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Review Of Nano Fluids And Its Effect On Heat Transfer Through Radiator

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Abstract

Vehicle engine thermal management is important to make the vehicle system more efficient and sustainable. To improve the efficiency, air cooling was shifted to water because of its availability and ability to absorb and carry heat efficiently. However, water has its limit of operating temperature range and inability to provide corrosion resistance. So heat transfer of coolant flow through the automobile radiators is of great importance for the optimization of fuel consumption. A nanofluid is a fluid containing nanometre-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in nanofluids are typically made of metals oxides, carbides, or carbon nanotubes. Common base fluids include water, ethylene glycol and oil. Nano fluids have improved thermal properties and possible heat transfer rate. Nano fluids plays major role in various applications which increases heat transfer rate and fulfill requirement of thermal properties like viscosity, specific heat, density, thermal conductivity, surface tension, stability in the operative environment because it contains metallic or non-metallic. Nano powders with a size of less than 100nm in base fluids so, it increases the heat transfer potential of the base fluids. Water is the working fluid in the heat exchanger and metal based (Cu or Al) nano fluid of particular concentration will act as a heat carrier.

Keywords *—Nanofluids, Automotive radiator, Heat transfer, Preparation of nanofluids, Thermophysical Properties, Application*

I. INTRODUCTION

The energy conservation is one of the vital issues of the twenty-first century, and it will certainly be one of the most significant challenges in the near future. Therefore, scientists, engineers and researchers are considerably trying to address this important concern. The advances made in heating or cooling in industrial devices cause energy saving and heat transfer improvement, and increase the operational life of the equipment. Energy savings can be performed by the efficient use of energy. Energy conversion, conservation and recovery are some routes for energy saving.

Different technologies are employed to improve the efficiency of heat exchangers. For decades, efforts have been made to progress heat transfer in heat exchangers, decrease the heat exchange time and finally improve the system efficiency. Augmenting the heat transfer area by adopting fins is frequently used. This technique, however, increases weight and volume of heat exchangers. Therefore, common approaches such as use of fins have now reached their boundaries.

In addition to geometrical modifications, improving the thermal characteristics of the heat transfer fluids can present greater convective heat transfer in heat exchangers. Application of additives to the working fluids to modify their thermo physical properties is an interesting technique for the heat transfer improvement. Recent development in nanotechnology has presented a way to this. To improve heat transfer characteristics of conventional fluids, the concept of “Nano fluid” was proposed by Choi in 1995. Combination of conventional fluids and solid nanoparticles called Nano fluid.

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Nano fluids are advanced heat transfer fluids which can overcome the restrictions of poor thermo physical characteristics related to conventional fluids such as low thermal conductivity. Researchers have proven that Nano fluids have advantages such as great thermal conductivity and proper stability. Many surveys have been carried out in the field of Nano fluids, and some of investigators have reviewed the studies conducted in this area in different fields such as applying Nano fluids in boiling heat transfer, convective heat transfer and friction factor correlations of Nano fluids, particle migration in Nano fluids, magnetic Nano fluids, entropy generation in Nano fluids, mass transfer in Nano fluids, and so forth.

Utilizing Nano fluids can be one of the most interesting techniques for heat transfer enhancement in heat exchangers. Several researchers have used Nano fluids for this purpose. For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence.

II. PROBLEM STATEMENT

Water based heat exchangers have less efficiency in transferring heat from hot to liquid domains. Hence, Effect of suitable Nano fluid will be compared based on heat transfer capabilities.

III. NANOPARTICLES AND NANOFLUIDS

In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport properties. Nanoparticles are between 1 and 100 nanometres ($1x10^{-9}$and 1×10^{-7}m) in size. Tubes and fibers with only two dimensions below 100 nm are also nanoparticles. Novel properties that differentiate particles from bulk Materials typically develop at a critical length scale of100 nm. They are made from ceramics, metals &metal oxides.

Nanofluids have novel properties that make them potentially useful in many applications in heat transfer, including microelectronics, fuelcells, pharmaceutical processes, and hybrid-powered engines, engine cooling/vehicle thermal management, domestic refrigerator, chiller, heat exchanger, in grinding, machining and in boiler flue gas temperature reduction. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid.

