Enhancement Performance of Automobile Radiator Using Nanofluid

Pritesh M Brahmbhatt[1], Keyur D Tandel [2]

[1] *Student, Mechanical Department, Government Engineering College, Valsad, Gujarat, India*
[2] *Assistant Professor, Mechanical Department, Government Engineering College, Valsad, Gujarat, India*

ABSTRACT

Conventionally, water and ethylene glycol are used in automobile car radiator as coolants. These coolants offer low thermal conductivity and therefore in the present work, thermal performance of the automobile radiator is carried out experimentally using convectional coolants and nanofluids. A critical literature review is carried out to understand various heat transfer properties of nanofluid. It is observed that thermal conductivity, viscosity depends strongly on concentration, particle size and temperature of nanofluid. There are many nanofluids which are used to improve thermal performance of car radiator. The objective of present study is to evaluate heat transfer performance of car radiator using Al_2O_3 nanofluid at different volume flow rate (4, 6, 8 l/min), different temperature (50, 60, 70, 80 °C) and at different concentration (0.25, 0.50, 0.75 w/w %). The same is compared with the base fluid.

Keyword: - *automobile car radiator, nanofluids, nanofluid flow rate, and temperature .etc….*

---

1. INRODUCTION

As we progress our heat exchangers becomes compact but the reduction in size restricts the surface available for the heat exchange giving rise to use of fluid which have higher thermal conductivity with other desirable property needed for good heat exchanger fluid. Recent development in nano technology gave us nanofluid which became an important candidate for fluid with high thermal conductivity.

An efficiency of heat exchanger can be increase by either introducing heat transfer enhancement techniques or efficient design or by using fluid with higher heat transfer capacity per unit mass flow rate then convectional fluid use for specific application. We have considered the later technique to increase heat transfer rate in our study.

1.1 Synthesis and Preparation of nano fluid.

Preparation of nanofluids is the first key step in experimental studies with nanofluids. Nanofluids are not just dispersion of solid particles in a fluid. The essential requirements that a nanofluid must fulfil are even and stable suspension, adequate durability, negligible agglomeration of particles, no chemical change of the particles or fluid, etc. Nanofluids are produced by dispersing nanometres scale solid particles into base liquids such as water, ethylene glycol, oil, etc. In the synthesis of nanofluids, agglomeration is a major problem. [1]

There are mainly two techniques used to produce nanofluids: 1) single-step and 2) two-step method. [1]

1.1.1 The Single-step Process.

In this method nanoparticle manufacturing and nanofluid preparation are done concurrently. The single-step method is a process combining the preparation of nanoparticles with the synthesis of nanofluids. [1]

Various methods have been tried to produce different kinds of nanoparticles and nano suspensions. The initial materials tried for nanofluids were oxide particles, primarily because they were easy to produce and chemically stable in solution. Various investigators have produced Al_2O_3 and CuO nanopowder by an inert gas condensation process that produced 2–200 nm-sized particles. The major problem with this method is its tendency to form agglomerates and its unsuitability to produce pure metallic nanopowder. [1]

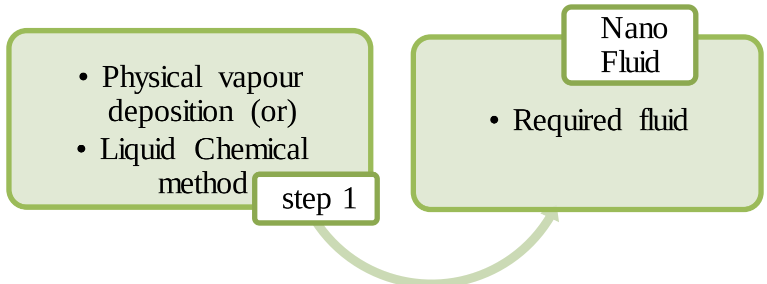

Fig -1: Single-step Process

1.1.2 Two-step Process.

The two-step method is extensively used in the synthesis of nanofluids considering the available commercial nano-powders supplied by several companies. In this method, nanoparticles were first produced and then dispersed in the base fluids. Generally, ultrasonic equipment is used to intensively disperse the particles and reduce the agglomeration of particles. As compared to the single-step method, the two-step technique works well for oxide nanoparticles, while it is less successful with metallic particles [1].

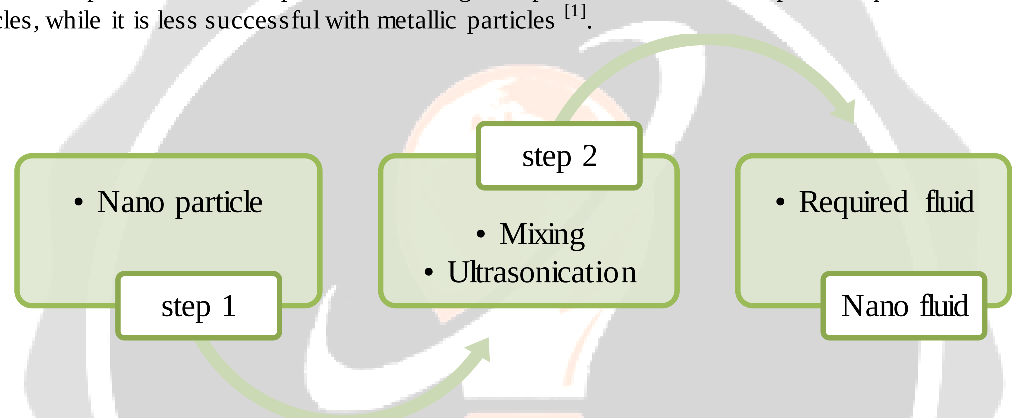

Fig -2: Two-step Process

1.2 Reason for choosing Al_2O_3 Nano fluid.

There are many nano materials available that can be used as nano particles in different applications. Some suitable nano materials that can be used in automobile radiator heat ex-changer application as per literature review are CuO and Al_2O_3.

