Numerical Study of Heat Transfer Enhancement using Water and Ethylene Glycol Mixture based Nanofluids as Coolants in Car Radiators

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Abstract: ***Conventional heat transfer fluids such as water and engine oil are widely used in the automobile radiator in recent times. However, to enhance the thermal performance of the system, a lot more is needed from the heat transfer fluid perspective. One of the important techniques to enhance heat transfer is that to improve the thermal conductivity of working fluid with inclusion of nano-sized solid particles as additives. The present paper includes the studies to evaluate the performance of the heat transfer characteristics of water/anti-freezing based nanofluid as a coolant for car radiator. Ethylene Glycol (EG), which is an anti -freezing agent that is added at 50% to water at 50% as base liquid. The metal oxide nanoparticles Al2O3 and CuO are dispersed into base fluid at 0.05%, 0.15% and 0.3% volume concentrations .The thermo physical properties of both nanofluids are calculated and assessed with the help literature work. The mass stream rate of nanofluid in the radiator tubes is varied from 4 to 6 lit/min. With the help ANSYS FLUENT 17.2 solver, the outlet temperature, convective heat transfer coefficient and Nusselt numbers for each concentration of each nanofluids is investigated by varying the mass flowrate.***

KEYWORDS: Nano fluids, heat transfer coefficient, thermal conductivity.

I. INTRODUCTION

In various applications, there is an essential pre-requisite for upgrading the poor thermal conductivity of conventional liquids with a particular ultimate objective to make powerful heat exchange liquids, this essential can be met through scattering nanoparticles in a given base fluid, for instance, water, ethylene glycol, oil or air. The ensuring nanofluids overhauled thermal conductivity of the base fluids. Remembering the true objective to evaluate this enhancement, nanofluid thermal conductivity is required to be assessed. For the base fluid, a mixture of water at 50% and ethylene glycol at 50%was used as base fluid. With the use of nanoparticles, the surface area of heat transfer of coolant can be increased, thus increasing the heat transfer performance of the coolant.

However, the concentration of the nanoparticles of Al_2O_3 and CuO that can optimally transfer heat must be determined This air cooler setup is louvered fin and flat tube and because of its complicated geometry less exploratory examinations can be found in the open writing.

Upgrades in nanotechnology have improved our capacities to synthesize nano-scale materials, for example, unique sorts of nanoparticles including non-metallic, carbon
situated in metallic ones, which have begun to be utilized in traditional liquids, for example, water, ethylene glycol and oil, making another class of liquids called nanofluids. It is proposed to explore the use of nanoparticle in the blend of water and liquid catalyst materials (as the base liquid) which is ordinarily utilized in the vehicle radiators

Usually in the region of cold or hot climates that a few added substances are added to the water in the car radiator which decline the freezing point and hoist boiling point of water. It shields the radiator liquid from freezing when it is cold and shields the vehicle from overheating on exceptionally hot days. Practically the majority of this added substances are from glycol family uniquely EG. The significant utilization of EG is as a mechanism for convective heat move in, for instance vehicle radiators, fluid cooled PCs, chilled water cooling frameworks, and so forth. Since water is a vastly improved motor coolant, the blend of water and EG has been utilized. The issue with water is that it stops or bubbles at outrageous temperatures. Against freezing operators like EG can withstand a lot more prominent temperature boundaries, so by adding it to water we can make a trade off. The greater part of the great cooling capacities of water or held however the capacity to withstand extraordinary temperatures originates from the radiator fluid.

II. LITERATURE REVIEW

The enhancement of thermal properties was characterized by nano-sized particles. Nanofluids have been recently considered as next generation coolants for car radiators. In this work, the highlights of advantages of nanofluids and a number of design directions are described for thermal conductivity balance and improvement of viscosity in nanofluids. Multi-scale models would make possible and systematize the translation of nanofluid technology small scale experiments to big scale industrial production and development [1].

