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Experimental Analysis of Heat Transfer Coefficient of CuO/Water Nanofluid using Shell and Tube Heat Exchanger

Dr Chandra Mohan

[1]Research Scholar, Department of Mechanical Engineering, St.Peter's University, Chennai, Avadi

[2]Department of Aeronautical Engineering, St.Peter's College of Engineering &Technology, Avadi, Chennai

Abstract-

Experimental investigations of heat transfer coefficient of CuO/Water Nano fluid are reported in this paper. The heat transfer coefficient of the CuO/water was measured with the help of shell and tube heat exchanger. The Nano fluid was prepared by dispersing a CuO nano particle in deionized water. CuO/water Nano fluid with a nominal diameter of 20nm at different volume concentrations (0.1 &0.5 vol. %) at shell and tube heat exchanger in boiler.This experimental result showed that the convective heat transfer coefficient increases with an increase in time also the increasing liquid flow rate.

Keywords: Heat transfer coefficient, Nano fluid, Nusselt number

I. INTRODUCTION

The modern trends in device miniaturization and process intensification have resulted to develop the alternate and effective heat dissipation methods from micro electronics systems and packages. Conventional heat removal methods have been found rather inadequate to use in high intensities of heat fluxes. Many researchers have been proposed different heat transfer techniques to increase the efficiency of the heat transfer systems. After the invention of high accuracy microscopes like Scanning Electron Microscope (SEM), Transfer Electron Microscope (TEM) etc. the researchers are trying to synthesize the materials in nanometer size. Over the past few decades there has been remarkable increase in interest in nanotechnology among the science and engineering communities. The US government now funds about $1 billion per year for the National Nanotechnology Initiatives (NNI). The Nano science and Foundation (NSF) predicts the market for nanotechnology related products will exceed 1 trillion in US alone by 2015 [1].The Fig.1. Shows the summary of R&D funding for nanotechnology related research work by the US Government from 2001 to 2012.

The conventional heat transfer fluids like water, ethylene glycol, propylene glycol etc. are widely used to remove the heat from the mechanical systems. However these conventional fluids have poor heat transfer properties. The Fig.2 shows the comparison of thermal conductivity of different conventional heat transfer fluids and solids. Because of these poor heat transfer characteristics the researchers showed their interest to develop a new kind of heat transfer fluids to enhance the efficiency of the systems. These special kinds of heat transfer fluids are named as "Nano fluids". Nano fluids are relatively new class of fluid containing suspension of nanometer sized particles in the base fluids like water, ethylene glycol, propylene glycol, oil etc. In the year of 1993 the scientist S.U.S. Choi developed a special kind of fluid by dispersing particle with a diameter of 1~100nm in the base fluids for his "Advanced fluid program" project at Argonne National Laboratory (ANL). The term Nanofluid was coined by Choi in 1995 [2].Many researchers have been carried out their research to measure the thermal conductivity of different Nano fluids. From the previous investigation results, Nano fluids have been found to possess enhanced thermal conductivity compared to base fluids. They found that the thermal conductivity of Ethylene glycol + Copper nanofluid (0.5vol %) is increased upto 40% compared to base fluids. Many researchers] were investigated the thermophysical properties of different nanofluids with different volume fractions. Their investigation results clearly showed that the thermophysical properties of nanofluids always increase with the base fluids.

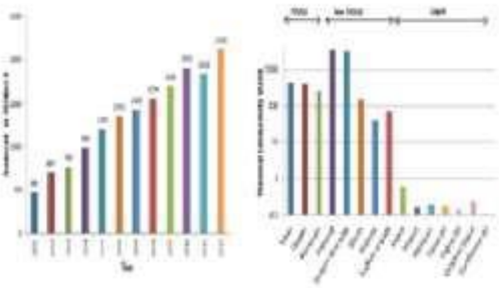

Fig 1 Fig 2

Fig. 1: Summary of R&D funding for nanotechnology related research work by the US Government from 2001 to 2012.

Fig. 2: Comparison of thermal conductivity of differrent conventional heat transfer fluids and solids

II. PREPARATION OF NANO FLUID

In the present study CuO nanoparticle was purchased from Sigma Aldrich chemicals Limited, India. The deionized water was used as a base fluid for this study. The Nano fluids of different volume concentrations were prepared by dispersing different quantity of CuO nanoparticles in deionized water. The solution was sonicated continuously for 1hour using a probe sonicator to disperse the nanoparticle uniformly. Following this, the nanofluid was stirred continuously for 3-4 hours to obtain uniform dispersion of nanoparticles in base fluid. The physical properties of CuO nanoparticle and water are shown in Table.1.

Table 1: Physical properties of CuO nanoparticle and water.

