Heat Transfer Enhancement in Automobile Radiator Using Copper Nanofluids

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Abstract-*In this paper, forced convective heat transfer in a water based nanofluid has experimentally been compared to that of pure water in an automobile radiator. Different concentrations of nanofluids in the specific range have been prepared by the addition of copper nano particles into the water. The test liquid flow through the radiator comprises of horizontal tubes of circular cross-section. Nanofluids are suspension of metallic or non-metallic particles in base fluid it can be used to increase heat transfer of various applications such as cooling system for automobile engine and gives the technique to implementation of the nanofluids in the car radiator for the cooling of engine. Evaluating the heat transfer enhancement due to the use of nanofluids has recently become the centre of interest for many researchers. This newly introduced category of cooling fluids containing ultrafine nano particles (30-50 nm) has displayed fascinating behaviour during experiments including increased thermal conductivity and augmented heat transfer coefficient compared to a base fluid. Nanofluids have great potential to improve the engine cooling system by increasing the thermal conductivity of base fluid. Results demonstrate that increasing the fluid circulating rate can improve the heat transfer performance while the fluids inlet has trivial effects.*

Keywords:-Heat Transfer enhancement, radiator, copper nano particles, etc.

I. INTRODUCTION

A reduction in energy consumption is possible by improving the performance of heat exchange systems and introducing various heat transfer enhancement techniques. Further enhancement in heat transfer is always in demand, as the operational speed of these devices depends on the cooling rate. New technology and advanced fluids with greater potential to improve the flow and thermal characteristics are two options to enhance the heat transfer rate and the present article deals with the latter option. Ultrahigh-performance cooling is one of the most vital needs of many industrial technologies. However, inherently low thermal conductivity is a primary limitation in developing energy-efficient heat transfer fluids that are required for ultrahigh-performance cooling. Modern nanotechnology can produce metallic or non metallic particles of nano meter dimensions. Nanomaterialshave unique mechanical, optical, electrical, magnetic, and thermal properties. Nanofluids are engineered by suspending nanoparticles with average sizes below 100 nm in traditional heat transfer fluids such as water, oil, and ethylene glycol. The high surface area of nanoparticles enhances the heat conduction of nanofluids since heat transfer occurs on the surface of the particle. The number of atoms present on the surface of nanoparticles, as opposed to the interior, is very large. Therefore, these unique properties of nanoparticles can be exploited to develop nanofluids with an unprecedented combination of the two features most highly desired for heat transfer systems: extreme stability and ultrahigh thermal conductivity. Furthermore, because nanoparticles are so small, they may reduce erosion and clogging dramatically. Other benefits envisioned for nanofluids include decreased demand for pumping power, reduced inventory of heat transfer fluid, and significant energy savings. A very small amount of guest nanoparticles, when dispersed uniformly and suspended stably in host fluids, can provide dramatic improvements in the thermal properties of host fluids. The goal of nanofluids is to achieve the highest possible thermal properties at the smallest possible concentrations by uniform dispersion and stable suspension of nanoparticles (preferably<50 nm) in host fluids. To achieve this goal it is neccessary to understand how nanoparticles enhance energy transport in liquids. Among the efforts for enhancement of heat transfer the application of additives to liquids is more noticeable. Recent advances in nanotechnology have allowed development of a new category of fluids termed nanofluids. Nanofluids are formed by suspending metallic or non-metallic oxide nanoparticles in traditional heat transfer fluids. These so called nanofluids display good thermal properties compared with fluids conventionally used for heat transfer and fluids containing particles on the micrometer scale. Nanofluids are the new window which was opened recently and it was confirmed by several authors that these working fluid can enhance heat transfer performance.[1]

