A Review on Thermal Conductivity of Carbon Nanotube with Water Different Applications

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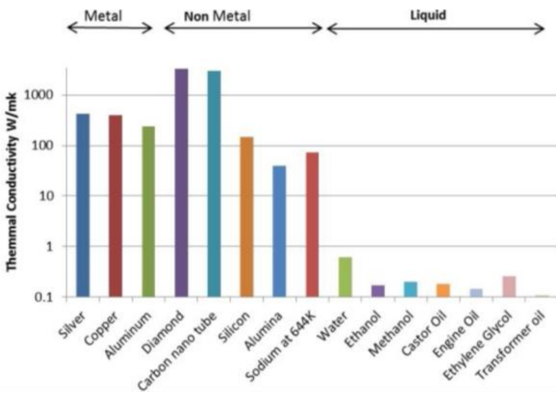
Abstract: **Because of rabbit assessment in an extensive variety of innovations in the twentieth century, thermal scattering prerequisite has expanded violently, particularly conservative frameworks. Numerous analysts focused on oxide nanofluids just, as a result of satisfying their particular prerequisite of thermal conductivity. In any case, nano metal nano liquids additionally have great thermal conductivity like carbon nanotubes, Jewel, and so forth in this paper for the most part focus on thermal conductivity and utilizations of nano liquids for CNT with water. Various scientists researched and connected such a large number of utilization, which prompts to got great thermal conductivity of CNTs with water. Different groupings of CNTs with water give great outcome and furthermore provided for disposal of the parts of the components. And additionally, this paper gives thought regarding planning and applications in point-by-point way. Thermal conductivity of nanofluids gives great outcome with or without surfactant. On the off chance that expansion the thermal conductivity naturally the life of the parts is build, wear, grating, fuel utilization is decrees. This Review paper gives thought regarding CNT with water nanofluid preparation, dispersing operator, and soundness level, thermal conductivity of most recent technique.**

Keywords: Nanofluid, Carbon nano tubes, concentrates, surfactant, Preparation, Thermal conductivity

1. INTRODUCTION

Despite numerous distributions of comparable research, fundamentally, the nanofluids research is still in introductory stage, when the present constrained research (reiteration of comfort) ought to considerably use in sort and degree, also numerous others but then to be found/built useful nanoparticles and creative added substances to upgrade and enhance nanofluids properties and stream qualities. The issue, in this current creator's sentiment, is to find or replicate the nanofluids which indicate upgraded properties. Inquiring about various nanoparticles with various added substances in various base liquids utilizing distinction combination techniques is a test, however (precisely as a result of it) likewise opportunity with numerous application possibilities! That what the future research ought to concentrate on "benchmark consider" [14] Mostly alumina nanoparticles (helpfully acquired) were tried and not those known to exhibit strange Thermal conductivity upgrades, similar to metallic and CNT nanoparticles with significant focuses. Why such nanofluids were not recreated by the taking an interest establishment in the benchmark considers? Nanofluids tried were 1 wt% Carbon multi-walled nanotube (CNT or MWCNT) suspensions in water with obscure added substances (sold under the Nano solve name from Zyvex Performance Materials Co.). The main test outcomes (CNT-1) were repeated later (CNT-2) under comparative conditions since the initially acquired outcomes have been "surprising" and fairly temperamental, likely because of obscure added substances (competitive innovation) used to balance out, generally insecure MWCNT suspensions in water; likewise, conceivably not being blended/ultrasonicated alright before testing. The thermal conductivity for the primary CNT nanofluids (CNT-1) were measured to be near water's (startling outcome) and the second set (CNT-2, with delayed ultrasonication) displayed 23% thermal conductivity upgrade (more sensible outcome). The second sort of tried nanofluids was with 1.0 wt% carbon-nanotube (CNT) nanoparticles. The watched improvement of the convective thermal exchange coefficient was up to 100% bigger than the refined water values at 5000 Re number. At 30,000 Re number the pattern of lessened convective thermal exchange execution was seen when contrasted with the refined water values, which is likely because of the turbulent thermal exchange diminishment because of added substances in CNT nanofluid.



Thermal conductivity that is larger than graphite or diamond. Hone et al[1] Measurements show a room-temperature thermal conductivity over 200 W/m K for bulk samples of single-walled nanotubes (SWNTs), and over 3000 W/m K for individual multiwalled nanotubes (MWNTs). Theoretical work predicts a room-temperature thermal conductivity of 6600 W/m K for individual nanotubes. Measurements show a room temperature thermal conductivity over 200 W/m K for bulk samples of single-walled nanotubes, and over 3000 W/m K for individual multiwalled nanotubes.

