Experimental Investigation of Thermal Performance of Radiator Using MWCNT as Nanocoolant

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Abstract- *The study consist experimental investigation of heat transfer performance using MWCNT nanofluid in automobile radiator.& its comparison with conventional coolants like water ,ethylene glycol-water mixture. Nanofluid concentration is varied in the range of 0.15 to 0.45 % by vol. using SDS (Sodium Dodecyl Sulfate) surfactant for stability enhancement .Coolant flow rate flowing through radiator is varied in range of 2 to 6 LPM. Effect of inlet temperature of coolant to radiator is studied by varying it from 50 to 70°C.To study effect of air velocity, it is varied between 2 to 4 m/s. From experimental result it is found that Nusselt number increases with increasing nanofluid concentration & coolant flow rate. Furthermore very small increment in Nusselt number is found with increase air velocity while enhancement decreases slightly at higher temperature. Maximum enhancement in Nusselt Number is found to be 51.1 % at 0.45% vol. concentration .*

Keywords- Nusselt Number, Nanofluid, Heat transfer enhancement.

I. INTRODUCTION

Continuous improvement in technology has created high competition in automobile industry for high engine efficiency. The reason for high efficiency is high working temperature but on other hand practically no material can withstand load at high temperature. Hence removal of extra heat produced is necessary but extraction of more heat results in thermodynamic loss. Hence for multi cylinder engines for heat dissipation unmixed flow type of heat exchanger called 'Radiator' is used.

Further development in automobiles created necessity of more heat dissipation from radiator. In general heat dissipation is calculated as

$$Q=h\ A\ \Delta T$$

where Q is heat transfer, A is heat dissipation area, h is convective heat transfer coefficient. From equation above it is clear that heat dissipation increased by increasing heat transfer coefficient h, increasing surface area A or increasing temperature difference . Increasing ΔT has some material constraint while increasing surface area A increases radiator size and weight which results in more aerodynamic drag. Also design changes in radiator for more heat dissipation has reached maximum limit and further design modification have manufacturing as well as cost constraints. Hence enhancing heat transfer coefficient h by increasing thermo-physical properties of coolant is best way of increasing heat dissipation.

In radiator to avoid freezing of coolant in low temperature country along with conventional coolant like water, antifreeze agent like Ethylene-glycol is mixed in different proportion according to requirement. But Ethylene-glycol water mixture has poor thermal conductivity results in decrease in heat dissipation. Many researcher revealed that suspending small amount of nano sized metallic or non-metallic oxide particles having high thermal conductivity in base fluid called 'nanofluid' enhances heat transfer. Invention of such high thermal conductivity material attracted many researcher to use them in heat transfer. Heat transfer using nanofluid is done with faster rate than conventional fluid. Hence size of radiator required becomes compact and air drag also gets reduced. Hence higher fuel economy and less weighted cooling system can be obtained. Many researchers have used different nanoparticles for increasing heat transfer

Nor Azwadi et al.[1] reviewed various applications of the nanofluid in vehicle engine cooling system to enhance heat transfer from vehicle engine. They also studied paper based on computational or numerical prediction of heat transfer augmentation using commercial available software. Durgshkumar et al.[2] experimentally compared forced convective heat transfer in an Al2O3/water nanofluid to that of pure water. They found enhancement heat transfer efficiency up to 40–45% in comparison with pure water. K.Y. Leong et al.[3] used ethylene glycol based copper nanofluid in an automotive cooling system & observed that 3.8% of heat transfer enhancement could be achieved with the addition of 2% copper particles in a base fluid. Adnan M. Hussein et al, [4] carried out experiment using TiO2 and SiO2 nanoparticle in pure water. Volume flow rate, inlet temperature and nanofluid volume concentration were in the range of 2–8 LPM, 60–80 °C and 1–2% respectively. They found that the

