IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 7.047 ⋇ Vol. 10, Issue 4, April 2022

DOI: 10.17148/IJIREEICE.2022.10481

ENHANCEMENT OF HEAT TRANSFER IN A THERMOELETRIC COOLER BY USING NANOFLUIDS

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Abstract: The thermal performance of a small heat sink thermoelectric cooling module using water, nanofluid, and ferrofluid as coolants is experimentally studied in this paper. At levels of 0.005 percent and 0.015 percent, respectively, the TiO2 nanofluid and Fe3O4 ferrofluid were investigated. A heat load was created by filling a fake battery pack with water at a consistent temperature. The Fe3O4 ferrofluid used to have a maximum heat transfer rate that was 11.17 percent higher and 12.57 percent higher than the TiO2 nanofluid and water, respectively. The 0.015 percent concentration of TiO2 nanofluid and Fe3O4 ferrofluid enhanced the Peltier effect by lowering the contribution of the Fourier effect of the thermoelectric cooler (TEC), lowering the temperature difference of the TEC cooling module by 4.6 percent and 9.6 percent, respectively, lowering the thermal resistance of the heat sink by 7 percent and 14 percent. More crucially, as compared to water, using nanofluids and ferrofluids with a 0.015 percent concentration as coolants increased pressure drop by 0.5 kPa and 2.7 kPa, respectively.

Keywords: Thermoelectric, Ferrofluid, Nanofluid, Heat transfer, Battery cooling

I. INTRODUCTION

Preparation of nanofluid is of prime importance to obtain better thermal and physical properties. Different preparation parameters used in nanofluid preparation sometimes perform contrarily even if prepared with same nanoparticles and base fluid. Stability, thermal conductivity, and viscosity of the nanofluid are significantly affected by the cluster (agglomerate) size of nanoparticles in the base fluid which deteriorate thermal performance. In order to break the agglomerates and improve the dispersion of nanoparticles, ultrasonication is a more prevalent method. Nanofluids react differently for different sonication time and the reaction of the nanofluid with the change in sonication time varies for different nanofluids, which is dependent on various factors. In this regard, research works pertinent to the effect of ultrasonication on different properties of nanofluids are confined. The idea of mixing nanoparticles into the conventional working fluids (i.e., water, ethylene glycol, oil, glycerol) to improve the thermo physical properties and heat transfer performance of the working fluids has been proposed for the first time by Choi and Eastman. Following this pioneering study, many researchers investigated different aspects of nanofluids (NFs), as a new class of working fluids,; thermal conductivity, dynamic viscosity, employing different neural networks to predict the thermophysical properties, and heat transfer performance. In recent decade,many researchers also tried to review the recent advances and introducing the knowledge gap in preparation methods ,viscosity , thermal conductivity heat transfer of NFs and their application, and modeling and simulation of NFs.There are numerous merits in dispersing NPs compared to millimeter-sized particles into working fluids such as better stability of NPs into base fluids, lower viscosity increase, higher thermal conductivity enhancement, lower corrosion, and so forth. All the mentioned merits will be achieved in the case that the NFs possess good stability, which means that the particles uniformly distributed in the base fluid with the minimum agglomeration and sedimentation. Thus it is understood that the sample preparation with good stability is the most crucial step in conducting experimental studies on thermophysical properties and heat transfer of NFs. There are two common methods in preparing the NFs' samples; single-step methods and two-step methods. In both of the methods, applying the ultrasonication is the crucial factor in breaking down the large clusters of the NPs into the smaller ones to achieve a long-time stable NFs. Generally, the ultrasonication process utilizes for the following purposes.

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 7.047 ⫹ Vol. 10, Issue 4, April 2022

DOI: 10.17148/IJIREEICE.2022.10481

- De-agglomeration of particles
- Particle size reduction
- Particles synthesis and precipitation
- Dispersing the particles into the working fluids

There are various parameters in appliying the ultra-sonication , which affect the stability of the NFs. The most important parameters are as Follow:

- The type of ultrasonic device; Both or Probe
- Ultrasonication time
- ultrasonication power