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The nanoparticles existence in nanofluids contribute good flow ability of mixing and thermal conductivity is high than pure fluid. The current work initializes the overview of methods of preparation and thermal conductivity increment of fluids with nanoparticles. For cooling of engines, there are two methods used in this work. One is nanoparticles are diffuses in the engine oil and another method is by spreading nanoparticles in a conventional coolant radiator.

The heat transfer coefficient is upgraded to 50% compared to the primary coolant [2].

metallic suspensions or nanopowders of non-metallic are nanofluids in base fluid. Present work depicts laminar stream constrained convection heat exchange of Al2O3/water nanofluid when goes in the center of a round cylinder with consistent divider temperature was examined. The modifications of particles and communications, mostly in huge Peclet number may the motivation to change in stream course of action and take to raises heat exchange because of the nearness of nanoparticles [3].

The cooling of circulating fluid performance in a car radiator by forced convection heat transfer was studied that consisted of water and anti-freezing materials like EG. From this work, the performance of heat transfer of pure water and pure EG had compared with their binary mixtures. High Nusselt number improvement up to 40% was obtained at the top conditions for both nanofluids used. These larger heat transfer coefficients got by using nanofluid instead of water permit the working fluid in the car radiator to be cooler [4].The experimental investigation of water-Al_2O_3 nanofluid on which it effects the temperature and particle volume concentration on the dynamic viscosity. By using a “piston-type”commercial viscometer for temperature ranging from room condition up to 75˚C, the viscosity data were collected. The particle sizes are 36 and 47nm respectively are considered [5].

The test setup incorporates a vehicle radiator, and the impacts on heat transfer enhancement under the working conditions are dissected under laminar stream conditions. the volume stream rate, inlet temperature and nanofluid volume focus are in the scope of 2-8 LPM, 60-80°C and 1-2% respectively .The consequences of the examination demonstrated that huge information parameters to improve heat transfer with vehicle radiator. These exploratory outcomes were observed to be in great acceptance with other researches data, with a deviation of just around 4% [6].

Numerical outcomes, as acquired for water–Al_2O_3 and Ethylene Glycol–Al_2O_3 blends, have obviously demonstrated that the consideration of nanoparticles into the base liquids has created an extensive growth of the heat transfer coefficient that unmistakably increments with an expansion of the molecule focus. For the instance of tube flow, results have additionally appeared, as a rule, the improvement likewise increments impressively with an expansion of the stream Reynolds number. Relationships have been accommodated processing the Nusselt number for the nanofluids considered as far as the Reynolds and the Prandtl numbers and this for both the heat limit conditions considered [7].

With the exception of the examinations from the main class where the nanofluids displayed a lot higher thermal conductivities than those of base fluids, the examinations on nanofluids conduct under convective heat exchange studies and stage change heat exchange considers have announced consequences of confusing nature. Alumina nanofluids of various fixations at different sonication times are readied and a temperamental state heat exchange examination of a warmed vertical cylinder cooled in the previously mentioned alumina nanofluids is done, with an exceptional spotlight on the heat exchange rate [8].

Huge improvement of the convective heat exchange is watched and the upgrade relies upon the stream conditions (Reynolds number, Re), CNT fixation and the pH, with the impact of pH littlest. For nanofluids containing 0.5 weight % CNTs, the most extreme improvement comes to over 350% at Re = 800, which couldn't be ascribed absolutely to the upgraded warm conduction [9].

The viscosity information were gathered utilizing a 'cylinder type ‘commercialized viscometer for temperatures extending from room condition up to 75^{o}C. Two diverse molecule sizes, to be specific 36 and 47 nm, have been considered. That, when all is said in done, nanofluid dynamic viscosity increments impressively with molecule volume portion however unmistakably diminish with a temperature increment. The viscosity esteems got for 36 and 47 nm molecule sizes are moderately close ones and others, aside from high molecule portions [10].

