"INVESTIGATE PERFORMANCE OF COOLING EFFECT ON AUTOMOBILE RADIATOR USING Cu – TiO2 NANOFLUID."

Rahul D. Pande1, Prof. S. S. Jawre2, Prof. A. A. Kanaskar3

1 M. Tech. Scholar, Mechanical Engg. Department, S.S.P.A.C.E-Wardha, Maharashtra, India
2 Assistant Professor, Mechanical Engg. Department, S.S.P.A.C.E-Wardha, Maharashtra, India
3 Assistant Professor, Mechanical Engg. Department, S.S.P.A.C.E-Wardha, Maharashtra, India

ABSTRACT

The basic aim of the experiments conducted was to determine the thermal performance of automobile radiator under real operating conditions using two different nanofluids and their different concentration. The Effect of coolant rate, effect of type of nanomaterial and effect of nanomaterial concentration on performance of automobile radiator were studied experimentally. In present study automobile radiator is used constructed of aluminum and plastic. The radiator is having 33 vertical tubes connected at the ends. Each tube is joined by louvered fins. Length of each tube is 37 cm. major and minor diameter of each tube is 18 mm and 2.5 mm. The test was conducted by filling radiator with water, TiO2-water nanofluid and Cu-water nanofluid and combination of Cu-TiO2nanofluids. The nanoparticles used having average size <20 nm and disperse in water with 0.1wt%. Magnetic stirring, Ultra sonication and surfactant (0.01wt % SLS) technique is use to enhance stability of nanoparticle in water. The series of test are conducted by varying coolant rate, nanomaterial and nanofluid concentration. From result it is observed that nanofluid automobile radiator gives better performance than water. Also performance of automobile radiator is increases with increase in concentration of nanomaterial. Cu nanofluid gives better performance than TiO2 nanofluid.

Keyword : - *heat transfer , automobile radiator , nanofluids, coolants, etc….*

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1. INTRODUCTION

Radiators also known as compact heat exchanger are classified as plate fin or tube fin heat exchangers. These heat exchangers can provide higher heat transfer coefficient in laminar flow than that offered by a highly turbulent flow in a plain tube situation. Experiments prove that by reducing the coolant flow rate, the time taken for the coolant to absorb heat from engine block and release it in the radiator will be expanded. Then the differential between temperature in and temperature out from the radiator will be at the highest stage. As the result, the heat dissipation from the radiator will be at the maximum point.

Many researchers have extensively investigated heat transfer enhancement by the various enhancement techniques, some of them had carried test using nanofluids in water. Nanofluids possess high specific surface area and therefore more heat transfer surface between particles and fluids, high dispersion stability with predominant Brownian motion of particles, reduced pumping power as compared to pure liquid to achieve equivalent heat transfer augmentation, reduced particle clogging as compared to convention slurries, thus promoting system miniaturization, adjustable properties, including thermal conductivity and surface wet ability, by varying particle concentrations to suit different applications.

1.1 Nanofluids

Nanofluids are a new class of fluids engineered by dispersing nanometer-sized materials (nanoparticles, Nanofibers, Nanotubes, Nanowires, Nanorods, Nanosheet, or droplets) in base fluids. In other words, nanofluids are nanoscale colloidal suspensions containing nanomaterials. They are two-phase systems with one phase (solid phase) in another (liquid phase). Nanofluids have been found to possess enhanced thermo physical properties such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficients compared to those of base fluids like oil or water. It has demonstrated great potential applications in many fields. For a two-phase system, there are some important issues we have to face. One of the most important issues is the stability of nanofluids and it remains a big challenge to achieve desired stability of nanofluids. In this section we will review the new progress in the methods for preparing stable nanofluids and summarize the stability mechanisms. In recent years, nanofluids have attracted more and more attention.

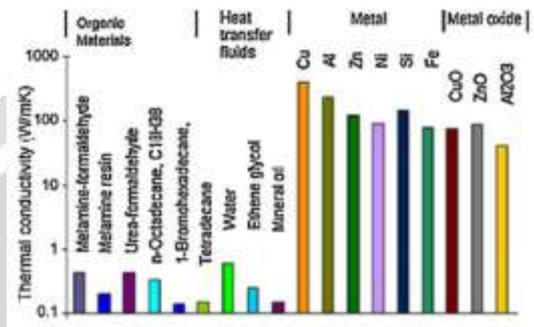

Fig -1: Thermal conductivity of typical materials

Figure 1 shows the thermal conductivity of typical materials. Solids have thermal conductivities that are orders of magnitude greater than those of traditional heat transfer fluids.

