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Experimental Investigation of Heat Transfer Enhancement of Cross Flow Heat Exchanger withHybridnanofluid as a Coolant

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ABSTRACT

Heat transfer of coolant flow through the automobile radiators is of great importance for optimization of fuel consumption. In this paper, forced convective heat transfer in a conventional coolant based Hybridnanofluid has experimentally beencompared to that of conventional coolant (green colour) in an automobile radiator. Three different concentrations of nanofluidsin the range of 0.5, 1.0 and 1.5 vol. % have been prepared by the addition of Fe_2O_3+CuO hybrid nanoparticles into the conventional coolant. Thetest liquid flows through the radiator consisted of 33 vertical tubes with elliptical cross section and airmakes a cross flow inside the tube bank with constant speed. Liquid flow rate has been changed in therange of 200LPH to 600 LPH to have the fully turbulent regime ($7\times 10^3 < Re < 2.3\times10^4$). Additionally, the effect offluid inlet temperature to the radiator on heat transfer coefficient has also been analyzed by varying thetemperature in the range of 55-75^{0}C. Results demonstrate that increasing the fluid circulating rate canimprove the heat transfer performance while the fluid inlet temperature to the radiator has trivial effects.Meanwhile, application of Hybridnanofluid with low concentrations can enhance overallheat transfer coefficient up to21% and convective heat transfer coefficient up to 67% in comparison with conventional coolant.

***Keywords*— Hybridnanofluid, Overall heat transfer coefficient, Turbulent flow, cooling performance, Automotive Radiator, Hybrid Nanopowder (Fe_2O_3+CuO).**

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I. INTRODUCTION

The main reason solid particles less than 100 nm are added to a liquid is to improve its thermal properties. A reduction in energy consumption is possible by improving the performance of heat exchange systems and introducing variousheat transfer enhancement techniques. Since the middle of the1950s, some efforts have been done on the variation in geometry ofheat exchanger apparatus using different fin types or various tubeinserts or rough surface and the like [1-7]. Some of the publishedinvestigations have focused on electric or magnetic field application or vibration techniques [8-11]. Even though an improvementin energy efficiency is possible from the topological and configurationpoints of view, much more is needed from the perspective ofthe heat transfer fluid. Further enhancement in heat transfer isalways in demand, as the operational speed of these devicesdepends on the cooling rate. New technology and advanced fluidswith greater potential to improve the flow and thermal characteristicsare two options to enhance the heat transfer rate and thepresent article deals with the latter option.Conventional fluids, such as refrigerants, water, engine oil,ethylene glycol, etc. have poor heat transfer performance andtherefore high compactness and effectiveness of heat transfersystems are necessary to achieve the required heat transfer. Amongthe efforts for enhancement of heat transfer the application ofadditives to liquids is more noticeable. Recent advances in nanotechnologyhave allowed development of a new category of fluidstermed nanofluids. Such fluids are liquid suspensions containingparticles that are significantly smaller than 100 nm, and havea bulk solids thermal conductivity higher than the base liquids [12].

The radiator is an important accessory of vehicle engine. Normally, it is used as a cooling system of the engine and generally water is heat transfer medium. This air cooler configuration is louvered fin and flat tube and due to its complicated geometry less experimental studies can be found in the open literature.

Nanofluids are formed by suspending metallic or non-metallic oxide nanoparticles in traditional heat transfer fluids. These socallednanofluids display good thermal properties compared withfluids conventionally used for heat transfer and fluids containingparticles on the micrometer scale [13]. Nanofluids are the newwindow which was opened recently and it was confirmed byseveral authors that these working fluid can enhance heat transferperformance.

Hybridnanofluid is one in which more than one nanopowder are mixed in a base fluid. Two different nanopowders are taken in same proportions and are added in base fluid.

II. LITERATURE REVIEW

Number of researchers worked in this field and there obtained results and conclusion were discussed briefly below.

Choi et al. [14] reported a project to target fuel savings for the automotive industries through the development of energy efficient nanofluids and smaller and lighter radiators. A major goal of the nanofluids project is to reduce the size and weight of the vehicle cooling systems by greater than 10% despite the cooling demands of higher power engines. Nanofluids enable the potential to allow higher temperature coolants and higher heat rejection in the automotive engines. It is estimated that a higher temperature radiator could reduce the radiator size approximately 30%. This translates into reduced aerodynamic drag and fluid pumping and fan requirements, leading to perhaps a 10% fuel savings. It is interesting idea in these years which humans involved in the energy and fuel shortage crisis. According to this idea, scarce experimental and theoretical studies were performed to analyse the application of nanofluids in the car radiator.

Leong et al. [15] attempted to investigate the heat transfer characteristics of an automotive car radiator using ethylene glycol based copper nanofluids numerically. Thermal performance of an automotive car radiator operated with nanofluids has been compared with a radiator using conventional coolants.

Vajjha et al. [16] have been numerically studied a three-dimensional laminar flow and heat transfer with two different nanofluids, Al_2O_3 and CuO, in the ethylene glycol/water mixture circulating through the flat tubes of an automobile radiator to evaluate their superiority over the base fluid. Convective heat transfer coefficient in the developing and developed regions along the flat tubes with the nanofluid flow showed considerable improvement over the base fluid.

Khan et al. [17] have experimentally studied forced convection cross-flow heat transfer of hot air over an array of cold water carrying elliptic tubes. Their experimental investigation was restricted to water as the coolant.

Cuevas et al. [18] have studied the heat transfer performance of a louvered fin and flat tube heat exchanger. Mixture of ethylene glycol and water was circulated .Through the tubes at a supply temperature of 90^0C. This fluid was cooled with ambient air at temperature of 20^0C. The thermo hydraulic performance (calculation of heat transfer coefficient and friction factor) of the heat exchanger has been compared with the classical correlations given in the literature.

Avramenko et al. [19] made theoretical estimation of the heat transfer enhancement in laminar flow of a nanofluid over a flat plate. For 1% concentration of nanoparticles, the respective increase in the Nusselt number reaches up to 5%.