Comparison of thermal conductivity of different conventional heat transfer fluids and solids

2. THERMALCONDUCTIVITY OF CNT WITH WATER NANOFLUIDS

The flow of heat in a process can be calculated based on [2]: $Q = hA\Delta T$ (1) where Q is the heat flow, h is the heat transfer coefficient, A is the heat transfer area, and ΔT is the temperature difference that results in heat flow. It can be stated from this equation that increased heat transfer can be achieved by:

(i) Increasing ΔT;
(ii) Increasing A;
(iii) Increasing h.

Kostic [3] emphasized that nanofluids are good to be used in following specific Heat-transfer area. Choi et al. [4], reported a 150% thermal conductivity enhancement of poly(α-olefin) oil with the addition of multiwalled carbon nanotubes (MWCNT) at 1% volume fraction. Similarly, Yang et al. [5], reported a 200% thermal conductivity enhancement for poly(α-olefin) oil containing 0.35% (v/v) MWCNT. Research has shown that the thermal conductivity and the convection heat transfer coefficient of the fluid can be largely enhanced by suspended nanoparticles [11, 6–8]. Choi et al. [4] observed that the thermal conductivity of this nanofluid was 150% greater than that of the oil alone. Based on literatures, it has been found that the improved thermal conductivities of nanofluids are the one of the driving factors for improved performance in different applications. It was found that thermal conductivity of nanofluids with MWCNT can be increased up to 150% [9].Similarly, Yang et al. [5], reported a 200% thermal conductivity enhancement for poly(α-olefin) oil containing 0.35% (v/v) MWCNT. Lee et al. [10] revealed thermal conductivity of nanofluids is affected by pH level and addition of surfactant during nanofluids preparation stage. Better dispersion of nanoparticles is achieved with addition of surfactant such as Sodium dodecyl benzene sulfonate.

3. PROPERTIES OF PURE MWCNT AND WATER

Sl.No	Particulars	MWCNT	Water
1	Density (g/cm3)	0.18	1.0
2	Molar mass (g/mol)	-	18.02
3	Freezing point (°C)	-	0
4	Boiling points (°C)	-	100
5	Viscosity (Ns/m2)	-	1.002×10^{-3}
6	Thermal conductivity (Wm/K)	2000-6000	0.609
7	Specific heat(KJ/Kg k)		4.178

3.1 Summary of literature review for thermal conductivity of CNT with Water nanofluids.

Non-Metallic Nanofluids

Sl.No	Particle	Base Fluid	Average particle size	Volume Fraction	Thermal conductivity enhancement	References
1	MWCNT	Water	100nm in diameter 70µm in length	0.6	38%	[25]
2.	Carbon nano tubes	Water	-	-	32.90%	[25]
3	Carbon nano tubes	Water	-	-	77.80%	[25]
4	MWCNT	poly(α-olefin)	-	1	150%	[4]
5	MWCNT	poly(α-olefin)	-	0.35	200%	[5]
6	MWCNT	Engine oil	-	0.5	12.7%	[13]
7	MWCNT	EG/Water	-	0.4	49.6%	[14]

3.2 The augmentation factor ($^{\alpha cond}$) of CNTnanofluids.

Sl.No	Particle material	Base fluid material	Tube size diameter (nm)/length (µm)	α_{cond}	References
1	Carbon nano tubes	Water	15/30	7.5	[25]
2	Carbon nano tubes	Water	150/10	44	[25]
3	Carbon nano tubes	Water	40/50	37	[25]
4	Carbon nano tubes	Ethylene glycol	15/30	12	[25]
5	Carbon nano tubes	Decene	15/30	81.8	[25]

3.3 Zeta potential of normal water and carboxylated water with CNTs

Sample	Zeta potential (mV)
Water + 0.025 % CNTs	20.5
Water + 0.1 % CNTs	18.8
Carboxylated water + 0.025 % CNTs	38.2
Carboxylated water + 0.1 % CNTs	30.11

(25) it can be found that CNTs are more stable in water with carboxylates than that with normal water.[25] It is found that the improvement in thermal conductivity from base fluid at 50^0 C with 0.025 % CNTs is 8.12 %, with 0.05 % CNTs is 14.58 % and with 0.1 % is 17.85 %.