- The reason of selection of Al_2O_3 nano fluid is due to following reasons: More thermal conductivity that is required for heat exchange application than base fluid like water and ethylene glycol.
- Less cost and ease of availability as compared to other metal oxide nano fluid.
- Material compatibility with the material of radiator.
- Stable at high temperature.

2. Experimental rig.

Experiment is carried out considering three different types of coolant in automobile radiator.

2.1. Water as coolant.

In this case, 10 liter water is heated in heating tank using electric heater and temperature is maintained using thermostat at 50 °C. Heated water from tank is pumped to radiator using pump. Volume flow rate is measured using rotameter fitted between pump and radiator which is maintained using bypass valve at 4 l/min. Temperature of water at inlet ($T_{w,in}$) and outlet ($T_{w,out}$) of radiator is measured using PT-100 type RTD (Resistance Temperature Detector).

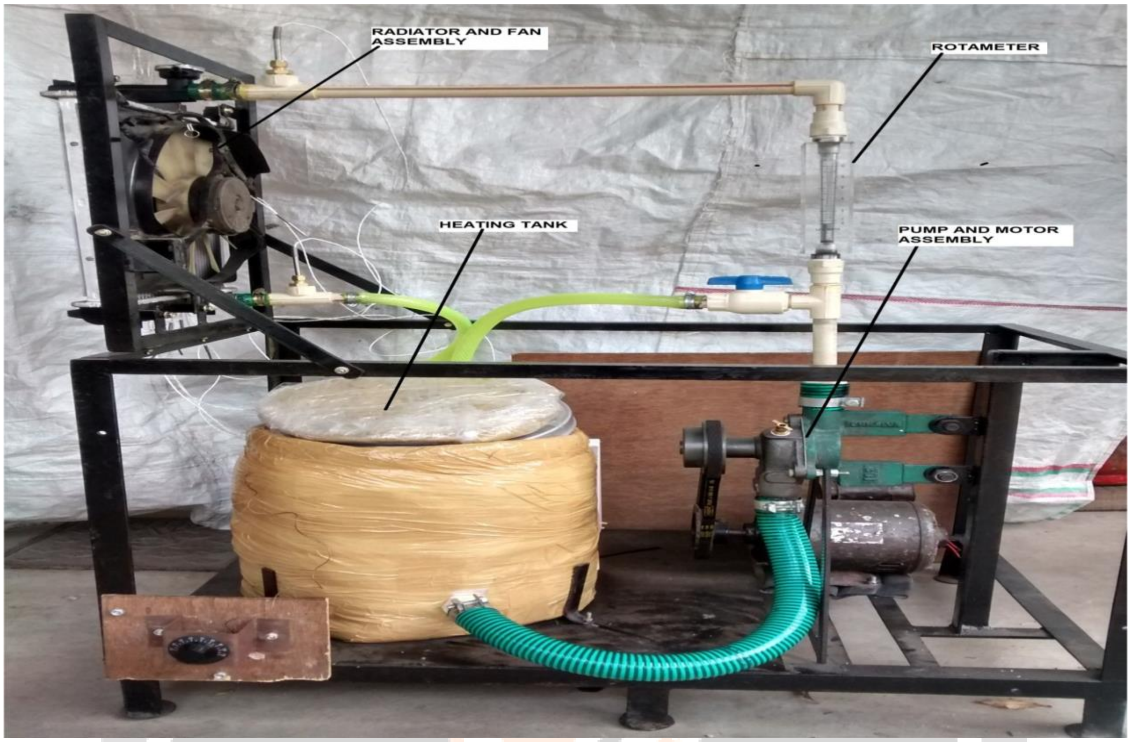

Fig -3: Experimental setup

Temperature of Air at inlet is equal to atmospheric temperature ($T_{a,in}$) which is measured using RTD. For proper analysis, outlet temperature of air at three different positions is measured and average of these three temperature is taken as outlet temperature ($T_{a,out}$). Temperature of wall (T_w) is measured at almost center of radiator longitudinally by using two PT-100 RTD thermocouple brazed on pipe wall at equal distance from center of radiator horizontally. Average of these two thermocouples is taken as reading for one time experiment.

Table -1: Experimental matrix for Water and Water: EG

Temperature (°C)	Volume flow rate (l/min)		
50	4	6	8
60	4	6	8
70	4	6	8
80	4	6	8

2.2. Water:EG (60:40):

In this case, 5 liter water and 5 liter EG (Ethylene Glycol) is mixed to form 10 liter coolant for radiator.
The Procedure and conditions are same as described above for water, only coolant is changed i.e water: EG (60:40).

2.3. Nano Coolant (NC):

In this case, Three different coolants are used i.e. NC_1, NC_2, NC_3.
For each type of nano coolant procedure is same as described for water, only coolant is changed.

Table -2: Experimental matrixes for nanofluid

Concentration (w/w)	Temperature (°C)				Volume flow rate (l/min)
0.25	50	60	70	80	4
	50	60	70	80	6
	50	60	70	80	8
0.50	50	60	70	80	4
	50	60	70	80	6
	50	60	70	80	8
0.75	50	60	70	80	4
	50	60	70	80	6
	50	60	70	80	8

3. Mathematical equation for Experiment

To carry out heat transfer analysis of automobile radiator, heat transfer co-efficient (h) and heat transfer rate (Q) for Water, Water: EG and nanofluid with three different concentrations (NC_1, NC_2, NC_3) are calculated. For this following equations are used.

3.1Heat transfer co-efficient (h)[13]:

$$\frac{h.d}{k} = \frac{\dot{m}C_p(T_{in} - T_{out})}{A(T_b - T_w)}$$

Where,

$\dot{m}$ = Mass flow rate of fluid (Kg/s).
C_p = Specific heat capacity of fluid (Kj/Kg.°C).
T_{in} = Fluid inlet temperature (°C).
T_{out} = Fluid outlet temperature (°C).
A = Peripheral area of radiator tubes (m^2).
T_b = Bulk mean temperature (°C).
T_w = Tube wall temperature (°C).
k = Thermal conductivity (W/m°C).
d = Hydraulic diameter of tube (m).

