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Experimental Studies on Automotive Radiator Performance using Water and Al_2O_3 Nanofluid

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***Abstract*-----The nano fluids have emerged as a new generation of heat transfer fluids attracted the attention of researchers over the past few years. Applications are chemical plants, automotive cooling, building heating, etc. Nanofluid is a new class of heat transfer fluid engineered by dispersing metallic or non metallic nanoparticles.**

The nano fluids like Al2O3, SiC,CuO,TiO2 are the very commonly used in thermal systems and heat exchangers. An experimental study of performance of Al2O3 nano fluid in a car radiator was studied in the present work. Nanofluid was tested in a car radiator by varying the percentage of nanoparticles mix with the water.

Pure water is used in a radiator and its performance was studied. Al2O3 nano particles are mixed in water in 0.025%, 0.05% and 0.1% volume concentration and the performance was studied. The performance comparison has made between pure water and nanofluid tested in a radiator.

1. INTRODUCTION TO NANOFLUIDS

Heat transfer fluids such as water, minerals oil and ethylene glycol play an important role in many industrial sectors including power generation, chemical production, air-conditioning, transportation and microelectronics. The use of nanofluids is one of the most effective mechanisms of increasing the amount of heat transfer in heat exchangers. The subject of the present paper is combining of the two mentioned methods for increase of heat transfer and parametric study of thermal and hydrodynamic performances of flow field.

2. THE CHARACTERISTIC FEATURES OF THE NANOFLUIDS INCLUDE:

1) Significant increase in the thermal conductivity with low volume concentrations.
2) Stronger dependence of thermal conductivity on temperature than the base-fluid alone.
3) Increased critical heat flux for pool boiling scenarios.
4) Substantial increase in heat transfer coefficient.

TYPES OF NANOFLUIDS

Some nanoparticle materials that have been used in nanofluids are oxide ceramics (Al2O3, CuO, Cu2O), nitride ceramics (AIN, SiN), carbide ceramics (Sic, TiC), metals (Ag, Au, Cu, Fe), semiconductors (TiO2), single, double or multi-walled carbon (SWCNT, DWCNT, NWCNT), and composite materials such as nanoparticle core-polymer shell composites. In addition new materials and structures are attractive for use in nanofluids where the particle-liquid interface is doped with various molecules.

The base fluids which are used in nanofluids are common heat transfer fluids such as water, engine oil, Ethylene glycol and ethanol.

Generally in the most researches, the following three kinds of nanoparticles were considered as the solid phase of nanofluid:

1.2.1 CuO and Cu2O Base Nanofluids:

Cu2O is a p-type semiconductor that has received appreciable attentions recently due to its potential applications in fields such as solar cells, pigments, and catalysts. Nanoscaled Cu2O is expected to possess improved properties than its bulk one. Although Cu2O nanocrystals have been successfully synthesized by different methods, few approaches to synthesize shape-controlled Cu2O nanocrystals at mild conditions have been reported. Xiaohao Wei et al. indicated that Cu2O nanofluids can be synthesized by using the chemical solution method (CSM). The nanoparticle can be varied from a spherical shape to an octahedral one by adjusting some synthesis parameters. The nanofluid thermal conductivity can also be controlled by either the synthesis parameters or its temperature. The reaction between cupric-sulfate (CuSO4) and sodium-hydrate (NaOH) yields cupric-hydroxide (Cu (OH)2) and sodium-sulfate (Na2SO4).

1.2.2 Al and Al2O3 Base Nanofluids:

Comparing micron-sized and Nano-sized alumina particles, Nano-alumina has many advantages. A smaller particle size would provide a much larger surface area for molecular collisions and therefore increase the rate of reaction, making it a better catalyst and reactant. Finer abrasive grains would enable finer polishing, and this would also give rise to new applications areas like nano-machining and nano-probes. In terms of coatings, the use of nano-sized alumina particles would significantly increase the quality and reproducibility of these coatings.

There are several methods to synthesize nano-alumina, and these are categorized into physical and chemical methods. Physical methods include mechanical milling, laser ablation, flame spray and thermal decomposition in plasma. Chemical methods include sol–gel processing, solution combustion decomposition and vapor deposition. Most of

the chemical methods have resulted in extremely low yield rates, and thus cannot be adapted to mass manufacturing.
Physical methods like mechanical milling are not efficient as the size of the nanoparticles cannot be easily controlled, and these methods are only limited to certain materials. Other methods such as laser ablation, vapor deposition and sol-gel are very costly as they require specialized equipment such as vacuum systems, high power lasers as well as expensive precursor chemicals. Finally, most systems are only possible for a specific range of materials.

