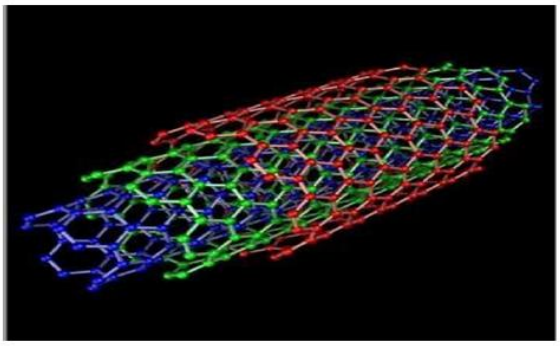

Figure 2: Multi walled Carbon Nano tubes

Nanofluids are the fluids that are formed by mixing nanoparticles into any base fluid like water, alcohol, etc. ethylene glycol, and oil. These have novel applications which help those to use in heat transfer applications. They found typical applications in microelectronics, Pharmaceuticals, Hybrid power engines, domestic refrigerators, in heat exchangers, reducing the boiler flue gas temperature. In nanofluids, the nanoparticles form a colloidal suspension in any base fluids and thus by enhancing the properties of the fluids. CNT's are one of the suspensions used in nanofluids. CNT's are immersed in a base fluid and a dispersant is added to form heat transfer fluids. *M.J. Assael at. el.* has given the various thermal conductivity enhancements of the CNT's solved in base fluids like Ethylene Glycol and Water with dispersants SDS, CTAB, and Triton X – 100. Generally, CNT's doesn't disperse into the fluids as a result dispersant are added to that nanofluids to avoid the agglomeration of CNT's in the nanofluids.

Thermal Conductivity in CNTs is very high is around 2800 – 6000 W/m K and it is used for enhancements of the thermal properties of liquids and is used as heat exchanger liquids. Carbon nanofluids exhibit higher thermal conductivity than the base fluid as it comprises of the solid particles of CNTs dispersed uniformly throughout the liquid.

II. MATERIALS AND METHODS

M. J. Assael et al., 2004 prepared a carbon-multiwall nanotube (C-MWNT) produced by MER Corporation, USA, by the catalytic decomposition method. To ensure the uniform dispersion of C-MWNT in water, sodium dodecyl sulphate (SDS) was employed. A 0.6% volume suspension of C-MWNT in water was employed in all measurements. In this experiment, they prepared three groups of suspensions were prepared i.e., Group A, B, and C. The group A suspensions were prepared by adding C-MWNT in water and then SDS. The suspensions were placed in an ultrasonic homogenization for a period of time from 10 to 180minutes. And the group B suspensions were formed without water content of other suspensions by evaporation. The resulting suspension was placed in ultrasonic homogenization for a period of time ranging from 70 to 320minutes. The suspensions were formed by regenerating C-MWNT from other suspensions in group C suspensions with the successive treatment of centrifugation, homogenization, and drying. The ultrasonic homogenization duration is ranging from 430 to 500 minutes [2].

Later, for further experimentation M.J Assael (*M.J Assael. et.al 2005*), has used hexadecyltrimethylammonium bromide (CTAB), and Nanosphere AQ as dispersant material for studying the homogenization and uniformity of the solutions prepared. He prepared samples of groups A, B, and C with these suspensions and concluded to use CTAB as dispersant as it exhibits more homogeneity of the solution and finally prepares 3 samples which have two samples with CTAB as dispersant and one sample with Nanosphere AQ as the dispersant. These three samples are experimentally analyzed for thermal conductivity.

M. J. Assael et al., 2006 prepared Cu nanospheres were dispersed in ethylene glycol, those provided by MER Corporation USA, with ultrasonic homogenization duration of 60minutes. The enhancement of thermal conductivity of various Nanofluids in the presence of oxide nanoparticles such as CuO and Al_2O_3. Moreover, attempts were made to use Nano diamond dispersed phase, but it seems not fruitful. Because the resulted samples were stable only for few minutes and only minimally increment in enhancement due to a large amount of surfactant needed to achieve the dispersion. M. J. Assael et al. attempted to disperse 0.025vol% C-MWNTs, with a mean diameter of 120nm, in ethylene glycol without the use of dispersants. And then the sample was subjected to ultrasonic vibration for 60minutes and an increase of thermal conductivity with relation to base fluid was measured [3].