Results have obviously uncovered the presence of a basic temperature past which the molecule suspension properties appear to be definitely changed, which, thusly, has triggered a hysteresis phenomenon. Such a basic temperature has been observed to be emphatically subject to both molecule fixation and size. The hysteresis marvel has raised genuine concerns with respect to the unwavering quality of utilizing nanofluids for heat exchange improvement pur-presents [11].

The compose nanofluid, containing just 0.035 volume portion of Al_2O_3 nanoparticles, shows a genuinely higher thermal conductivity than the base liquid and a most extreme improvement(knf/kbf) of ∼10.41% is seen at room temperature[12].

Reviewed and proposed the comprehension of the fundamentals of heat exchange and wall friction is prime significance for creating nanofluids more exploratory results and the theoretical comprehension of the components of the particle movements are expected to comprehend heat exchange and fluid flow behavior of nanofluids Sadik Kakac [13].

Sharma completed an analysis on vehicle radiator utilizing coolant as nanofluid and clarified constrained convection heat exchange upgrade by TiO2 and SiO2 suspended in water as a base liquid inside the level copper container of a vehicle cooling framework has been evaluated [14].

III. PROBLEM STATEMENT

The demonstrating of the vehicle radiator was planned in auto cad programming which was later brought into ANSYS Fluent programming, based on the plan parameters gathered from different written works. The vehicle radiator comprised of flat tube and louvered fins.

The material of the radiator, which is aluminum, was likewise connected to the plan. Fig. 1 demonstrates the detail delineations of the geometrical designs of the vehicle radiator. Fig. 1A demonstrates the measurements of the flat tube, delineates the coincided and auto cad show individually of the proposed geometry of the radiator. [15]

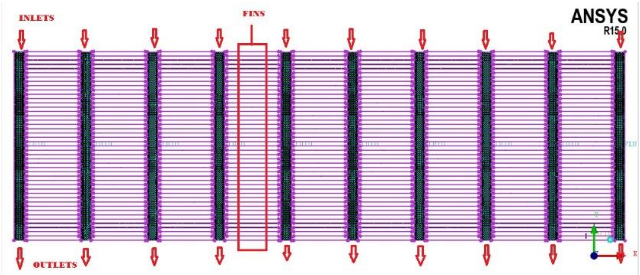

Fig 1 (schematic of flat tube)

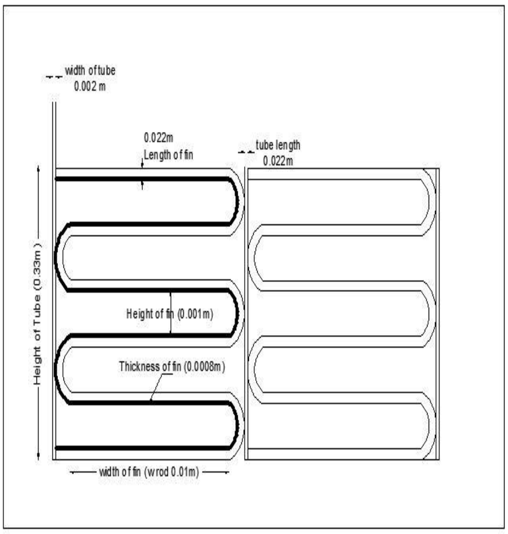

Table 1. The radiator water side dimensions:

Dimensions	**Value**
Radiator length	0.384m
Radiator height	0.33m
Radiator width	0.022m
Tube length	0.022m
Tube height	0.33m
Tube width	0.002m
Tube thickness	1 m
Number of tubes	34
Tube hydraulic diameter	0.0039m
Total tube side area	0.505m^2

The radiator and air side dimensions

Fin length	0.022 m
Fin height	0.001 m
Fin width	0.01 m
Fin thickness	0.00008 m
Number of mini channels per column	242
Number of all the mini channels	8470
Fin thermal conductivity	238 w/m^{o}c
Total air side area	4.1 m^2

