Experimental Investigation of Heat Transfer Enhancement using Water-EG-CuO based Nanofluid in Automotive Radiator

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***Abstract* - Thermal scientists and engineers always pursuit modern methods to enhance the heat removal of the engine. It seems nanofluids introduced in automotive cooling system promises to achieve high efficiency radiators. Nanofluids can be described as colloidal suspensions of solid particles smaller than 100 nm diluted in a base fluid. These fluids exhibit better thermal properties than conventional coolants. Nanofluids can be considered to be the next-generation heat transfer fluids because they offer exciting new possibilities to enhance heat transfer performance compared to pure liquids. Micrometer-sized particle-fluid suspensions exhibit no such dramatic enhancement. The paper summarizes the current research in the nanofluid studies on convective heat transfer performance, thermo-physical properties. In this work, copper oxide (CuO) nanoparticles to base fluid (water + ethylene glycol) in car radiator is investigated experimentally. Effects of fluid inlet temperature (55^{0}C), the flow rate (2-5lpm) and nanoparticle volume fractions(0.5%,1%,1.5%,2%2.5%) on rate of heat transfer are considered. From the experiments it was found that the heat transfer can be enhanced by 14% for 2% at 5 lpm.**

***Keywords*-Nanofluid, heat transfer enhancement, CuO, radiator, concentrations, water + ethylene glycol**

I. INTRODUCTION

Automotive internal combustion engines generate large amount of heat, of which only some amount of heat is used to generate power. Some amount of heat is rejected into atmosphere and remaining must be removed by using engine cooling system. Traditional coolants like water, oils and ethylene glycol, are having less heat transfer capability. These liquids have constant values for their thermo-physical property. So, the only way to improve their heat transfer capability has to be done through the device, through augmenting the heat exchange area or the flow rates of coolants. Nevertheless, this solution implies a higher heat exchange potential, but it does not enhance the efficiency of the procedure. Hence nanotechnology appears as an option to consider, in order to analysing the possibilities, it offers to fix heat exchange transfer demands at industrial scale.Nanofluids are homogeneous mixtures of solids and liquids when these solid particles are smaller than 100 nm. These added solid particles are supposed to improve thermo-physical properties and heat transfer behaviour of its base fluid. Traditional coolants are an option to be improved from thermo-physical view point in order to cover the needs of cooling in electronic systems; because of that, nanofluids are expected to fill this gap.The aim of this paperis to measure thermal conductivity and viscosity of nanofluids in a small micro-tube in order to evaluate their heat transfer performance based on different criteria.

II. LITERATURE REVIEW

Peyghambarzadeh et al. [1],performed experiments to see effect on the heat transfer performance of car radiator.Pure water and pure EG has been compared with their binary mixtures. Furthermore, different amounts of Al_2O_3 nanoparticle have been added into these base fluids and its effects on the heat transfer performance of the car radiator have been determined experimentally. Liquid flow rate has been changed in the range of 2–6 lpm and the fluid inlet temperature has been changed for all the experiments and the heat transfer enhancement of about 40% compared to the base fluids has been recorded.Madheshaet al.[10], performed experiment for various nanoparticle volume concentrations added in the base fluid ranging from 0.1% to 1.0%. The results showed that the convective heat transfer coefficient was found maximum by 48.4% up to 0.7% volume concentration of HyNC. Raja et al. [3],studied about various characteristics of nanofluids. The TiO_2–water and SiO_2–water nanofluids perform well with the automotive radiator, and the Nusselt number increased with volume flow rate and slightly increased with inlet temperature. The heat transfer performance of MWCNT-water nanofluid in a coaxial heat exchanger is appreciable and found 10% enhancement by the addition 0.026% in volume of carbon nanotube.Ahmed et al. [4], studied use of TiO_2-water nanofluid's as a coolant in car engine radiator. When results of TiO_2 and $A1_2O_3$ systems are compared by taking the base fluid as reference the former shows significantly higher thermal conductivity as compared to the later despite its larger particle size)mean size of 44 nm and 13 nm, respectively(. These results indicate that particle's thermal conductivity has more influence than particle size. TiO_2-water nanofluid offers a better overall performance than base fluid. Heat transfer coefficient significantly improves for 0.2% nanoparticle concentration as compared to pure water. Hussein et.al.[5], performed experiment to study the force convection and friction factor effect on heat transfer.The heat transfer coefficients at particle volume concentrations of 2.3% and 19%have been determined as 10% and 50% respectively greater than the values obtained with water. The maximum values of friction factor increased to 22% for SiO_2 nanoparticles dispersed in water with 2.5% volume concentration. A highest Nusselt number enhance up to 40% obtained for SiO_2 nanoparticles in water.

III. EXPERIMENTAL SETUP

The experimental system used in this setup includes, a storage tank (27 litre), a heater, a submersible pump, thermocouple, a forced draft fan and a cross flow heat exchanger (an automobile radiator). For heating the working fluid an electric heater of capacity 2000 watt and controller were used to maintain the temperature 50-60°C. Two K type thermocouples are installed on the radiator to measure inlet (Tin) and outlet (Tout) the temperature of the radiator. Other two thermocouple are mounted on either side of radiator (T1 and T2) are used to measure temperature of air on either side of radiator. Ammeter and voltmeter are provided to measure effective load of the setup. A rotameter is used to measure the flow through the radiator. The specification of the Rotameter is 0-9 lpm and measurement of 1/4" BSP(M).