1.2.3 TiO2 Base Nanofluids:
Titanium dioxide (TiO2) is a very useful semiconducting transition metal oxide material and exhibits unique characteristics such as low cost, easy handling and non toxicity, and resistance to photochemical and chemical erosion. The properties of TiO2 are significantly dependent on the crystalline phase, i.e. anatase, rutile, or brookite.

LITERATURE REVIEW

In this section, the works done by various authorshave been reported as a literature review.
[*1] M. Ebrahimi et al.* (2014) – Effect of adding SiO2 nanoparticle to base fluid (water) in car radiator is investigated experimentally. Effects of fluid inlet temperature, the flow rate and nanoparticle volume fraction on heat transfer are considered. Results show that Nusselt number increases with increase of liquid inlet temperature, nanoparticle volume fraction and Reynolds number.
[2]M. Naraki et al. (2013) – In this research, the overall heat transfer coefficient of CuO/water nanofluid is investigated experimentally under laminar flow regime in a car radiator. The results show that the overall heat transfer coefficient with nanofluid is more than a base fluid. The overall heat transfer coefficient increases with the enhancement in the nanofluid concentration from **0 to 0.4 vol. %.** Conversely, the overall heat coefficient decreases with increasing the nanofluid inlet temperature from 50 to 80ºC. The implementation of nanofluid increases the overall heat transfer coefficient up to 8% at nanofluid concentration of 0.4 vol. % in coefficient with nanofluid, effect on each operating parameter on overall heat transfer coefficient and the optimum values of each parameter are determined.
[3] S. M. Peyghambarzadeh et al. (2012) – The heat transfer performance of the automobile radiator is evaluated experimentally by calculating the overall heat transfer coefficient according to the conventional Ɛ-NTU technique. The effects of these variables on the overall heat transfer coefficient are deeply investigated. Results demonstrate that both nanofluids show greater overall heat transfer coefficient in comparison with water up to 9%. Furthermore, increasing the nanoparticle concentration, air velocity and the nanofluid velocity enhances the overall heat transfer coefficient. In contrast, increasing the nanofluid inlet temperature, lower overall heat transfer coefficient was recorded.

SCOPE OF PRESENT WORK

In this, forced convection heat transfer coefficients are reported for pure water and water/Al2O3 nanopowder mixtures under fully turbulent conditions. The test section is made up with a typical automobile radiator, and the effects of the operating conditions on its heat transfer performance are analyzed at different flow rates and at different inlet temperatures. The Nusselt number, Reynolds number and friction factor are also estimated.

ANALYSIS OF AL2O3 NANOPARTICLES

Product Name	Alumina Powder Nano Grade
Color	White
CrystalForm	Alpha
PH Value	6.6
SSA, m^2/g	15
Particle Size	20nm
Al_2O_3 Content	99.99%
Si	10.8 ppm
Na	9.01 ppm
K	10.6 ppm
Fe	9.75 ppm
Cu	0.12 ppm
Ti	0.86 ppm
Mn	0.72 ppm

EXPERIMENTAL SETUP OF AUTOMOTIVE RADIATOR

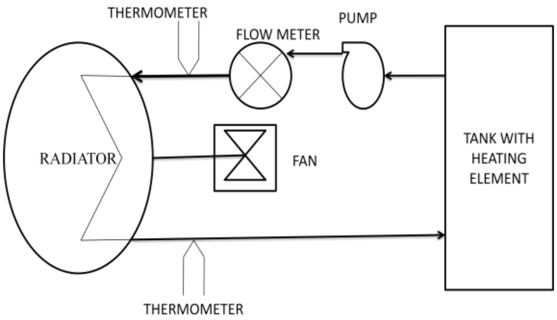

Figure 1: Schematic diagram of test setup

FORMULAE

1. Heat transfer coefficient
   $Q = h \times As\ (Tb-Tw)$
2. Heat transfer rate
   $Q = m\ Cp\ \Delta T = m\ Cp\ (Tin-Tout)$
3. Nusselt Number
   $Nu = 0.332 \times Re^{0.5} \times Pr^{0.33}$
4. Reynolds Number
   $Re = \frac{\rho_{nf} D_h V}{\mu_{nf}}$
5. Friction factor
   $f = (0.79\ \ln Re - 1.69)^{-2}$
6. Volume concentration of Nanoparticle %
   $\text{volume concentration} = \frac{\frac{w_p}{\rho_p}}{\frac{w_p}{\rho_p}+\frac{w_f}{\rho_f}}$
7. Density of nanofluid $\rho nf = (1-\phi)\rho f + \phi\rho p$
8. Thermal conductivity of nanofluid
   $knf = kf\ \frac{k_p+2k_f+2(k_p-k_f)\phi}{k_p+2k_f-(k_p-k_f)\phi}$
9. Viscosity
   $\mu nf = (1+2.5\phi)\mu w$
10. Heat capacity of nanofluid
   $Cpnf = \frac{(1-\phi)Cp_f\rho_f+\phi Cp_p\rho_p}{\rho_{nf}}$
11. Heat transfer enhancement
   $E = \frac{Nu_{nf}-Nu_f}{Nu_f}$