Nusselt number behaviours of the nanofluid highly depended on the volume flow rate, inlet temperature and nanofluid volume concentration. Peyghambarzadeh et al.[5] studied heat transfer performance of the automobile radiator Copper oxide (CuO) and Iron oxide (Fe_2O_3) nanoparticles are added to the water at three different concentrations with appropriate pH. Results demonstrate that both nanofluid show greater overall heat transfer coefficient in comparison with water up to 9%. Ebrahimi et al. [6] studied performance of radiator ,by adding SiO_2 nanoparticle to base fluid (water) experimentally From results they have found that Nusselt number increases with increase of liquid inlet temperature, nano particle volume fraction and Reynolds number. M. Naraki et al. [7] investigated experimentally the overall heat transfer coefficient of CuO /water nanofluid is under laminar flow regime. Results are statistically analyzed using results using Taguchi method by implementing Qualitek-4 software. Sandesh et al. [8] experimentally studied, the forced convective heat transfer performance of two different nanofluid Al_2O_3-water and CNT-water in an automobile radiator. Concentration of nanofluid is varied in the range of 0.15–1 % into the water as base fluid by functionalization acid treatment method. The maximum heat transfer performance for 1.0 vol. % nanoparticle concentration were found to be 90.76% and 52.03% higher for CNT-water and Al_2O_3-water, respectively compared with water. Beriache M'hamed et al. [9] carried out experimental analysis effect of water/ethylene glycol based multi-walled carbon nanotube (MWCNT) nanocoolant on the heat transfer enhancement of vehicle radiator. tested different nanoparticle volume concentrations (0.1%, 0.25%, 0.50%) in 50:50 water/ethylene glycol with liquid flow rate maintained in the range of 2, 4 and 6 l/min and the experimental analysis carried out in laminar flow region. Optimum average heat transfer coefficient enhancement was found to be 196.3% for 0.5% nanoparticle volume concentration compared with base fluid. Tun-Ping Teng et al. [10] carried out experimentation of the heat dissipation performance of a motorcycle radiator filled with (MWCNTs) nano-coolant using two-step synthesis method Nusselt number and pumping power under different volumetric flow rates 4.5, 6.5, 8.5 L/min and temperatures (80, 85, 90, and 95°C) is studied They found maximum enhanced ratios of heat exchange, pumping power, and EF for all the experimental parameters in this study were approximately 12.8%, 4.9%, and 14.1%, respectively.

Hence it is found that very few researchers done work on CNT nanofluid. Also very few researchers studied effect of inlet temperature & air velocity on heat transfer performance of radiator. As MWCNT possess high thermal conductivity, large specific surface area & shows high heat transfer as compared to other nanofluid, MWCNT is selected for this study for evaluating heat transfer performance of radiator

II. EXPERIMENTAL SETUP

Schematic diagram of experimental setup used for this study is shown in Fig.1 It includes radiator test section, pump, variable speed fan, rotameter , storage tank with heater. Flow control valve is installed at outlet of pump to regulate the coolant flow. For measuring flow rate, rotameter of range 0 to 6 LPH with accuracy of 0.1 LPM is used. For maintaining constant temperature in tank at 50, 60, 70°C, 2 KW electric heater with temperature controller is installed. For measuring inlet & outlet temperature of coolant in radiator, two K type thermocouples are installed at inlet & outlet of radiator. For measuring wall temperature of radiator, five different thermocouples are installed at five different position of outside surface of radiator such that they will give average wall temperature of radiator tubes. For varying air velocity dimmer is used for varying fan speed.

Specifications of MWCNT nanoparticles purchased is shown in Table1. The characterization of CNT purchased is done with Scanning Electron Microscopy (SEM). SEM image of purchased CNT is shown in fig.2