3.1 Heat transfer rate (Q)-[13]:

$$Q = \dot{m}\, Cp\, \Delta T$$

Where,

$\Delta T = T_{in} - T_{out}$

3.2 Estimation of physical properties for nanofluid:

- Density of nanofluid (ρ_{nf})[17]:

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

Where,

ρ_p = Density of nano particle (Kg/m^3)

ρ_{bf} = Density of base Fluid (Kg/m^3)

φ = Nano particle mass fraction (%)

- Specific heat capacity of nano fluid (C_p)[17]:

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

$(c_p)_p$ = Specific heat capacity of particle (KJ/Kg°C)

$(c_p)_{bf}$ = Specific heat capacity of base fluid (KJ/Kg°C)

- Thermal conductivity of nano fluid (k_{nf})[17]:

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

Where,

k_p = Thermal conductivity of particle (W/mK)

k_{bf} = Thermal conductivity of base fluid (W/mK)

ϕ = Shape factor (ϕ = 3)

- Percentage Enhancement:

$$\text{Percentage Enhancement} = \frac{X_2 - X_1}{X_1} \times 100$$

Where,
X_2 = Obtained Value
X_1 = Original Value

4.RESULT AND DISCUSSION

In Experiment different coolants are used at different volume flow rate and different inlet conditions. In these parameters like Reynolds number, Nusselt number, Heat transfer rate and Heat transfer co-efficient are worked out. Relations between these parameters are as follows:

4.1 Effect of Volume flow rate on Heat transfer co-efficient and heat transfer rate at inlet temperatures (50°C, 60°C, 70°C, 80°C) for all types of coolants.

According to Figure (4.1- 4.2), with the increase in volume flow rate, heat transfer rate and heat transfer coefficient increase for all type of coolants at (50°C) temperature. So heat transfer rate and heat transfer coefficient directly depends on volume flow rate at (50°C) constant inlet temperature of fluid.It is observed from the graph that heat transfer rate and heat transfer coefficient both have maximum value at all volume flow rate for NC_2 and minimum for water: EG radiator coolant.Same types of plots Figure (4.3-4.8), are obtained for heat transfer rate and heat transfer coefficient against volume flow rate at temperature (50°C, 60°C, 70°C, 80°C) for all type of coolant and similar results are obtained at all temperature.