IV. ESTIMATION OF THERMOPHYSICAL PROPERTIES OF NANOFLUIDS

By accepting that the nanoparticles are all around scattered inside the base liquid, for example the particle concentration can be viewed as uniform all through the framework; the successful thermo physical properties of the blends can be assessed utilizing some traditional formulas as a rule utilized for two stage stream. The accompanying relationships have been utilized to estimate nanofluid density, thermal conductivity and specific heat separately at various temperatures and concentrations [16–18]:

$$\rho_{nf} = \varphi_{bf} + (1-\varphi)\rho_{bf} \qquad (1)$$

$$(\rho C_p)_{nf} = \varphi(\rho C_p)_p + (1-\varphi)(\rho C_p)_{bf} \qquad (2)$$

$$k_{nf} = \frac{k_p + (\varphi-1)k_{bf} - \varphi(\varphi-1)(k_{bf}-k_p)}{k_p + (\varphi-1)k_{bf} + \varphi(k_{bf}-k_p)} \qquad (3)$$

Where Φ is experimental shape factor given by Φ=3/ψ, and ψ is the molecule sphericity that is characterized as the proportion of the surface zone of a sphere with volume equivalent to that of the molecule, to the surface zone of the molecule, and in this paper Φ is viewed as 3. For count of water based nanofluid viscosities, the accompanying connection has been connected [16– 18]:

$$\mu_{nf} = \mu_{bf}(123\varphi^2 + 7.3\varphi) \qquad (4)$$

For EG based and blend based nanofluids, the relationship proposed by Masoumi et al. [19] has been used:

$$\mu_{nf} = \mu_{bf} + \frac{\rho_p V_B d_p^2}{72C\delta} \qquad (5)$$

Where the second term is the evident viscosity emerging from the impacts of nanoparticles in the liquid. The separation between the focuses of the nanoparticles, δ and correction factor (C) are determined respectively

$$\delta = \sqrt[3]{\frac{\pi}{6\varphi}}\, d_p \qquad (6)$$

$$C = \mu_{bf}^{-1}(a\varphi + b) \qquad (7)$$

Where a and b are test parameters, which for the motor coolant– Al_2O_3 nanofluids were assessed to be 0.00004 and 7.1274×10^{-7}, separately [20]. Different relationships were proposed for temperature reliance of the nanofluid consistency.

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Kole and Dey [20] demonstrated just that the accompanying relationship proposed by Namburu etal. [21] can give an adequate consent to the temperature reliance of viscosity of

% Volume Proportion, ϕ	Density, ρ(kg/m^3)	Specific heat, C_p(J/kg-K)	Thermal conductivity, k(W/m-K)	Viscosity, μ(kg/m-s)	Prandtl number, Pr
0.05	1156.10	3461.123	0.668	0.0019	9.8445
0.15	1452.30	2685.322	0.874	0.0019	5.8376
0.30	1896.60	1975.971	1.287	0.0019	2.9171

the Al_2O_3/customary coolant nanofluids.

$$\text{Log}\,(\mu_{nf}) = M \exp(NT) \quad (8)$$

Where two parameters (M and N) are functions of nanoparticle concentration [20].

Table 2. Thermophysical properties of 50% water and 50% EG mixture based Al_2O_3 nanofluids [21, 22, 23,24]

Table 3. Thermophysical properties of water and EG mixture based CuO nanofluid

% Volume Proportion, ϕ	Density, ρ (kg/m^3)	Specific heat, C_p(J/kg-K)	Thermal conductivity, k (W/m-K)	Viscosity, μ (kg/m-s)	Prandtl number, Pr
0.05	1282.600	3137.082	0.664	0.0019	8.97
0.15	1831.800	2165.382	0.858	0.0019	7.09
0.30	2655.600	1461.414	1.241	0.0019	2.23

V. CALCULATION OF NUSSELT NUMBER

The heat exchange characteristics were assessed by strategies for Nusselt number, thermal conductivity, heat trade coefficient additionally, rate of heat exchange. A couple of relations are available for evaluating the Nusselt number of the base fluid, in this work the comprehensively used relationship of Dittus and Boelter [25] was grasped for surveying the Nusselt number of the base fluid (see Eq. (10).