Peyghambarzadeh et al. [20] have recently investigated the application of Al_2O_3/water nanofluids in the car radiator by calculating the tube side heat transfer coefficient. They have recorded the interesting enhancement of 45% comparing with the pure water application under highly turbulent flow condition. In the other study, **Peyghambarzadeh et al. [21]** have used different base fluids including pure water, pure ethylene glycol, and their binary mixtures with Al_2O_3 nanoparticles and once again it was proved that nanofluids improves the cooling performance of the car radiator extensively. In the two latter studies, tube side heat transfer coefficient was calculated according to the temperature measurement at the thin walls of the radiator flat tubes. It is very hard to accurately measure the temperature at the wall and therefore, the data may have not adequate accuracy.

Y.Vermahmoudi et al.[22] performed Experimental investigation on heat transfer performance of Fe_2O_3/water nanofluid in an air-finned heat exchanger the maximum enhancements of the overall heat transfer coefficient and heat transfer rate compared with base fluid (distilled water) are respectively equal to 13% and 11.5% which is occurred at the concentration of 0.65 vol.%.

S. Suresh et al. [23] performed experiment to study Effect of Al_2O_3–Cu/water hybrid nanofluid in heat transfer a fully developed laminar convective heat transfer and pressure drop characteristics through a uniformly heated circular tube using Al_2O_3–Cu/water hybrid nanofluid is presented. For this we synthesized Al_2O_3–Cu nanocomposite powder in a thermo chemical route that involves a hydrogen reduction technique and then dispersed the prepared hybrid nano powder in deionised water to form a stable hybrid nanofluid of 0.1% volume concentration. The convective heat transfer experimental results showed a maximum enhancement of 13.56% in Nusselt number at a Reynolds number of 1730 when compared to Nusselt number of water. The experimental results also show that 0.1% Al_2O_3–Cu/ water hybrid nanofluids have slightly higher friction factor when compared to 0.1% Al_2O_3/water nanofluid.

III.EXPERIMENTAL RIG

As shown in Fig. 1, the experimental system used in this research includes flow lines, a storage tank, a heater, a centrifugal pump, a flow meter (Rotameter), a forced draft fan and a cross flow heat exchanger (an automobile radiator). The pump gives a flow rate of 2800 LPH; the flow rate to the test section is regulated by appropriate adjusting of a globe valve on the recycle line shown in Fig.1. The working fluid fills 70% of the storage tank whose total volume is 30 l (45cm×45cm×45cm). The total volume of the circulating liquid is constant in all the experiments. The CPVC tubes (18 mm diameter) have been used as connecting lines. A flow meter (Rotameter) was used to control and manipulate the flow rate with the precision of 10 LPH. For heating the working fluid, athree phase electrical heater and a controller were used to maintain the temperature between 55 and 75^{0}C. Two RTDs (PT-100, Rod end type) were implemented on the flow line to record radiator fluid inlet and outlet temperatures. Five RTDs (PT-100, Bare type) were used for radiator wall temperature measurement.

These thermocouples were installed at the Different locations on the radiator wall. The locations of the surface thermocouples have been chosen so that they give the average wall temperature. For this purpose, 5RTDs were attached by silicon paste to various positions of the external walls on each side of the radiator.

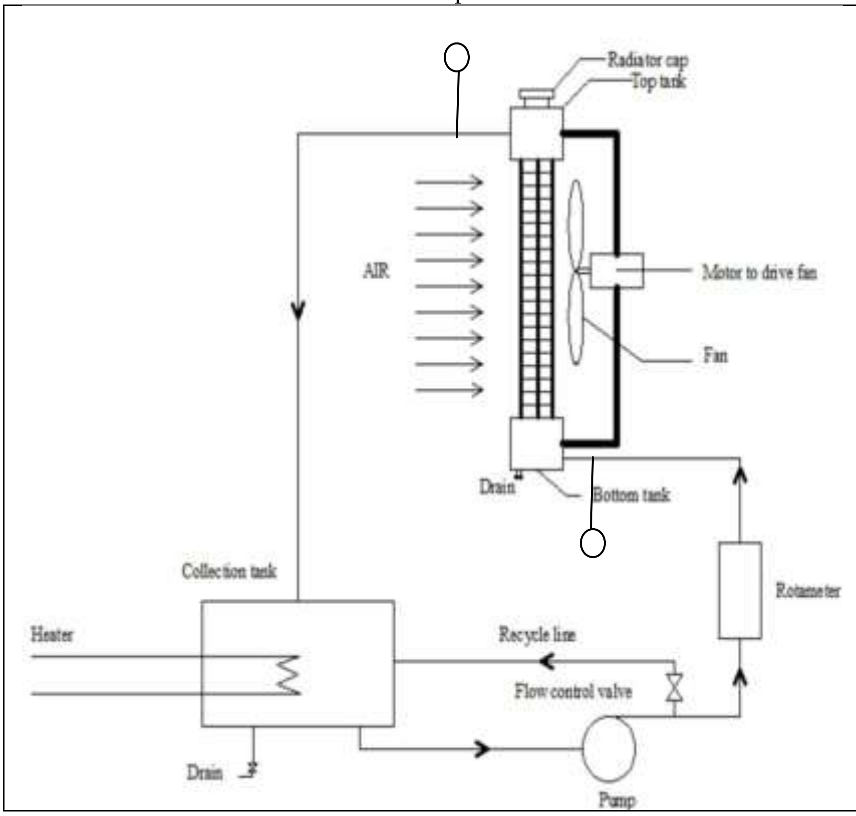
When the experiment started, the location of the thermocouple presented the average value of the readings was selected as a point of average wall temperature. It would be interesting that these two locations on each side of the radiator did not exactly correspond.

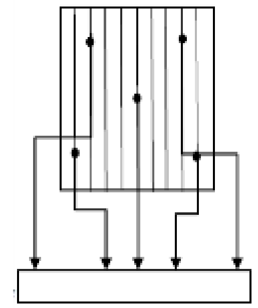
Due to very small thickness and very large thermal conductivity of the tubes, it is reasonable to equate the inside temperature of the tube with the outside one. The temperatures from the RTDs were measured by two digital meters, one is showing continuously inlet and outlet temperature of fluid entering and leaving the radiator.