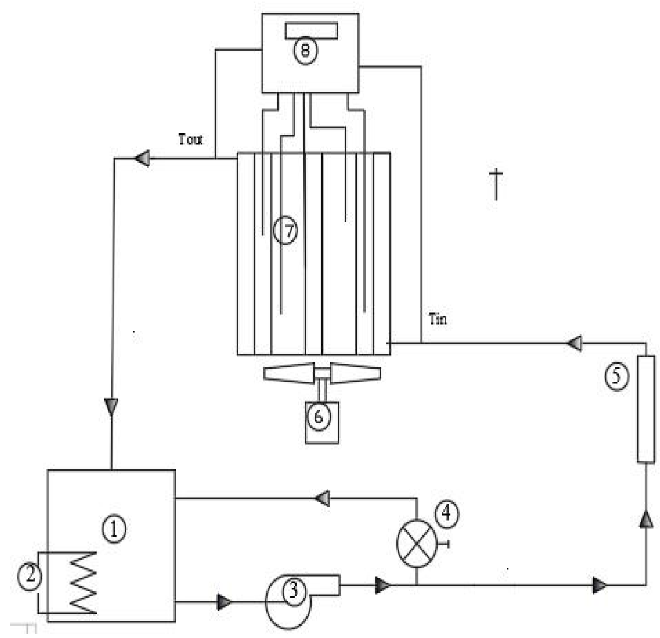

Figure 1. Schematic Diagram of Experimental Setup

1. Insulated tank
2. Heating coil
3. Pump
4. Flow control valve
5. Rotameter
6. Variable speed fan

7. Radiator
8. Control Panel

Nanofluid is prepared by adding MWCNT into water as base fluid. Specification detail of nanoparticle is shown in Table1. SEM image of MWCNT is shown in Fig.2 For increasing stability of nanofluid 0.25% by weight SDS (Sodium Dodecyl Sulfate) surfactant is added [8] . For further increasing stability of nanofluid, 1 hour sonication is done with ultrasonic cleanser followed by 45 minutes magnetic stirring

Table 1. Specification of MWCNT nanoparticles

Material	**Multi Walled Carbon Nanotubes**
Diameter	20-30nm
Length	15-30μm
Purity	>90% (MWCNT)
Special surface area	90-350* m^2/g
Real density	1-2 g/cm^3

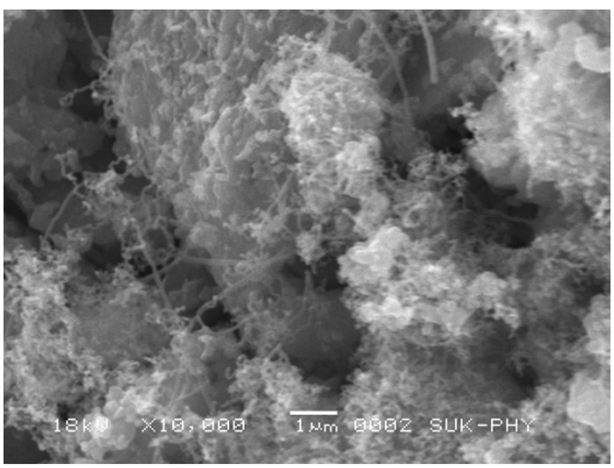

Figure 2. SEM Image of MWCNT at ×10000 Magnification

III. THERMOPHYSICAL PROPERTIES OF NANOFLUID

For finding thermo physical properties of nanofluid it is assumed that particles are uniformly dispersed in base fluid .Density of nanofluid is calculated by following correlations. [2]

$$(\rho)_{nf} = \emptyset \times (\rho)_{np} + (1-\emptyset) \times (\rho_{bf})$$

where $(\rho)_{nf}$, $(\rho)_{np}$, (ρ_{bf}) are density of nanofluid, density of nanoparticle, density of base fluid respectively. ,Ø is percentage volume fraction of nanoparticles

Specific heat of nanofluid is calculated by correlation which assumes thermal equilibrium between particles & surrounding fluid[3].

$$(C_p)_{nf} = \frac{\emptyset \rho_{np} C_p + (1-\emptyset) C_{pbf}}{(\rho)_{nf}}$$

where $(C_p)_{nf}$, C_p, C_{pbf} are specific heat of nanofluid, nanoparticle & base fluid respectively

Thermal conductivity of nanofluid is calculated by correlation given by Haifeng Jianga et al. [12] which takes into account the effect of interfacial resistance based on multiple scattering theory and model of Maxwell, considering also the Kapitza resistance at the CNTs medium.

$$\frac{k_{nf}}{k_{bf}} = \frac{3 + (\beta_{11} + \beta_{33})\emptyset}{3 - \beta_{11}\emptyset}$$