In first stage experiment were conducted only on water and later on stages test were conducted by taking different concentrations of nanofluid in binary base fluid (Water(80%) + EG(20%)). Nanofluid concentrations were varied from 0.5 - 2.5% with increment of 0.5%.

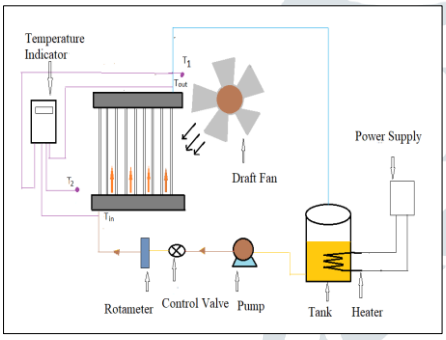

Fig. 1 Schematic of Experimental Setup

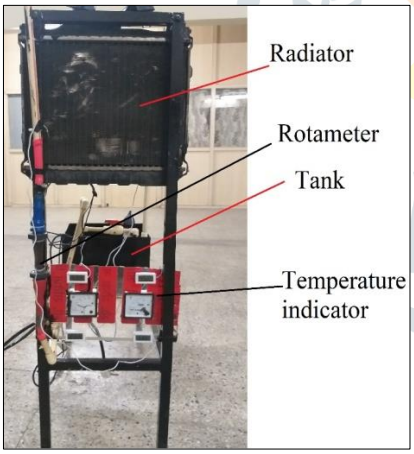

Fig 2 Experimental Setup

Fig 3. Brownish Black CuONanopowder

Fig 4 Preparation of Nanofluid Sample

A) *Preparation of Nanofluids*:

This method is used for preparation of nanofluids by dispersing nanoparticles into base fluid. In first step, dry powder is produced by chemical vapour deposition method and then in second stage this powder is dispersed in base fluid. During this process agglomeration of nanoparticles takes place, this results in decrease in thermal conductivity of nanofluid. In order to avoid agglomeration ultrasonic agitation method is used.

B) Base fluid:

Base fluid properties that will influence the formation could divide into two groups which are physical and chemical properties. Properties from these groups are investigated to improve the understanding on their influence on base fluid overall performance whereby could divided into different groups, mineral, synthetic or ester and are classified in various ways. Mostly water and ethylene glycol are used as base fluid.

Table 1
Table of Properties [1]

Sr No	Properties	CuO	Mixture of Water+ EG
1	Density(Kg/m3)	6310	1008
2	Specific heat (J/KgK)	531	4020

C) Estimation of nanofluid Properties

Properties of nanofluid are estimated by the relation proposed by Xuan Y. and Roetzel [6]

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

$$(\rho c_p)_{nf} = \varphi(\rho c_p)_p + (1-\varphi)(\rho c_p)_{bf} \quad (2)$$

ρ - Density (kg/m3)

Cp - Specific heat capacity (J/kg K)

bf - Base fluid

φ - Volume concentration

IV. EXPERIMENTAL DATA ANALYSIS

Heat transfer rate for water is given by:

$$Q = m_w C_{pw} \Delta T = m_w C_{pw}(T_{in} - T_{out}) \quad (3)$$

Tin and Tout are inlet and outlet temperatures of radiator

Mass flow rate: $m_w = \rho_w V$ (4)

Heat transfer by convection mode is given by:

$$Q = hA\Delta T = hA_s(T_2 - T_1) \quad (5)$$

T1 and T2 are temperatures on both side of radiator

Heat transfer coefficient:

$$h_{exp} = \frac{mC_p(T_{in} - T_{out})}{A_s(T_2 - T_1)} \quad (6)$$

Maximum heat transfer is given by:

$$Q = m_a C_{pa}(T_{in} - T_2 \quad (7)$$

Effectiveness

$$\varepsilon = \frac{m_w C_{pw}(T_{in} - T_{out})}{m_a C_{pa}(T_{in} - T_1)} \quad (8)$$

V. RESULTS AND DISCUSSION

The experiments were conducted on automobile radiator setup at different flow rates and different concentration of nanofluid. The results obtained are as listed below:

Table 2
Result table

Fluid	Flow (lpm)	h W/m²k	Q (W)	effectiveness
WATER	3	15.71	1548.82	0.2639
	4	16.12	1618.587	0.2720
	5	16.85	1744.167	0.2912
W+EG	3	17.62	1458.778	0.2538
	4	18.17	1512.806	0.2688
	5	23.80	1587.096	0.2732
W+EG+0.5	3	18.10	1479.818	0.2592
	4	18.31	1562.03	0.2717
	5	22.32	1884.027	0.3300
W+EG+1	3	18.51	1496.701	0.2613
	4	22.42	1564.12	0.2809
	5	23.60	1887.731	0.3295
W+EG+1.5	3	23.53	1515.612	0.2742
	4	22.88	1616.652	0.2883
	5	27.01	1919.775	0.3411
W+EG+2	3	19.19	1534.488	0.2727
	4	22.40	1642.172	0.2918
	5	29.79	1985.413	0.3528
W+EG+2.5	3	20.41	1613.846	0.2788
	4	21.77	1721.436	0.2995
	5	29.97	2050.93	0.3593

