Experimental Analysis of Automobile Radiator using MWCNT-Water Nanofluid

Archit Deshpande
Department of Mechanical Engineering
Smt. Kashibai Navale College of Engineering
Pune, India

Viraj Patil
Department of Mechanical Engineering
Pune Vidyarthi Griha's
College of Engineering and Technology
Pune, India

Rohit Patil
Department of Mechanical Engineering
Smt. Kashibai Navale College of Engineering
Pune, India

Abstract- **The heat generated in an automobile engine needs to be extracted and dissipated for its efficient working. The objective of this experiment was to improve the thermo-hydraulic performance of the radiator which can be achieved by using nanofluids as engine coolant for increasing the heat rejection capacity on the coolant side. The present study investigates the performance of MWCNT-water nanofluid at different temperatures (50, 60, and 70ºC). The results indicate that maximum increase in thermal capacity was observed to be 32% at 50ºC (0.2% particle concentration).**

Keywords— Nanofluid, MWCNT, radiator coolant

I. NOMENCLATURE

Nu	Nusselt Number	-
Re	Reynold Number	-
Pr	Prandtl Number	-
Pe	Peclet Number	-
Q	Thermal Capacity	kW
Cp	Specific Heat	kJ/kg-K
T	Temperature	ºC
K	Thermal Conductivity	W/mK
m	Mass flow-rate	kg/s

GREEK SYMBOLS

ρ	Density	kg/m^3
μ	Dynamic viscosity	Ns/m^2
ϕ	Particle concentration	g/ltr

SUBSCRIPT

nf	Nano-fluid
bf	Base-fluid
p	Particle
a	Air
w	Water
HE	Heat Exchanger
ao	Air outlet
ai	Air inlet
wo	Water outlet
wi	Water inlet
1,2,3	Thermocouple number

II. INTRODUCTION

The function of engine coolant is to absorb the excessive heat generated in the engine and dissipate it to the surrounding air using the radiator. Most commonly used coolants are ethylene glycol, water and heavy oils. These fluids have a high specific heat capacity but low thermal conductivity, which results in lesser heat transfer rates. Nanofluids exhibit enhanced thermal conductivity and the convective heat transfer as they are prepared by dispersing metallic and non-metallic nano sized particles in base fluid. Thus these fluids can be studied for their effective use in the conventional radiator.

Nanofluids need to be stabilized, with suitable surfactant, if they are to be used for a long duration of time. The nanoparticles experience a strong Van der Waal's force of attraction. Due to this the particles are pulled towards each other and they tend to form large particle size (agglomerate). The agglomeration of nanoparticles results in not only settlement and clogging of channels but also decreasing the thermal conductivity of nanofluids. A surfactant molecule has a hydrophilic (water-loving) head and a long hydrophobic (water-hating or oil-loving) tail. Surfactants play major roles in the formation of nano-emulsions: By lowering the interfacial tension, Laplace pressure P (the difference in pressure between inside and outside the droplet) is reduced and hence the stress needed to break up a drop is reduced. Thus surfactants prevent coalescence of newly formed drops.

Several types of nanoparticles can be employed for nanofluid preparation including metals (gold, copper, silver, etc.), metal oxides (Al_2O_3, CuO, TiO_2, Fe_2O_3, SiO_2, etc.) & organic compounds (glucose, sucrose, etc.). They have a plethora of applications like electronics, semi-conductors,

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 11, November-2016

medicine, cosmetics, biosensors, paints, solar panels, automobiles, etc.

The use of nanoparticles in base fluid results in increase in viscosity which would results in higher pressure drop and hence an increase in pumping power requirements in various industrial and automotive applications.