Knowledge of the rheological behaviour of nanofluids is found to be critical in deciding their suitability for convective heat transfer applications. Nanofluids also have special acoustical properties and in ultrasonic fields display additional shear wave reconversion of an incident compressional wave; the effect becomes more pronounced as concentration increase

IV. PREPARATION OF NANOFLUIDS

A. Two Step Method:

Two-step method is the most widely used method For preparing nanofluids. Nanoparticles, nanofibers, Nanotubes, or other nanomaterials used in this Method are first produced as dry powders by Chemical or physical methods. Then, the nanosized Powder will be dispersed into a fluid in the second Processing step with the help of intensive magnetic Force agitation, ultrasonic agitation, high-shear Mixing, homogenizing, and ball milling. Two-step Method is the most economic method to produce Nanofluids in large scale, because nanopowder Synthesis techniques have already been scaled up to Industrial production levels. Due to the high surface

Area and surface activity, nanoparticles have the Tendency to aggregate. The important technique to Enhance the stability of nanoparticles in fluids is the Use of surfactants. However, the functionality of the Surfactants under high temperature is also a big Concern, especially for high-temperature applications.

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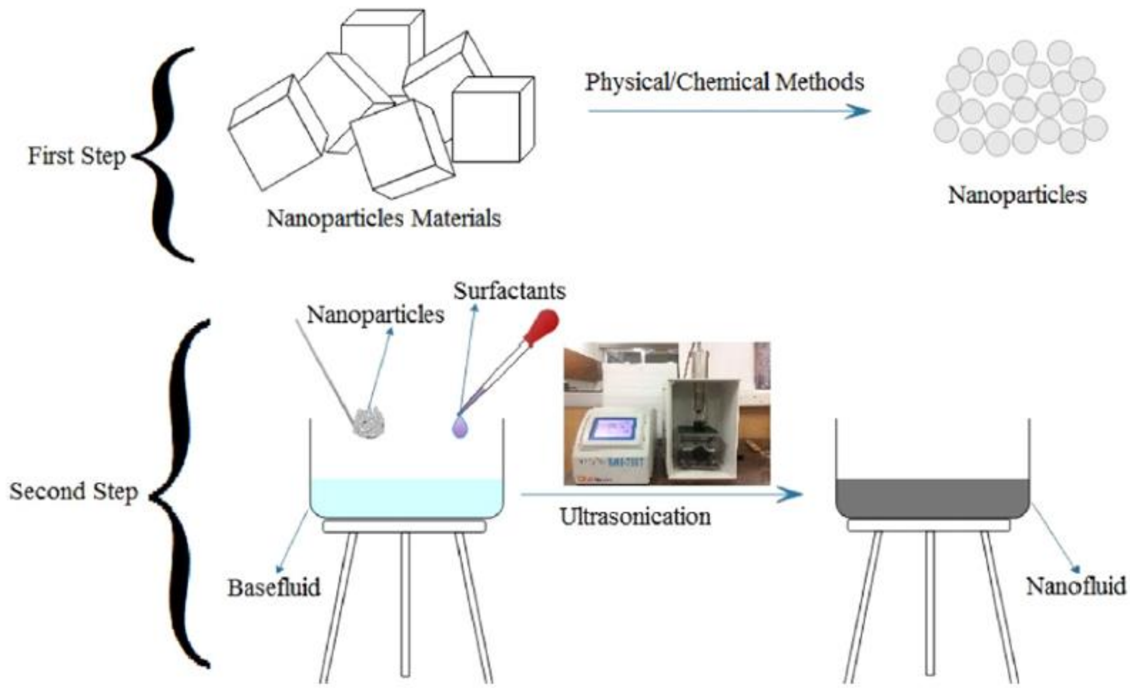

Fig. 1 Two-step method to prepare Nanofluid.