3.4 Specific heat results of base fluid and various combinations of nanofluids

S. no	Fluid	Specific heat (Cp)
1	Base fluid	4.223
2	Base fluid +0.025 % CNTs	4.185
3	Base fluid +0.05 % CNTs	4.178
4	Base fluid + 0.1 % CNTs	4.165

3.5 Overall Heat Transfer Coefficient, U(W/mk)

V (m/s)	Base fluid (carboxylates)	Base fluid + 0.025 % MWCNTs	Base fluid +0.05 % MWCNTs	Base fluid +0.1 % MWCNTs
5	574.96	745.08	953.85	1073.67
10	713.10	882.35	1038.70	1102.77
15	884.51	1040.48	1136.20	1213.36

CNTs dispersed in carboxylated water did not alter the corrosion behavior and hence are suitable to automotive environment.[25]The zeta potential of carboxylated water dispersed with CNTs is found to be better compared to normal water dispersed with CNTs. Carboxylated water dispersed with 0.025, 0.05 and 0.1 % of CNTs could improve the heat transfer characteristics of nanofluids.

4. APPLICATIONS ORIENTED THERMAL CONDUCTIVITY

(i)Thermal conductivity of CNT with Water nanofluids in Car Engine

Experimental investigation on the performance of nanofluid in vehicle cooling system of an actual car engine was initiated by Tzeng et al. [12]. Ettefaghi et al.[13] MWCNT–engine oil Maximum enhancement of thermal conductivity of the nanofluids was 12.7% with 0.5 vol.% of MWCNT nanoparticles at 20 °C. Teng and Yu [14] MWCNT–EG/water (50 vol.% of EG) Maximum enhancement of thermal conductivity of the MWCNT–EG/W nanofluids was 49.6% with 0.4 vol.% of nanoparticles compared to EG/W. Maximum efficiency factor was 14.1% at low concentration of MWCNT nanoparticle.

(ii)Thermal conductivity of CNT with Water nanofluids in Radiator

Experimental research on the convective heat transfer performance of nanofluids has been published with various combinations of base fluids and suspensions [15–24]. The suspended nano material remarkably increased the forced convective heat transfer performance of the base fluid. At the same Reynolds number, the heat transfer of the nano fluid found to be increased with the particle volume fraction. Sahu and Chougule [20] have done studies on convective heat transfer enhancement of CNT-water nanofluid inside an automobile radiator. They found that both nano coolants exhibit enormous change in Nusselt number compared to normal water. It is observed that coolant with lower pH exhibits better performance compared to coolant with pH above 7. Sahu and Chougule [21] in another paper studied the forced convective heat transfer performance of two different nanofluids Al_2O_3-water and CNT-water in an automobile radiator. The coolant flow rate is varied in the range of 2–5 l/min. It is found that the heat transfer performance of CNT-water nanofluid was found to be better than Al_2O_3-water nano coolant Most of the researchers studied the effect of normal distilled water with nano particle addition. However, normal water is not suitable as coolant in automotive systems due to its poor corrosion properties. Base fluids are prepared with water and carboxylates of sebacic acid/2-ethylhexanoic acid with sodium nitrate as stabilizer and sodium hydroxide as pH buffer. Further to organic inhibiters, 0.1 % of Tolyltriazole is added to the solution [25]

Development in industries is facing a lot of confrontation on cooling demand because the already existing coolants attained the level of their limitations. The nano materials undergo dispersion and creates base fluids which are then called as nano fluids. The nano fluids are developed to deal with the thermal systems coolant problems. A two step method have been made on the base liquids such as distilled water, coolant oil, engine oil, gear oil, vegetable oil and grown oil at 0.1% volume concentration to prepare the nanofluids. The level of dynamic kinetic viscosities and the flash and fire point was also measured. It is studied that the MWCNT/ Vegetable oil nanofluid gives highest flash point than the other fluids. Fire points of nanofluids prepared are comparatively higher than the conventional fluid. The MWCNT/Vegetable oil has highest fire point than other fluids.[26]