The uncertainty range of Re comes from the errors in the measurement of volume flow rate and hydraulic diameter of the tubes and the uncertainty of Nu refers to the errors in the measurements of volume flow rate, hydraulic diameter, and all the temperatures.

As shown in Fig. 2, the configuration of the automobile radiator used in this experiment is of the louvered fin-and-tube type, with 33 vertical tubes with stadium-shaped cross section. The fins and the tubes are made with aluminium. For cooling the liquid, a forced fan (Techno Pars 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 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 Conventional Coolant (Green colour) and Hybridnanofluid (Combination of conventional coolant + [(Fe_2O_3+CuO) Hybrid nanopowder]). The mean grain size of Fe_2O_3+CuO Nanopowder is 60 nm and some other properties are shown in Table 2. And Table No. 1 shows important dimensions of radiator. There was no dispersant or stabilizer added to nanofluid. This is due to the fact that the addition of any agent may change the fluid properties.Due to highly turbulent flow condition in the radiator tubes and connectingpipes guarantees the stabilization of the nanoparticle inHybridnanofluid





Location of RTD's on tube surface of radiator

Figure No. 1. Schematic of Experimental setup

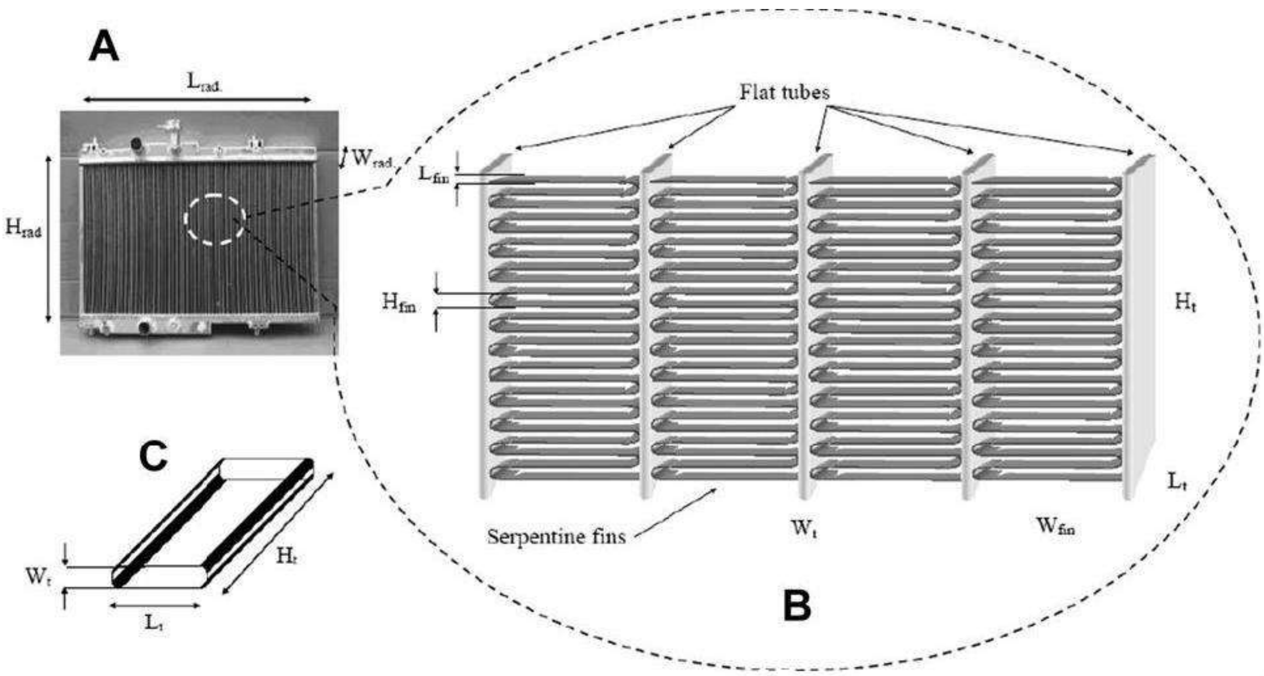


Figure No. 2. (A) The applied serpentine finned tubes automobile radiator (B) magnified scheme of the radiator dimensions (C) schematic of a flat tube of radiator.

IV. HYBRIDNANOFLUID PREPARATION

In the present work, hybrid nanofluids are prepared by two step method. Copper oxide (CuO) nanopowder and Ferrous oxide (Fe_2O_3) are purchased from Sisco Research Laboratory Pvt. Ltd. Mumbai. The average particle size (APS) of CuO and Fe_2O_3nanopowder is 60 nm and this nanopowder was mixed in 0.5%, 1.0%, 1.5 % proportion in 16 Litres of base fluid (conventional coolant). We added 482 grams of nanopowder in 16 Litres of conventional coolant every time to achieve required concentration of hybrid nanofluid with conventional coolant (green colour). Then the hybrid nanofluid was stirred well for proper mixing of nanopowder. The prepared nanofluid was then filled into a tank.

TABLE NO. 1. THE RADIATOR SIDE IMPORTANT DIMENSIONS.

Dimension	Notation	Value
Radiator length	$L_{rad.}$	0.370m
Radiator height	$H_{rad.}$	0.420m
Radiator width	$W_{rad.}$	0.040m
Tube length	L_t	0.015m
Tube height	H_t	0.315m
Tube width	W_t	0.002m
Tube thickness	d_t	0.00008m
Number of tubes	-	33
Tube hydraulic diameter	d_h	0.003530m

V. HYBRIDNANOFLUID 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 thermo physical properties of the nanofluids at different temperatures and concentrations can be evaluated using some classical formulas as usually used for two phase flow. In this paper, the following correlations are used to calculate the density and the specific heat of Hybridnanofluid (Fe_2O_3+ CuO+dilute conventional Coolant)

$$\rho_{nf} = ((\Phi\times\rho_{np}) + (1-\Phi)\times\rho_{bf}) \quad (1)$$

$$Cp_{nf} = ((\Phi\times Cp_{np}) + (1-\Phi)\times Cp_{bf}) \quad (2)$$

In the above equations, the subscripts "np", "bf" and "nf" refer to the nanoparticles, base fluid, and nanofluids, respectively. Φ is volume fraction of the nanoparticle added to the base fluid. The characteristics of Fe_2O_3 and CuO nanoparticles at room temperature are summarized in Table 2.