II. LITERATURE REVIEW

Peyghambarzadeh et al. (2011)experimentally studied the forced convective heat transfer in a water based nano-fluid and compared with that of pure water in an automobile radiator. They conducted experiments with Al_2O_3/water nano-fluid with volume concentration ranging from 0.1 to 1.0 %. For preparation of nano-fluids they neglect the use of the dispersant and stabilizer in nano-fluids. Liquid flow rate were varied in the range of 2-5 liter/min to have the fully turbulent regime i.e. the Reynolds number changed from $9x10^3$ to 2.3 x 10^4. They concluded that increasing the fluid circulating rate can improve the heat transfer performance, but with the fluid inlet temperature to the radiator has trivial effects. Meanwhile, application of nano fluid with low concentrations can enhance heat transfer efficiency up to 45% in comparison with pure water.[1]

Etemadet al. (2006), presents the experimental results of the convective heat transfer of CuO / water and Al_2O_3 / water nano-fluids. The experiments carried out for the laminar flow regime under constant wall temperature boundary condition. The experimental results indicate that for both nano-fluid systems, heat transfer coefficient enhances with increasing nano particles concentrations as well as Peclet number. But the Al_2O_3 / water nano-fluids show more enhancement compared with CuO/water. Also an optimum concentration can be found for each nano-fluid systems in which more enhancements available. It is concluded that heat transfer enhancement by nano-fluid depends on several factors including increment of thermal conductivity, nanoparticles chaotic movements, fluctuations and interactions. [2]

Nguyen et al. (2007),experimentally investigated the heat transfer enhancement and behaviour of a particular nano-fluid, Al_2O_3 nanoparticle–water mixture, for use in a closed cooling system that is destined for microprocessors or other heated electronic components. Data obtained have clearly shown that the inclusion of nanoparticles into distilled water has produced a considerable enhancement of the cooling convective heat transfer coefficient. For a particular particle volume concentration of 6.8%, the heat transfer coefficient has been found to increase as much as 40% compared to that of the base fluid. We have observed that an increase of particle volume concentration has produced a clear decrease of the heated block temperature. Experimental results have also shown that a nano-fluid with 36 nm particle size provides higher convective heat transfer coefficients than the ones givenby nano-fluid with 47 nm particles.[3]

Das et al. (2003),concluded that can be drawn from the reviewed studies is that nano-fluids show great promise for use in cooling and related technologies. Oxide nanoparticle-based nano-fluids are relatively less promising in the enhancement of thermal conductivity of fluids. Also the enhancement diminishes rapidly with the increase in particle size. Metallic nanoparticles seem to enhance thermal conductivity anomalously, with very large enhancement at very low volume fraction. This finding opens the prospect of increasing thermal conductivity enhancement without making large changes in viscosity,which can erode the gain in convective conditions.[4]

Hussein et al. (2014)studied experimentally convection heat transfer enhancement by TiO_2 and SiO_2 suspended in water as a base fluid inside the flat copper tubes of an automotive cooling system has been measured. Significant heat transfer enhancement was observed and was associated with the concentration of the nano particles. Maximum Nusselt number enhancements of up to 11% and 22.5% were obtained for TiO_2 and SiO_2nano particles, respectively, in water. The experimental results showed that the Nusselt number behaviors of the nano-fluids highly depended on the volume flow rate, inlet temperature and nano-fluid volume concentration. The results showed that the SiO_2nano-fluid produces a higher heat transfer enhancement than the TiO_2 nano-fluid; likewise, TiO_2nano-fluid enhanced heat transfer more than pure water. The results also proved that TiO_2 and SiO_2nano-fluid have a high potential for heat transfer enhancement and are highly appropriatefor industrial and practical applications.[5]

Parashurama et al. (2015), presented a experimental investigation of the use of CuO-water nano-fluid as a coolant in a radiator of army tanker diesel engine. The heat transfer rate for CuO-water nano-fluid at volume fraction 10% was studied. The results indicate that the overall heat transfer coefficient of nano-fluid is greater than that of water alone and therefore the total heat transfer area of the radiator can be reduced. However, the considerable increase in associated pumping power may impose some limitations on the efficient use of this type of nano-fluid in automotive diesel engine radiator.[6]