1. Maximum heat transfer is obtained at maximum flow rate i.e 5lpm.
2. For pure water Q_{max} is 1744.167W.
3. For water + EG solution heat transfer rate is slightly decreased.
4. For Water, EG and 0.5% nanofluid solution heat transfer rate is increased by 8.01%.
5. For 1% nanofluid solution heat transfer rate is increased by 8.23% as compared to pure water and heat transfer coefficient is increased by 60.24%.
6. For 2% nanofluid solution Q is increased by 13.83% and heat transfer coefficient is increased by 76.77%.
7. Further increase in nanofluid concentration does not show any significant change in heat transfer rate.
8. Further increase in concentration may lead to the problem of agglomeration.
9. The various plots are shown against mass flow rate.

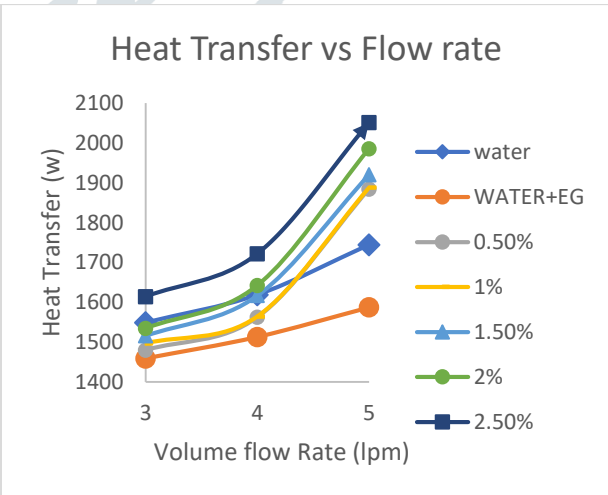

Fig.5 Graph of Q vs Flow Rate

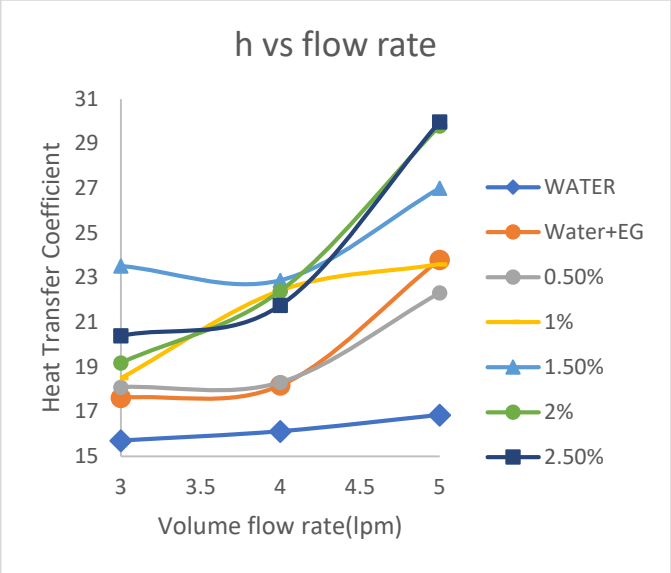

Fig.6 Graph of h vs Flow Rate

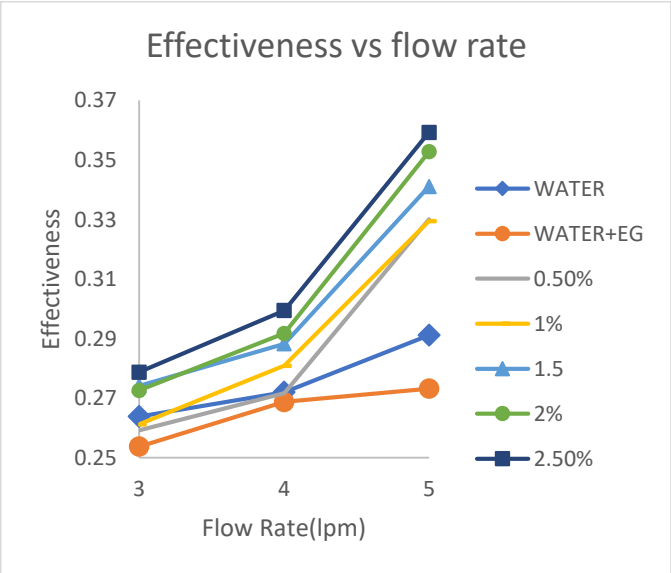

Fig.7 Graph of Effectiveness vs Flow Rate

VI. CONCLUSION

From the above experimental study, the optimum results are obtained for 2% concentration of CuO nanofluid for which, heat transfer is enhanced by 14%. Effectiveness of the radiator is also increased with the addition of nanofluid to the base fluid.

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