TABLE NO. 2. SOME THERMO PHYSICAL CHARACTERISTICS OFCUO AND FE2O3 NANOPARTICLES.

Nano particle	Particle Size (nm)	Density (kg/m^3)	Sp. Heat (J/Kg.K)	Thermal Conductivity (W/m^2K)	Specific Surface area (m^2/g)	purity
Fe_2O_3	60	5250	650	20[24]	60	99%
CuO	60	6400	531	76.5[25]	80	98%

The thermal conductivity of the Hybridnanofluid (Fe_2O_3+ CuO + Conventional coolant) is calculated using Hamilton and Crosser [26] model. The thermal conductivity, in which the ratio of conductivity of the solid particles to base fluid is larger than 100 can be expressed as follows:

$$Knf= \frac{(Knp+(n-1)Kbf-\Phi(n-1)(Kbf-Knp))}{Knp+(n-1)Kbf+\Phi(Kbf-Knp)} Kbf \quad (3)$$

In above equation the abbreviations "K_{np}", "K_{bf}", and "K_{nf}" are thermal conductivity of Nanopowder, base fluid(Conventional coolant) and Hybridnanofluid.

Almost all formulas for the calculation of nanofluids viscosity derived from the pioneering work of Einstein, which is based on the assumption of a linearly viscous fluid containing dilute, suspended, spherical particles. The Einstein formula is:

$$\mu_{nf} = (1+(2.5\times\Phi)) \times\mu_{bf}) \qquad (4)$$

Here μ_{nf} is the viscosity of suspension; μ_{bf} is the viscosity of base fluid (dilute conventional coolant).

VI. DATA REDUCTION

To obtain heat transfer coefficient and corresponding Nusselt number, the following procedure has been performed. According to Newton's cooling law:

$$Q_{lost} = m \times Cp_{bf}\times (T_{in}-T_{out}) \qquad (5)$$

$$Q_{gain}= h\times A_s\times (Tb-Tw) \qquad (6)$$

A_s is surface area of tube, T_b is the bulk temperature:

$$Tb =\frac{Tin+Tout}{2} \qquad (7)$$

(T_{in}, T_{out}) are inlet and outlet temperatures and T_w is the tube wall temperature which is the mean value measured by the five surface RTDs.

$$Tw=\frac{T1+T2+T3+T4+T5}{5} \quad (8)$$

The heat transfer coefficient can be evaluated by collecting Equation

$$h_{exp.}=\frac{mCp(Tin-Tout)}{As(Tb-Tw)} \qquad (9)$$

Nusselt number can be calculated as:

$$Nu=\frac{hexp.\times Dh}{K} \qquad (10)$$

$D_h$is hydraulic mean diameter and can be calculated as

$$D_h= 4A/p$$

Here A= C/S area of Radiator tubes
P= Perimeter of radiator tubes
P= ((2×W) + (2×B))

Reynolds number can be calculated by using equation below

$$Re=\frac{\rho\times Vbf\times Dp}{\mu bf} \qquad (11)$$

In above equation (11) "V_{bf}" is velocity of base fluid
And is given by

$$V_{bf}=\frac{Q}{Ap}$$

Where
Q= Volume flow rate through pipe near Rotameter in m^3/s
A_p= C/S Area of pipe near Rotameter in meter.

Because we calculating Reynolds number in flowing through pipe hence dimensions at that point is considered.

Overall heat transfer coefficient (U) is calculated as follows

$$U= \frac{1}{\Sigma RthAo}=\frac{1}{\frac{Ao}{Aihi}+\left(\frac{Ao}{2\pi LK}\times ln^{do}/_{di}\right)+\frac{1}{ho}} \qquad (12)$$

Above equation (12) reduces to
In above equation A_o=A_i
d_o=d_i

$$U=\frac{1}{\Sigma RthAo} = \frac{1}{\frac{1}{hi}+\frac{1}{ho}} \qquad (13)$$

In above equation "hi" and "ho" are the coolant side heat transfer coefficient and air side heat transfer coefficient respectively

Nanopowder is required for producing hybrid nanofluid and mass of nanopowder required is calculated as follows per following procedure.

Density of CuONanopowder = 6.3×10-3 Kg/m3
Density of Fe_2O_3Nanopowder = 5.75×10-3 Kg/m3 Density of [CuO + Fe_2O_3] Nanopowder = 6025 kg/m^3

For experimentation requires 0.5%, 1.0% and 1.5% Volume concentration

First of all calculate mass of nanopowder for 0.5 % volume concentration

The total 16 litres of Hybridnanofluid is required and for this 16 litres 0.5% volume fraction amount of nanopowder required is calculated

$$0.5\%=\frac{volume\ of\ [CuO+Fe2O3]}{Volume\ of\ [base\ fluid+(CuO+Fe2O3)]} \qquad (14)$$

$$0.5\%=\frac{\frac{mass\ of[CuO+Fe2O3]}{density\ of\ [CuO+Fe2O3]}}{Volume\ of\ [Base\ fluid+(CuO+Fe2O3)]}$$

$$0.005 =\frac{\frac{mass\ of[CuO+Fe2O3]}{6025}}{0.0016} \qquad (15)$$

After solving equation (15)

Mass of [CuO+Fe_2O_3] for 0.5% volume concentration= 482 grams

To prepare 0.5% volume fraction hybrid nanofluid we have to add 241 grams each of CuO and Fe_2O_3 in base fluid (Conventional coolant green colour) Repeat above procedure for calculation of mass of nanopowder for 1.0% and 1.5% volume concentration

VII. RESULTS AND DISSCUSSION

A number of experimental runs with base fluid (conventional coolant) were conducted with the setup and compared with Hybridnanofluid with different volume concentration. The results obtained from the experimentation carried out on the cross flow heat exchanger with hybrid nanofluid as a coolant by the mentioned testing methodology the obtained results are presented in the following section.

Figure No.3 to 7 shows the variation of convective heat transfer with respect to Reynolds number for different temperature ranges. It shows the heat transfer enhancement obtained due to the replacement of conventional coolant with hybrid nanofluid with different concentrations.