1.2 Preparation Methods for Nanofluids

In this section various methods Two-step method of nanofluid preparation methods is discussed.

Two-step method

Two-step method is the most widely used method for preparing nanofluids. Figure 2 shows flow diagram for Two-step preparation process of nanofluids. Nanoparticles, nanofibers, nanotubes or other nanomaterials used in this method are first produced as dry powders by chemical or physical methods. Then the nano sized powder will be dispersed into a fluid in the second processing step with the help of intensive magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenizing and ball milling. Two-step method 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. Due to the high surface area and surface activity, nanoparticles have the tendency to aggregate. The important technique to enhance the stability of nanoparticles in fluids is the use of surfactants. However the functionality of the surfactants under high temperature is also a big concern, especially for high temperature applications. Due to the difficulty in preparing stable nanofluids by two-step method, several advanced techniques are developed to produce nanofluids, including one-step method. In the following part, detail of one-step method is given.

Fig -2 Two-step preparation processes of nanofluids.

2. EXPERIMENTAL METHOD

Experimental setup consists of an automobile radiator used for investigate the performance of cooling effect of Automobile radiator with Cu – TiO2 hybrid nanofluid and studying effect of them. For the base test the water is used as test fluid in the system and then each nanofluid is charged one by one, to avoid contamination of nanofluid, each time whole system is washed out with pure water. Experiments are carried out by varying coolant rate. Main component of experimental setup is automobile radiator. In subsequent paragraphs detail description about setup are given.

2.1 Experimental Apparatus

Fig. 3 shows, the experimental test apparatus used in this research includes flow pipes, a storage tank, a heater, a centrifugal pump, a flow meter, a forced draft fan and an automobile radiator. The pump gives a constant discharge of 10 liters/min; the flow rate to the test part is adjusted by appropriate adjusting of a globe valve on the recycle line. The fluid used as test fluid fills 50% of the storage tank whose total volume is 10 lires. The total volume of the circulating fluid is same in all the experiments. A Rotameter was used to control and regulate the discharge with the accuracy of 0.5 liters/min. For heating the test fluid, an electrical heater used to maintain the temperature between 65 and 70°C.Two digital temp gauge were used on the pipes to measure radiator fluid inlet and outlet temperatures. Infrared temp. gauge were used for radiator wall temperature measurement.