When it comes to carbon nanotubes. CNTs are more fascinating materials. They combine macroscale and microscale dimensions. They also exhibit the properties like high thermal conductivity (6,600 W.m-1. K-1 for carbon single-walled nanotubes, C-SWNT) and their low density and M. J. Assael et al. prepared carbon nanotube suspensions with anionic dispersant, sodium dodecyl sulfate was chosen as the anionic dispersant. The aliphatic and hydrophilic parts help in interacts with carbon material and suspend them in the polar environment of ethylene glycol or water. The resulted suspensions were more uniform and stable when compared to the ones prepared without the addition of a dispersant. M. J. Assael examined the suitability of cationic dispersants and selected the hexadecyltrimethylammonium bromide (CTAB) and monitor the effect in thermal conductivity by addition CTAB.T- octylphenoxypolyethoxyethanol (Triton X-100) was selected as the representative substance for non-ionic dispersants to prepare samples.

Phuoc et al. prepared a base fluid by mixing an appropriate amount of lower molecular chitosan (>75% deacetylation) into deionized water of 0.5 vol% acetic acids and stirred with a magnetic stirrer for 24hours. There are three different weight percent's (0.1wt %, 0.2wt %, and 0.5wt %) of chitosan and four different weight percent's of MWCNTs (0.5wt%, 1wt%, 2wt%, 5wt %) were used for the study. For all the samples Phuoc at el. prepared nanofluids by dispersing an appropriate amount of MWCNTs in the base fluid (200ml). the resulted sample was subjected to ultrasonicated for 10minutes at 100% amplitude using a 130W, 20KHz ultrasonic processor (VCX 130, Sonics & Materials Inc.) and it was followed by 10 minutes stirring using magnitude stirrer and the same process was repeated until the total mixing time was 1hour. And the samples were at rest for 24 hours before conducting the thermal conductivity measurements.

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The SAE 20 W50 engine oil was used as a base fluid in *Ettefaghi at. el*. Also, the multi-walled carbon nanotubes with a purity of 95 wt.% were synthesized. They are different methods like bath and probe ultrasonic planetary ball mill and functionalized Ehsan-o-Allah Ettefaghi at el., prepared carbon nanotubes with dodecyl amine (dda) and were dispersed inside the base oil using a planetary ball mill. For animation MWCNTs, 300 mg of carboxylate MWNTs was added to a solution of SoCal2 and DMF (20:1) at 70^0 and stirred for 24 hours. And then MWNTs were filtered and washed with THF several times and dried in a vacuum oven at 50 ^{0}C. Then 200mg of the resulted MWNTs was added to 1kg of dodecyl amine. The black suspension was washed with a sufficient amount of ethanol. Finally, the MWCNTs were dried at 65 ^{0}C overnight, and then MWCNTs – dda was operated on.

III. RESULTS

M. J. Assael et al (2004) have reported that the results of thermal conductivity are shown in Fig. 3. The total homogenization time was employed as the abscissa. As we discussed earlier, three groups of suspensions were prepared, resulted in two curves in Fig.3. The maximum thermal conductivity enhancement reported was 38% using the transient hot-wire method. The suspensions which were prepared as Group A with a length of more than 50μm, showed the highest enhancement of the thermal conductivity while Group B has nanotubes with a length less than 5μm and Group C with a length less than 3μm. M. J. Assael et al (2004) note: (a) effect of SDS concentration: resulted that there is no apparent significance for the thermal conductivity of the suspension. (b) Effect of homogenization time: From Fig.3 showed that increasing the homogenization time reduced the enhancement of the thermal conductivity of the suspension.