RESULTS AND DISSCUSSION

The experiments are conducted on fabricated model of experimental setup by using water as base fluid, 0.025%, 0.05%, 0.1% nanofluids as test fluids. The obtained results are recorded. The parameters like Nusselt number (Nu), Reynolds number (Re), friction factor, heat transfer enhancement are recorded and shown graphically below

EFFECT OF REYNOLDS NUMBER ON HEAT TRANSFER ENHANCEMENT

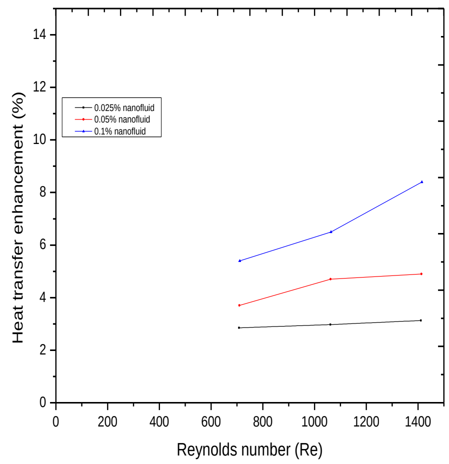

Figure a: Effects of the Reynolds number on heat transfer enhancement at 60º

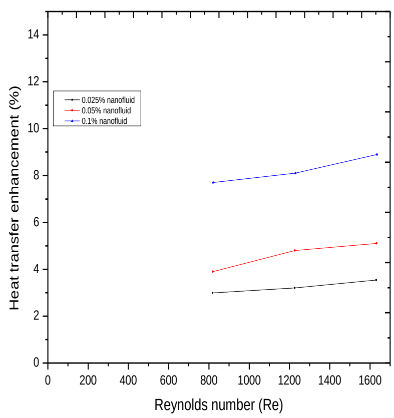

Figure .b: Effects of the Reynolds number on heat transfer enhancement at 70ºC

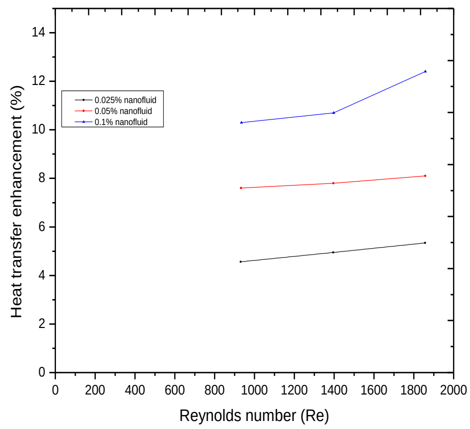

Figure .c: Effects of the Reynolds number on heat transfer enhancement at 80ºC

. The enhancement in heat transfer has increased by augmentation in the concentrations of nanoparticle, Improvement in the heat transfer rate when $\phi = 0.1\%$ and the E value is about 4.56% for 0.025% Al_2O_3 nanofluid at 80ºC and this value is about 12.4% for 0.1% Al_2O_3 nanofluid at 80ºC

CONCLUSION.

The convective heat transfer performance and flow characteristics of Al_2O_3 nanofluid flowing in an automotive radiator have been experimentally investigated. Significant increase in heat transfer was observed with the used different volume concentrations of nanoparticles mixed with water.

The experimental results have shown that the heat transfer enhancement was about 4.56% for 0.025% Al_2O_3 nanofluid at 80ºC and this is about 12.4% for 0.1% Al_2O_3 nanofluid at 80ºC.The results have shown that Al_2O_3 nanofluid has a high potential for hydrodynamic flow and heat transfer enhancement in an automotive radiator.

SCOPE OF FUTURE WORK

Experiments can be further carried out with higher particle concentrations for measurement of heat transfer coefficients. Experiments can also be extended for different base fluids e.g. transformer oil, ethylene glycol etc for investigation of heat transfer characteristics. Carbon nanotubes (CNT) have very high thermal conductivity about 3000 w/m K. So, CNT/water nanofluid can be studied with different surfactants at various particle concentrations. Limited work has been reported on the cooling applications of nanofluid using carbon nanotubes (CNT).

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