S. No	Nanoparticle /fluid	Mean Diameter (nm)	Specific surface (m2/g)	Density (Kg/m3)	Thermal conductivity (W/mK)	Specific Heat (J/kg K)
1.	CuO	20	27	5820	30.7	555.5
2.	Water	-	-	997.5	0.628	4178

Thermo physical properties

At the first step, the heat characteristics of the Nano fluid have been evaluated and at the next step the application of Nano fluid coolant has been investigated to improve the heat transfer performance of the heat exchanger. The main characteristics of heat exchanger are discussed. However, following assumptions are made:

The flow is an incompressible, steady state and turbulent.

The effect of body force is neglected.

The thermo physical properties of Nano fluids are constant.

The characteristics of nanoparticles and base fluid used in this study are summarized. The necessary thermo physical properties in this paper are den-sity, viscosity, specific heat and thermal conductivity.

III. Experimental Setup

The setup used in this experiment as shown in Fig.3. This experimental setup consists of shell andtubes with a capacity of 10 ltrs were used to circulate the water. 2kW immiscible heater is fitted in the shell to heat the water. Two pumps were used to circulate the water into the test section. One pump is used to circulate the Nano fluid in the outer shell and the other pump is used to circulate the hotwater in the inner tube. The shell of the test section is made of Galvanized Iron (GI), 30mm outside diameter and 27mm inner diameter with a heat exchange length of 1.5m. The inner tube is madefrom smooth copper tubing with 9mm outer diameter and 8mm inner diameter and 1.5m length. To reduce the heat loss from the system the test section is perfectly insulated by using glasswool. The K- type thermocouples are used to measure the temperature at the inlet and outlet side tubes.

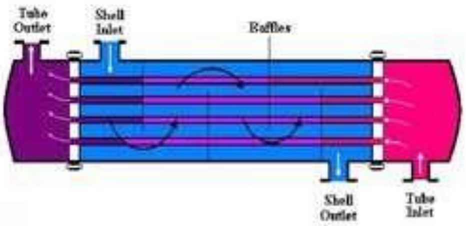

Fig. 3 Shell and Tube Heat Exchanger

Applications of nanotechnology

The 2000s have seen the beginnings of the **applications of nanotechnology** in commercial products, although most applications are limited to the bulk use of passive nano materials. Examples include titanium dioxide and zinc oxidenanoparticles in sunscreen, cosmetics and some food products; silver nanoparticles in food packaging, clothing, disinfectants and household appliances such as Silver Nano; carbon nanotubes for stain-resistant textiles; and cerium oxide as a fuel catalyst. As of March 10, 2011, the Project on Emerging Nanotechnologies estimated that over 1300 manufacturer-identified nanotech products are publicly available, with new ones hitting the market at a pace of 3–4 per week.

Nanotechnology is being used in developing countries to help treat disease and prevent health issues. The umbrella term for this kind of nanotechnology is Nanomedicine.

Nanotechnology is also being applied to or developed for application to a variety of industrial and purification processes. Purification and environmental cleanup applications include the desalination of water, water filtration, wastewater treatment, groundwater treatment, and other nanoremediation. In industry, applications may include construction materials, military goods, and Nano-machining of Nano-wires, Nano-rods, few layers of grapheme,etc.

IV. Result and Discussion

4.1 Heat Transfer

The ratio of thermal conductivity and heat transfer coefficient of Nano fluid in comparison with the base fluid emphasize the local heat transfer augmentation. This analysis is carried out at Re_{nf}= 7000. This reveals that as the concentration increases, the effect of increasing nanoparticles concentration on changing the thermal conductivity is lower than changing the heat transfer coefficient. As an example, for a volume concentration of 2 vol%, the local heat transfer coefficient ratio is about hr= 2.05 while the thermal conductivity ratio is kr= 1.55. The effect of nanoparticles concentration on the heat transfer coefficient and Nusselt number. Results show that the heat transfer coefficient and Nusselt number can be enhanced by adding nanoparticles to the base fluid. Enhancement of heat transfer by the Nano fluid may be resulted from the following two aspects: first the incremented particles which increase the thermal conductivity of the mixture; second, chaotic movement of ultrafine particles accelerates the energy exchange between the fluid and the wall of the heat exchanger. However, it should be noted that increasing the particles concentration raises the fluid viscosity and decreases the Reynolds number and consequently decreases the local heat transfer behavior. But the results indicate that increasing in particles concentration raises the heat transfer coefficient. This is due to the fact that the change in the thermal conductivity is more effective than the change in the fluid viscosity on heat transfer enhancement of nano- fluid at higher concentration.