III. LITERATURE SURVEY

Tun-Ping Teng et al. [1] analyzed the characteristics of Al_2O_3-water nanofluid produced by the direct synthesis method at three different concentrations (0.5, 1.0, and 1.5 wt. %). Experimental results show that the nanofluid as a coolant has higher heat transfer capacity than water and a higher concentration of nanoparticles provides an even better ratio of the heat exchange. The maximum enhanced ratio of heat transfer and pressure drop for all the experimental parameters in this study was about 39% and 5.6%, respectively. In addition to nanoparticle concentration, the temperature and mass flow rates of the working fluid can affect the enhanced rate of heat transfer and pressure drop of nanofluid. Ramgopal Varma Ramaraju et al. [2] observed in “SUZUKI (800 cc) - CAR RADIATOR”, cooling circuit using different nanofluids to replace the conventional engine coolant. In the study, the effect of nano-fluid heat transfer to enhance in water and coolant based systems with multi walled carbon nanotubes was investigated and enhancement of heat transfer up to 30% when coolant and CNTS are used as a cooling medium. Navid Bozorgan et al. [3] numerically investigated in a radiator of Chevrolet Suburban diesel engine under turbulent flow conditions. He investigated with CuO-water nanofluid having particle size of 20 nm and a particle concentration of 2%. The heat transfer relations between airflow and nanofluid coolant have been obtained to evaluate local convective and overall heat transfer coefficients and also pumping power for nanofluid flowing in the radiator with a given heat transfer capacity. The nanofluid was circulating through the flat tubes with Re_{nf} = 6000 while the automotive speed is 70 km/hr., the overall heat transfer coefficient and pumping power have showed an increment of approximately 10% and 23.8% respectively. Hafiz Muhammad Ali et al. [4] studied water based MgO nanofluids for different volumetric concentrations (i.e. 0.06%, 0.09% and 0.12%). All concentrations showed enhancement in heat transfer compared to the pure base fluid. Heat transfer enhancement of 31% was obtained at 0.12% volumetric concentration of MgO in base fluid. The fluid flow rate was kept in a range of 8-16 liter per minute. Lower flow rates resulted in greater heat transfer rates as compared to heat transfer rates at higher flow rates for the same volumetric concentration. Heat transfer rates were found weakly dependent on the inlet fluid temperature. An increase of 8^oC in inlet temperature showed only a 6% increase in heat transfer rate. Sandesh S. Chougule et al. [5] studied heat transfer performance of CNT- water nanofluids and water in an automobile radiator. The CNT nano-coolants are synthesized by two different methods such as: Functionalized CNT (FCNT) and surface treatment (SCNT) method. The effects of various parameters, namely synthesis method, variation in pH values and nanoparticle concentration on the Nusselt number were examined through the experimental investigation. For 1.0 vol. % nano particle concentration and coolant flow rate of 5 l/min, the maximum enhancement in heat transfer of FCNT-water nanofluid was found to be 90.76% higher compared with water. The thermal performance of the acidic nano-coolant with pH 5.5 was found to be better compared to the nano-coolant with pH value of 6.5 and 9.0. The surface treated CNT nano-coolant exhibits the deterioration in heat transfer performance. In addition, Nusselt number found to increase with the increase in the nanoparticle concentration and nanofluid velocity. Rahul A. Bhogare et al. [6] observed effect of adding Al_2O_3 nanoparticle to base fluid (mixture of Ethylene Glycol +Water) in automobile radiator, experimentally. Effects of fluid inlet temperature, the flow rate and nano particle volume fraction on heat transfer were considered. Heat transfer rate increased with increase in volume concentration of nanoparticles (ranging from 0% to 1%). About 40% heat transfer enhancement was achieved with addition of 1% Al_2O_3 particles at by using TiO_2 and SiO_2 nanoparticles dispersed in water as a base fluid was studied experimentally. The test rig is setup as a car radiator with tubes and container. The range of Reynolds number and volume fraction are (250 – 1750) and (1.0% – 2.5%) respectively. Results showed that the heat transfer increases with increasing of nanofluid volume fraction. There was 20% and 32% of the energy rate enhancement and 24% and 29.5% effectiveness enhancement for TiO_2 and SiO_2 nanofluids respectively. The experimental data had agreed with other investigator.