$$Pr = \frac{v}{a} = \frac{C_p\mu}{k} \quad (9)$$

$$Nu = 0.023Re^{0.8}Pr^{0.3} \quad (10)$$

$$h = \frac{Nu.k}{d} \quad (11)$$

where k is the thermal conductivity of the liquid and d is hydraulic diameter of the flat tube. For the For the Al2O3/CuO nanofluids, the Nusselt numbers are enlisted using connections proposed by Pak and Cho [28]

$$Nu=0.021Re^{0.8}\, Pr^{0.5} \quad (12)$$

The rate of the heat exchange, $\dot{Q}$ of the nanofluids was gotten by techniques for the numerical model as seeks after:

$$\dot{Q} = \dot{m}C_p\,(T_{inlet} - T_{outlet}) \quad (13)$$

VI. RESULTS AND DISCUSSION

A. Mesh independence test

The mesh independencestudy has been made to identify the optimum mesh size. The results have been tabulated as shown in Table 1. It is found that 32,22,189 elements was optimum mesh size owing to the reason that outlet temperature found to be just 0.7% error.

Table 4. Mesh independence test results

Number of elements	Outlet temperature for Al_2O_3at 4 lit/min	Residue (%)
26,42,531	332.11K	-
29,81,923	346.23 K	4.08
31,74,189	356.82 K	2.97
32,22,189	359.34 K	0.70
34,32,913	363.54 K	1.16

The optimum mesh size is used for mesh generation and temperature contours are plotted using ANSYS Fluent at various concentrations, viz., 0.05, 0.15 and 0.3, of Al_2O_3 and CuO nano particles in respective nanofluids. Figures 1 and 2 represent the temperature contours in radiator for water and EG mixture based Al_2O_3 nanofluid and CuO nanofluid respectively at 0.3% volume concentration flowing at 4 lit/min.

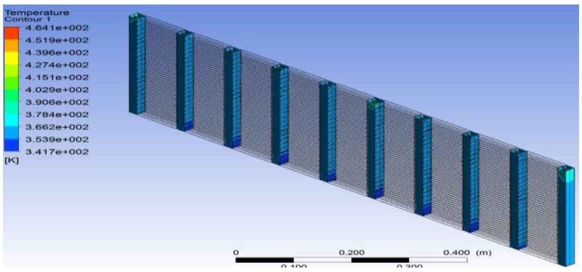

Fig. 2 Temperature contours in radiator for water and EG mixture based Al_2O_3 nanofluid at 0.3% volume concentration flowing at 4 lit/min.

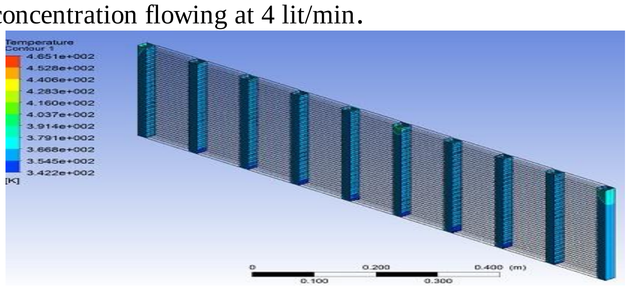

Fig. 3 Temperature contours in radiator for water and EG mixture based CuO nanofluid at 0.3% volume concentration flowing at 4 lit/min.

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A. Validation of simulation results with mathematical modelling data

In order to ensure the accuracy, the simulation results are validated with mathematical modelling data of the same working fluid that used for the simulation. In the current paper, both Al_2O_3, CuO nanofluids were used for the validation purpose. Comparison of the Nusselt number obtained from simulation data to that obtained through correlation suggested by Pak and Cho was to ensure the accuracy of the results obtained from the simulation. Table 2 shows the tabulated data of Nusselt number from the simulation compared to that obtained through correlation suggested by Pak and Cho for Al_2O_3nanofluid. An average error of 3.17%was recorded. The error may be due to the constraints of number of elements in the FLUENT software. However, the average error is observed to be satisfactory within limits of ±5%.