In this regard, researchers have conducted different experimental studies on the effects of ultrasonication time, power, and type of ultrasonic devices on the stability and thermo physical properties of different nanofluids. Mahbubul et al. studied the effects of ultra-sonication time on the stability and rheological properties of Al_2O_3-water NF. They prepared the sample containing 0.5 vol.% spherical Al_2O_3 NPs with a mean diameter of 13 nm. They applied different ultrasonication times of 1, 2, 3, 4, and 5 h using an ultrasonic probe device with the power of 500 W on the pulse mode (2 s ON, 2 s OFF). They observed that prolonging the ultrasonication time leads to enhancing the quality of the colloidal dispersion. They also declared that increasing the ultrasonication time results in decreasing the dynamic viscosity of the NF. The effects of ultrasonication energy on the stability and viscosity of the Al_2O_3-glycol NF has been experimentally studied by Adio et al. They used the ultrasonic probe device with the power of 200 W to disperse the NPs in different solid concentrations (SCs) up to 5 vol.%. They observed that increasing the sonication time leads to decreasing the viscosity and increasing the stability of the NF.other experimental investigation, the effects of ultrasonication on stability, dynamic viscosity, and thermal conductivity of a NF containing multi-walled carbon nanotubes (MWCNT) have been studied by Kumar.

II. LITERATURE SERVEY

Amin Asadi et al: In the present study, the possible effects of ultrasonication time on the stability and thermal conductivity of MWCNT-water NF has been experimentally investigated. The samples have been prepared in three different SCs of 0.1, 0.3, and 0.5 vol.% subjecting the samples to different ultrasonication times of 10, 20, 40, 60, 70, 75, and 80 min. Furthermore, the thermal conductivity measurements have been done over different temperatures ranging from 25 to 60 °C employing KD2 Pro thermal analyzer. The stability of the samples has been evaluated by conducting the visual observation and Zeta potential analysis in different time steps; 1st day, 5th day, 10th day, and 30th day after the preparation. It is observed that increasing the ultrasonication time until 60 min results in enhancing the stability quality of the samples while prolonging the ultrasonication leads to deteriorating the stability of the samples. Moreover, the thermal conductivity measurements showed that adding MWCNT nanoparticles to the base fluid leads to enhancing the thermal conductivity of the samples. It is also observed that increasing the temperature leads to increasing the thermal conductivity of the samples in all the studied SCs. The thermal conductivity of the samples subjected to different ultrasonication times revealed that the samples with 60 min ultrasonication possesses the highest thermal conductivity. Increasing the ultrasonication time until 60 min results in a gentle increase in thermal conductivity and after that point, it started to decrease. Thus, it is concluded that the 60 min ultrasonication is the optimum time in which the samples possess the highest stability and thermal conductivity. Based on the achieved results of thermal.

Asif Afzal et al: Ultrasonication time has twofold effect on the nanofluids. At the optimum processing time, the ultrasonication aids in forming better dispersions, however, once the optimum time has been reached further ultrasonication results in an re-agglomeration.
Theoptimum ultrasonication time is dependent on sonicator power, frequency used, volume concentration, nanomaterial type, base fluid, ultrasonicator type, etc.
It is also observed that the sonication process not only reduces the agglomerate sizes but also decreases the size of the nanoparticle.
Initially, at the beginning of ultrasonication, thermal conductivity of nanofluids were found to be decreased and further ultrasonication, the thermal conductivity of he nanofluids increases for a certain optimum time depending on nanofluid.

Impact Factor 7.047 ⚟ Vol. 10, Issue 4, April 2022

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In the case of viscosity two types of trends were observed where one trend is that viscosity of nanofluid was decreased with increasing ultrasonication and other trend is the viscosity of nanofluids increases to the maximum for certain ultrasonication time then decreases, finally approaching the viscosity of the pure base fluid.
Density of nanofluids was found to be increased with increasing ultrasonication durations. • The stability of the nanofluid also depends on type of surfactant used. Surfactant used are usually nanomaterial specific. The concentration of surfactant used is also of concern. Using lesser concentration may lead to lower stability and over use may increase viscosity and thus increasing pressure drop. The stability of the nanofluid with surfactant is very much enhanced in comparison with the nanofluid without surfactants With surfactant the nanofluids achieved stability for over months.