β_{11} & β_{33} factors calculated as

$$\beta_{11} = \frac{2(k_{11} - k_{bf})}{k_{11} + k_{bf}} \qquad \beta_{33} = \frac{k_{33}}{k_{bf}} - 1$$

Constants k_{11} & k_{11}calculated as below

$$k_{11} = \frac{k_p}{1 + \left(\frac{2a_k k_p}{d_p k_{bf}}\right)} \qquad k_{33} = \frac{k_p}{1 + \left(\frac{2a_k k_p}{L_p k_{bf}}\right)}$$

In above equation $a_k = R_k \times k_{bf}$, where R_k is CNT liquid interface thermal resistance which is 8.33×10^{-8} $m^2/K\,W$

$$a_k = (8.33 \times 10^{-8}) * k_{bf}$$

IV. DATA REDUCTION

For finding heat transfer performance following procedure is adopted

1) Wall temperature of radiator tube is calculated as

$$T_w = \frac{T_1 + T_2 + T_3 + T_4 + T_5}{5}$$

where $T_1, T_2, \ldots, T_5$ are temperature of five thermocouples placed at various longitudinal & transverse location of radiator.

2) Bulk mean temperature is calculated as

$$T_B = \frac{T_{in} + T_{out}}{2}$$

where T_{in} & T_{out} are inlet & outlet temperature of coolant at inlet & outlet of radiator

3) By Newtons law of cooling heat rejected to surrounding is given as

$$Q = h\, A_s\, \Delta T = h\, A_s\, (T_B - T_W) \ldots\ldots(1)$$

4) Heat transfer rate is also calculated as

$$Q = m\, C_{pnf}\, \Delta T = mC_{pnf}\, (T_{in} - T_{out}) \ldots.(2)$$

Equating equation (1) & (2)

$$h\, A_s\, (T_B - T_W) = mC_{pnf}\, (T_{in} - T_{out})$$

5) hence heat transfer coefficient can be calculated as

$$h = \frac{mC_{pnf}\, (T_{in} - T_{out})}{A_s\, (T_B - T_W)}$$

6) Experimental Nusselt number is calculated as

$$Nu = \frac{h \times d_{hyd}}{k}$$

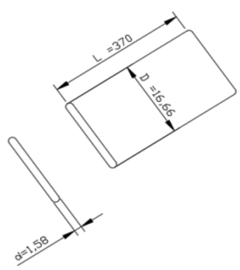

Figure 3. Schematic diagram of radiator tube

where D_h is hydraulic diameter of tube & can *be* calculated as

$$D_h = \frac{4 \times Area}{Perimeter} = \frac{4[\frac{\pi d^2}{4} + (D - d)d]}{\pi d + 2(D - d)}$$

V. RESULTS AND DISCUSSIONS

1. Validation of Experimental Setup

Before conducting systematic experiments using MWCNT nanofluid in radiator, firstly it is necessary to check for accuracy & reliability of experimental setup. Fig. 5.1 shows experimental results & theoretical results for water at inlet temperature of 50°C & air velocity 2 m/s. It is found that Nusselt number increases with increase in flow rate of water. Theoretical Nusselt number is calculated with correlation given by Dittus Boelter. given as

$$Nu = 0.023\, Re^{0.8}\, Pr^{0.3}$$

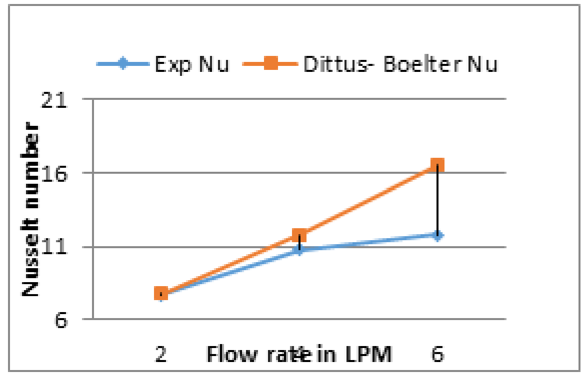

Figure 4. Validation of Experimental Setup

Experimental Nusselt number value is nearly equal to that of obtained with Dittus Boelter. Average error between experimental & theoretical Nusselt number is 12.9 %.

