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Heat Transfer Enhancement in Car Radiator by Using Nano Fluid

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Abstract

Nanofluid is suspension of nano sized particle of size smaller than 100 nm which is made of metals, oxides and carbides in a base fluid. Nanofluids are considered to proposalsignificantbenefits over conventional heat transfer fluids. It has high thermal conductivity than base fluid. The aim of present study is to investigate application of aluminum oxide nanofluid to enhance heat transfer rate of heat exchanger and reducing the total area of radiator. The performance evaluation of traditional Maruti 800 car radiator of shell and tube type heat exchanger carried out at RIT, Sakharale. The coolant selected for present investigation is plane water as base fluid with different volume concentration of Al_2O_3 nanofluid (0.001 – 0.003) and different turbulent flow condition (150 LPH – 350 LPH). The inlet fluid temperature is 50^0C. The alumina nanoparticle of 40 nm size is used for present study. While experimental work it was observed that as heat transfer rate increases with increase in mass flow rate and volume concentration. Also 27% heat transfer increment was noted which allows the decrement in 16% radiator volume was noted from study.

Keywords:*Automobile radiator, Nanofluid, heat transfer rate, Nusselt number*

1. Introduction

In prior time of car industry the vehicles are made vast in size and weight. The need of car producer is to make a capable motor. These all vehicles are air cooled engines. As more intense motors are made the issues of lacking cooling of vehicle is begun. The radiator is made by Franz San Galli a Russian agent who created the radiator in 1855. Be that as it may, it is huge in size and unusable. These water cooled radiator require up to 30 liter water stockpiling which made it unusable. The other part of innovations is done in it to make it usable. The present day tube sort radiator is made by Wilhelm Maybach in 1901 and fitted it for Mercedes 35 hp display, which is appropriate for auto and diminishes utilization of water by one fourth of past utilize.

In a car engine, fuel an air produces control in the motor by burning. Just some segment of created power supplies to car as power the rest is squandered as fumes and warmth. So enhancing effectiveness of radiator including added substances in the water is one of the best approach to improve the warmth exchange rate of water and ethylene glycol is one of the well known alternatives as added substance in water. Between the endeavors for upgrade of warmth exchange the use of nanoparticle added substances to fluids is more perceptible way and as of now an expansive number of examinations are given to this subject. [1-6]. Nanofluid is new sort of coolants in which nanometer estimated particles were included base liquid. The utilization of this nanoparticle in base liquid is initially examined by (Choi, et al, 1995). Nanoparticle is little molecule of size below100 nm and high warm conductivity than water (Dilek, et al, 2009).

2. Literature Review

Sadik Kakac, et al [9] in his writing overview demonstrated that nanofluids fundamentally enhance the warmth exchange capacity of customary warmth exchange liquids, for example, oil or water by suspending nanoparticles in these base fluids. The comprehension of the essentials of warmth exchange and divider rubbing is prime significance for creating nanofluids for an extensive variety of warmth exchange application. He inferred that in spite of the fact that there are late improvements in the investigation of warmth exchange with nanofluids, more exploratory outcomes and the hypothetical comprehension of the instruments of the molecule developments are expected to comprehend warm exchange and liquid stream conduct of nanofluids.
C. J. Ho, et al. [10] had done their investigations on roundabout tubes to supplant immaculate water by Al2O3 nanoparticle with base liquid as working liquid. constrained convection warm move in roundabout tubes was researched with water-based nanofluid containing different mass portions of the Al2O3 nanoparticles (2, 5, and 10wt%) under the accompanying working conditions: the volume stream rate of = 23.6–183.5 cm3/min (the Reynolds number Ref,0=188–2095), the warming force connected at the

external mass of the tube qo,eff =1908–7362 W/m2, and the bay liquid temperature Tin=24.5–25.5 °C or 49.5–50.5 °C. Measured information demonstrated that the scattering of expanding mass portion of Al2O3 nanoparticles can successfully enhance the warm conductivity in respect to the unadulterated water. In addition, higher normal warmth exchange viability εh; is noted for the cases with higher channel liquid temperature Tin.