Rizwan Farade et al: the current research, long term stable cottonseed oil(CSO) based nanofluid were synthesized for the application as DNFs. Graphene nanoparticles were used at different weight fractions (0.0015 wt%, 0.003 wt%, 0.006 wt%, and0.01 wt%) and nanofluids were prepared with different ultra-sonication periods (10, 20, 30 and 60-minute). The graphene morphology and stacking were successfully characterized R. A. Farade et al. Investigation of Effect of Sonication Time on Dispersion Stability, Dielectric Properties, and Heat Transfer using SEM, TEM, EDX, and XRD. For nanofluids, the pre-pared samples were kept stationary for a period of 2 week and thus were examined by visual inspection. It was found that the samples prepared with the ultrasonication period of 60-minute and 30-minute are more stable than others (10-minute and 20-minute). Thus, these periods were adopted for quantitative evaluation of stability through using UV-Vis spectroscopy, and for dielectric and thermal property measurements DNFs with 60-minute ultrasonication time had higher absorbance and subsequent more homogenous dispersion and stable suspension of nanoparticles at every measured wavelength as compared to the same DNFs with 30-minute ultrasonication time. Based on relative concentration, stability after 90 days for 60- minute ultrasonicated samples was measured to be 96.13%,94.16%, 93.11%, and 91.13%, where for 30-minute ultrasonicated samples it was 95.17%, 93.21%, 92.04%, and 90.22%, respectively at 0.0015 wt%, 0.003 wt%, 0.006 wt%, and 0.01 wt%. This was reflected positively on the dielectric and thermal properties.
For the dielectric properties, the base value for finding a percentage enhancement in the AC BDV is the AC BDV of DBF, the percentage enhancements in AC BDV (at RTP) of 60-minute ultrasonicated DNFs were higher than that of 30-minute ultrasonicated DNFs at all weight fractions. The highest percentage enhancement in mean AC BDV was obtained at 0.01 wt% and was measured as 41.49% for 60-minute ultrasonicated sample, while for the same weight fraction it was measured as 37.23% for 30-minute ultrasonicated sample.
Similarly, all DNFs with 60-minute ultrasonication period showed higher relative permittivity, lower tan δ, and higher resistivity compared to those with 30-minute ultrasonication period at given temperatures (i.e., 45◦C, 60◦C, 75◦C and 90◦C).

Rajesh Choudhary et al : The stability of nanofluids is analysed using two m ethods: zeta potential and visual inspection method. The zeta potential is varied with the addition of acid, base and surfactant, and also with the variations of sonication periods. It is observed that the zeta potential is higher on the higher sides of acidic and basic regions of nanofluids for both 120 and 180 minutes sonication times. It is also observed that the zeta potential increases with the decrease in the concentration in the basic region after the IEP point for both 120 and 180 minutes sonication time. The zeta potential is directly related to stability period of nanofluids; higher the absolute value of zeta potential, higher the stability period. It is also observed that the optimum value of sonication time (where stability period is maximum), increases with the increase in the concentrations of nanofluids.

Abu Raihan Ibna Ali : The present study presents recent developments of nanofluid in heat transfer enhancement. The study extends to the preparation of nanofluid, stability of nanofluid, enhancing the stability of nanofluid, thermophysical properties, heat transfer characteristics, application. Nanofluid has some challenges for which further research should be conducted. Some probable studies that can be carried out in future research are listed below: • Preparation of nanofluid is costly. Hence, efforts are required to identify cost-effective techniques for the nanofluid preparation.

III. METHODOLOGY

Preparation of nanofluids:

Stable nanofluid preparation is the one of the major stepand key issue in assessing the thermophysical properties of nanofluids for any application. Wu et al. described reparation of nanofluids is not as straightforward as adding nanoparticles into base liquid. There are two distinct systems primarily utilized for combining nanoparticles into a base fluid: single-step process and two-step method. In single-step method, the nanoparticles are directly dispersed and condensed in the based fluid solution at a single/one time. Normally, physical vapor deposition (PVD) procedure/fluid

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compound technique/VEROS (vacuum evaporation to a running oil substrate) is utilized for singlestep processing technique. This technique has favorable circumstances, for example, stability increment and limited agglomeration the nanofluids preparation aspects by three different methods: kinetic stability, dispersion stability, and chemical stability.