Table 5. Comparison of Nusselt numbers obtained through simulation for Al_2O_3 nanofluid with mathematical modelling data for the same nanofluid

S. No.	Reynolds number, Re	Nusselt number, Nu	
		Simulation data	Mathematical modelling data
1	11392.1	125.08	120.26
2	14240.2	150.46	146.63
3	17088.2	176.06	171.08

Figure 4 represents the variation of Nusselt number with respect to Reynolds number from simulation and mathematical modelling for 0.3% volume concentration at 6 lit/min flow rate.

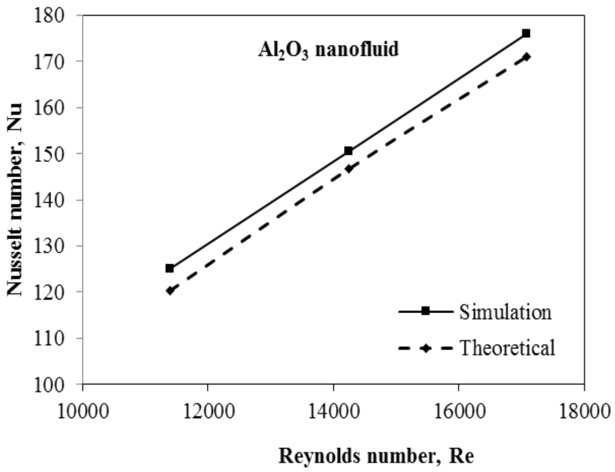

Fig. 4. Comparison of Nusselt numbers obtained through simulation for Al_2O_3 nanofluid with mathematical modelling data for the same nanofluid

Table 6 shows the tabulated data of Nusselt number from the simulation compared to that obtained through correlation suggested by Pak and Cho for CuO nanofluid. The error percentage of 1.83% due to substitution of CuO nanofluid. The error found for CuO nanofluid when compared to Al_2O_3nanofluidwas less due to little change in their specific heats.

Table 6. Comparison of Nusselt numbers obtained through simulation for CuO nanofluid with mathematical modelling data for the same nanofluid

S. No.	Reynolds number, Re	Nusselt number, Nu	
		Simulation data	Mathematical modelling data
1	11392.1	160.61	156.96
2	14240.2	182.04	178.23
3	17088.2	200.28	197.78

The variation of Nusselt number with Reynolds number for both simulation and mathematical modelling for CuO nanofluid is shown in Fig. 5.

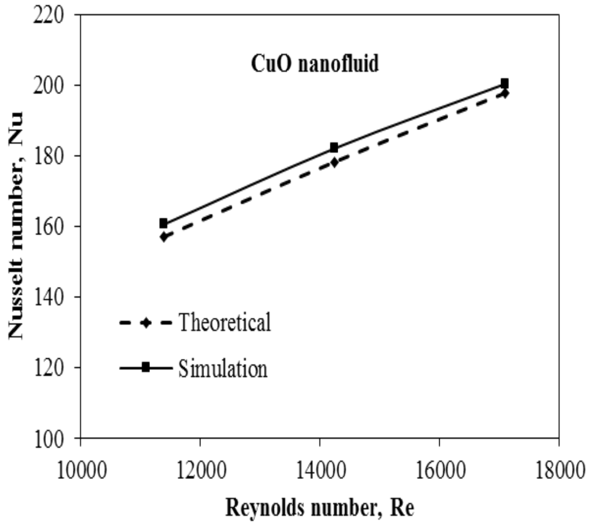

Fig. 5 Comparison of Nusselt numbers obtained through simulation for CuO nanofluid with mathematical modelling data for the same nanofluids

After a thorough validation of simulation results with standard data obtained through correlation suggested by Pak and Cho, various studies have been made to understand the variation of Nusselt number with Reynolds numbers at different volume concentrations of nanoparticles in their respective nanofluids. These studies are as follows:

B. Variation of Nusselt number with respect to Reynolds number for various concentrations of Al_2O_3 nanoparticle

The Nusselt numbers calculated through simulation results have been tabulated in Table 7 for various Reynolds numbers at various concentrations of Al_2O_3 nanoparticle.