B. One Step Method:

To reduce the agglomeration of nanoparticles, Eastman et al. developed a one-step physical vapour condensation method to prepare Cu/ethylene glycol nanofluids. The one-step process consists of simultaneously making and dispersing the particles in the fluid. In this method, the processes of drying, storage, transportation, and dispersion of nanoparticles are avoided, so the agglomeration of nanoparticles is minimized, and the stability of fluids is increased. The one-step processes can prepare uniformly dispersed nanoparticles, and the particles can be stably suspended in the base fluid. The vacuum-SANSS (submerged arc nanoparticle synthesis system) is another efficient method to prepare nanofluids using different dielectric liquids. The different morphologies are mainly influenced and determined by various thermal conductivity properties of the dielectric liquids. The nanoparticles prepared exhibit needle-like, polygonal, square, and circular morphological shapes. The method avoids the undesired particle aggregation fairly well. One-step physical method cannot synthesize nanofluids in large scale, and the cost is also high, so the one-step chemical method is developing rapidly. Zhu et al. presented a novel one-step chemical method for preparing copper nanofluids by reducing $CuSo4 \cdot 5H2O$ with $NaH2PO2 \cdot H2O$ in ethylene glycol under microwave irradiation. Well-dispersed and stably suspended copper nanofluids were obtained. Mineral oil-based nanofluids containing silver nanoparticles with a narrow-size distribution were also prepared by this method. The particles could be stabilized by Korantin, which coordinated to the silver particle surfaces via two oxygen atoms forming a dense layer around the particles. The silver nanoparticle suspensions were stable for about 1 month. Stable ethanol-based nanofluids containing silver nanoparticles could be prepared by microwave assisted one-step method. In the method, polyvinylpyrrolidone (PVP) was employed as the stabilizer of colloidal silver and reducing agent for silver in solution. The cationic surfactant octadecylamine (ODA) is also an efficient phase transfer agent to synthesize silver colloids. The phase transfer of the silver nanoparticles arises due to coupling of the silver nanoparticles with the ODA molecules present in organic phase via either coordination bond formation or weak covalent interaction. Phase transfer method has been developed for

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preparing homogeneous and stable graphene oxide colloids. Graphene oxide nanosheets (GONs) were successfully transferred from water to n-octane after modification by oleylamine.

TABLE 1: THERMAL CONDUCTIVITY OF DIFFERENT MATERIALS

Material	CNT	Diamond	Cu	Al	Si	CuO	Al2O3	TiO2	Oil
Thermal Conductivity (W/mK)	1800 to 6600	2200 to 2300	350 to 400	200 to 250	100 to 150	20 to 40	30 to 40	0.4 to 11.8	0.1 to 0.2

V. APPLICATION OF NANOFLUIDS IN RADIATOR

The coolant used in automobile radiators must have good thermal properties such as coolant have high thermal conductivity, low freezing point and high boiling point. Conventional coolants used in radiators are water or mixture of water and ethylene glycol with certain additives, since these conventional coolant have very low thermal conductivity hence heat transfer rate from radiator is very low due to which we need to increase the surface area to get required heat transfer rate, this makes the radiator bulky, increase the material cost and also occupies large space in automobile, hence aesthetically vehicle not looking good. From above discussion we conclude that there is a need of new type of coolant in automotive cooling system. From the last decade researchers try to use nanofluid as a coolant in automotive radiator and very good results are obtained from their work.

As we know that metals or metal oxides have good thermal conductivity compared to liquids so if we mix the nano sized metals or metal oxides particles in base fluid then the resultant mixture expected to have larger thermal conductivity than the base fluid hence we get a good heat transfer rate. Due to the use of nano sized particles the problem related to sedimentation and pressure drop is negligible and hence nanofluid is able to use as a coolant in automobile radiators.

Ravikanth S. Vajjha et al. [4] consider the two different nanofluids, Al2O3 and CuO, in an ethylene glycol and water mixture circulating through the flat tubes of an automobile radiator and studied numerically to evaluate their superiority over the base fluid.

Report found that Heat transfer computations for Al2O3 and CuO nanofluids with varying particle volumetric concentrations exhibit substantial increase in the average heat transfer coefficient with concentration. Also Convective heat transfer coefficient in the developing and developed regions along the flat tubes with the nanofluid flow found marked improvement over the base fluid and The pressure loss found to be increased with increasing particle volumetric concentrations of nanofluids.

M. Naraki et al. [5] did parametric study of overall heat transfer coefficient of CuO/water nanofluids in a car radiator, Fig. 2 shows that the overall heat transfer coefficient of the CuO/water nanofluid as a function of nanofluid flow rate at various volume concentrations. The overall heat transfer coefficient of nanofluid increases with nanofluid flow rate. The maximum value of the overall heat transfer coefficient of CuO/water nanofluids occurs at 0.4 vol.% concentration of nanoparticle which is approximately 8% comparing with the base fluid.