A techno-economic evaluation has been made on a PVT system. There is a tank attached to the PV Cooling system and on the panel back side is filled with PCM (Paraffin wax) which is mixed with nano-SiC in order to increase the thermal conductivity and the recycling nanofluids (water + nano-SiC) are used to cool down the reservoir. For economic evaluation, MATLAB program was used. The data obtained from the experimental work was used for evaluation. The nano-fluids are used along with nano-PCMs to improve the efficiency of heat transfer. The study was made with Silicon Carbide and Paraffin wax. The percentage cost of the system, cost of per item and the life cycle was determined using economic evaluation. The efficiency of the inverter, the specific yield and the capacity factor of 97.3%, 190.4kWh/kWp, and 25.9% were the factors of technical side. The thermal and electrical efficiencies and the output power of this system are 72.0%, 13.7% and 12.7W respectively. The cost of electricity was determined as 0.125$/kWh and the payback period is set as 5-6 years. This shows that the system is economically promising.[27]

An indoor experiment has been carried out of a PV module under controlled operating conditions and parameters. A novel design of thermal collector has been introduced, a complete PVT system assembled and water/MWCNT nanofluids used to enhance the thermal performance of PVT. An active cooling for PVT system has been maintained by using a centrifugal pump and a radiator have been used in the cycle to dissipate the heat of nanofluids in the environment to maintain proposed inlet temperature. 3D numerical simulation has been conducted with FEM based software COMSOL Multiphysics and validated by the indoor experimental research at different irradiation level from 200 to 1000 W/m2, weight fraction from 0 to 1% while keeping mass flow rate 0.5 L/min and inlet temperature 32 °C. The numerical results show a positive response to the experimental measurements. In experimental case, percentage of enhanced PV performance is found as 9.2% by using water cooling system. Higher thermal performance is obtained as approximately 4 and 3.67% in numerical and experimental studies, respectively by using nanofluids than water. In the PVT system operated by nanofluids at 1000 W/m2 irradiation, the numerical and experimental overall efficiency are found to be 89.2 and 87.65% respectively.[28]

The heat transfer efficiency and aqueous suspensions of multi-walled carbon nanotubes (CNT nanofluids) which are flowing through a horizontal tube was recorded. Significant enhancement of the convective heat transfer is observed. Depending on the flow conditions (Reynolds number, Re), the CNT concentration and the pH has been enhanced. The enhancement is considered as a function of axial distance from the inlet, increasing first, reaches a maximum, and then decreases with increasing axial distance. The CNT concentration and Re affects the axial position of maximum enhancement. A considerable increase in the convective heat transfer coefficient occurs due to the CNT Concentration and Re. The shear thinning behavior occurs due to this increase. For nanofluids containing 0.5 wt.% CNTs, the maximum enhancement reaches over 350% at Re = 800, which could not be attributed fully to the enhanced thermal conduction. Particle re-arrangement, shear-induced thermal conduction enhancement, reduction of thermal boundary due to the presence of Nanoparticles, as well as the very high aspect ratio of CNTs are the possible mechanisms proposed to occur.[29]

Characterization and the sensitivity study of thermal conductivity of Al2O3 nanofluids in different base fluids with change in concentration and temperature. In this work, the solution combustion synthesis method was used for synthesis and samples were combusted at three different temperatures. It was observed that increase in combustion temperature leads to the increase in particle size. Al2O3 Nanoparticles combusted at 1000°C, having average particle size 53 nm, were used for preparation of nanofluids in distilled water and ethylene glycol base fluids using two step approach. For change in temperature from 10 to 70 °C and concentration variation from 0 to 2 vol%; 30 and 31% increase in thermal conductivity was observed for distilled water and ethylene glycol based Al2O3 nanofluids, respectively. Finally, sensitivity analysis for thermal conductivity was also performed. Results of sensitivity analysis revealed that change in thermal conductivity is more sensitive to increase in volume percent at higher concentration.[30]

A set of three nanofluids of different blends were prepared with ethylene glycol–water and TiO2 Nanoparticles and are characterized for thermal conductivity as a function of temperature and volume concentration of Nanoparticles. The measurements were taken in the temperature range from 30 °C to 70 °C, which happens to be most widely used range of temperature for many cooling applications in heat transfer equipment. Nanofluids were prepared by dispersing the Nanoparticles in base fluids such as (1) water, (2) ethylene glycol plus water in the ratio of 40%:60% and 3) ethylene glycol plus water in the ratio of 50%:50% by weight. Based on the experimental results, it is observed that the thermal conductivity of TiO2 nanofluids, considered in the present investigation, increases with increase in percentage of volume concentration of TiO2 and also with temperature. Current experimental investigation presents valuable data on the measured thermal conductivity of TiO2 nanofluids for very low volume concentrations from 0.2% to 1.0% of Nanoparticles in the temperature range of 30 °C–70 °C.[31]