Leong et al. (2005),focused on the application of copper/ ethylene glycol nano-fluids in automotive cooling system. They fixed the Reynolds number for nano-fluids and the air. They selected the inlet temperature range 70^0-95^0C for nano-fluids and the concentration of nano particles in base fluid 0-2 Vol. %, and the mass flow rate of the nano-fluids was 0.106-0.118 m^3/hr. From experimentation they observed about 3.8 % of heat transfer enhancement could be achieved with addition of 2% copper particles in a base fluid at the Reynolds number of 6000 and 5000 for air & coolant respectively. And they also conclude that there is need of additional 12.13% pumping power for radiator using the 2% copper particles at 0.2 m^3/s coolants volumetric flow rate compared to that of the same radiator using the only pure ethylene glycol.[7]

Esfahany et al. (2006),studiedConvective heat transfer of Al_2O_3/water nano-fluid in laminar flow through circular tube with constant wall temperature boundary condition was investigated experimentally. The experimental results indicate that heat transfer coefficient of nano-fluids increases with Peclet number as well as nanoparticles concentration. The increase in heat transfer coefficient due to presence of nanoparticles is much higher than the prediction of single phase heat transfer correlation used with nano-fluid properties. It is concluded that thermal conductivity increase is not the sole reason for heat transfer enhancement in nano-fluids. Other factors such as dispersion and chaotic movement of nanoparticles, Brownian motion and particle migration may play role in heat transfer augmentation due to nanoparticles. Particle fluctuations and interactions, especially in high Peclet number may cause the change in flow structure and lead to augmented heattransfer due to the presence of nanoparticles. [2]

III. EXPERIMENTATION

a) Experimental Setup

As shown in Fig. 1, the experimental system used in this research includes flow lines, a storage tank, a heater, electrical motor, a flow meter, and a heat exchanger (an automobile radiator). The pump gives a constant flow rate. The total volume of the circulating liquid is constant in all the experiments. A flow meter was used to control and manipulate the flow rate with the precision of 0.1 l/min. For heating the working fluid, an electrical heater and a controller were used to maintain the temperature between 40 and 80^0C. Six thermocouples (K-type) were used for radiator temperature measurement. Four thermocouples were attached to different positions.

When the experiment started, the location of the thermocouple presented the average value of the readings was selected as a point of average temperature. Due to very small thickness and very large thermal conductivity of the tubes, it is reasonable to equate the inside temperature of the tube with the outside one. The temperatures from the thermocouples were measured by one digital indicator, respectively with an accuracy of 0.1^0C. The fins and the tubes are made with aluminium. For cooling the liquid, a forced fan was installed close and face to face to the radiator and consequently air and water have indirect cross flow contact and there is heat exchange between hot water flowing in the tube-side and air across the tube bundle. The test liquids are water based nanofluids which consist of water and small amount (varying 0.1 to 0.5 vol. %) of copper nanoparticle. The mean grain size of this copper nanoparticles is 30-50 nm. This is due to the fact that the addition of any agent may change the fluid properties and the authors were interested to simulate the easiest actual condition encountered in the automobile radiator. Additionally, creating highly turbulent flow condition in the radiator tubes and connecting pipes guarantees the stabilization of the nanoparticle in water.