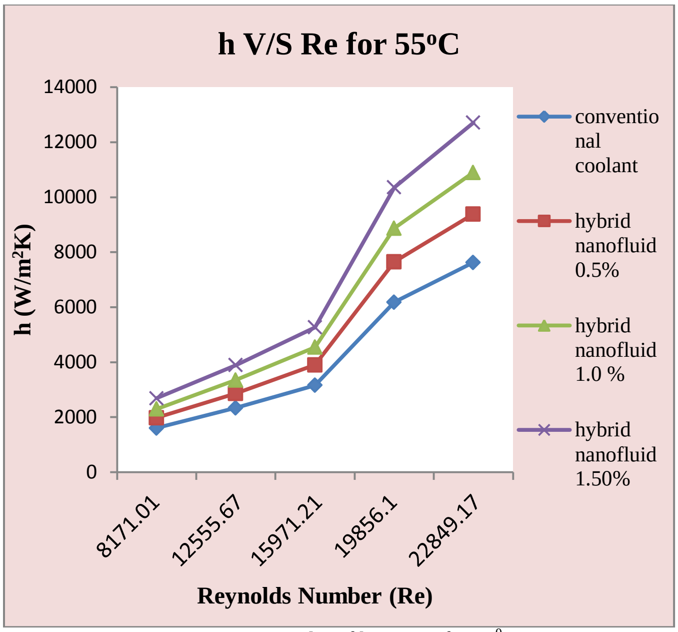


Figure No. 3 Plot of h V/S Re for 55^0C

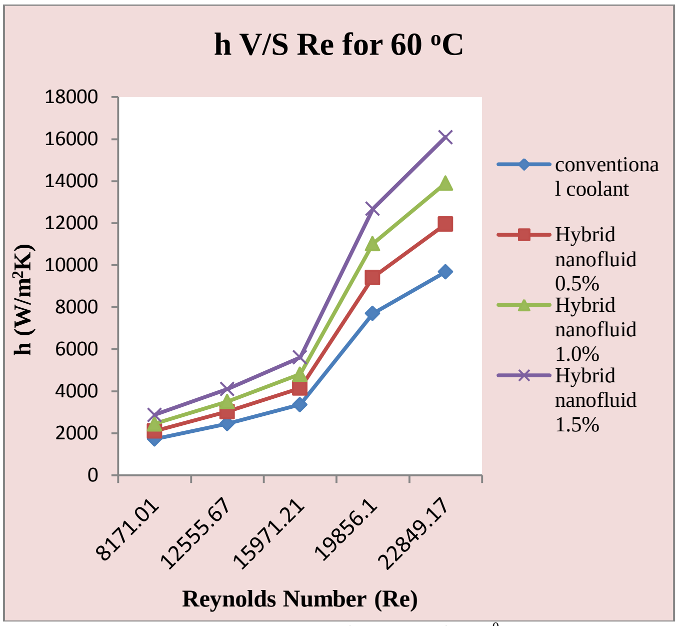


Figure No.4 Plot of h V/S Re for 60^0C

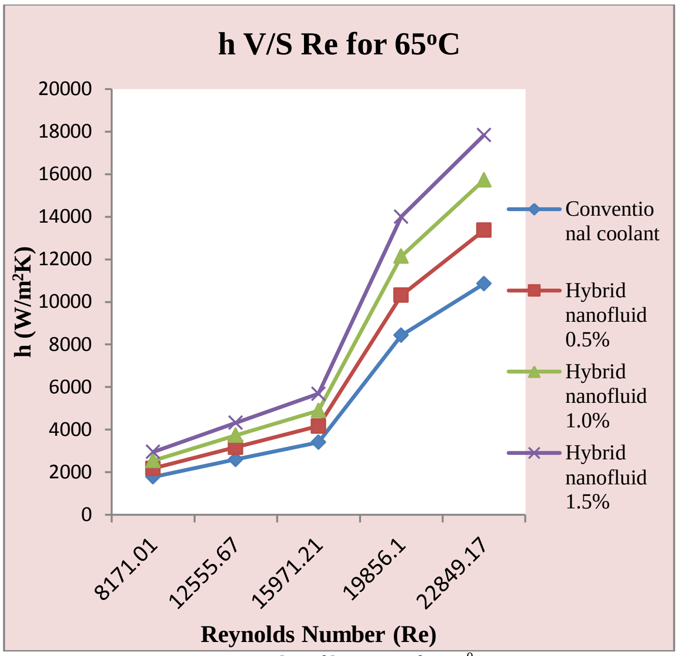


Figure No. 5 Plot of h V/S Re for 65^0C

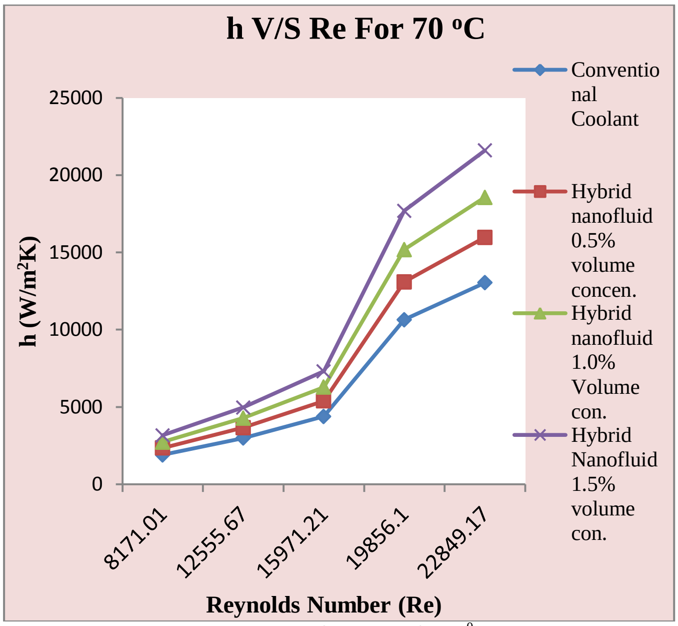


Figure No. 6 Plot of h V/S Re for 70^0C

From graph it is clearly identified as the Reynolds number goes to higher side corresponding convective heat transfer coefficient increases and it is least for the base fluid and it is much higher for 1.5 % volume Concentration of Hybridnanofluid. Thus from above graphs we conclude that as mass flow rate increases of base fluid it will increase Reynolds number and it will enhance heat transfer rate. The range of Reynolds number is in between 7000 to 23000 thus flow is in highly turbulent region and due to turbulence in the flow nanoparticles will not settle down and they were suspending well.