Table 7 Nusselt numbers for different Reynolds numbers at different concentrations of Al_2O_3 nanoparticle

S. No.	Reynolds number, Re	Nusselt number, Nu		
		Φ = 0.05	Φ = 0.15	Φ = 0.3
1	11392.1	115.9049	118.51	120.26
2	14240.2	138.5571	140.74	146.63
3	17088.2	160.3148	162.15	171.08

The variation of Nusselt number with Reynolds number for various flow rates, viz., 4, 5, 6 lit/min, for Al_2O_3nanofluid is shown in Fig. Three volume concentrations 0.05%, 0.15% and 0.3% of Al_2O_3 nanoparticles are taken up for the study. It is observed that the Nusselt number increases with increase in Reynolds number for any concentration of nanoparticle.

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The increment of Nusselt number is 9.3% obtained with increase of Reynolds numbers corresponding to flow rates from 4 to 6 lit/min for 0.3% volume concentration. The increase in Nusselt number was found to be minimum, i.e. 3.6% at 4 lit/min as concentration is varied from 0.05% to 0.3%, while the same was found to be maximum, i.e.4.2% at 6 lit/min for the same concentration rise.

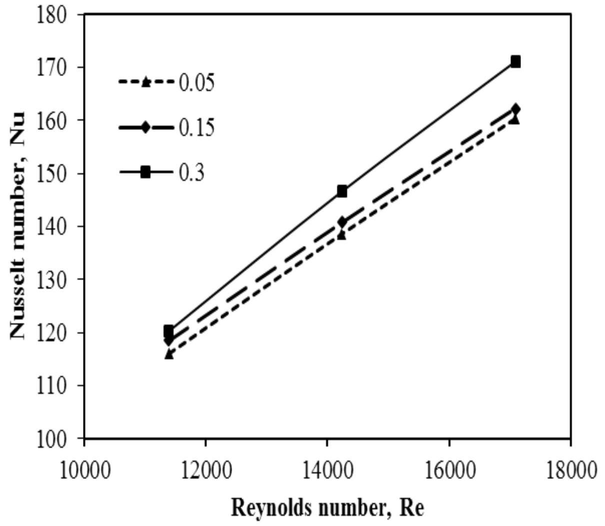

Fig 6 Variation of Nusselt number with respect to Reynolds number for various concentrations of CuO nanoparticle

The Nusselt numbers calculated through simulation results have been tabulated in Table 7 for various Reynolds numbers at various concentrations of CuO nanoparticle.

Table 8 Nusselt numbers for different Reynolds numbers at different concentrations of CuO nanoparticle

S. No.	Reynolds number, Re	Nusselt number, Nu		
		Φ = 0.05	Φ = 0.15	Φ = 0.3
1	11392.1	120.6750	148.20	156.96
2	14240.2	152.3041	168.15	178.23
3	17088.2	173.0800	187.25	197.78

Figure indicates the study of variation of Nusselt number with Reynolds number for various flow rates, viz., 0.05, 0.15, 0.3 lit/min, for CuO nanofluid. For three volume concentrations such as 0.05%, 0.15% and 0.3% are taken up for the study. . It is observed that the Nusselt number increases with increase in Reynolds number for any concentration of nanoparticle. The increment of Nusselt number is 9.3% obtained with increase of Reynolds numbers corresponding to flow rates from 4 to 6 lit/min for 0.3% volume concentration. The increase in Nusselt number was found to be minimum, i.e. 2.6% at 4 lit/min as concentration is varied from 0.05% to 0.3%, while the same was found to be maximum, i.e. 4.3%at 6 lit/min for the same concentration rise.