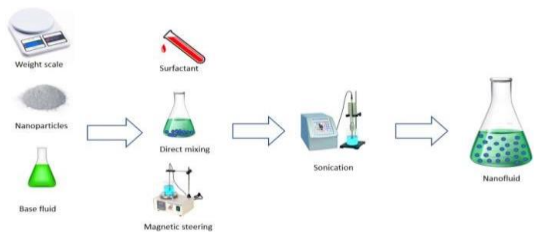

Fig 5.1: - Nanofluid Preparation

Bath Sonicator:

Sonication is the act of applying sound energy to agitate particles in a sample, for various purposes such as the extraction of multiple compounds from plants, microalgae and seaweeds .ultrasonic frequencies (>20 kHz) are usually used, leading to the process also being known as ultrasonication or ultra-sonication. In the laboratory, it is usually applied using an ultrasonic bath or a , colloquially known as sonicator. In paper machine an ultrasonic foil can distribute cellulose fibres more uniformly and strength the paper.

Effect of ultrasonication on oxide nanofluids:

Effect of ultrasonication on Al2O3 nanofluids-

the effect of ultrasonication duration on the stability (as zeta potential) of Al2O3–water nanofluid was studied in and found zeta potential to increase with ultrasonication time and reached a maximum at 5 h of duration and later reduced. Nguyen et al. investigated the effect of dispersion stability and ultrasonication on the cluster size of alumina nanofluid. The increased ultrasonication time on suspended nanoparticles in aqueous solution could lead to nanoparticle re-agglomeration. In work ,the ultrasonication effect on Al2O3–W nanofluid was analyzed. Their results showed that the dispersion was dependent on ultrasonication time. Sufficient sonication time aided in obtaining better stability and less agglomeration, insufficient sonication time lead to lower stability and agglomeration. The results also show that sedimentation % of nanoparticles was more for nanofluid prepared by longer storage duration. The particle size diameter reduced with the increase in ultrasonication duration. Another research study carried out on properties of Al2O3–W nanofluids for ultrasonication with two types of pulses and found that continuous pulses developed more stable solution than discontinuous pulses for similar sonication time. The effect of ultrasonication duration on colloidal structure and viscosity of alumina–water nanofluid was investigated by.

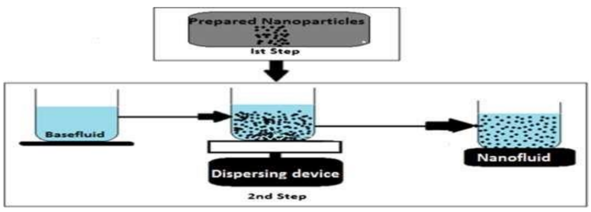

Fig 5.3: - Nano fluid Synthesis

2)Effect of ultrasonication on TiO2 nanofluids:

Chen et al. studied the rheological behavior of EG-based TiO2 nanofluid for different temperature and ultra-sonication time. The results indicated that the nanofluids were Newtonian and the shear viscosity was found to be the strong function of the temperature and particle concentration. Average nanoparticle size reduced with the increase in ultrasonication time as can be seen .An experimental investigation was done on addition of Ag nanoparticles to TiO2 nanofluid to achieve recyclability of nanofluid and retract the nanoparticles from the used waste base fluid. Segregation and recycling of waste fluid by rapid settling of TiO2 using increasing Ag nanoparticles and sonication was achieved.

3) Effect of ultrasonication on ZnO nanofluids:

Chung et al. synthesized ZnO–W nanofluid of varying purity by different preparation methods and checked the effectiveness of dispersion. Their result showed that ultrasonic horn was effective in reducing particle size, sedimentation

Impact Factor 7.047 ⋇ Vol. 10, Issue 4, April 2022

DOI: 10.17148/IJIREEICE.2022.10481

rate and in obtaining minimum achievable size than other types of sonication method . Effect of ultrasonication on thermal conductivity of ZnO–EG nanofluids was studied in. They observed that excess sonication broke the particles into finer segments and better dispersion of ZnO, as observed by light scattering intensity % and TEM images of the nanofluid, which are shown, respectively. Variation in thermal conductivity at different sonication hours obtained is shown . More details of investigations carried out related to ZnO nanofluids are presented .