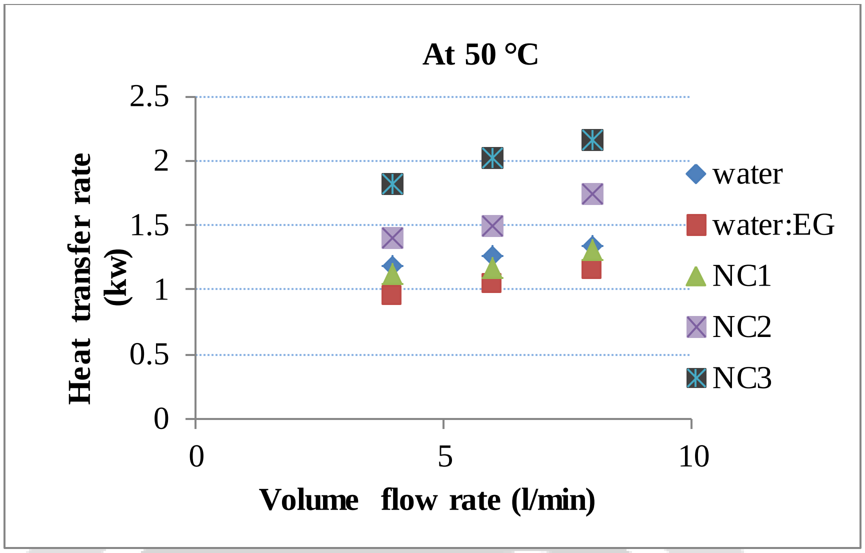

Chart-Relation between Heat transfer rate and volume flow rate at 50°C

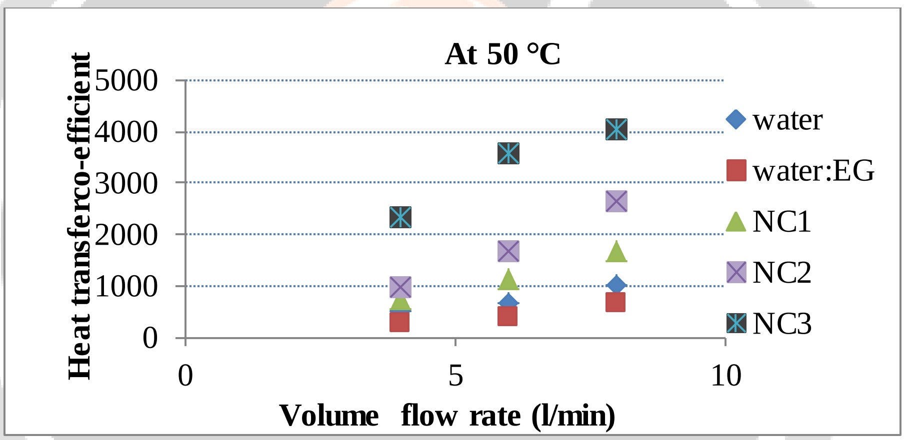

Chart-Relation between Heat transfer co-efficient and volume flow rate at 50°C

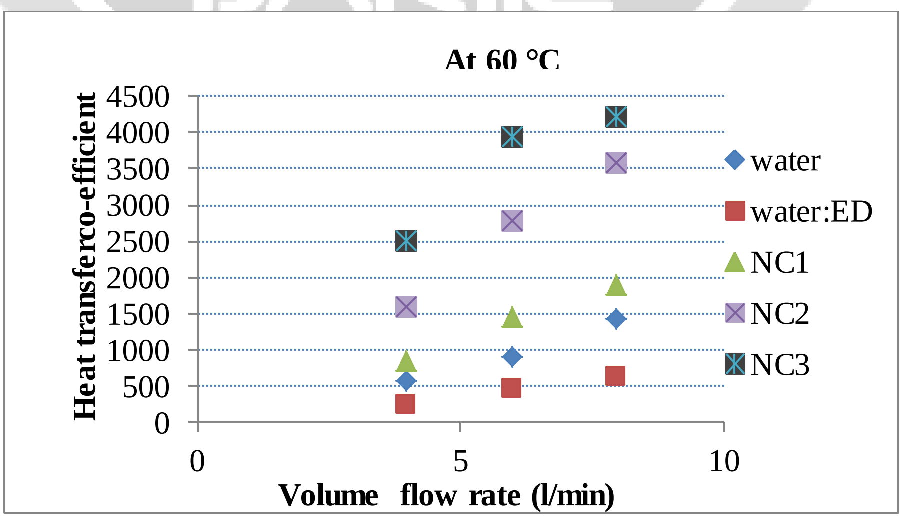

Chart-Relation between Heat transfer co-efficient and volume flow rate at 60°C

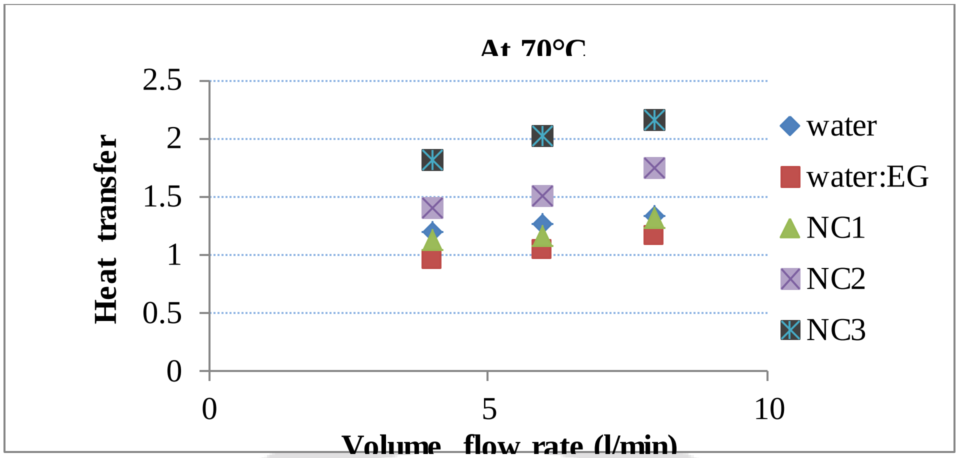

Chart-4.4 Relation between Heat transfer rate and volume flow rate at 70°C

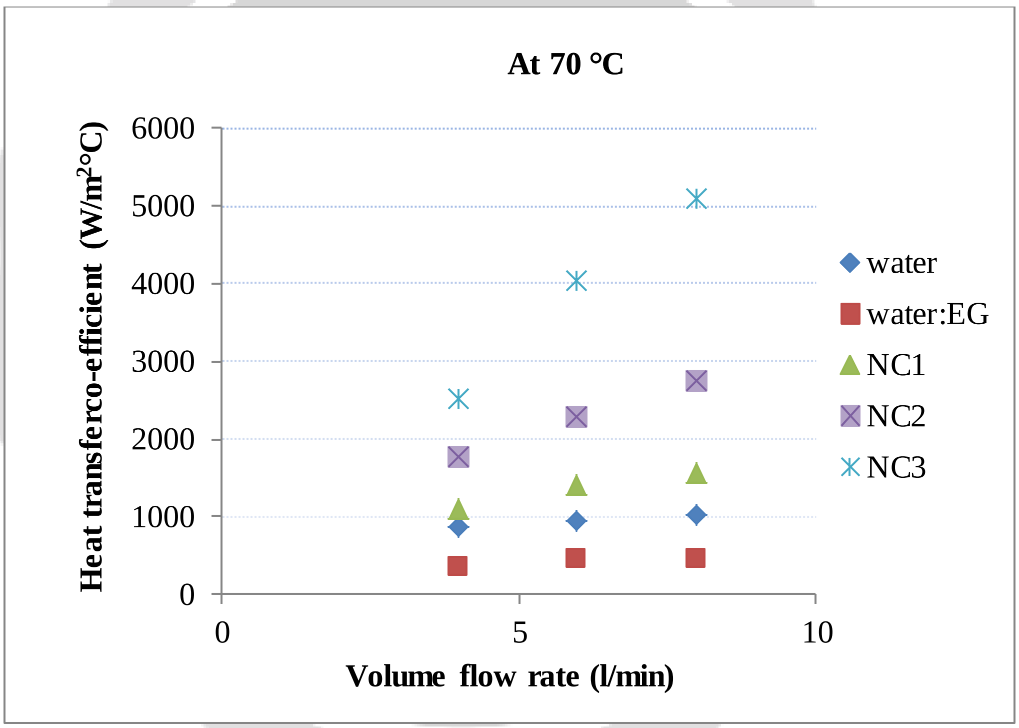

Chart-4.5 Relation between Heat transfer co-efficient and volume flow rate at 70°C