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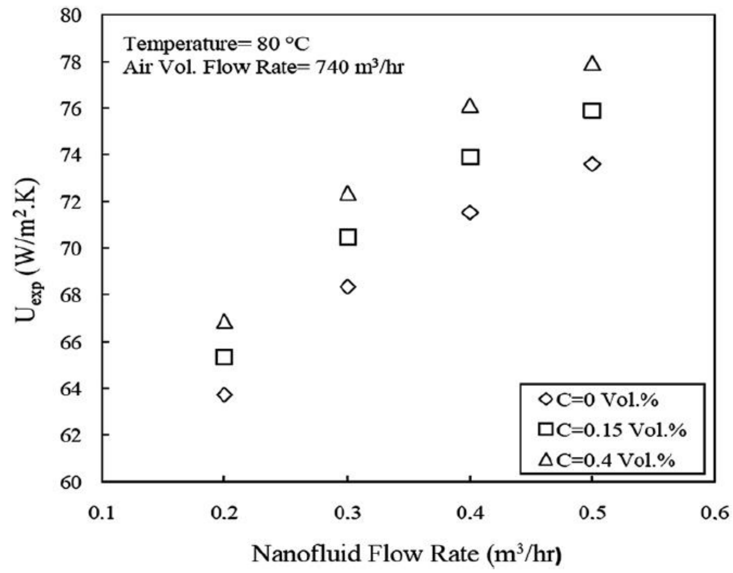
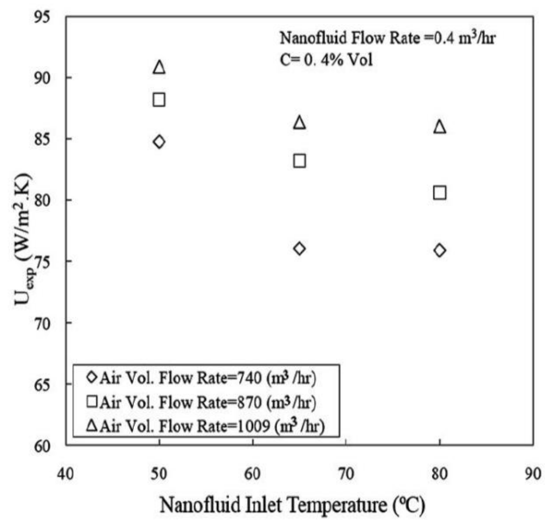


Figure 2. Effect of nanofluid concentration and nanofluid volumetric flow rate on the overall heat transfer coefficient with nanofluid.



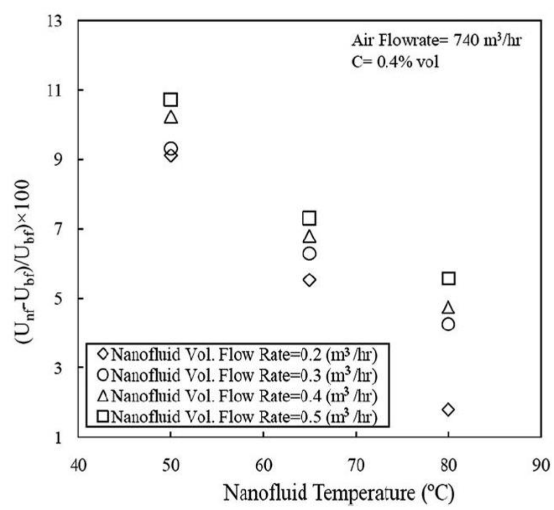


Figure 3. Effect of inlet nanofluid temperature on the heat transfer enhancement of nanofluid to base fluid.

Figure 4. Effect of inlet nanofluid temperature on the overall heat transfer coefficient with nanofluid.