Figure No. 8 to 12 shows variation of outlet temperature from radiator with respect to variation of inlet temperature and different volume fraction of the hybrid nanofluid. Outlet temperature is a function of fluid volume flow rate circulating in the radiator. Four series of data shown in above graphs belong to conventional coolant and also three different concentrations of nanofluids. It should be noted that all the data in above graph is obtained when the fluid inlet temperature to the radiator was 55°C, 60°C, 65°C, 70°C, and 75°C. One can clearly

observe that fluid outlet temperature has decreased with the augmentation of nanoparticle volume concentration. From above graphs we can conclude addition of nanoparticles enhances the heat transfer rate as outlet temperature from radiator is decreased.

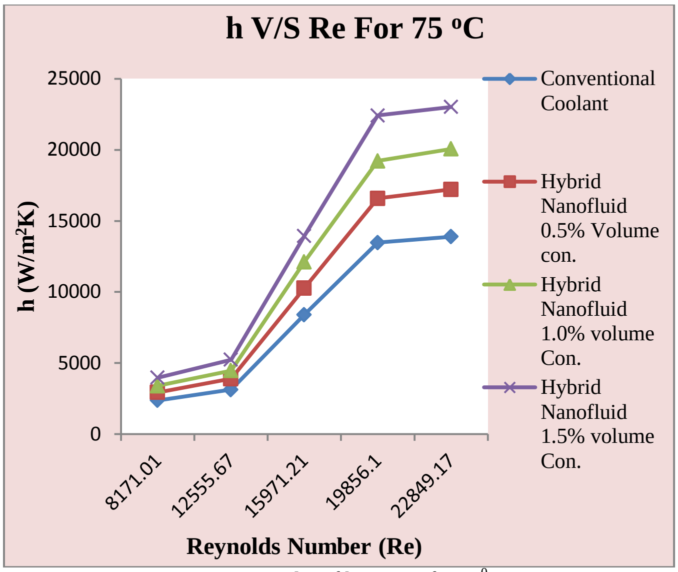


Figure No. 8 Plot of h V/S Re for 75^{0}C

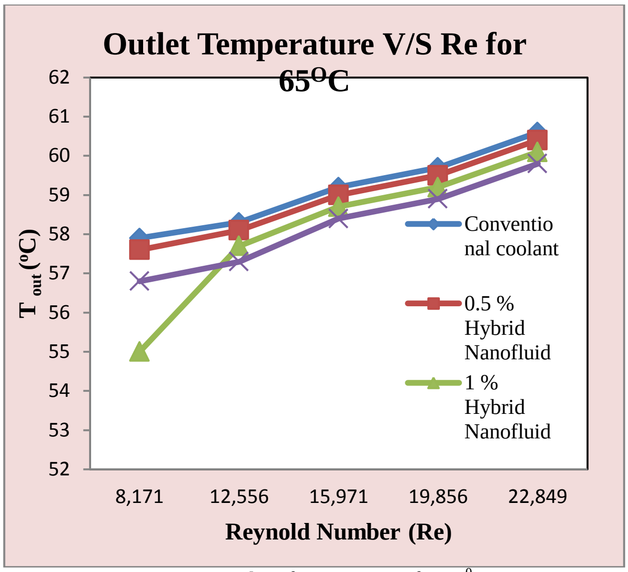


Figure No. 11 Plot of Tout V/S Re for 65^{0}C

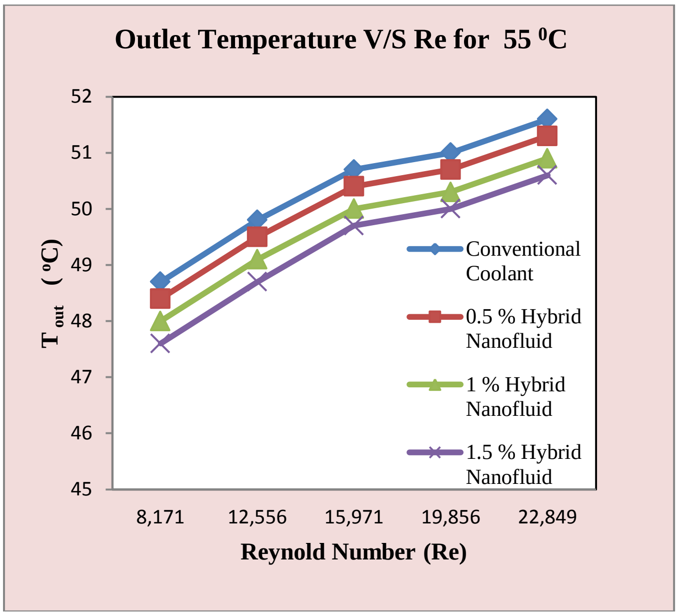


Figure No. 9 Plot of T_{out} V/S Re for 55^{0}C

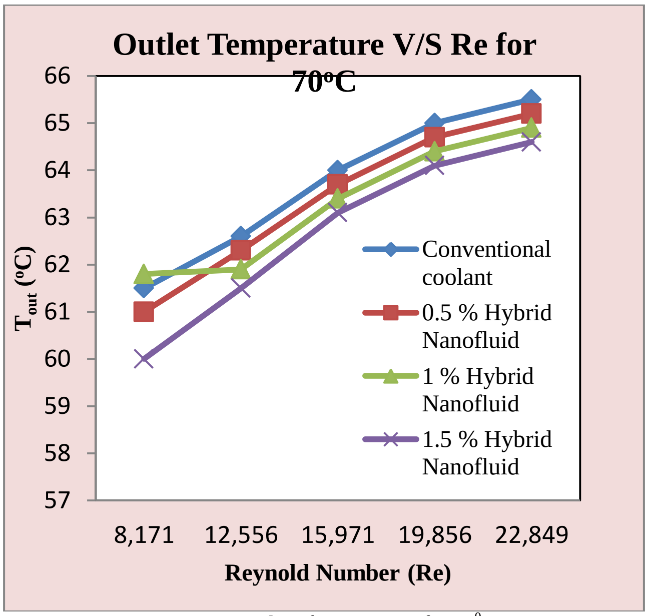


Figure No. 12 Plot of T_{out} V/S Re for 70^0

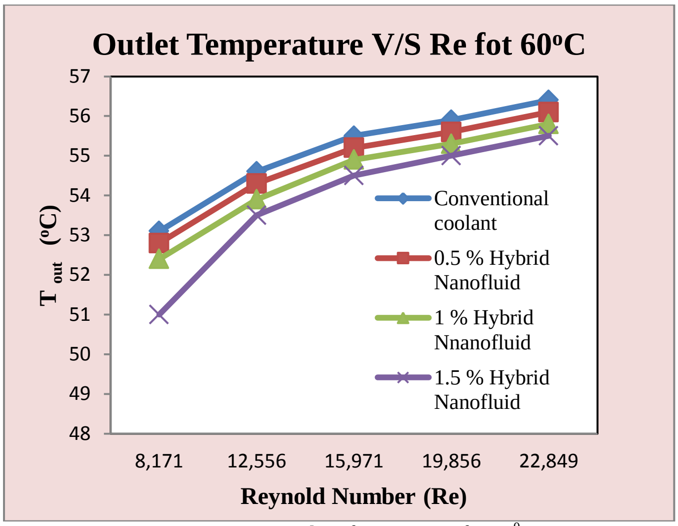


Figure No. 10 Plot of T_{out} V/S Re for 60^{0}C

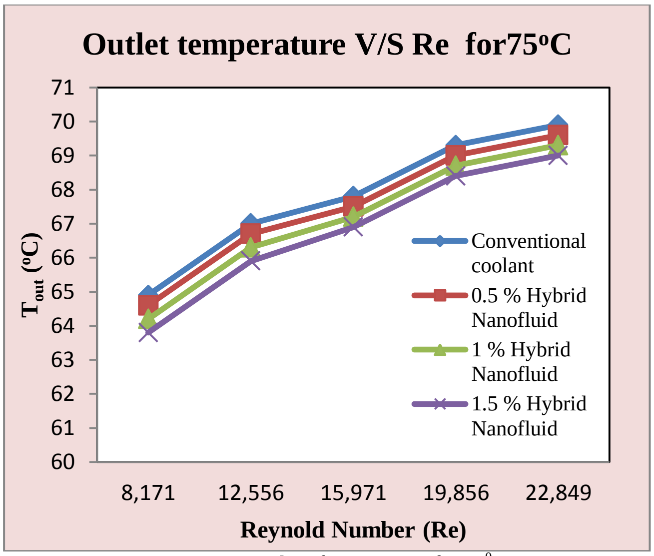


Figure No. 13 Plot of T_{out} V/S Re for 75^{0}C