2. Effect of Coolant Flow Rate

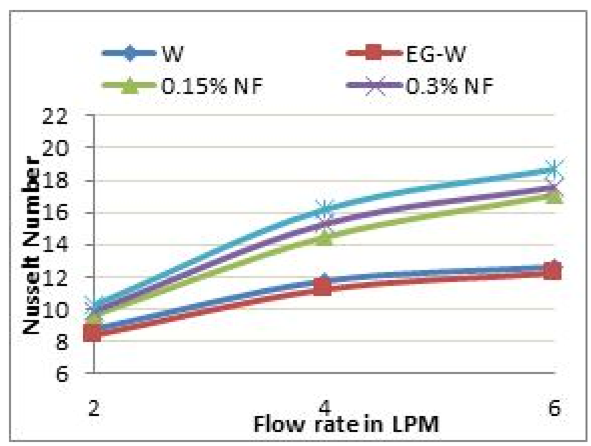

Figure 5. Effect of coolant flow rate on Nusselt Number at 70 °C inlet temperature &2 m/s air velocity

Fig.5 shows variation of Nusselt number with coolant flow rate.. From fig it is clear that Nusselt number increases with increase in coolant flow rate due to increase in Reynolds number. For 50°C inlet temperature & 0.15 % concentration, increase of 9.7%, 24.3%, 37.2% in Nusselt number is found for 2,4 & 6 LPM flow rate respectively. Similarly at 0.3% concentration enhancement is 12.3%, 31.4%, 40.7% while at 0.45% concentration it is found to be 37.2%, 41%, 51% for 2, 4, 6 LPM flow rate respectively.

3. Effect of Nanoparticle concentration

Variation of Nusselt number with nanoparticle concentration is shown in Fig.5 With addition of MWCNT in water, Nusselt number is found to be increased due to increased thermal conductivity .For 50 °C inlet temperature, 2 m/s velocity of air & 2 LPM flow rate, increase in Nusselt number is found to be 9.7%,12.3%, 17.89% for 0.15%, 0.3% ,0.45% concentration respectively compared to water as coolant. For 4 LPM flow rate at above condition enhancement is found to be 24.3%, 31%, 40.7% for 0.15%, 0.3% ,0.45% concentration respectively. While at 6 LPM this enhancement is 37.2%, 41%, 51.1%. Maximum enhancement is found at 0.45% concentration.

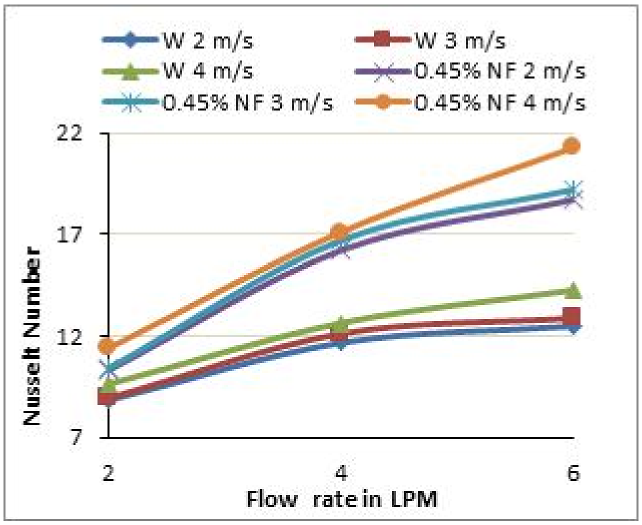

Figure 6. Effect of coolant flow rate on Nusselt Number at 0.45% concentration & 70°C inlet temperature

4. Effect of inlet fluid temperature

Effect of inlet fluid temperature on heat transfer performance is shown in Fig.7. As the inlet temperature of coolant increase from 50 to 70°C, Nusselt number is found to be increases. For 0.15% concentration & 2 LPM flow rate, enhancement in Nusselt number is found to be 9.8%, 9.6%, 9.3% at 50°C, 60°C & 70°C respectively. Similar enhancement as 24.3%, 24.1%, 23.7% at 4 LPM & 37.3%, 36.9%, 36.2 % at 6 LPM is found. Similar enhancement is observed with 0.3%,0.45% concentration