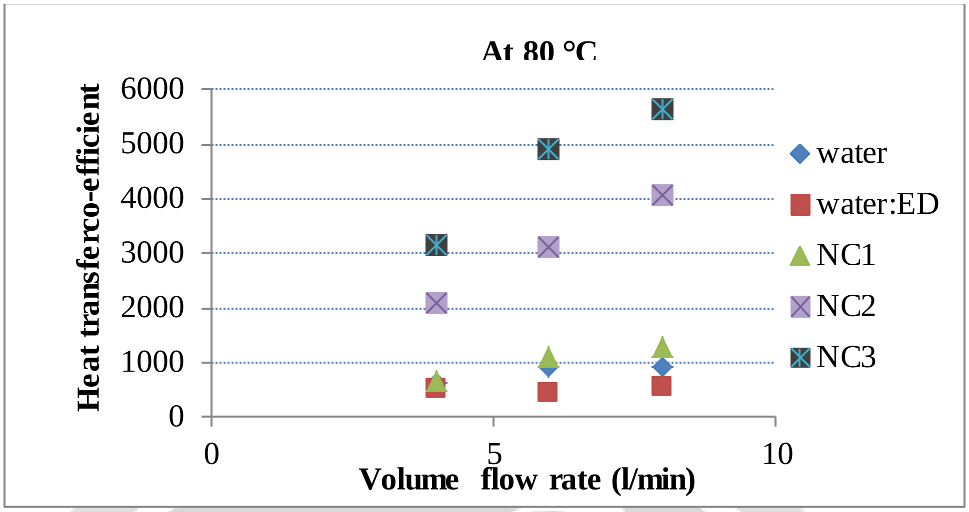

Chart-4.6 Relation between Heat transfer co-efficient and volume flow rate at 80°C

4.2 Effect of Volume flow rate on outlet temperature of coolants at (50°C, 60°C, 70°C, 80°C) inlet temperature for all coolants.