The addition of nanoparticles in the base fluid enhances the heat transfer rate and it is shown in below graphs that Tout outlet temperature is less as compared conventional coolant so that ΔT is increased by adding nanoparticles and which directly enhances the overall as well as convective heat transfer coefficient.

Figure No. 14 to 18 shows the variation of the overall heat transfer coefficient with respect to Reynolds number for different inlet temperatures of conventional fluid and hybrid nanofluid concentration. From above graphs it is clear that overall heat transfer coefficient is a function of Reynolds number, volume concentration of hybrid nanofluid and inlet temperature of fluid, as Reynolds number increases the overall heat transfer rate increases see Figure no. 14 is for inlet temperature of fluid 55^{0}C as Reynolds number increases we can see the enhancement in "U" but this enhancement is high for 1.5% volume concentration as compared with conventional coolant, from this graph it is clear that "U" is a function Reynolds number and volume concentration of hybrid nanofluid. As Reynolds number increases "U" also increases and it is high for 1.5% volume concentration compared with base fluid (conventional coolant).

Similarly consider Figure No. 17 it is for inlet temperature of fluid 70^{0}C when we compare this with Figure no. 18 it is for inlet temperature of fluid 75^{0}C with we observe that as inlet temperature increases from 70^{0}C to 75^{0}C we can see the increase in "U". For all sets i.e. conventional coolant and three different volume concentrations.