IV. EXPERIMENTAL SETUP

The duct was manufactured using an Aluminium sheet of thickness 0.3 mm. The duct was divided into two parts, inlet duct and outlet duct. The radiator was mounted between an inlet duct and outlet duct. The length of outlet duct was 300 mm and inlet duct 750 mm. The length of outlet duct was kept less so that the hot air from the radiator did not accumulate in the duct. If the hot air had accumulated it would have provided ambiguous results. Fan was mounted at the inlet duct for providing desired air flow rate.

For measuring the temperature of fluids, K-type thermocouples were used. The thermocouples were connected to the joints using compression fittings. A digital temperature indicator (DTI) was used to display the temperature at different positions of temperature measurement. The thermocouples were arranged in a grid formation at air outlet section of the radiator to get the variation in temperature. The inlet air temperature was measured with a single thermocouple mounted in the inlet duct. The inlet and outlet coolant temperatures were measured using a single thermocouple at inlet and outlet section respectively. The air velocity at the inlet of duct was measured by digital Anemometer.

For circulating the coolant, heat resistant hose were used as the experimental analysis was going to be conducted at high temperature range of 45^oC to 70^oC. The hose were connected to different joints using hose clips. Centrifugal pump of 0.5 HP was used to circulate the coolant. The flow rate was kept constant at 24 lpm. The coolant flow rate was varied using a bypass valve. The temperature of coolant was raised using a 3 kW heater. The inlet temperature was

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 11, November-2016

maintained constant for one run and if the temperature was raised above the desired temperature range the power supply was tripped. The values were noted at the steady state condition. Foot valve was used in the coolant reservoir in order to avoid blockage in the radiator tubes due to contaminants if any.

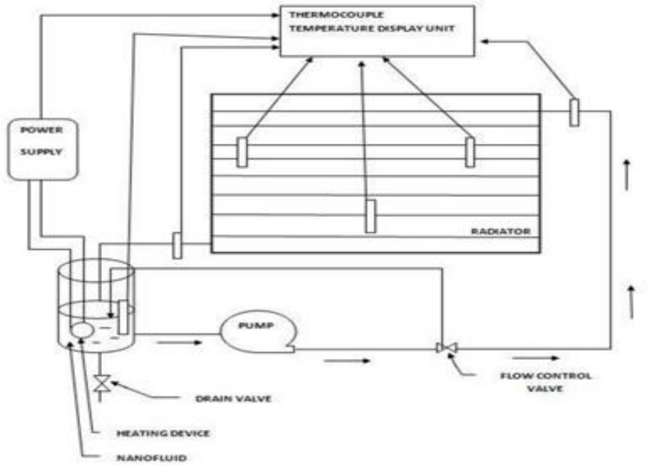

Fig.1. Schematic of Experimental Setup

Fig.2. Photograph of Experimental Setup

V. PREPARATION OF NANOFLUID

The nanoparticles were obtained from United Nanotech Innovation Private Limited, Bangalore. The properties of MWCNT are listed in the following table:

Table.1. Properties of MWCNT nanoparticles

MWCNT	Description	Characterization
Production Method	Chemical Vapour Deposition[SLV]	Proprietary method
Available Form	Black powder	Visual
Diameter	Avg Outer Diameter: 5-20 nm	TEM, SEM
Length	Avg. 1-10 micron	TEM, SEM
Nanotubes Purity	>98%	TGA, RAMAN
Metal Particles	<1%	TGA
Amorphous Carbon	<1%	TGA, XRD
Specific Surface Area	$330 m^2/gm$	BET
Bulk Density	0.2-0.35 gm/cc	Pycnometer

MWCNT nanofluid requires Sodium Dodecyl Benzene Sulphonate (SDBS) as a surfactant to remain stable. The nanofluid was prepared in 4 batches. Each batch was prepared in a plastic beaker of 1.5 litre capacity. The dispersion technique used was Ultra-sonification. Each batch was subjected to 4 hours of intense ultrasonic waves in a beaker with the help of Ultrasonic machine. This process led to a homogeneous mixture of nanoparticles and dispersant in distilled water. The particle concentration was maintained at 0.2% gm/ltr.