Satinder Tayal, et al. [11] contemplated on constrained convective warmth exchange and stream qualities of nanofluid (Al2O3) comprising of water at various fixation (0.3 – 2%) streaming in shell and tube sort warm exchanger at turbulent stream condition. At the molecule volume grouping of 2% the general warmth exchange coefficient is 700.242 W/m2K and for water it is 399.15 W/m2K at the mass stream rate 0.0125 L/s. The measure of the general warmth exchange coefficient of the nanofluid is 57% more noteworthy than that of refined water. The estimation of Nusselt number for 2% volume focus is 587 and for the refined water it is 367.759 at 0.0125 L/s, this implies Nusselt number of the nanofluid is 62.6% more noteworthy than that of refined water. Grating variable increments with the expansion in molecule volume fixation. It implies that the nanofluid bring about little punishment in weight drop.

S.M. Peyghambarzadeh, et al. [12] has utilized diverse sorts of base liquid, for example, unadulterated water, immaculate ethylene glycol and their twofold blend utilized with Al2O3 as a nanofluid. Nanofluid fixation, liquid stream rate and liquid delta temperature changes all through the analysis. Most elevated warmth exchange improvement gotten up to 40%, best case scenario condition. Warm exchange practices of the nanofluids were exceedingly relied on upon the molecule focus and the stream conditions and feebly subject to the temperature. The expansion of nanoparticles to the coolant can possibly enhance car and substantial obligation motor cooling rates or similarly causes to expel the motor warmth with a diminished size cooling framework. Littler cooling frameworks result in littler and lighter radiators, which thus advantage of vehicle execution and prompt expanded mileage.

3. Experimental setup and procedure

Fig.1 Experimental setup

The experimental setup for this study is shown in figure (1). It includes the flow lines, forced draft fan, car radiator, flow meter. Maruti 800 car radiator is used with constant air velocity fan of 5 m/s. Electric motor with collection tank and rheostat is used. Flow meter is placed above the electric motor. Four thermocouples are used to measuring the temperature which shows the digital temperature indicator. The working fluid fills the 40% of tanks total volume and total fluid flowing in experiment is constant. By using the rheostat the constant 50^0 temperature is maintained while flow meter maintain constant flow rate in the range 0 LPH to 600 LPH.For air the constant velocity and temperature is considered throughout the experiment to clearly investigate the internal heat transfer.

3.1 Preparation of nanofluid

Eastman et al. [13] measured the thermal conductivity of water based nanofluids containing 0.3% copper nanoparticles with time. They found slightly reduction in thermal conductivity of nanofluid which is stabilized two months before. This might due to reduced dispersion stability of nanoparticles with respect to time. The water in which the nano powder is mixed it must be well PH maintained. The PH of water affects many parameters of nanofluid (Fedel, et al, 2008). The two step method is used for preparation of nanofluid. In this method dry Nano powder is dispersed into a fluid with the help of ultrasonic agitation (Saidur, et al, 2011).

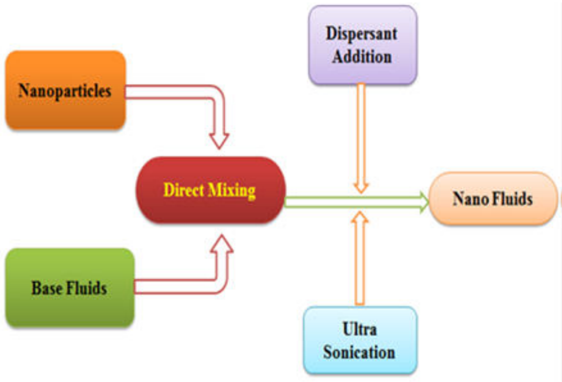

Fig.2 Two-step method

Step one –
In this step nanoparticle are mixed with the base fluid and stirred it. It have poor suspension stability and due to gravity it is settle down at the bottom
Step two-
After mixing the nanoparticle it is put in the sonication equipment for 6 hours. The pallets are made and it is inserted for 30 minutes and repeats the process for six hours. When it gets cooled then it is removed from the equipment.