4)Effect of ultrasonication on other oxide based nanofluids:

A work on copper oxide nanoparticles (10–30 nm) dispersed in ethylene glycol and experimented for viscosity and thermal conductivity is reported in . TEM images showed prolate spheroid shaped particles having an aspect ratio of 3, and despite of sonicating for a long time particles were still in aggregated state. Thermal conductivity increased only when the particle concentration was under dilute limit. A study on agglomeration and stability of Silica– W nanofluid prepared using ultrasonic probe is found in . Necessary ultrasonication time required to completely disperse the nanoparticles in the base fluid was 5 min at a pH of 10. Asadi et al. experimented the effect of sonication time and surfactant on stability and thermal conductivity of Mg(OH)2 nanoparticle for varying solid concentration, sonication time and for different surfactant. They realized that cetyl trimenthyl ammonium bromide (CTAB) surfactant improved stability compared with other surfactants. The zeta potential of the nanofluid with surfactant after a week is shown and relative thermal conductivity for different sonication time is shown . gives studies carried out on different nanofluids and details are mentioned in different columns.

5)Effect of ultrasonication on CNT nanofluids:

Yang et al. investigated the rheological and thermal properties of MWCNTs dispersed in olefin oil by varying sonication energy and time. They found that the nanoparticle agglomeration and its colloidal suspension has major effect on heat transfer characteristics of the nanofluid. If the agglomeration of particle is high, it leads to increased thermal conductivity and more viscosity . Effect of sonication time on the dispersion of MWCNT in water and actors which optimize the efficiency were studied using TEM and UV–vis in . MWCNTs dispersed to its maximum when stabilized by SDS for a certain amount of sonication energy. The adsorbed SDS molecules on the surface of MWCNTs prevented agglomeration maintaining the colloidal stability for few months which were seen through TEM images as shown , the investigation was done on influence of ultrasonication time, temperature and volume fraction on thermophysical properties of carbon nanofluid using thin layer technique.

IV. WORKING

The experimental system used in this research is as shown in Fig. It includes flow lines, a storage tank, a heater, a centrifugal pump, a flow meter, a forced draft fan, and a cross flow heat exchanger (an Thermoeletric cooler). The D.C. pump is used which gives a variable flow rate to achieve Reynolds number in the range 8000 to 22,000. Also globe valves are used in the test section to adjust flow rate as shown in Fig. 1. The working fluid fills 40% of the storage tank whose total volume is 20 l. The total volume of the circulating liquid is constant in all the experiments. The storage tank and the flow lines are covered with an insulating material to avoid heat loss. G. I. Pipe with a diameter of 12.5 mm is used as connecting lines. A flow meter (0–600 liters per hour (LPH)) is used to control and manipulate the flow rate with the precision of 0.1 l/min. For heating the working fluid, an electrical heater and a controller are used to maintain the temperature between 40 C and 80 deg. Two thermocouples (K type) are implemented on the flow line to record radiator fluid inlet and outlet temperatures, for which insulated thermowells with small copper tubes are provided at the inlet and outlet of the radiator, for getting true bulk temperature of the inlet and outlet fluids. Eight thermocouples (K-type) are used for a radiator wall temperature measurement. These thermocouples are installed at the different positions of the radiator surfaces (both sides). The locations of the surface thermocouples have been chosen so that they give the average wall temperature.

The fins and the tubes are made with aluminum. For cooling the liquid, a forced fan was installed close and face to face with the radiator and consequently air and water have indirect cross flow contact and there is heat exchange between hot water flowing in the tube-side and air across the tube bundle. Constant velocity and temperature of the air are considered throughout the experiments in order to clearly investigate the internal heat transfer. The test liquids are water based nanofluids which consist of water and small amount (0–1 vol. %) of gamma alumina nanoparticles. The mean grain size of this gamma alumina is 20 nm and some other properties are shown in Table 1. There is no dispersant or stabilizer added to the nanofluid. This is due to the fact that the addition of any agent may change the fluid properties and also to simulate the easiest actual condition encountered in the thermoelectric cooler. Additionally, creating highly turbulent flow condition in the radiator tubes and connecting pipes guarantees the stabilization of the nanoparticles in water.
Actual Experimental Setup