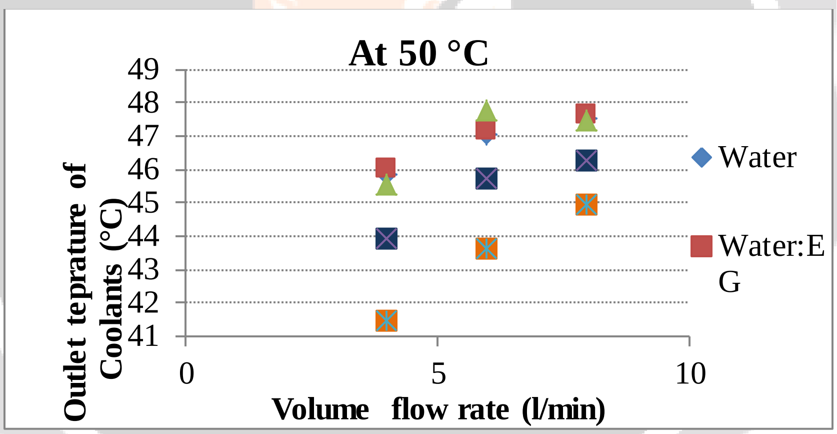

Chart-4.7 Effect of volume flow rate on outlet temperature of coolants for 50°C

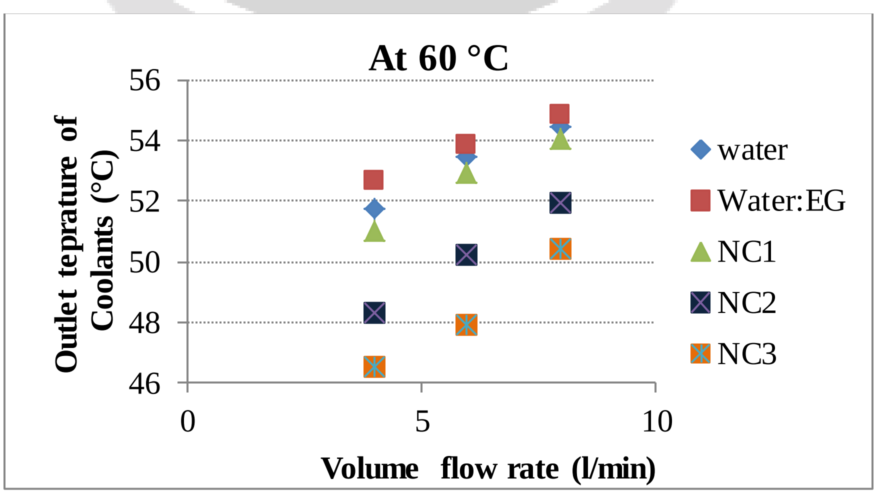

Chart-4.8 Effect of volume flow rate on outlet temperature of coolants for 60°C

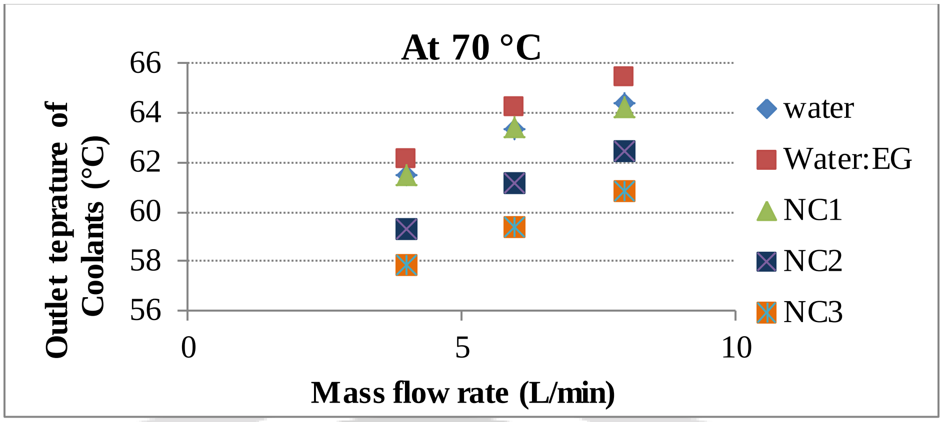

Chart-4.9 Effect of Mass flow rate on outlet temperature of coolants for 70°C

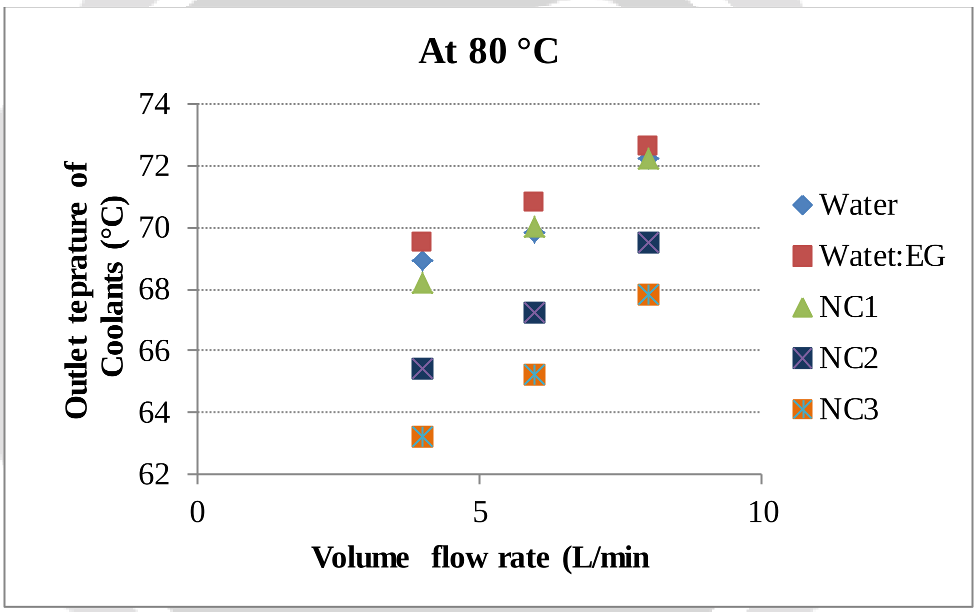

Chart-4.10 Effect of volume flow rate on outlet temperature of coolants for 80°C

Figure (4.9-4.10) Shows relation between effect of volume flow rates on outlet temperature of water at constant inlet temperature (50°C, 60°C, 70°C, 80°C) for all nano coolants. Figure shows that at constant inlet temperature, outlet temperature decreases with increase in volume flow rate for all coolants. Also the decrease in outlet temperature is maximum for NC_2 and minimum for water: EG at all inlet temperature.

4.3 Relation between Reynolds number and Heat transfer rate at constant inlet temperature for all coolants are plotted:

To study effect of Reynolds number on heat transfer coefficient on Reynolds number graphs at constant inlet temperature 70°C is plotted. The result shows that heat transfer increases with increase in Reynolds number for all type of coolants.

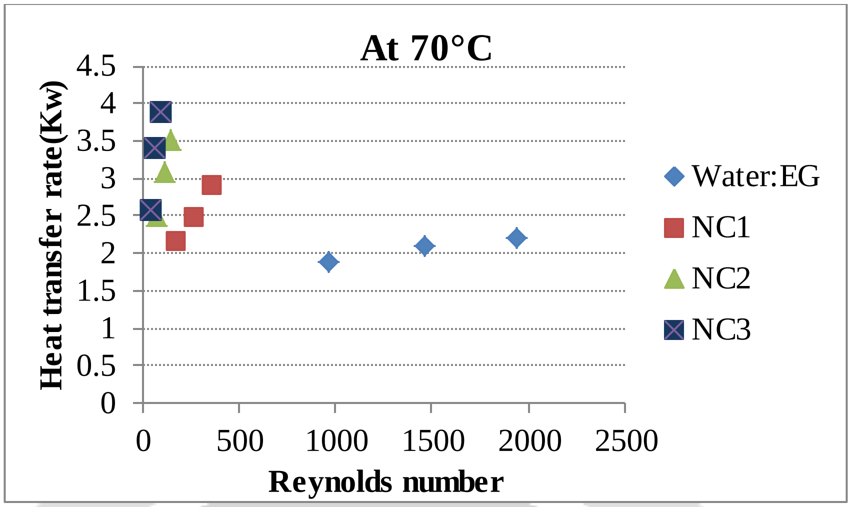

Chart-4.11 Effect Reynolds number on heat transfer rate for all coolants at 70°C

4.4 Relation between Reynolds number and Nusselt number at constant inlet temperature for all coolant are plotted:

Graph (4.12-4.16) shows relation between Nusselt number and Reynolds number at constant temperature of 70°C and for different coolants. The result shows that when Reynolds number increases Nusselt number also increases for all types of coolants.

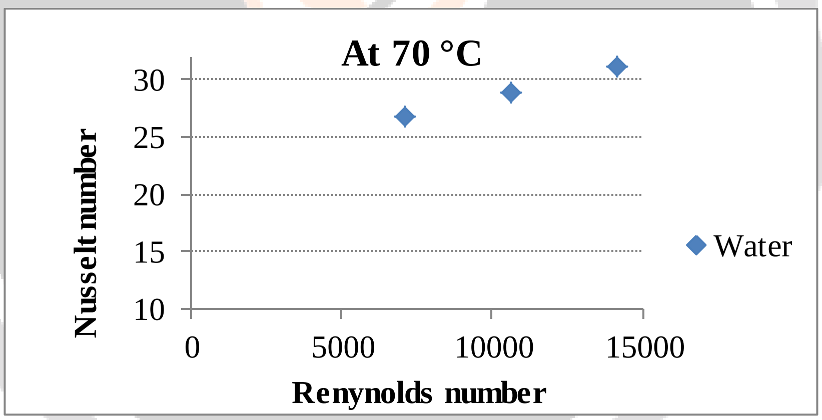

Chart-4.12 Effect Reynolds number on Nusselt number for water coolant at 70°

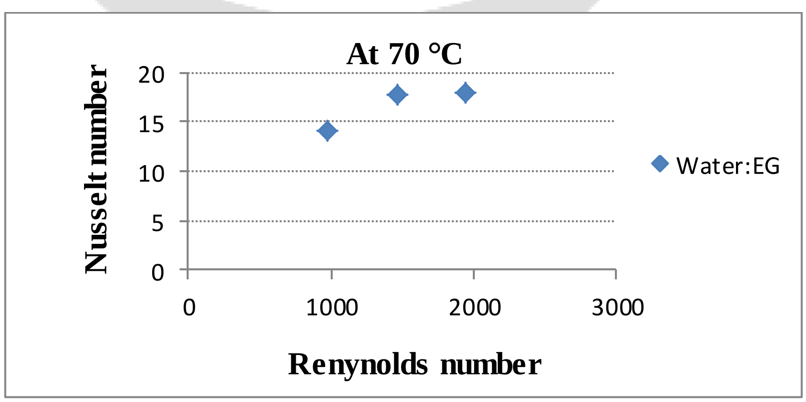

Chart-4.13 Effect Reynolds number on Nusselt number for water: EG coolant at 70°C