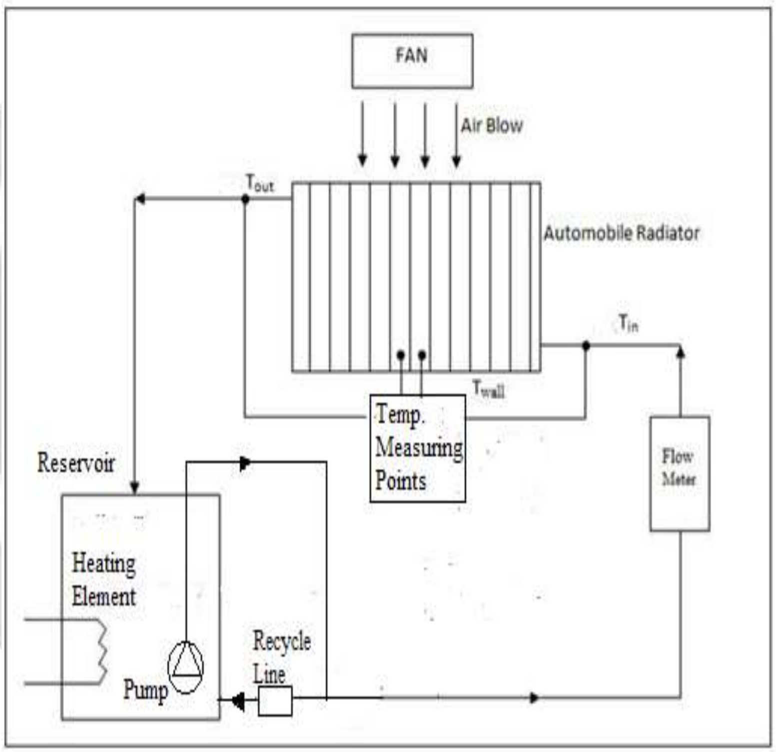

Fig -3 Schematic of Experimental setup

When the experiment started, the location of the infrared presented the average value of the readings was selected as a point of average wall temperature. The radiator wall is constructed with aluminum tubes so the tubes are having high thermal conductivity. The tubes are having very small thickness so that it can be assumed that inside temperature is same as outside wall temperature. Rotameter also known as flowmeter are calibrated with the standard volume flask. The temperature reading is obtained by digital display with an accuracy of 0.1°C. All thermocouples were calibrated using ice bath and constant temperature water bath. The configuration of the automobile radiator used in this experiment is of the louvered fin-and-tube type, with 37 vertical tubes with ellipse-shaped cross section. The fins and the tubes are made with aluminum. For cooling the liquid, a forced fan (1400 rpm) was installed close and face to face to the radiator and consequently air and water have indirect cross flow contact and there is heat exchange between hot fluid 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.

1	Automobile radiator	Details
	Make	Tata Ace
	Type	Heat Exchanger with louvered Fins
	Material	Aluminum
	Coolant capacity	1 Liter
	Length	33.2 cm
	Height	37 cm
	No. of tubes	33 tubes with single pass
2	Radiator Fan	
	Fan RPM	1400 rpm
	No. of Blades	4 blades
3	Heater	
	Material	Nichrome Coil heater
	Power	1.5 kW
4	Pump	
	Type	Submersible Pump
	Head	3m
	Maximum Discharge	10 lpm
5	Tank	
	Material	Stainless Steel
	Dimensions	Ø 234 mm x 255 mm.
6	Rotameter	0-9 lpm
7	Digital Temperature Indicator	1)Thermometer -15to110 °C 2)IR Thermometer.

Fig -4 Experimental Specification

Parameters	**CopperNanoparticles**	**Titanium dioxide Nanoparticle**
Average particle size	10-20 nm	10-20 nm
Morphology	spherical	spherical
True density	8.9 g/cm3	4.01 g/cm3
Contents (%)	Cu≥99 Sn≤0.1 Fe≤0.02 Ni≤0.04	TiO2 ≥99 S≤0.1 Si≤0.02 Mg≤0.067 Al≤0.20

Fig -5 Characteristics of nanoparticles

2.6 Test Procedure

Experimentation was done to calculate heat transfer coefficient for distill water and TiO2 and Cu nanofluids. Experiment was carried out with changing mass flow rate as operational parameters. Initially tank was filled with the fluid for which heat transfer coefficient is to be calculated. Fluid in the tank is assumed to be surrounded by engine. For varying mass flow rate pump was used. First Pump was started and fluid in the tank started filling radiator water, the excess fluid from the radiator was diverted through recycle line and nanofluids circulated through circuit. The fluid in the tank was heated constantly so as to maintain the required temperature. Readings were taken at mass flow rate varying from 1 to 5 lpm. Temperature readings were recorded with the help of thermocouples mounted on various parts of setup at steady state.

Same readings were taken with for changing fluids and their concentration as given in table. Test conducted are given in table 6

Sr. No.	Working Fluid	Fluid Flowrate (Lpm)	Air Flow Speed (m/s)
1	Distilled Water		2
2	Nanofluid		2
2.1	Distill Water + TiO2 (8g) (0.1% wt.)		2
2.2	Distill Water + Cu (8g) (0.1% wt.)	1,2,3,4,5	2
2.3	Distill Water + Cu+ TiO2 (0.8g + 7.2g) (0.1%wt.)		2
2.4	Distill Water + Cu+ TiO2 (1.6g + 6.4g) (0.1%wt.)		2
2.5	Distill Water + Cu+ TiO2 (2.4g + 5.6g) (0.1%wt.)		2

Fig -6 Test conducted

2.7 Nanofluid preparation

In this work, two step methods is use for preparation of nanofluid of different composition as shown in Table. Powder TiO2 and Cu of average size 20 nm and 99% pure were purchased from M/s Nanolab Pvt. Ltd. (Jharkhand) whose properties are listed in Table 6.