Fig.3 Prepared nanofluid samples for different concentration

4. Calculation of different thermophysical properties of nanofluid

It is assumed that nanoparticle is mixed with base fluid completely that is particle concentration is constant throughout. Thermophysical properties are calculated from different formulas used for thermal conductivity, density, specific heat and viscosity. It is used for different concentration and flow rate [16 - 18].

Table 1 Comparison of thermo physical properties [16]

Property	Aluminum oxide	Water	Air
Thermal Conductivity(Kp) W/mK	40	0.605	0.4508
Density (ρ_p) Kg/m^3	3700	997.1	1025.38
Specific heat(Cp) J/Kg K	880	4179	3551

$$K_{nf} = K_f \frac{K + 2K_f - 2\emptyset(K_f - K)}{K + 2K_f + \emptyset(K_f + K)}$$

$$\rho_n = (1 - \emptyset)\rho_{nf} + \emptyset\rho_p$$

$$C_P = \frac{(1\text{-}\emptyset)(\rho C_p)_{bf} + \emptyset(\rho C_p)}{\rho_{nf}}$$

$$\mu_{nf} = \mu_w \left[\frac{1}{((1-\emptyset)^2)}\right]$$

Where $\emptyset$ is volume fraction of nanoparticle

4.1 Data Reduction

In the present study hot water and nanoparticle flowing inside the tube and it transfer heat to the outside air flow channel. Heat transfer rate at air side and tube side is calculated as follows (Albdar, et al, 2013)

$$Q = m_{nf} C_p \Delta T$$

Where, ΔT is the temperature difference between inlet and outlet temperature of nanofluid.

The performance of radiator is analyzed by ε – NTU method it is given by [20]

$$\varepsilon = \frac{Actual\ heat\ gransfer}{Maximum\ heat\ transfer} = \frac{m_{nf}C_{pnf}(T_{nfi} - T_{nfo})}{m_a C_{pa}(T_{nfi} - T_a)}$$

NTU is Number of Transfer Unit which is given by,

$$NTU = \frac{U * A}{C_{min}}$$

Heat capacity ratio from larger to smaller is given by,

$$C = \frac{C_{min}}{C_{max}}$$

Where, C_{min} is minimum of heat capacity of hot and cold fluid and C_{max} is maximum of heat capacity of hot and cold fluid.

Nusselt number calculation -

General equation is,

$$N_u = \frac{hD}{k}$$

The air side heat transfer coefficient is obtained using (Hewitt et. al) for high fin staggered array heat exchanger

$$N_u = 0.242 * Re^{0.658} * \left(\frac{s}{h}\right)^{0.297} * \left(\frac{Xt}{Xl}\right)^{-0.091} * Pr^{\frac{1}{3}}$$

The Dittus Bolter equation can be expressed as, (Wais, et al, 2009)

$$Nu = 0.023 * Re^{0.8} * Pr^{0.4}$$

4.2 Radiator Design Modeling

In this study, with the help of use of nanofluid heat transfer rate is in comparison of base fluid that is water. By using mixture of 0.003% alumina fraction achieved 4978.16 W heat transfer rate and with water 1910.25 W is achieved at constant flow rate (350 LPH) and constant air velocity (5 m/s). From this new area using overall heat transfer coefficient at air side can be calculated. From known value of temperature the LMTD is calculated as, (Aberoumad, et al, 2013)

$$\Delta T_{lm} = \frac{(T_{nfi} - T_{ao}) - (T_{nfo} - T_{ai})}{In\left(\frac{(T_{nfi} - T_{ao})}{T_{nfo} - T_a}\right)}$$