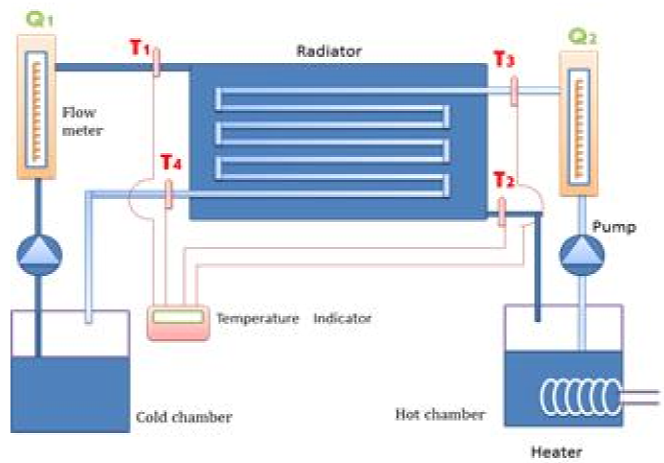


Fig. No. 1

b) Preparation of Nanofluids

In the study of nanofluid including CuO nanoparticle with average size 30-50 nm. in water as base fluid with different concentrations (0.1 to 0.3%) were prepared. To prepare the proper volume for each suspension, nanoparticles were mixed with distilled water in a flask and then kept under ultrasonic probe sonicator (model dolphin) vibration 2-4 hr.
Nano particles were settling down in water because of its high density than water, by using ultrasonic vibration some gap is generated in the water molecules and it makes a suspension of copper particle and water. Therefore copper particle does not settle down.

Fig. No. 2

IV. CALCULATION

The automotive radiator is made of four major components, coolant inlet tank, outlet tank, pressure cap and core. Coolant tanks are positioned either on top and bottom of the core. The major sub components of the core are coolant tubes and fins. Flat tubes are more popular for automotive applications due to their lower profile drag compared with round tubes. The mathematical model has been developed based on first law of thermodynamics including heat transfer and fluid flow effects. Following assumptions have been made for analysis: Properties of nanofluid as well as air assumed to be constant, Steady state process, all the heat rejected from nanofluid absorbed by air flow inside radiator.

a) Calculation of heat transfer coefficient for water

To obtain heat transfer coefficient and corresponding Nusselt number, the following procedure has been performed.

According to Newton's cooling law:

$$Q = h\ A\ \Delta T = h\ A\ (T_b - T_w)$$

Heat transfer rate can be calculated as follows:

$$Q = m\ C_p\ \Delta T = m\ C_p\ (T_{in} - T_{out})$$

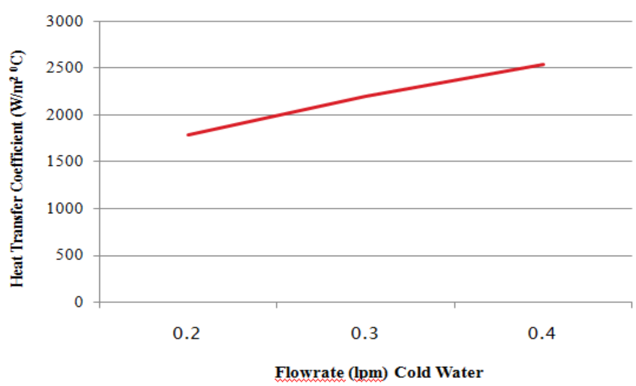
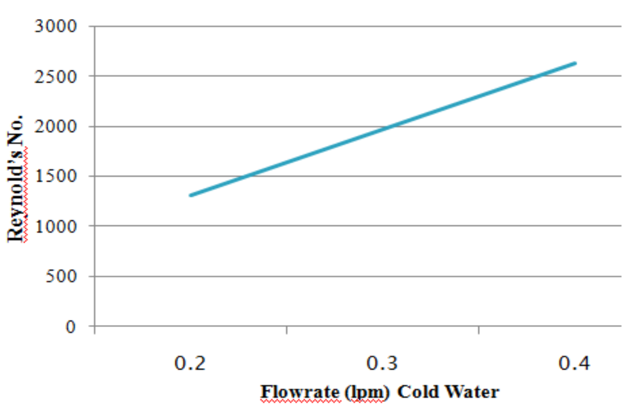