Base fluid	Nanomaterial	Concentration
Distill Water	TiO2	0.1% wt
Distill Water	Cu	0.1% wt
Distill Water	Cu +TiO2 (0.8g + 7.2g)	0.1% wt (Total)
Distill Water	Cu +TiO2 (1.6g + 6.4g)	0.1% wt (Total)
Distill Water	Cu +TiO2 (2.4g + 5.6g)	0.1% wt (Total)

Fig -7 Nano-material and its composition

Fig -8 Nanofluid preparation.

2.8 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; the effective physical properties of the mixtures studied can be evaluated using some classical formulas as usually used for two phase fluids. These relations have been used to predict nanofluid physical properties like density (equation 1), specific heat (equation 2), viscosity (equation 3) and thermal conductivity (equation 4) at different temperatures and concentrations. In this paper, the following correlations [25] [26] were used to calculate these physical properties of nanofluid:

Property	Water	TiO2	Cu
C(J/kg K)	4180	690	390
ρ(kg/m3)	998	4230	8960
k(W/m K)	0.6	25	400

$$\rho_{nf} = \varphi\rho_p + (1-\varphi)\rho_w \qquad \text{(equation 1)}$$

$$(\rho C_p)_{nf} = \varphi(\rho C_p) + (1-\varphi)(\rho C_p)_w \qquad \text{(equation 2)}$$

$$\mu_{nf} = \mu_w(123\varphi^2 + 7.3\varphi + 1) \qquad \text{(equation3)}$$

$$K_{nf} = \frac{K_p+(n-1)K_p-\varphi(n-1)(K_w-K_p)}{K_p+(n-1)K_w+\varphi(K_w-K_p)}Kw \qquad \text{(equation4)}$$

These relations give variations of physical properties of nanofluid when the volume fraction is varied by addition of nanoparticles.

3. Result and Discussions

This chapter summaries result obtained during the experimentation with relevant discussion. Here results include addition of nanomaterial to the base fluid i.e. distilled water, variation in composition of different nanomaterial, different mass flow rate of the fluid on the thermal properties of the radiator. Finally experimental results are validated by using theoretical analysis. All measured parameter with computed parameter are reported in appendix. These results are broadly classified on the basic of working fluid i.e. water and nanofluid. Within the automotive industry, the area of vehicle design is moving rapidly into the use of new, high technology techniques. The purpose of automobile cooling system is to ensure that engine is maintained at its most efficient practical operating temperature. The current trend in car design is towards smaller more efficient engines, but this result in less waste energy being available for heating purposes and passengers comfort. Current high- efficiency engine systems create hot engine compartments, hot exhausts, hot lubricating oil, but poor heat output to passenger compartment, at least from cold starting conditions. There is a need to look at the total heat balance and control system for the vehicle in order to search poor performance optimization and cost saving. Consequently, a more detailed analysis is required by the designer to optimize the available heat distribution resources.

3.1 Distilled water

Before conducting systematic experiments on the application of nanofluids in the radiator, some experimental runs with pure water were done in order to check the reliability and accuracy of the experimental setup.

3.1.1 Comparison of outlet temperature and discharge

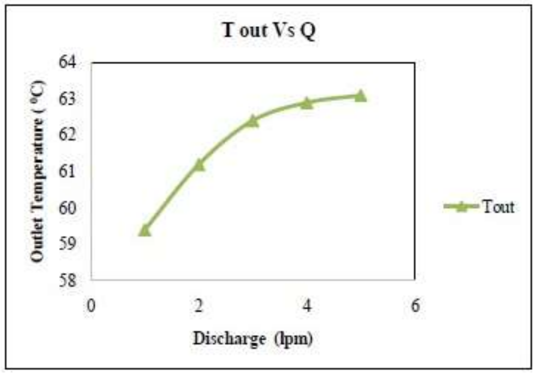

Fig -9 Comparison of outlet and discharge

The figure 9 shows variation of water outlet temperature when the inlet temperature was maintained constant at 70°C. Temperature drop go on reducing as the flowrate of the fluid increases. The reason for such behavior can be stated as lower flowrate to maximize heat rejection by maximizing contact time of the coolant and radiator tube walls.