Where, $P = \left[\frac{(T_{ao} - T_{ai})}{T_{fi} - T_{ai}}\right]$

$$R = \left[\frac{(T_{fi} - T_{fo})}{T_{ao} - T_{ai}}\right]$$

Air side heat transfer coefficient which is expressed as, [23]

$$U_a = [(1/\eta_o * h_a) + (1/h_{nf})(\alpha_a/\alpha_{nf})]$$

From this new outlet area is calculated as, [20]

$$A_o = \frac{Q}{U_a F \Delta T_{lm}}$$

From above new area the number of fins is calculated as,

New area=

$N_f * (Fin\ area) + (total\ outlet\ area\ of\ tube)$

5. Results and Discussion

5.1 Pure Water

Before conducting test on radiator with using Al_2O_3/water nanofluid initially test is done on water. From this test the reliability and accuracy of set up is tested and it is compare with well-known correlation such as Dittus bolter (Bolter, et al, 1930). The experimental nusselt for water with respect to reynolds number is shown in figure (4). The experiment reading of Nusselt number Vs Reynolds number shows good agreement with Dittus bolter correlation

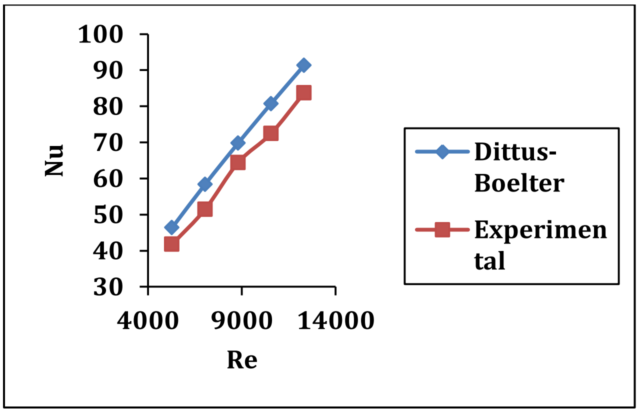

Fig.4 Validation of experimental Nu against correlation

5.2 Nanofluid

The nanofluid is used at different concentration that is, 0.001, 0.002 and 0.003 vol% and different flow rate which is 150 LPH to 350 LPH used as working fluid. The figure shows the replacement of water by nanofluid

From the figure (5) it is seen that by increasing the flow rate the heat transfer coefficient also increases. The nanofluid concentration also plays important role in this experiment. As the concentration of nanofluid increases the heat transfer rate also increases.

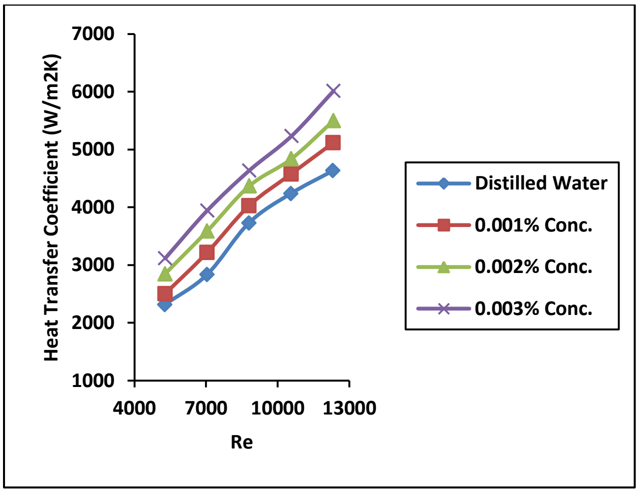

Fig.5 Heat transfer coefficient against Re for different concentration

Figure (6) shows the experimental nusselt number. The Nusselt number is increases as increase in flow rate i.e. Reynolds number it also increases with increase in nanofluid concentration. By small change in concentration of nanofluid gives good result than distilled water.