A recent remarkable advance in the field of nanotechnology has been achieved in the last few years especially in the fabrication of sensors that have wide number of applications. Nanomaterials are the foundation of nanotechnology that are measured on nanoscale. Carbon nanotubes (CNTs) are tube-like materials that are made up of carbon with a diameter calculating on a nanometer scale. They are originated from graphite sheet and these graphite layers seems similar to a rolled up non-stop unbreakable hexagonal like mesh structure and the carbon molecules appears at the apexes of the hexagonal structures. Depending upon the number of carbon layers, carbon nanotubes can be single-walled carbon nanotubes (SWCNTs), double-walled carbon nanotubes (DWCNTs) and multi-walled carbon nanotubes (MWCNTs). Carbon nanotubes (CNTs) can be fabricated by three main methods i.e., chemical vapor deposition, electric arc method and laser deposition method. Carbon nanotubes exhibit various characteristic properties such as high elasticity, high thermal conductivity, low density and they are chemically more inert etc. Due to these interesting properties, carbon nanotubes have played a significant role in the field of nanotechnology, electronics, optics and other fields of materials science. Carbon nanotubes are being positively applied in drug delivery, sensing, water treatment etc. Functionalization of their surface can result in highly soluble materials, which can be further derivative with active molecules, making them compatible with biological systems. Surface Functionalization enables adsorption or attachment of various molecules or antigens, which subsequently can be targeted to the desired cell population for immune recognition or a therapeutic effect. 32]

The demand for increasing the strength of the structural element without an increase in the size of the elements leads to the introduction of reinforcements. Employing carbon nanotubes for increasing the strength of the material has been successfully carried out in the last decade of the twentieth century. In the present work, a review has been carried regarding predicting material properties of single-walled carbon nanotubes (SWCNTs) using computational models. Different approaches related to predicting the properties are discussed in detail. Also, the present work summarizes the review on the analysis of SWCNT reinforced composite beams, plates, and shells under static, vibration, and buckling conditions. After the detailed review, gap areas are also reported in the present work which will help in the research work to be carried out in near future on the related topic. [33]

Carbon Nanotubes (CNTs) are the allotropes of carbon which belong to the fullerene structural family. These are cylindrical structures with at least one end closed with a buckyball structure hemisphere. They are few nano meter in diameter and have tensile strength of ∼63 GPa and young's modulus of ∼1TPa. On the basis of structures carbon nanotubes can be classified as Single-walled (SWNT), Multi-walled (MWNT), Polymerized SWNT, Nan torus and Nan buds. Carbon Nanotubes can behave as metal or as a semiconductor depending on the nature of its helix. They are good thermal conductors along their axis but act as insulators in the lateral direction. Major manufacturing techniques employed for fabrication of CNTs are Arc discharge, Laser Ablation and Chemical vapor deposition. Carbon Nanotubes are extending our ability to fabricate devices such as molecular probes, pipes, wires, bearings, springs, gears and pumps.[34]

Nanofluids are the new engineering material which consists of nanometer-sized particles that are dispersed in base fluid. To enhancing thermal conductivity and lubricity, various Nanoparticles like multi-walled carbon Nanotube (MWCNT), fullerene, copper oxide, and silicon dioxide have been used to manufacture nanofluids. DI water, ethylene glycol, and oil have been used as base fluids. Thermal conductivity has been recorded to check the thermo-physical properties of nanofluids. The experimental inferences of thermal conductivity of nanofluids have been compared with the modeling results predicted by Jang and Choi model [14]. The stability of nanofluids was measured using UV–vis spectrophotometer. Increase in the volume fraction of nanofluids increases its thermal conductivity except for water-based fullerene nanofluids. It has lower thermal conductivity of 0.4 W/mK than that of base fluid. The characteristics between base fluid and suspended Nanoparticles determines the stability of nanofluids.[35]

Direct method to measure the thermal conductivity of epoxy in the liquid (nanofluids) and solid (nanocomposite) states using both rod like and platelet-like carbon-based nanostructures. Comparing the experimental results with the theoretical model, an anomalous enhancement was obtained with multiwall carbon nanotubes, probably due to their layered structure and lowest surface resistance. Puzzling results for functionalized graphene sheet nanocomposite suggest that phonon coupling of the vibration modes of the graphene and of the polymeric matrix plays a dominant role on the thermal conductivities of the liquid and solid states.[36]