Fig. 3 shows the comparison of the results for nanofluid at the concentration of 0.4 vol.% and at different inlet temperatures in order to analyse the effect of temperature variation on the overall heat transfer coefficient of the automobile radiator. It also shows that by increasing the fluid inlet temperature the overall heat transfer coefficient of nanofluid decreases. Fig. 4 show that the ratio of the overall heat transfer coefficient with nanofluid to that of base fluid increases with decreasing inlet temperature and increasing volumetric flow rate of nanofluid at the constant air flow rate. Fig. 5 shows that the overall heat transfer coefficient with nanofluid as a function of nanofluid flow rate at constant air flow rate and the nanoparticle concentration. Also it conclude that the overall heat transfer coefficient significantly increases with increasing flow rate of nanofluid. From Fig. 6 the at volumetric flow rate of 0.4 m3/h and nanofluid concentration of 0.4 vol.%, the overall heat transfer coefficient with nanofluid increases with increasing air Reynolds numbers.

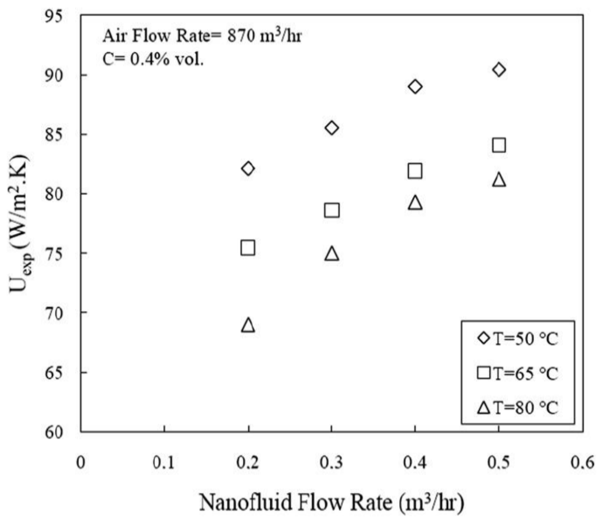


Figure 5. Effect of nanofluid volumetric flow rate on transfer coefficient of CuO/water nanofluid in car radiator.

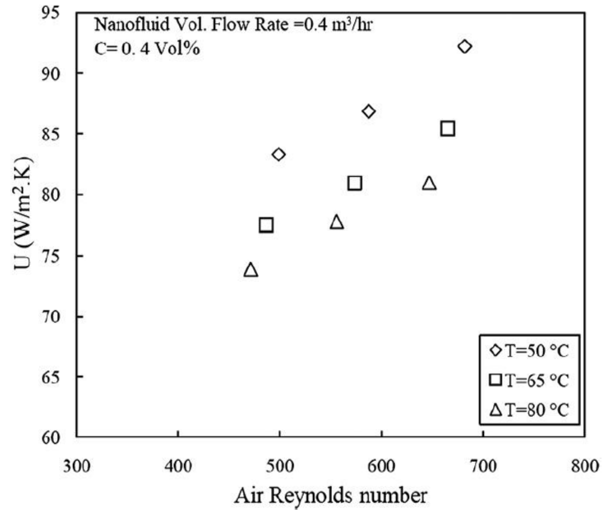


Figure 6. Effect of air Reynolds number to heat the overall heat transfer coefficient of CuO/water nanofluid in the car radiator.

K.Y. Leong et al. [6] studied the application of ethylene glycol based copper nanofluids in an automotive cooling system. The input data, nanofluid properties and empirical correlations taken from literatures to investigate the heat transfer enhancement of an automotive car radiator operated with nanofluidbased coolants. Research reported that Prandtl number of nanofluids based coolant decreases exponentially with volume fraction of copper nanoparticles, due to the higher thermal conductivity of nanofluids (fig.7)

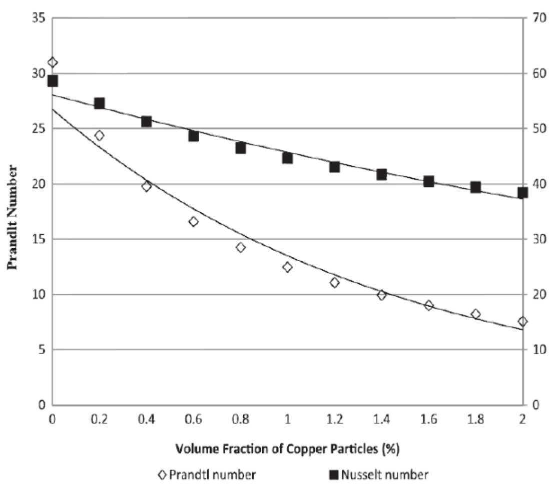


Figure 7. Effect of copper volume fraction to coolant prandtl and Nusselt number at constant air and coolant reynolds number.