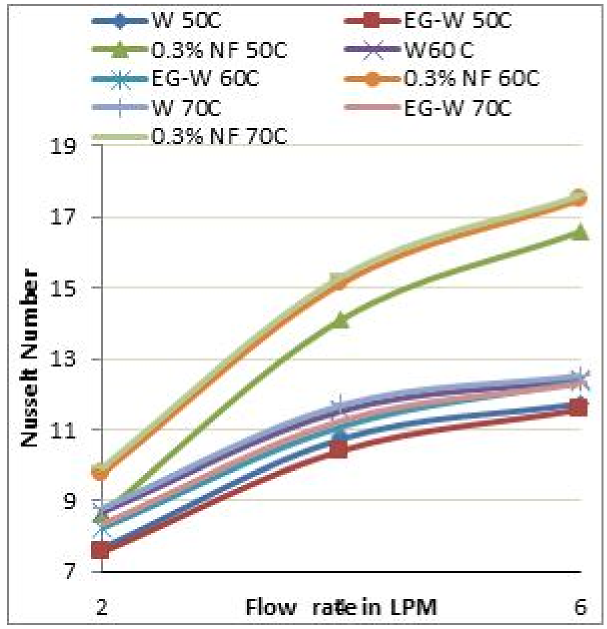

Figure 7. Effect of coolant inlet temperature on Nusselt Number at 0.3% concentration & 2 m/s air velocity

5. Effect of air velocity

Figure.8 shows variation of Nusselt number with change in air velocity. From figure it is clear that Nusselt number increases with increase in velocity. For 50°C inlet temperature of water at 2 LPM flow rate Nusselt number increases by 1.26 %, 5.69% for increasing air velocity from 2 to 3 m/s & 3 to 4 m/s respectively.

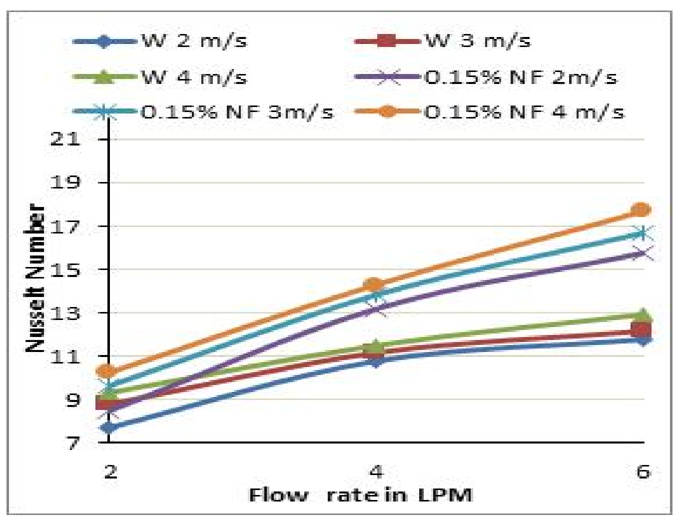

Figure 8. Effect of air velocity on Nusselt Number at 0.15% concentration & 50 °C inlet temperature system

VI. CONCLUSION

Following are the conclusions made from the experimental results:

1. With increase in flow rate of coolant Nusselt number is found to be increase. It is due to increase in Reynolds number of coolant flow which results in breaking of boundary layer adjacent to wall.
2. Increase in concentration of nanofluid increases in Nusselt number. Maximum increase in Nusselt number is found to be 51.2 % at 0.45% volume concentration at 6 LPM. This enhancement is may be due to increase in thermal conductivity, mixing of nanoparticle near the wall, decrease in boundary layer thickness.
3. Due to Brownion motion, heat transfer at boundary of tube wall takes place at higher rate. Also increase in collision rate between particles increases heat transfer..
4. As the air velocity increases, Nusselt number increases slightly due to increase in heat dissipation to surrounding. Maximum enhancement in Nusselt number is found to be 5.69% at 4 m/s
5. At high temperature percentage enhancement in Nusselt number decreases slightly. This may be due to change in stability of nanofluid at high temperature.

VII. ACKNOWLEDGMENT

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