The exciting coolants have reached their limitations of heat dissipating capacity. It is studied from the literature review that nanofluids are the novel and alternate heat transfer medium with significant temperature-dependent thermal conductivity even at very low particle concentrations than the conventional heat transfer fluids. In this experimental investigation, the multi walled carbon Nanotube (MWCNT) water is used as a coolant in four stroke single cylinder diesel engine to assess the performance of the engine. The MWCNT/ water nanofluids is prepared with surfactant to get the stable suspension of nanofluids. Tests are performed by constant the mass flow rate 330 LPH of

coolant nanofluids and by changing the load and by keeping the speed constant. It is found that the brake thermal efficiency increases by 10 to 15%, exhaust temperature decreases by 8 to 10% decreases and the specific fuel consumption decreases when compared to water as a coolant at the same testing condition.[37]
Heat transfer enhancement techniques refer to different methods used to increase the rate of heat transfer without affecting much the overall performance of the system. These techniques are used in manufacturing industries. Some of application of cooling of electronics, cooling of transformer oil, improving diesel generator efficiency, cooling of heat exchanging devices based on results available in the literatures, It has been found nano fluids have much higher and strongly temperature--dependent, thermal conductivity at very low particle concentration than conventional fluids. So many researchers have shown that the thermal conductivity and the convection heat transfer co-efficient of the fluid can largely enhance by suspended nano particles. The most of the oxide nanofluids are ineffective as heat transfer liquids and certain CNT nanofluids are effective. 38]
Recent advances in the customization of nanofluids to obtain specific thermo physical properties have led to an increase in the need for a better understanding of the various factors that impact thermal conductivity. The term nanofluids refer to the combination of any nanoscale material with a base fluid. Although investigations of the development and application of nanofluids have expanded dramatically over the past decade, the number of commercialized applications of nanofluids is somewhat limited, with the majority of the research focused on investigations of the theory and fundamental science. This review discusses the various applications of nanofluids briefly. It focuses on a discussion of the various parameters that have been found to impact the thermal behavior in general significantly and the thermal conductivity of these nanofluids, including parameters such as particle size and shape, the pH of the fluids, surfactant, solvent type, hydrogen bonding, temperature, base fluids, and particular interest here, the alignment of the Nanoparticles utilized (carbon nanotubes, Graphene, and metal oxides Nanoparticles). These parameters have been found to affect the thermal conductivity of the nanofluids directly and can either increase or decrease the thermal conductivity. In contrast, other parameters, such as the viscosity, have an "indirect" effect on the thermal conductivity. While there is broad agreement that these parameters govern the thermal conductivity and hence, the heat transfer capability of the nanofluids, there is a lack of a clear consensus about the relative importance and impact of these thermo physical properties and, in some cases, actually conflicting data in the literature. This lack of clarity in the effect of these various parameters has resulted in the relatively slow adoption, implementation, and application of these nanofluids in commercial applications. The stability of the nanofluids and the Nanoparticles suspension duration are other issues that limit commercialization efforts. The information presented here helps to clarify these issues and also explores the effects of factors such as Nanoparticles size and type, which may lead to additional opportunities for commercial applications.[39]

CONCLUSION

In this Article described Carbon with traditional fluids which gives more amount of heat transfer as well as efficiency of the system. Diamond is highest thermal conductivity material in the world then Carbon. Diamond is too cost material compare than any other materials. So that we are reviewed on Carbon based Nanofluids as following criteria. (i)Thermal Conductivity of CNT with Water Nanofluids is 200% thermal conductivity enhancement for poly(α-olefin) oil containing 0.35% (v/v) MWCNT. (ii)The augmentation factor ($_{\iota}^{\alpha cond}$) of CNT nanofluids which give more on Carbon Nanotube with base nanofluids material in Decene. (iii)Zeta potential of normal water and carboxylated water with CNTs, can be found that CNTs are more stable in water with carboxylated than that with normal water. (iv) Specific heat results of base fluid and various combinations of nanofluids decrease when increases volume concentration of nanoparticles. (v) Overall Heat Transfer Coefficient CNTs dispersed in carboxylated water did not alter the corrosion behavior and hence are suitable to automotive environment.