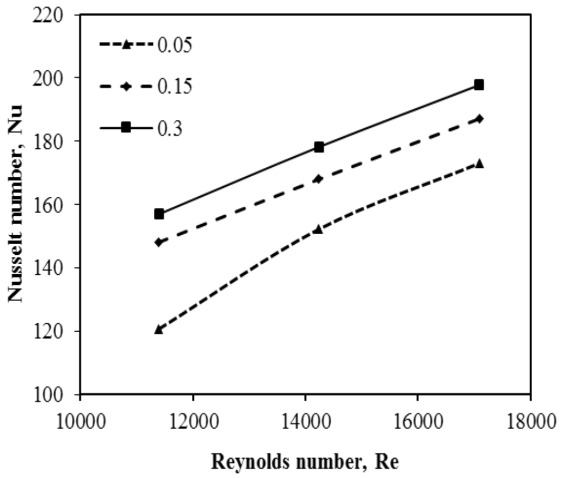

Fig 7 Comparison of Nusselt number with respect to Reynolds number between Al_2O_3 nanofluid and CuO nanofluid at 0.3% volume concentration

The Nusselt numbers calculated through simulation results have been tabulated in Table 7 for various Reynolds numbers at various concentrations ofAl_2O_3andCuO nanoparticles.

Table 9 Comparison of Nusselt numbers for different Reynolds numbers at 0.3% concentration of nanoparticle

S. No.	Reynolds number, Re	Nusselt number, Nu	
		Al_2O_3	CuO
1	11392.1	125.08	160.61
2	14240.2	150.46	182.04
3	17088.2	176.06	200.28

Comparing both Al_2O_3 and CuO nanofluids, the highest nusselt number for Al_2O_3 and CuO nanofluid were 176.06 and 200.28 respectively at 0.3% concentration and at 6 lit/min volume flow rate. For Al_2O_3 and CuO nanofluids, the maximum values of heat transfer coefficients are 27572.86557 W/m^2K and 28285.75056 W/m^2K.the heat transfer coefficient of CuO is high when compared toAl_2O_3.

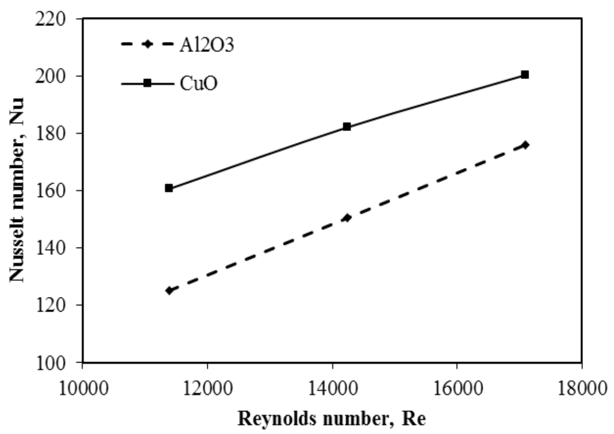

Fig.8 Comparison of Nusselt numbers for different Reynolds numbers at 0.3% concentration of nanoparticle

VII. CONCLUSION AND SCOPE FOR FURTHER STUDY

The present investigation studies the application of metal oxide nanofluids Al2O3/(EG+Water) and CuO/(EG+Water) in louvered fin and flat tube car radiator.The following conclusions are made with help of Ansys FLUENT solver:

1. When the mass flow rate is varying from 4 to 6 Lit/min, the outlet temperature at the bottom of tube is also increasing .At the flow rate of 6 lit/min the highest outlet temperature of 356.23 K is observed at bottom of the tube.

2. As we increase the mass flow rate the convective heat transfer coefficient and nusselt number are increasing.

3. The highest nusselt number 200.28 and heat transfer coefficients28385.78W/m^{2}K are observed at 0.3% volume concentration of CuO and at mass flow rate 6 lit/min compared to Al_2O_3

4. As the volume concentration of nanofluid is increasing the nusselt number and heat transfer coefficients also increasing.

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AUTHORS PROFILE

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