3.1.2 Effect of heat transfer coefficient

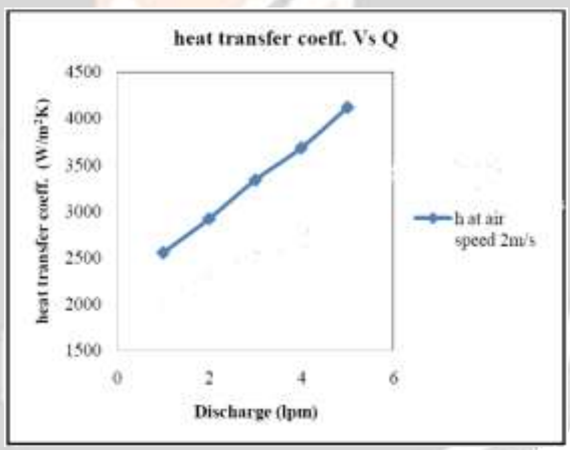

Fig -11. Effect of heat transfer coefficient

Figure 11 shows variation of heat transfer coefficient as the air flowing over the radiator is increased. Heat transfer coefficient shows large enhancement as it is directly proportional to temperature drop across the radiator inlet and outlet. Thus it causes other parameters such as Nusselt number, overall heat transfer coefficient to augment in the same manner.

3.2 Distill water + Titania

This section covers the results obtained using distilled water and titania as working nanofluid in the experimental setup.

3.2.1 Comparison of outlet temperature and discharge

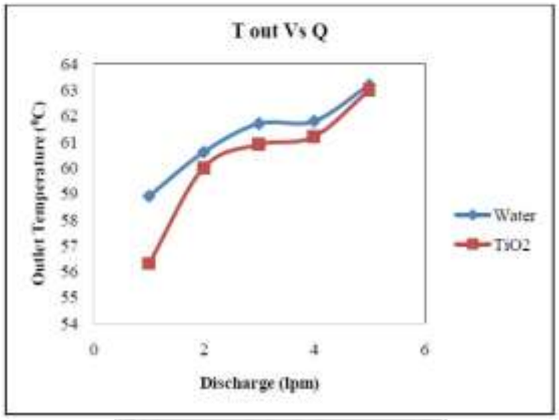

Fig -12 Comparison of outlet temperature and discharge when using nanofluid and distilled water.

After extensive experimentation the result obtained were shown in the figure 4.4 for the effect of coolant rate, effect of nanomaterial concentration. The experimentation were carried out with nanomaterial i.e. Titania concentration used as 0.1wt%. Thermal conductivity of the Titania particles is about 25 W/mK which is much greater than thermal conductivity of distilled water which is 0.6 W/mK Figure shows the trend of outlet temperature drop by the addition of nanomaterial to the base fluid. The higher thermal conducting material particles in the base fluid act as the extended surfaces for heat transfer phenomenon. Therefore the graph shows much greater drop in the outlet temperature of the fluid. Nanoparticles in the base fluid interact with the energy transmission during the flow and contribute towards better results for the cooling system.

3.3 Distill water + Copper

This section covers the results obtained using distilled water and copper as working nanofluid in the experimental setup.

3.3.1 Comparison of outlet temperature and discharge

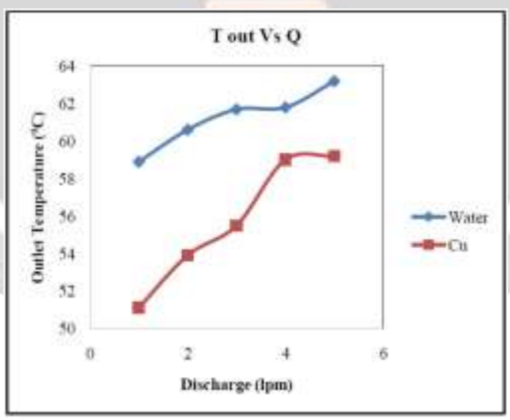

Fig -13 Comparison of the radiator cooling performance when using nanofluid and distilled water

Figure 13 shows results obtained after addition of copper nanoparticles to the base fluid as coolant in the radiator. Similarly as that of Titania addition of copper nanoparticles creates extended surfaces for heat transfer phenomenon. As the copper is having thermal conductivity 400 W/mK which is much higher thanthermal conductivity of distilled water. The chaotic movements of nanoparticles, with the energy interaction between the nanoparticles and the fluid medium would vitally contribute to the improved heattransfer characteristics of nanofluids. The phenomenon related to the Brownian motion and the aggregation (clustering effect) of the suspended nanoparticles plays a vital role in the enhancement of the thermal conductivity of the base fluid, besides the effects realized due to their high surface to volume ratio. This, in turn, facilitates the nanofluids to exhibit better heat transfer characteristics when compared to the conventional heat transfer fluids.