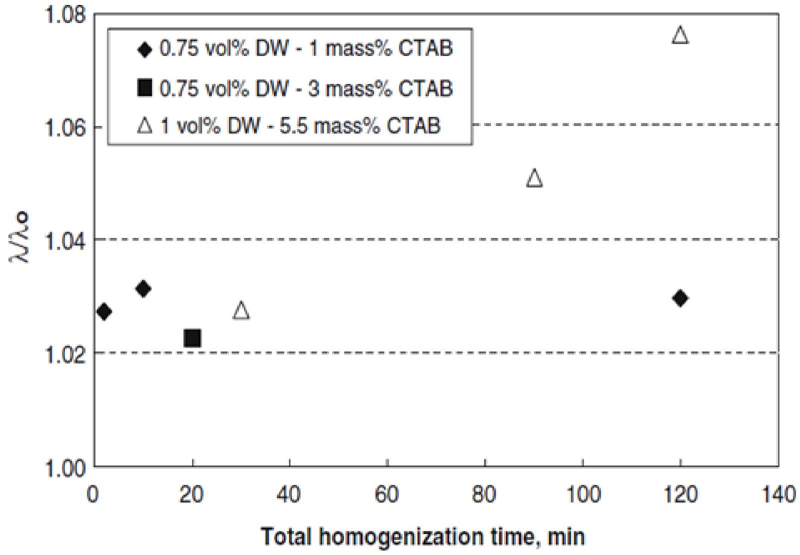

Figure 3: Thermal conductivity measurements of C-DWNT suspensions in water

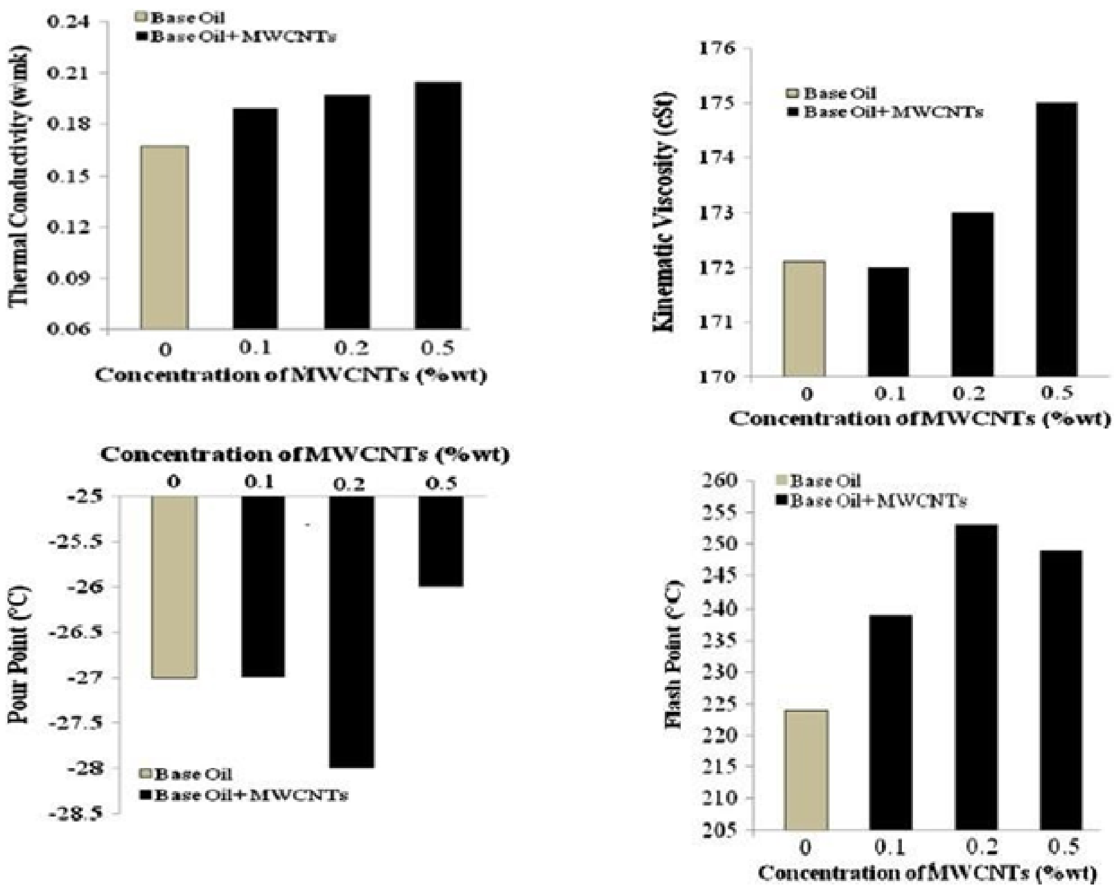

Figure 4: Source Ettefaghi .at. el, show different properties of nano fluids.

M. J. Assael et al 2005. Group A samples shown the largest enhancement in thermal conductivity of 34%. These samples comprised of 0.6 vol% C-MWNT aqueous suspensions, with 1 and 3mass % of CTAB, these are subjected to 10 min of ultrasonic homogenization. He also reported that the concentration of CTAB affects thermal conductivity. For the same homogenization time dispersants variation in thermal conductivity.

Ettefaghi et al 2013 has observed that in engine oil (base fluid) the thermal conductivity increased with an increase in the concentration of the CNT's as shown in Fig. 4. The relation between the concentration and of CNT's and enhancement of thermal conductivity is not linear. The results obtained are 0.1, 0.2 and 0.5wt% concentration had an increase of 13.2%, 18% and 22.7% increase respectively. The base oil viscosity has not shown any significant variation by the addition of small concentrations of the CNT's [5].

III. CONCLUSION

The above results show that the addition of CNT's in various base fluids enhances the properties of the fluids as per requirement. It also shows the maximum enhancement percentage of the thermal conductivity.

- Maximum percentage of enhancement is observed in the sample with base fluid synthetic (α – olefin) oil, dispersant C – MWNT 1 vol%, and the L/D ratio of CNT is 2000. The enhancement percentage is 160%.
- Minimum enhancement percentage of thermal conductivity in the sample Water as base fluid suspended by Nano diamonds 1 mass%.
- The percentage of enhancement is 2% and the dispersant used is SDS 45 mass%.
- As ultrasonic homogenization time increases, the CNT's break down as powders.

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