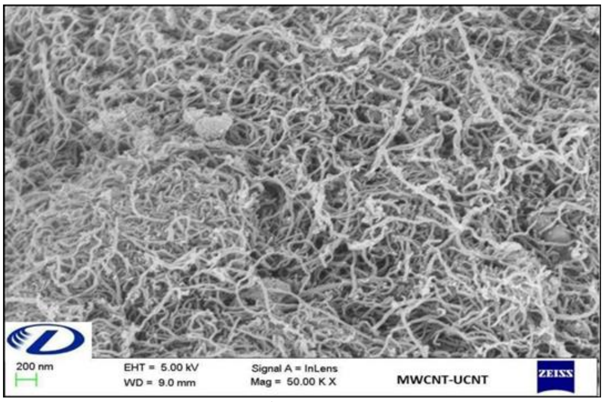

Fig.3. SEM image of MWCNT provided by UNI

VI. THERMAL CALCULATIONS

The thermal properties of nanofluid where calculated as follows:

Empirical correlations proposed by Pak [7] for density and Xuan [8] for specific are as follows:

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

$$cp_{nf} = (1-\phi)\rho_{bf}cp_{bf} + \phi cp_p\rho_p\rho_{nf} \qquad (2)$$

Thermal conductivity and viscosity for nanofluid have been estimated based on two semi-empirical equations presented by Hamilton and Crosser [9] in 2013 on the basis of a wide variety of experimental date available in the literature as following equations:

$$\frac{K_{nf}}{K_{bf}} = \frac{K_p + (z-1)K_{bf} + \phi(z-1)(K_{bf} - K_p)}{K_p + (z-1)K_{bf} + \phi(K_{bf} - K_p)} \qquad (3)$$

Where, z is empirical shape factor given by z = 3/ψ, and ψ is the particle sphericity, defined as the ratio of the surface area of a sphere with volume equal to that of the particle, to the surface area of the particle.

M. Eftekhar [10] in 2013 proposed on the basis of a wide variety of experimental date available in the literature proposed the following equations:

$$\mu_{nf} = \left(\frac{1}{(1-\phi)^{2.5}}\right) * \mu_{bf} \qquad (4)$$

Yimin Xuan [11] proposed a correlate experimental data of heat transfer for nanofluids, Nusselt number for turbulent flow of nanofluids inside a tube is obtained as follows:

$$Nu = 0.0059\left(1 + 7.6286(\phi^{0.6886}) * {P_e}^{0.001}\right) * {Re_{nf}}^{0.9238} * {Pr_{nf}}^{0.04} \qquad (5)$$

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 11, November-2016

The experimental calculation for the radiator is done by calculating heat transfer rate of hot fluid (water) and heat transfer rate of cold fluid (air). The inlet and outlet of both nanofluid and the air is measured. The outlet temperature of air is calculated as follows:

$$T_{ao} = \frac{T_1 + T_2 + T_3}{3} \quad (6)$$

The thermal capacity of radiator is given by mean of heat transfer rate of water and heat transfer rate of air. Ideally the heat transfer rate of hot and cold fluid remains same but practically due to thermal resistances some amount of heat is absorbed by intermediate materials which are tube and fins of radiator in this case, so $Q_w > Q_a$. The thermal capacity is calculated as follows:

a) Heat transfer Rate of water:

$$Q_w = m_w * c_{pw} * (T_{wi} - T_{wo}) \quad (7)$$

b) Heat transfer Rate of air:

$$Q_a = m_a * c_{pa} * (T_{ao} - T_{ai}) \quad (8)$$

c) Thermal Capacity of Radiator:

$$Q_{HE} = \frac{(Q_w + Q_a)}{2} \quad (9)$$

VII. RESULTS AND DISCUSSION

Experiments were conducted using MWCNT-water nanofluid and Water as engine coolants at varied temperatures (50ºC, 60ºC, 70ºC). The particle concentration of nanofluid being 0.2% gm/litre.