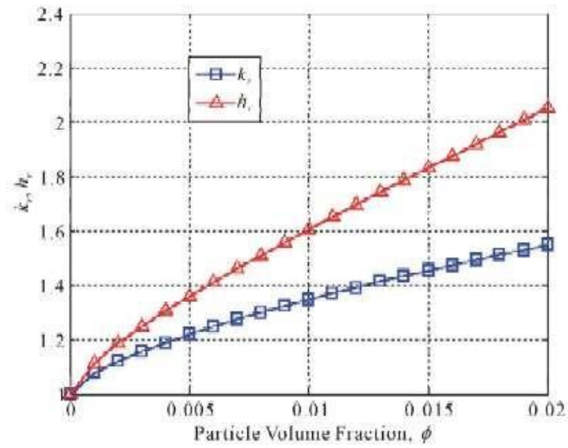

Figure 4. Comparison between *kr*and *hr*for CuO-water Nano fluid heat transfers at different volume fractions**.**

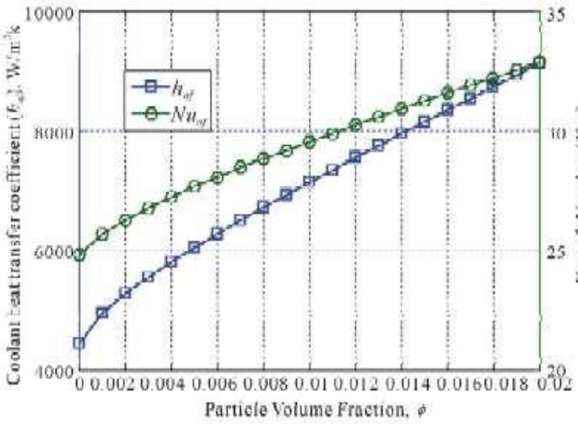

Figure 5. The Local heat transfer coefficient and Nusselt number for CuO-water nanofluid coolant at various concentrations.

4.2. Overall Heat Transfer

The below shows the overall heat transfer coefficient for CuO-water Nano fluid coolant in an heat exchanger that has been calculated. In this analysis, Reynolds number of the Nano fluid is 7000. As shown in this figure, the overall heat transfer coefficient is high when the probability of collision between nanoparticles and the wall of the tubes has increased under higher concentration conditions. It confirms that Nano fluids have considerable potential to use in the heat exchanger. A further inspection shows that the overall heat transfer coefficient of the CuO-water nano- fluid for volume concentrations in the range of 0.1% to 0.5% is about 162 and 467.9 W/m2k, respectively.

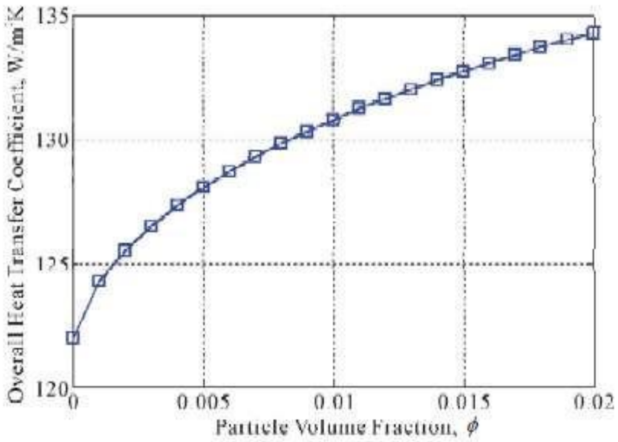

Figure 6. Variations of overall heat transfer coefficient for nanofluid at different volume fractions.

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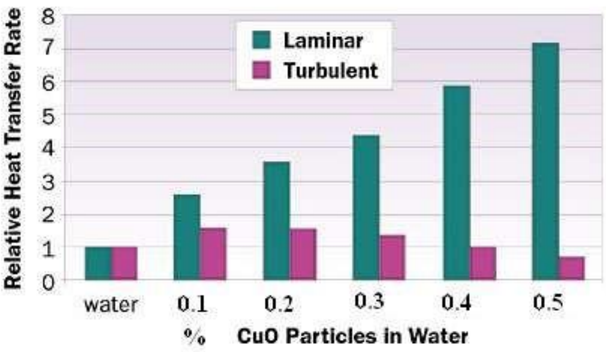
4.3 Properties of Various Nano fluids with Varying Concentrations

Fluid	Density kg/m^3	Specific Heat J/kg-K	Thermal Conductivity W/m-K
Water	997.8	4183.2	0.602
Water + .1% CuO	1094.8	3493.3	0.694
Water + .2% CuO	1332.8	3479.3	0.756
Water +.3% CuO	1491.5	3403.4	0.799
Water +.4% CuO	1529.6	3389.4	0.868
Water +.5% CuO	1688.3	3313.5	0.916



V. Conclusion

The convective heat transfer coefficient of a CuO/water Nano fluid flowing in a shell and tube heat exchanger was investigated. The Nano fluid was prepared by dispersing CuO (20nm) particles in deionized water. This experimental result showed that the convective heat transfer coefficient of Nano fluids were remarkably increase compared to base fluid (water). The enhancement of Nano fluid is directly proportional to the particle volume concentration.

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