REFERENCE

[1] J. Hone *Columbia University*, New York, *U.S.A.* Dekker Encyclopedia of Nanoscience and

Nanotechnology DOI: 10.1081/E-ENN 120009 128/2004

[2] Beck M. Thermal conductivity of metal oxide nanofluids. PhD thesis. Georgia Institute of Technology; 2008.

[3] Kostic. www.kostic.niu.edu/DRnanofluids; 2009 [14.11.2009].

[4] Choi SUS, Zhang ZG, Yu W, Lockwood FE, Grulke EA. Anomalous thermal conductivity enhancement in nanotube suspensions. Appl Phys Lett 2001;79(14):2252–4.

[5] Yang Y. Carbon nanofluids for lubricant application. *PhD thesis. University of Kentucky*; 2006.

[6] Xuan YM, Roetzel W. Conceptions for heat transfer correlation of nanofluids. Int *J Heat Mass Transfer* 2000;43(October (19)):3701–7.

[7] Choi SUS, Yu W, Hull JR, Zhang ZG, Lockwood FE. Nanofluids for vehicle thermal management, 2001-01-1706. *Society of Automotive Engineers*; 2001. p. 139–144.

[8] Keblinski P, Nayak SK, Zapol P. Charge distribution and stability of charged carbon nanotubes. *Phys Rev Lett* 2002;89(December (25)) [article number: 255503].

[9] Choi SUS, Zhang ZG, Yu W, Lockwood FE, Grulke EA. Anomalous thermalconductivity enhancement in nano tube suspensions. *Appl Phys Lett* 2001;79:2252–4.

[10] Lee J-H, Hwang KS, Jang SP, Lee BH, Kim JH, Choi SUS, et al. Effective viscositiesand thermal conductivities of aqueous nanofluids containing low volume concentrations of Al_2O_3 nanoparticles. *Int J Heat Mass Transfer* 2008;51(11–12):2651–6.

[11] Choi SUS. In: Singer DA, Wang HP, editors. Development and application of non-Newtonian flows, vol. FED 231. New York: *ASME*; 1995. p. 99–105.

[12] S.-C. Tzeng, C.-W. Lin, K.D. Huang, Heat transfer enhancement of nanofluids in rotary blade coupling of four-wheel-drive vehicles, *Acta Mech*. 179 (2005) 11–23.

[13] E.-O.-L. Ettefaghi, H. Ahmadi, A. Rashidi, A. Nouralishahi, S.S. Mohtasebi, Preparation and thermal properties of oil-based nanofluid from multi-walled carbon nanotubes and engine oil as nano-lubricant, *Int. Comm. Heat Mass Transfer* 46 (2013) 142–147.

[14] T.-P. Teng, C.-C. Yu, Heat dissipation performance of MWCNTs nano-coolant for vehicle, Exp. *Thermal Fluid Sci.* 49 (2013) 22–30.

[15] S. Lee, S.U.S. Choi, S. Li, J.A. Eastman, Measuring thermal conductivity of fluids containing oxide nanoparticles. *J. Heat Transf.* 121(2), 280–289 (1999).

[16] L. Vaisman, W.H. Daniel, G. Marom, The role of surfactants in dispersion of carbon nanotubes. *Adv. Colloid Interface Sci*. 128–130, 37–46 (2006).

[17] F.D.S. Marquis, L.P.F. Chibante, Improving the heat transfer of nanofluids and nanolubricants with carbon nanotubes. *JOM* 57(12), 32–43 (2005).

[18] B.C. Pak, Y.I. Cho, Hydrodynamic and heat transfer study of dispersed fluids with submicron metallic oxide particles. *Exp. Heat Transf.* 11(2), 151–170 (1998).

[19] R. Prasher, W. Evans, P. Meakin, J. Fish, P. Phelan, P. Keblinski, Effect of aggregation on thermal conduction in colloidal nanofluids. *Appl. Phys. Lett.* 89, 143119 (2006).

[20] S.S. Chougule, S.K. Sahu, Thermal performance of automobile radiator using carbon nanotube-water nanofluid—experimental study. *J. Therm. Sci. Eng. Appl.* 6(4), 041009 (2014).

[21] S.S. Chougule, S.K. Sahu, Comparative study of cooling performance of automobile radiator using Al2O3-water and carbon nanotube-water nanofluid. *J. Nanotechnol. Eng. Med.* 5(1), 011001-1–011001-5 (2014).