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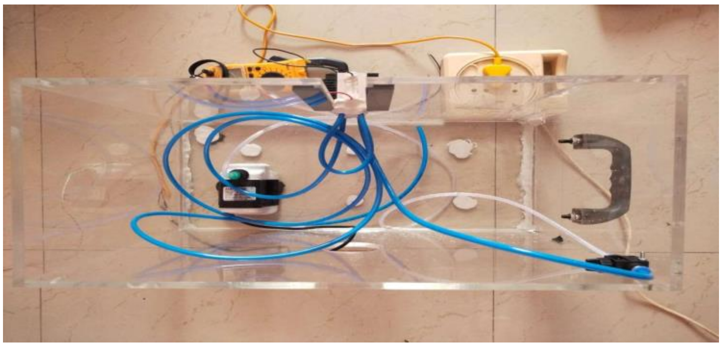

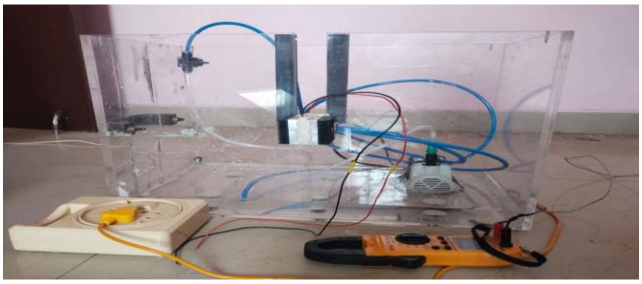

V. CALCULATIONS

Nanofluid Physical Properties

By assuming that the nanoparticles are well dispersed within the base fluid, i.e., the particle concentration can be considered uniform throughout the system, effective physical properties of the mixtures studied (nanofluid) can be evaluated using classical formulas usually used for two phase fluids. The important properties of the Al2O3 are as shown in fig. The following correlation has been used to predict nanofluid density at different temperatures and concentrations:

ῤnf = ῤ + (1 – ϕ)ῤbf where qnf is density of nanofluid, q is density of nanoparticles, qbf is density of base fluid and / is the volume fraction of nanoparticles. The specific heat of nanofluid can be calculated by using energy balance, given by Eq. (2) :

Cnf = (ϕῤpCp + (1 – ϕ) ῤbf Cbf) / ῤnf

(2) where Cnf; Cp, and Cbf are the specific heat of nanofluid, nanoparticles, and base fluid, respectively.

The effective thermal conductivity of nanofluid at different temperature is calculated by using a modified Maxwell equation which is modified by Yu and Choi [16]. The modified equation includes the effect of a liquid nanolayer on the surface of

Nanoparticle. This equation is given as

(-)( ) knf =

________________________________ Kbf

B is the ratio of n nanolayer thikness to the original particle radius and is taken as 0.1 for this study. The viscosity data for AL2O3-water was estimated by using Einstein's equation which was given as

For better understanding, Fig. 6 depicts variations of dimensionless physical properties of the nanofluid, i.e., the ratios of physical properties of the nanofluid to those of pure water as a function of volume concentration.

$$\mu nf = \mu w(1 + 2.5\phi)$$

Heat Transfer Coefficient Calculation

To obtain a heat transfer coefficient and corresponding Nusselt number, the following procedure has been adopted. According to

Newton's cooling law

$$Q = hA\Delta T = hA(Tb – Tw)$$

Heat transfer rate can be calculated as follows:

DOI: 10.17148/IJIREEICE.2022.10481

$$Q = mCp\Delta T = mCp(Tin - Tout)$$

Regarding the equality of Q in the above equations

* (-

Nu = — * —

(-)

In the above equation, Nu is an average Nusselt number for the whole radiator; m is a mass flow rate which is a product of density and volume flow rate of fluid and Cp is fluid specific heat capacity. A is a peripheral area of radiator tubes, Tin and Tout are inlet and outlet temperatures, TB is a bulk temperature which is assumed to be average values of inlet and outlet temperature of fluid moving through the radiator and TW is tube wall temperature, which is the mean value of eight surface thermocouples. In above equations, k is the thermal conductivity, and dhyd is the hydraulic diameter of the tube.