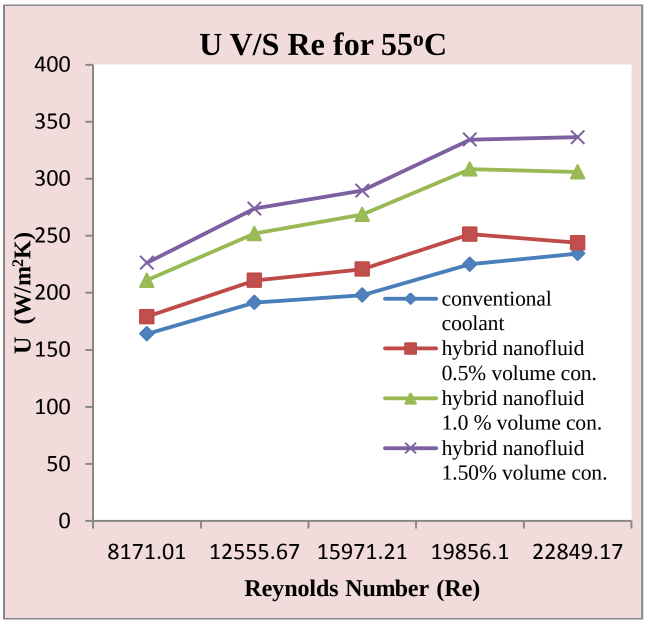


Figure No. 14 Plot of U V/S Re for 55^{0}C

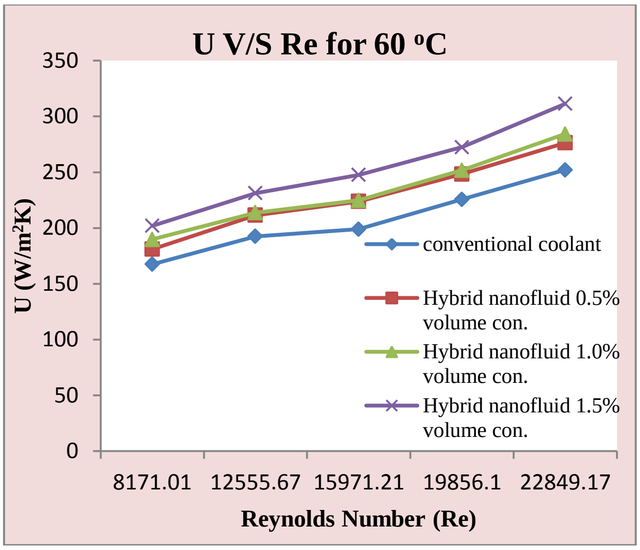


Figure No. 15 Plot of U V/S Re for 60^{0}C

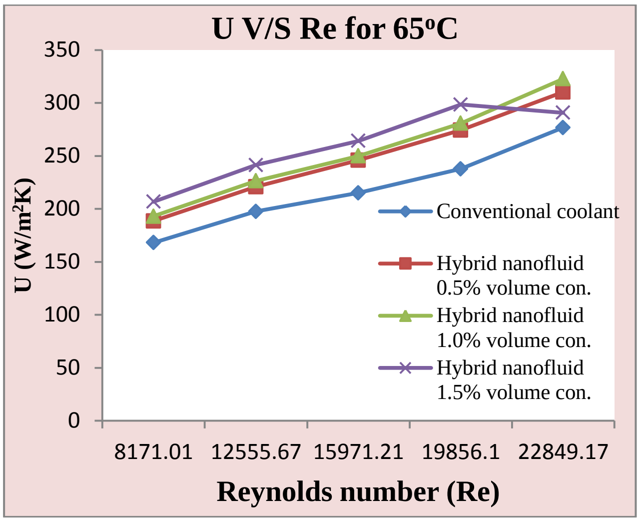


Figure No. 16 Plot of U V/S Re for 65^{0}C

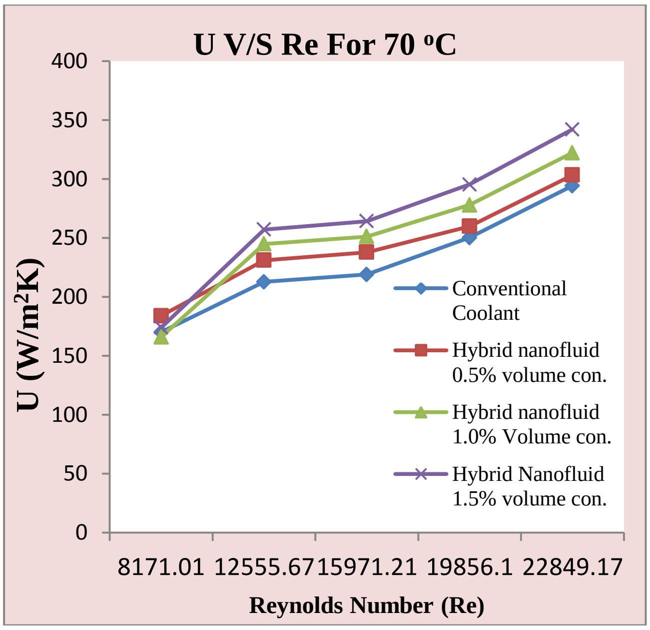


Figure No. 17 Plot of U V/S Re for 75^{0}C

VIII. RESULTS AND DISSCUSSION

The experimental heat transfer coefficients in an automobile radiator have been measured with two distinct working liquids: conventional coolant and conventional coolant based hybrid nanofluid (small amount of CuO+ Fe_2O_3 nanoparticle in conventional coolant) at different concentrations (0.5%, 1.0% & 1.5% by volume) and temperatures and the following conclusions were made.

The overall heat transfer performance and flow characteristic of Copper oxide+ Ferrous oxide hybrid nanofluid flowing in a cross flow heat exchanger (Automobile radiator) was experimentally investigated. Experiments were carried out under turbulent flow conditions, and with three concentrations of Fe_2O_3+CuO-Conventional coolant hybrid nanofluid viz. 0.5%, 1.0% and 1.5% volume concentration. The effects of particle concentrations and Reynolds number on the overall and convective heat transfer coefficients of Hybridnanofluid are determined. Important conclusions have been obtained and are summarized as follows:

1. Dispersion of the nanoparticles into the base liquid increases the thermal conductivity and viscosity of the nanofluids, and this augmentation increases with increasing particle concentrations.
2. At a volume concentration of 1.5%, the use of Hybrid nanofluid increases convective heat transfer coefficient up to 67% and overall heat transfer coefficient up to 21% than that of conventional coolant at same flow conditions. Also at a particle concentration of 1.0%, Hybrid nanofluid increases convective heat transfer coefficient up to 45% and overall heat transfer coefficient up 8% to than that of conventional coolant at same flow conditions.
3. This significant increase in overall and convective heat transfer coefficient is mainly contributed by increased thermal conductivity of Hybridnanofluid and increased convection by molecular collisions. Other parameters like particle size, particle shape, agglomerations and nanolayer also augments heat transfer by convection.
4. Nusselt number of the flow also increases from 1.5% to 8.41% for Hybridnanofluid for volume concentration 0.5 % to 1.5%.
5. Increasing the flow rate of working fluid enhances the overall and convective heat transfer coefficient for both conventional coolant and hybrid nanofluid considerably while the variation of fluid inlet temperature to the radiator slightly changes the heat transfer performance.
6. It seems that the increase in the effective thermal conductivity and the variations of the other physical properties are not responsible for the large heat transfer enhancement. Brownian motion of nanoparticles maybe one of the factors in the enhancement of heat transfers. 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 behaviour of nanofluids.
7. This new working fluid (Hybrid nanofluid) with higher heat transfer performance would promote the car engine performance and would reduce fuel consumption. Therefore, it can be followed by other investigators to eliminate the probable deficiencies for industrialization in the car industries. Some associated problems like stability and sedimentation should be studied with details.

IX. REFRENCES

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