3.4 Distill water + Copper + Titania

This section covers the results obtained using distilled water, titania and copper as hybrid working nano fluid in the experimental setup.

3.4.1 Comparison of outlet temperature and discharge

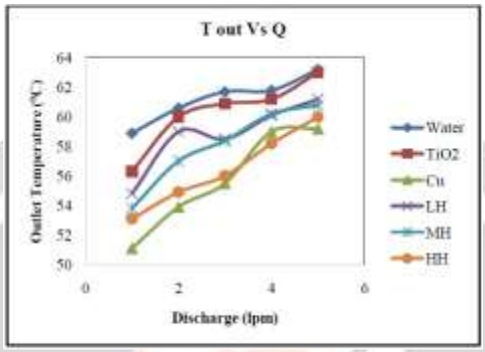

Fig -14 Comparison of outlet temperature and discharge when using nanofluid and distilled water

Figure 14 shows the effect on outlet temperature of radiator by the addition of different concentration of pure nanoparticles as well as hybrid nanoparticles. Each time distill water is kept constant as base fluid and nanoparticles concentration is varied. As previously stated higher thermal conductivity of nanoparticles rais es thermal properties of base fluid. Here different concentrations of nanoparticles are used. Each time when percentage of copper is increased in the fluid it affects the thermal conductivity of fluid; therefore it shows decrease in the outlet temperature of the radiator with increase in copper nanoparticle concentration. Hence it can be stated as Hybrid nanofluids are a class of fluids containing a combination of two dissimilar nanoparticles (i.e. hybrid nanocomposite) effectively dispersed in the fluid medium. The intention of incorporating the hybrid nanocomposite in the fluid medium was to improve the heat transfer characteristics of the base fluid through the combined thermo physical properties of the efficient nanomaterials.

3.4.2 Comparison of heat transfer coefficient and Reynolds number

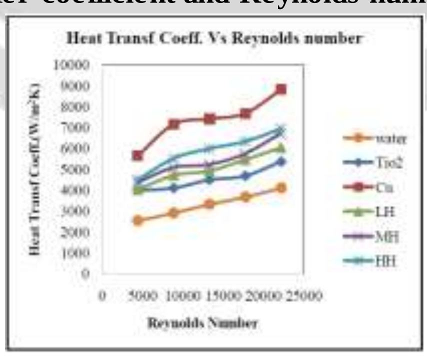

Fig -15 Comparison of heat transfer coefficient and Reynolds number when using hybrid nanofluid and distilled water

The above figure shows comparison of heat transfer coefficient against Reynolds number. It can be s een that heat transfer coefficient increases with the mass flow rate of fluid. The convective heat transfer coefficient was observed to increase with the hybrid nanocomposite weight concentration and Reynolds number, which could be described to the improved heat transfer potential of nanofluids, compared to that of the base fluid. The significant enhancement of the convective heat transfer coefficient and Nusselt number of hybrid nanocomposite was due to the improved thermal conductivity of these particles, and the reduced thermal resistance offered by the flowing nanofluid on the wall surface of the inner side tube.

3.4.3 Comparison of Nusselt number and discharge and Reynolds number

The variations of the convective heat transfer coefficient and Nusselt number (Nu) with the Reynolds number are depicted in figure 4.9. The convective heat transfer coefficient and Nusselt number were increased by 15% and 10% respectively, up to a weight proportion of 0.1% of nanofluids.

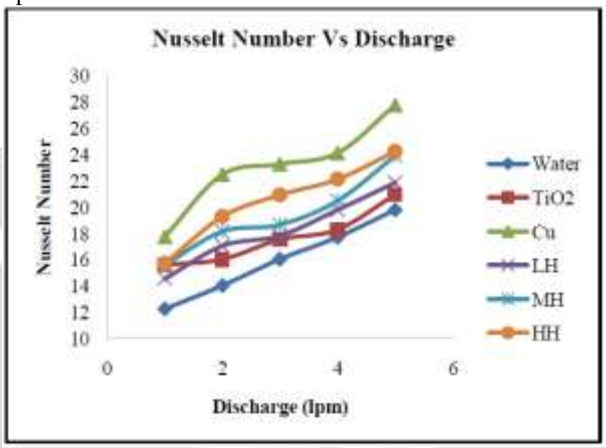

Fig -16 Comparison of Nusselt number and discharge when using hybrid nanofluid and distilled water