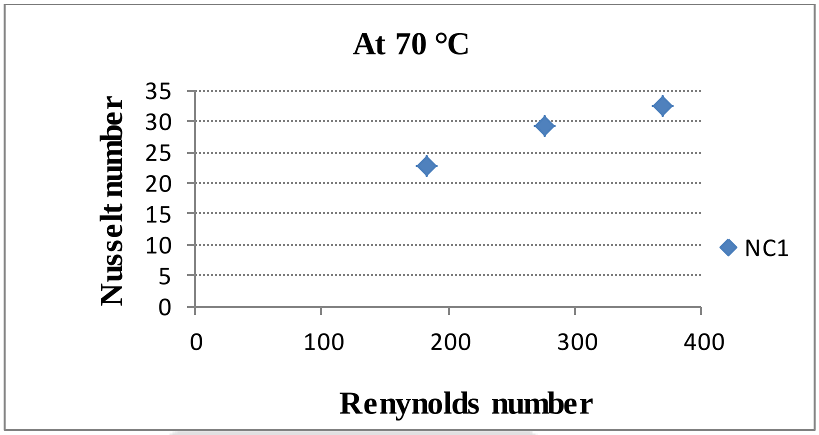

Chart-4.14 Effect Reynolds number on Nusselt number for NC_1 at 70°C

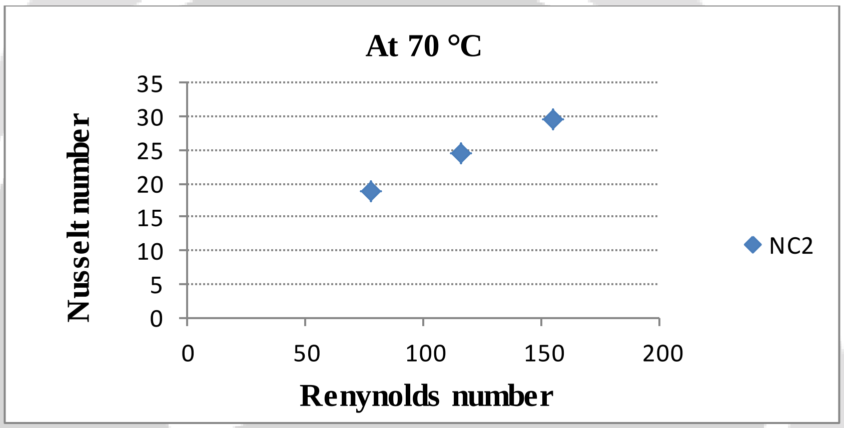

Chart-4.15 Effect Reynolds number on Nusselt number for NC_2 at 70°C

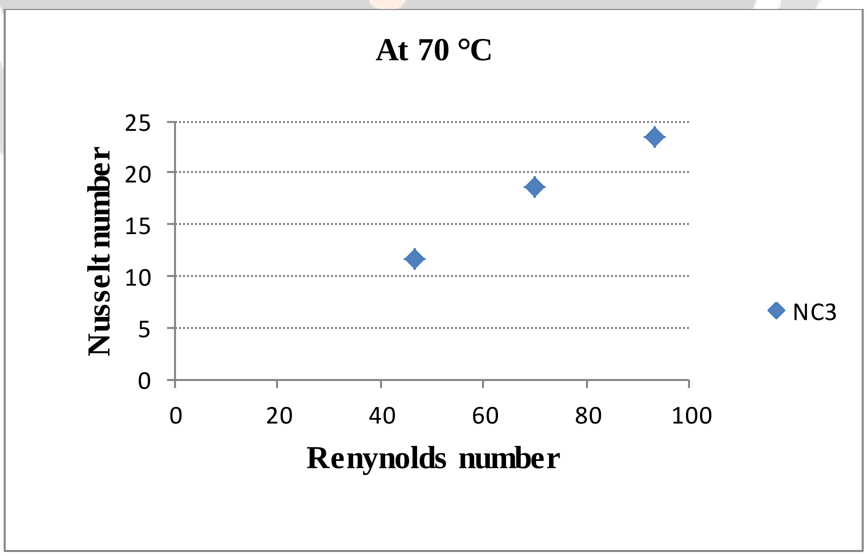

Chart-4.16 Effect Reynolds number on Nusselt number for NC_3 at 70°C

4.5 Relation between Nusselt number and Concentration of nano particle for all coolants at 50°C and 4 (l/min):

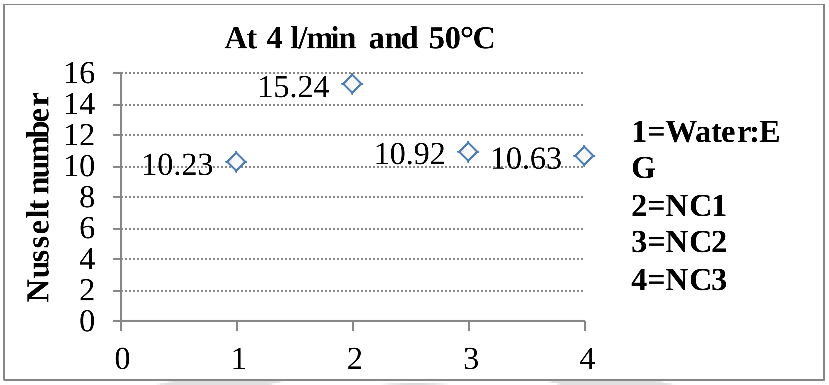

Chart-4.17 Nusselt number of different coolant at 4 l/min for 50°C

Nusselt number increases when 0.25 (%w/w) Al_2O_3 is added to water: EG and further decreases with increase in concentration. This can be explained as, with increase in concentration of nano particle, thermal conductivity of nano coolant increases so Nusselt number decreases.