[22] S. Sarkar, R.P. Selvam, Molecular dynamics simulation of effective thermal conductivity and study of enhanced thermal transport mechanism in nanofluids. *J. Appl. Phys.* 102, 074302(2007).

[23] S. Ozerinc, S. Kakac, A.G. Yazicioglu, Enhanced thermal conductivity of nanofluids : *a state-of-the-art review. Microfluid. Nanofluid.* 8(2), 145–170 (2010).

[24] T.-P. Teng, C.-C. Yu, Heat dissipation performance of MWCNTs nano-coolant for vehicle. *Exp. Therm. Fluid Sci.* 49, 22–30 (2013).

[25] Chellapilla V. K. N. S. N. Moorthy,Corrosion and Heat Transfer Characteristis of water Dispersed Carboxylate Additives and MWCNTs. *The Institution of Engineers (India)* 2016 .

[26] M. Muruganandam ,Flow and Thermal properties evaluation of MWCNT Nanofluids with Different

base fluids, *International Journal of Transactions on Innovations in Science and Technology*, pp26-31, 2016/2/3

[27] AHA Al-Waeli, HA Kazem, MT Chaichan, K Sopian Experimental investigation of using nano-PCM/nanofluid on a photovoltaic thermal system (PVT): *Technical and economic study Thermal Science and Engineering Progress*, pp 213-230,9 April 2019.

[28] Rehena Nasrin, Nasrudin Abd Rahim, Hussain Fayaz, Md Hasanuzzaman Water/MWCNT nanofluid based cooling system of PVT: *Experimental and numerical research Renewable Energy* pp286-300, 2018/6/1.

[29] YulongDing, HajarAlias, DongshengWen, RichardA. Williams, Heat transfer of aqueous suspensions of carbon nanotubes (CNT nanofluids),*International Journal of Heat and Mass Transfer* Pages 240-250, January 2006.

[30] RaviAgarwal, KamaleshVerma, Narendra KumarAgrawal, RamvirSingh Sensitivity of thermal conductivity for Al2O3 nanofluids, *Experimental Thermal and Fluid Science*, pp19-26,January 2017.

[31] M. Chandra SekharaReddy, V.VasudevaRao, Experimental studies on thermal conductivity of blends of ethylene glycol-water-based TiO2 nanofluids, International *Communications in Heat and Mass Transfer*, Pages 31-36,August 2013.

[32] Nigar Anzar, Rahil Hasan, Manshi Tyagi,NeelamYadav, Jagriti Naranga ,Carbon nanotube - A review on Synthesis, Properties and plethora of applications in the field of biomedical science, *Sensors International*,10 March 2020.

[33] A.Garga, H.D.Chalak, M-O.Belarbi, A.M.Zenkour, R.Sahoo, Estimation of carbon nanotubes and their applications as reinforcing composite materials–An engineering review, *Composite Structures*,15 September 2021.

[34] Rajesh Purohit, Kuldeep Purohit, Saraswati Rana,R.S.Rana, VivekPatel, Carbon Nanotubes and Their Growth Methods, *Procedia Materials Science*, Pages 716-728,9 September 2014.

[35] Y.Hwang, J.K.Lee, C.H.Lee, Y.M.Jung, S.I.Cheong, C.G.Lee,B.C.Ku, S.P.Jang,Stability and thermal conductivity characteristics of nanofluids, *Thermochimica Acta*, Pages 70-74, 1 April 2007.

[36] Mario Martin-Gallego, Raquel Verdejo, Mohamed Khayet, Jose Maria Ortiz de Zarate, Mohamed Essalhi& Miguel Angel Lopez-Manchado, Thermal conductivity of carbon nanotubes and graphene in epoxy nanofluids and nanocomposites, *Nanoscale Research Letters*,01 December 2011.

[37] Muruganandam M[1] P. C. Mukesh Kumar[2], Experimental analysis of four stroke diesel engine by using carbon nano tubes based nano fluids as a coolant, *Journal of Applied Fluid Mechanics*, pp 1-5,2017/1/1.

[38] Muruganandam M[1] P. C. Mukesh Kumar[2] ,A review of heat transfer enhancement using nano fluids with different base fluids: *Advances in Natural and Applied Sciences*, Vol. 11, Issue 8, June 2017.

[39] HammadYounes, MingyangMao, S.M.Sohel Murshed, DingLou, HaipingHong, G.P.Peterson, Nanofluids: Key parameters to enhance thermal conductivity and its applications, *Applied Thermal Engineering*,5 May 2022.