The effect of temperature change on thermal capacity of radiator is evident from the following graph for MWCNT:

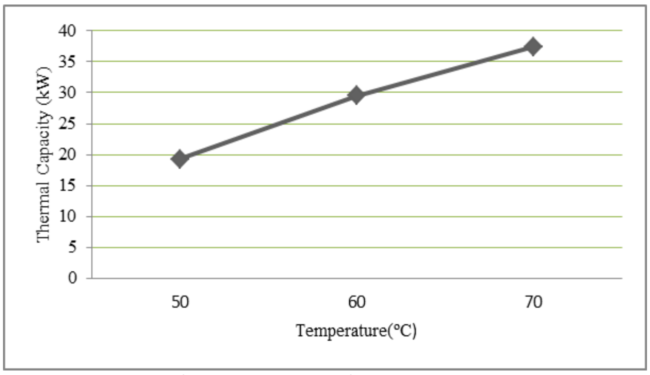

Fig.4. Variation of thermal capacity of radiator using MWCNT-Water as coolant.

The thermal capacity was observed to be 19.26 kW at 50ºC. There was a rise of 53.27% in capacity as temperature was increased to 60ºC. The capacity further enhanced to 37.45 kW at 70ºC. Thus as the temperature increases there is an increase in thermal capacity.

Similar experiment was performed with water as coolant and the results were found to be 14.547kW, 26.137kW & 31.748kW at 50ºC, 60ºC and 70ºC respectively. The following graph depicts the aforementioned results.

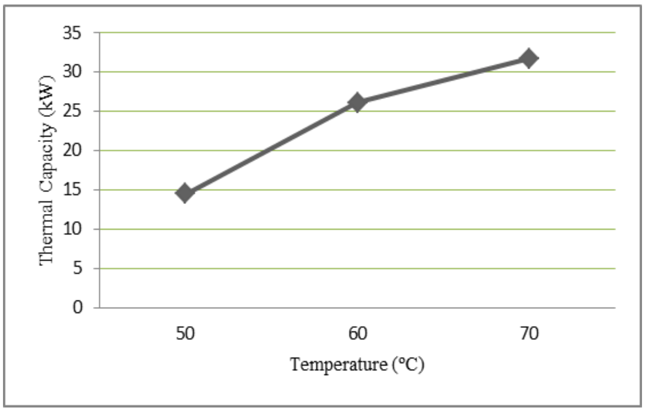

Fig.5. Variation of thermal capacity of radiator using Water as coolant

The following graph illustrates the percentage difference in the capacity of radiator when MWCNT nanofluid and water were used as coolants. It can be observed that at 50ºC there was maximum difference of 32.14% between the two fluids. At 60ºC this difference plummets to 12.97% and again rises to 17.96% at 70ºC (with MWCNT nanofluid being greater in all cases).

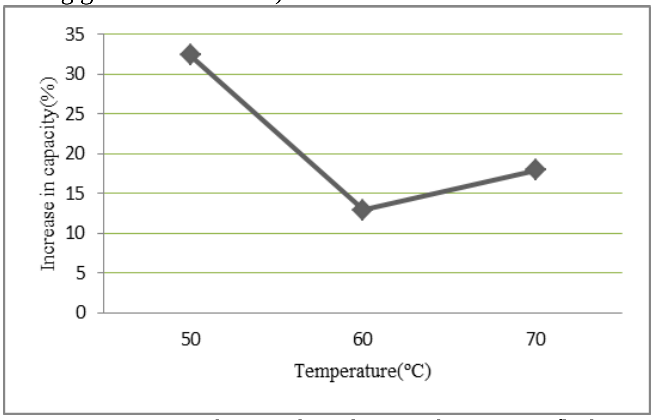

Fig.6. Percentage change in thermal capacity by using nanofluid.