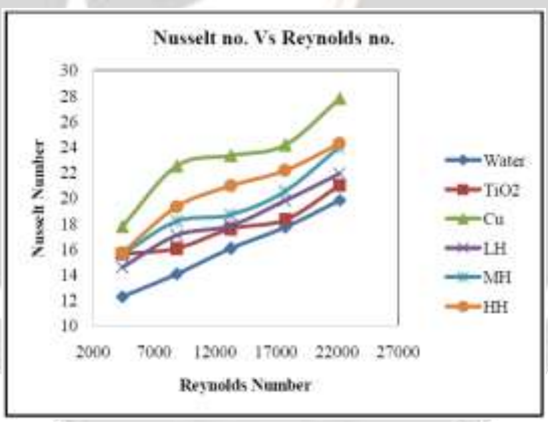

Fig -17 Comparison of Nusselt number and Reynolds number when using hybrid nanofluid and distilled water

The convective heat transfer coefficient was observed to increase with the hybrid nanocomposite weight concentration and Reynolds number, which could be described to the improved heat transfer potential of nanofluids, compared to that of the base fluid. The significant enhancement of the convective heat transfer coefficient and Nusselt number up to 0.1% weight concentration of hybrid nanocomposite was due to the improved thermal conductivity of these particles, and the reduced thermal resistance offered by the flowing nanofluid on the wall surface of the inner side of tube.

3.4.5 Comparison of Effectiveness and Reynolds number.

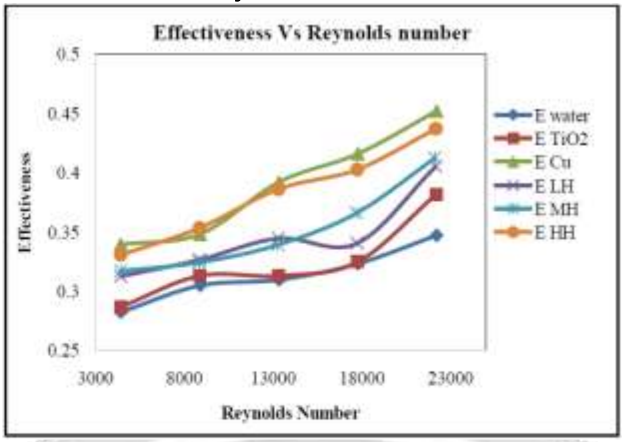

Fig -18 Comparison of Effectiveness and Reynolds number when using hybrid nanofluid and distilled water

Variation of effectiveness of the radiator for different nanofluids with respect to Reynolds number is shown in the figure 4.14. As heat transfer coefficient goes on increasing with increased flowrate through radiator in the same manner it enhances effectiveness of the radiator. Copper nanofluid having greater thermal conductivity contributed to the creation of increased effective thermal interfaces with the fluid medium, helping to maximize heat rejection from the radiator. As the concentration of copper nanoparticles in the hybrid nanofluid is lowered it gives decrement in heat transfer and effectiveness of the radiator.

4. Conclusions

This chapter deals with conclusion drawn from the experimentation. The basic aim of the experiments conducted was to determine the thermal performance of automobile radiator under real operating conditions using two different nanofluids at various concentrations and with their different combinations. The Effect of various parameters i.e. coolant rate, type of nanomaterial and its concentration on performance of automobile radiator were experimentally studied.

I. For distilled water

- Outlet Temp. increases as flow rate Increases.
- Because outlet Temperature increase reduction in Temp. drop take place.
- Increasing the flow rate of working fluid or equally Reynolds number enhances the heat transfer coefficient for distilled water considerably.

II. For Nanofluids

- Increase in effective thermal conductivity of nanofluids and also chaotic movement of the nanoparticles i.e. Brownian motion of nanoparticles may be the factors of heat transfer enhancement.
- Increase in concentration of nanomaterial increases the thermal performance of radiator for both nanomaterials.
- The surface functionalized and highly crystalline nature of hybrid nanocomposite have contributed to the creation of effective thermal interfaces with the fluid medium; thereby enabling the achievement of achieving improved thermal conductivity and heat transfer potential of nanofluids.

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