4.6 Enhancement in Nusselt number:

The percentage enhancement is calculated for 6 l/min at 50°C for NC_1:

% Enhancement = ((Obtained value -- Original value)/Original value)*100

= ((23.32-15.22)/15.22)*100

% Enhancement = 53.21%

The percentage enhancement at constant inlet temperature increases with increase in volume flow rate but increment is non-linear.

5. CONCLUSIONS

An experiment evaluation of a car radiator was conducted by using Al_2O_3 nano fluid (Al_2O_3 in water: EG (60:40) as coolant in place of conventional coolant. The volume flow rates selected were 4, 6, 8 l/min and temperature range was 50 – 80 °C. These flow conditions were used to calculate heat transfer performance for different coolants (water, water: EG, nano coolants i.e. $NC_{1,}$ $NC_{2,}$ NC_3).

- The enhancement in the heat transfer rate was observed in the range of 13 % to 94 % at various combinations of volume flow rate and concentration.
- Heat transfer co-efficient at 50°C, increased by 1.49 to 8.56 times at various combinations of volume flow rate and concentration.
- For NC_1, heat transfer co-efficient was increased by 0.32 to 7.8 times at various combinations of volume flow rate and temperature.
- The enhancement in the heat transfer rate at 6 l/min was observed in the range of 1.56 to 10.65 times at various combinations of concentration and temperature.
- The optimum concentration for maximum enhancement was observed for NC_1 at 50°C and 6 l/min which was around 53.21%.

6. ACKNOWLEDGEMENT

Words are often less to revels one's deep regards. With an understanding that work like this can never be the outcome of a single person, I take this opportunity to express my profound sense of gratitude and respect to all those who directly or indirectly helped me through the duration of this work. I take the opportunity to express my heartfelt adulation and gratitude to my supervisor, Prof.keyur tandel for his unreserved guidance, constructive suggestions, thought provoking discussions and unabashed inspiration in the nurturing work.

7. REFERENCES

Ghadimi, A., SaidurR., and Metselaar H. S. "A review of nanofluid stability properties and characterization in stationary conditions", International Journal of Heat and Mass Transfer. 54.17 (2011) pp.4051-406

[01]Timofeeva, Elena V. "Nanofluids for Heat Transfer–Potential and Engineering Strategies." Two Phase Flow, Phase Change and Numerical Modelling InTech, Croatia. (2011) pp. 435-450.

[02]Manna, I. "Synthesis, Characterization and Application of Nanofluid—An Overview", Journal of the Indian Institute of Science. 89.1 (2012) pp.21-33.

[03]Elias M.M., Mahbubul I.M., Saidur R., Sohel, I.M. Shahrul M.R., Khaleduzzaman S.S., Sadeghipour S. "Experimental investigation on the thermo-physical properties of Al_2O_3 nanoparticles suspended in car radiator coolant", International Communications in Heat and Mass Transfer. 54 (2014) pp. 48–53.

[04]Gaurav Sharma,Master in thermal engineering thesis, "An experimental investigation into thermal conductivity and viscosity of Al_2O_3Based engine coolant (nanocoolant)", Thapar university, July 2013.

[05]Xie, H., Wei Y., Yang L., Lifei C. "Discussion on the thermal conductivity enhancement of nanofluids", Nanoscale research letters. 6.1 (2011) pp. 124.

[06]Chandrasekar, M., Suresh S., Chandra A.B. "Experimental investigations and theoretical determination of thermal conductivity and viscosity of Al_2O_3/water nanofluid", Experimental Thermal and Fluid Science. 34.2 (2010) pp.210-216.

[07]Pelević, N., and. Van M. "Numerical investigation of the effective thermal conductivity of nano-fluids using the lattice Boltzmann model", International journal of thermal sciences. 62 (2012) pp.154-159.

[08] Leong, K. Y., SaidurR., KaziS. N., Mamun A. H. "Performance investigation of an automotive car radiator operated with nanofluid-based coolants (nanofluid as a coolant in a radiator)", Applied Thermal Engineering. 30.17 (2010) pp. 2685-2692.

[09] Vajjha, R.S., Debendra K.D, Praveen K. N. "Numerical study of fluid dynamic and heat transfer performance of Al_2O_3 and CuO nanofluids in the flat tubes of a radiator", International Journal of Heat and Fluid Flo. 31.4 (2010) pp. 613-621.

[10] Peyghambarzadeh, S. M., HashemabadiS. H., HoseiniS. M., Seifi J.M. "Experimental study of heat transfer enhancement using water/ethylene glycol based nanofluids as a new coolant for car radiators",International Communications in Heat and Mass Transfer. 38.9 (2011) pp.1283-1290.

[11] Peyghambarzadeha S.M., Hashemabadi S.H. , Seifi J. M., Hoseini S.M. "Improving the cooling performance of automobile radiator with Al2O3/water nanofluids", Applied Thermal Engineering. 31 (2011) pp.1833-1838.

[12] Nieh, H., Tun-Ping T.,Chao-Chieh Y. "Enhanced heat dissipation of a radiator using oxide nano-coolant", International Journal of Thermal Sciences. 77 (2014) pp. 252-261.

[13] Delavari, V., and Seyed H.H. "CFD Simulation of Heat Transfer Enhancement of Al_2O_3/Water and Al_2O_3/Ethylene Glycol Nanofluids in a Car Radiator",Applied Thermal Engineering. (2014).

Kays WM., London AL. Compact heat exchangers; 3rd Edn; McGrow-Hill Book Company, USA, 1984, pp 304-313