Hot Side Temperature (°C)	25°C	50°C
Qmax (Watts)	50	57
Delta Tmax (°C)	66	75
Imax (Amps)	6.4	6.4
Vmax (Volts)	14.4	16.4
Module Resistance (Ohms)	1.98	2.30

VI. CONCLUSION & FUTURE SCOPE

Conclusion

In this study, experimental heat transfer coefficients in the automobile radiator have been measured with two distinct working fluids pure water and water based nanofluid (with varying vol. % concentration and different flow rates). Following conclusions are obtained based on the present experimental work. the presence of nanoparticles in water enhances the heat transfer rate of automobile radiator. The degree of the heat transfer enhancement depends on the amount of nanoparticles added in the pure water. Ultimately, at the concentration of 1 vol.%, the heat transfer enhancement of 40–45% compared to water was recorded. increase in turbulence (increase in Re number) enhance heat transfer coefficient of both water and nanofluid considerably. many heat transfer correlations do not predict the heat transfer behavior of nanofluids. New correlation which will predict heat transfer performance using nanofluid is required to be developed.

It seems that increase in effective thermal conductivity (about 3% in this study) and variation in other physical properties are not responsible for the large heat transfer enhancement. Brownian motion of nanoparticles may be one of the factors in the enhancement of heat transfer as it produces convection like effect at nanoscale [21,22]. As particle size reduces, random motion becomes more evident and convection like effect becomes dominant. The presence of nanoparticles and their random motion within the base fluid cause the thickness of thermal boundary layer to reduce which may results to contribution to heat transfer enhancement. Although there are recent advances in the study of heat transfer with nanofluids, more experimental results and theoretical understanding of the mechanisms of the particle movements are needed to explain heat transfer behavior of nanofluid.

Future Scope

Following analysis is envisaged to be important for industrial application of nanofluids at a large scale:

1) Use of machine learning for modelling the underlying governing mechanics of sonication process for better dispersion of nanofluids.

2) Experimental analysis with different combinations of nano-particles and base fluids.

3) In system sonication of nanofluid coolants in automobiles for prolonged stability

DOI: 10.17148/IJIREEICE.2022.10481

VII. REFERENCES

[1] A. Asadi, I. M. Alarifi, V. Ali and H. M. Nguyen, "An experimental investigation on the effects of ultrasonication time on stability and thermal conductivity of MWCNT-water nanofluid: Finding the optimum ultrasonication time," Ultrasonics sonochemistry, vol. 58, p. 104639, 2019.

[2] A. Afzal, I. Nawfal, I. M. Mahbubul and S. S. Kumbar, "An overview on the effect of ultrasonication duration on different properties of nanofluids," Journal of Thermal Analysis and Calorimetry, vol. 135, p. 393–418, 2019.

[3] R. A. Farade, N. I. A. Wahab, D.-E. A. Mansour, N. B. Azis, V. Veerasamy, M. Thirumeni, A. X. R. Irudayaraj, A. S. Murthy and others, "Investigation of the effect of sonication time on dispersion stability, dielectric properties, and heat transfer of graphene based green nanofluids," IEEE Access, 2021.

[4] Rajesh Choudhary, Deepak Khurana, Aditya Kumar & Sudhakar Subudhi, "Stability analysis of Al2O3/water nanofluids, Journal of Experimental Nanoscience, 12:1, 140-151, : 08 Feb 2017.

[5] A. R. I. Ali and B. Salam, "A review on nanofluid: preparation, stability, thermophysical properties, heat transfer characteristics and application," SN Applied Sciences, vol. 2, p. 1–17, 2020.

[6] Ying-Qing Song, B.D. Obideyi, Nehad Ali Sha, I.L. Animasaun, Y.M. Mahrous, Jae Dong Chung, Significance of haphazard motion and thermal migration of alumina and copper nanoparticles across the dynamics of water and ethylene glycol on a convectively heated surface, Case Stud. Therm. Eng. 26 (2021) 1–11.

[7] K. Goudarzi, H. Jamali, Heat transfer enhancement of Al2O3- EG nanofluid in a car radiator with wire coil inserts, Appl. Therm. End. 118 (25) (2017) 510–517.

[8] K.S. Pavithra, Fasiulla, M.P. Yashoda, S. Prasannakumar, Synthesis, characterization and thermal conductivity of CuO – water based nanofluids with different dispersants, Int. J. Particulate Sci. Technol. 38 (5) (2019) 559–567.