The increase in heat capacity of MWCNT nanofluid and water was observed for 10ºC change in temperature. It was seen that from 50ºC-60ºC there was increase of 10.26% for MWCNT nanofluid while 11.58% for that of water. The change in the next 10ºC was 7.92% for MWCNT nanofluid and 5.61% for water.

VIII. CONCLUSION

The experiment investigates the comparison between MWCNT-water nanofluid and water as engine coolants. From the experiment we can conclude the following:

- Introduction of MWCNT nanoparticles in water increases the thermal capacity of radiator.
- Increasing the concentration of MWCNT nanoparticles increases the capacity of radiator.
- The viscosity of nanofluid is greater than that of base fluid.
- Capacity of radiator is directly proportional to temperature.
- Maximum enhancement in thermal capacity of 32% was observed at 50 ºC. At 60 ºC and 70 ºC there was an increase of approximately 13% and 18% respectively.

ACKNOWLEDGEMENT

The authors would like to thank Tata Toyo Radiator Ltd., Pune for their support and guidance throughout the experiment. We are also grateful to Centre for Materials for Electronics Technology (C-MET), Pune for providing laboratory assistance.

REFERENCES

[1] Teng et al.: "Performance evaluation on an air-cooled heat exchanger for alumina nanofluid under laminar flow". Nanoscale Research Letters 2011 6:488.

[2] Ramgopal Varma Ramaraju et al. "Enhancement of Heat Transfer Coefficient in an Automobile Radiator Using Multi Walled Carbon Nano Tubes (MWCNTS)" ASME 2014 International Mechanical Engineering Congress and Exposition IMECE2014.

[3] Navid Bozorgan et al.: "Numerical Study on Application of CuO-Water Nanofluid in Automotive Diesel Engine Radiator" Modern Mechanical Engineering, 2012, 2, 130136.

[4] Hafiz Muhammad Ali et al.:"Heat Transfer Enhancement of Car Radiator Using Aqua Based Magnesium Oxide Nanofluids".

[5] Sandesh S. Chougule et al.: "Thermal Performance of Automobile Radiator Using Carbon Nanotube-Water Nanofluid—Experimental Study" ASME DECEMBER 2014, Vol. 6 / 041009-5.

[6] Rahul A. Bhogare et al.: "Performance investigation of Automobile Radiator operated with Al2O3 based nanofluid" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 11, Issue 3 Ver. V (May- Jun. 2014), PP 23-30.

[7] B. C. Pak and Y. I. Cho, "Hydrodynamic and Heat Transfer Study of Dispersed Fluids with Submicron Metallic Oxide Particles" Experimental Heat Transfer, Vol. 11, No. 2, 1998, pp. 151-170.

[8] Y. Xuan and W. Roetzel, "Conceptions of Heat Transfer Correlation of Nanofluids" International Journal of Heat and Mass Transfer, Vol. 43, No. 19, 2000, pp. 37013707.

[9] Hamilton, R. L. and Crosser, O. K., (1962), Thermal conductivity of heterogeneous two component systems, IndEngChemFundam, vol. 1(3), pp.187–191.

[10] M. Eftekhar, A. Keshavarz A. Ghasemian, and J. Mahdavinia, "The Impact of Nanofluid Concentration Used as an Engine Coolant on the Warm-up Timing" International Journal of Automotive Engineering, Vol. 3, Number 1, March 2013.

[11] Y. Xuan, Q. Li, Investigation of convective heat transfer and flow features of nanofluids, Journal of Heat Transfer 125 (2003) 151e155.