Fig. No. 3



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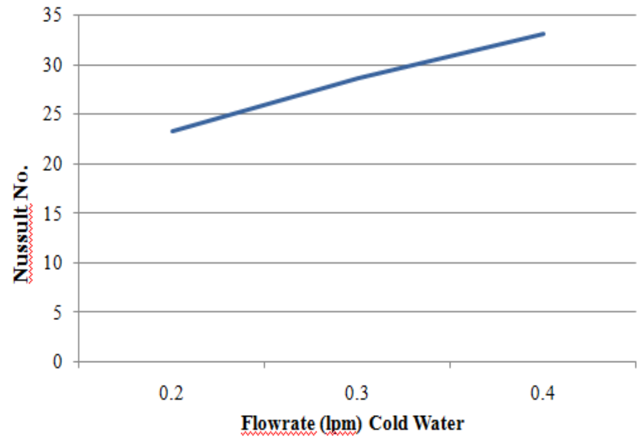

Fig. No. 5

b) Calculation of different parameter for nanofluids

Heat transfer rate can be expressed as

$$Q = m\ C_{pnf}\ (T_{out} - T_{in})$$

The effective density of nanofluids is

$$\rho_{nf} = (1-\Phi)\rho_f + \Phi\ \rho_p$$

C_{pnf} is effective specific heat of nanofluid which can be calculated as

$$(\rho\ C_p)_{nf} = (1-\Phi)\ (\rho\ C_p)_f + \Phi\ (\rho\ C_p)_p$$

Overall heat transfer coefficient is calculated as

$$Q = U\ A\ (LMTD)$$

Where, h – Heat transfer coefficient
C_{pnf} – Effective Specific Heat of Nano Fluid
LMTD – Logarithmic mean temp difference
U – Overall heat transfer coefficient
ρ_{nf} - Density of nanofluid
ρ_p – Density of particle
m – mass flow rate of the nanofluids
A – Area
T_{in} – Inlet Temperature of cold water
T_{out} – Outlet Temperature of cold water
ρ_f – Density of fluid
Φ – Volume Concentration
nf -nano fluid

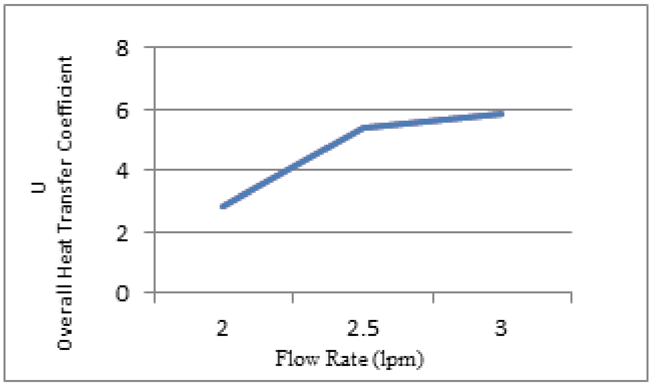

Fig No. 6

V. CONCLUSION

The above graph shows that increasing in flow rate of cold water increases the overall heat transfer coefficient.

- Cooling capacity and effectiveness increase with increase in mass flow rate of air and coolant.
- Cooling capacity of radiator using nanofluid is greater than radiator using base fluid alone.

VI. FUTURE SCOPE

Many industries have a strong need for improved fluids that can transfer heat more efficiently. Nanofluids transfer heat more efficiently than do conventional fluids. Therefore, when used to improve the design and performance of thermal management systems, nanofluids offer several benefits, including improved reliability, reduction in cooling system size, decreased pumping-power needs, increased energy and fuel efficiencies, and lower pollution. Thus, nanofluids can have a significant impact in cooling a number of high-heat-flux devices and systems used in consumer, industrial, and defence industries. Although nanofluids offer very promising opportunities, there are still a number of technical issues on the road to commercialization. Some technical barriers facing the development of commercially available nanofluid technology were identified, where we suggested some research needed to overcome these barriers and to achieve cost-effective high-volume production of nanofluids. Nanofluids offer challenges related to production, properties, heat transfer, and applications. In this section we highlight some future directions in each of these challenging areas.

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