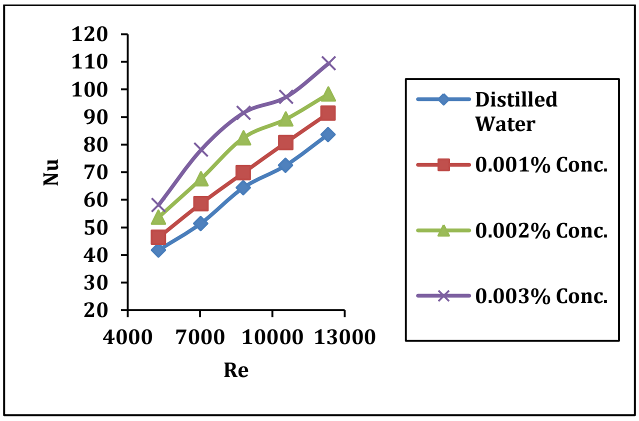

Fig.6 Nu vs Re for different concentrations

5.3 New design of radiator

By using LMTD method the effective temperature is calculated. New outside heat transfer area is calculated by using air side overall heat transfer coefficient. The new outside heat transfer area is 2.9606 m² which is 16% less than the existing outside area of car radiator. The comparision of radiator design parameter is shown in table (2).

Table 2 Comparison of design parameter of radiator

Parameters	Old Radiator	New Radiator
Area (m²)	3.5437	2.9606
Number of Fins (N_F)	201	164
Number of Tubes(N_T)	33	28
Length of Tube (L) mm	306	269

The design of new radiator is drawn in solid works. It is shown in figure (6). The 3-D view of optimized radiator model is shown in figure (7).

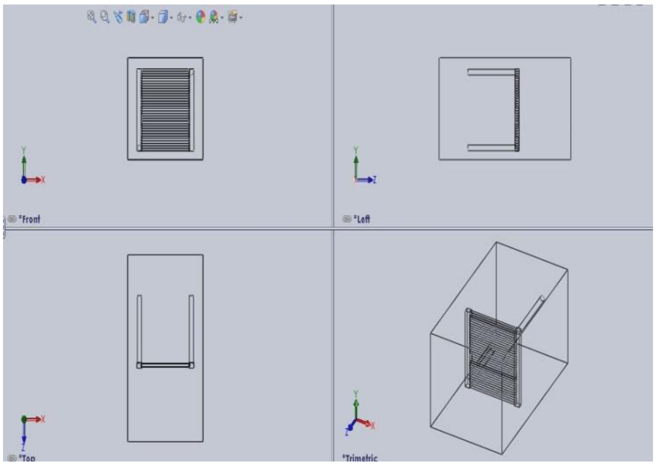

Figure.6 Optimized radiator design

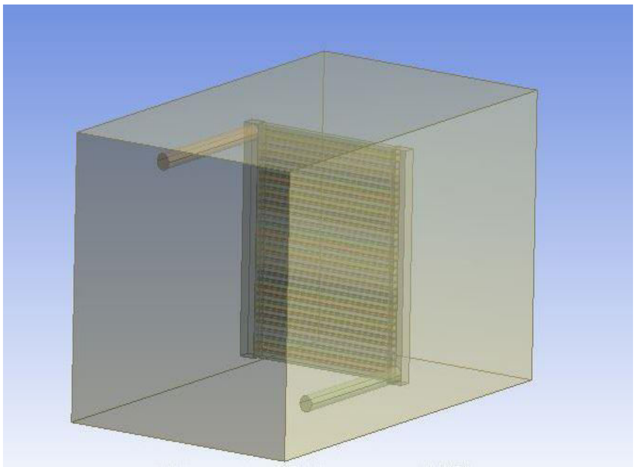

Figure.7 Three dimensional view of radiator

6. Conclusions

To determine the heat transfer coefficient experiment on radiator is conducted and comparison between two fluids i.e. pure water and nanofluid is done. Following conclusions were obtained:

1) Suspension of nanoparticle in base fluid leads to increase heat transfer rate with respect to Reynolds number and concentration.
2) The experimental result shows that, enhancement in heat transfer coefficient is dependent on particle concentration and flow rate condition.
3) Heat transfer rate increased by 27% for 0.003% volume concentration and 350LPH flow rate.
4) It is estimated that 16% reduction in air frontal area of radiator for 27% increment in heat transfer rate.

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