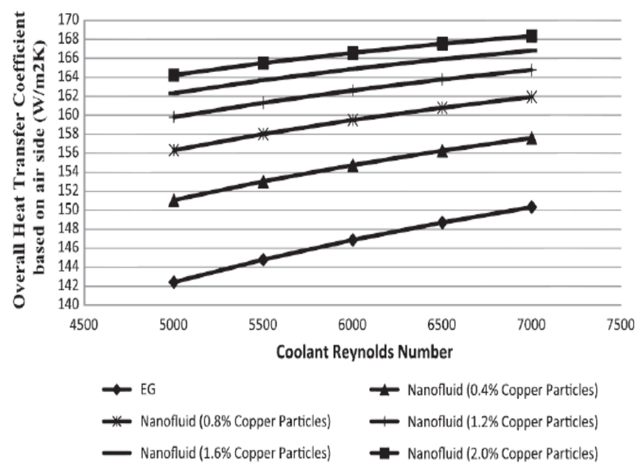


Figure 8. Effects of coolant Reynolds number to overall heat transfer coefficient based on air side.

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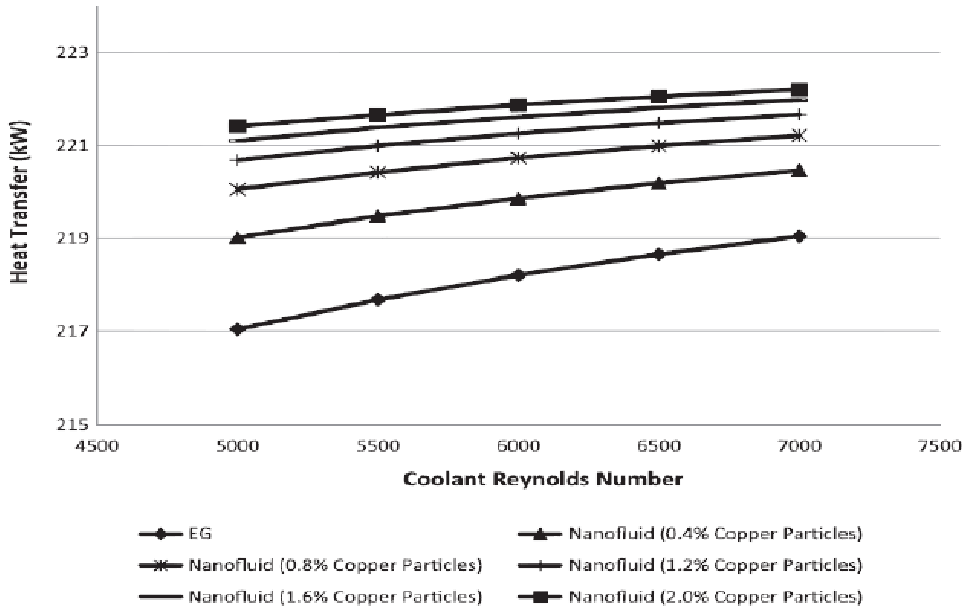

Figure 9. Effect of coolant Reynolds number to heat transfer rate of radiator.

Fig.8 shows that the overall heat transfer coefficient based on air side is increased with coolant Reynolds number. Fig.10 also shows that by the addition of 2% copper particles, 1.4% improvement of heat transfer rate has been achieved at 4000 and 7000 Reynolds number for air and coolant respectively. Fig.9 shows that the heat transfer rate of a radiator using nanofluid is higher than that of a radiator using ethylene glycol.

VI. CONCLUSION

As per discussion, use of nanoparticle in radiator would be a effective replacement for conventional coolant as it provides higher heat transfer rate resulting in better performance of radiator. This offers an opportunity for engineers to develop highly compact and effective automotive radiators.

Due to higher heat transfer performance increases the performance of automotive engine and would also reduce fuel cost. The main reason for the heat transfer enhancement of nanofluids is that the suspended nanoparticles increase the thermal conductivity of the fluids and reduction of temperature of radiator.

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