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EXPERIMENTAL STUDY ON EVALUATION OF HEAT TRANSFER RATE IN CONCENTRIC TUBE HEAT EXCHANGER USING CUO TRANSFORMER OIL BASED NANO FLUIDS

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Abstract- Heat exchangers are the equipments used to transfer the heat from one fluid to another which are at different temperatures. Different types of heat exchangers are extensively used in various industries to transfer the heat between cold and hot fluids. The key role of the heat exchanger is to transfer heat at maximum rate. Concentric tube heat exchanger has potential application such as heat recovery from engine cooling circuit, oil cooling, de superheating in refrigeration and air conditioning, dairy, and chemical industry, pharmaceutical industry, refinery, etc. In this paper concentric tube heat exchanger is designed and fabricated with inner pipe made of copper and outer pipe made of galvanized iron. The CuO nanoparticles of about30 nm diameter are used in the present study. Nanoparticles were dispersed in the base fluid to enhance the rate of heat transfer and overall heat transfer coefficient. The results shows that heat transfer rate and overall heat transfer co-efficient of nano fluid is slightly higher than that of the base liquid at same mass flow rate .The heat transfer rate and overall heat transfer co-efficient of nano fluid increases with the increase of the volume concentration of the CuO nano fluid .There is a wide scope on performance of heat exchanger and applications of nano fluid in the coming years.

Key words: Concentric tube heat exchanger, Nano fluids, Heat Transfer, Overall heat transfer coefficient

I. INTRODUCTION

A heat exchanger is a device that transfers thermal energy from a high-temperature fluid to a low-temperature fluid with both fluids moving through the device. Heat exchangers facilitate the exchange of heat between the fluids that are different temperature while keeping them from mixing with each other. Heat exchangers find widespread use in power generation, chemical processing, electronics cooling, air-conditioning, refrigeration, and automotive applications. A Nano fluid is a fluid contain nanometer size metal particle, called nanoparticles. These fluids are engineering colloidal suspension of nanoparticles in base fluid. Nanoparticles used in nano fluids are typically made of metals, oxides, carbides or carbon nano tube. Common base fluids include water, ethylene glycol and oil. They exhibit high thermal conductivity and convective heat transfer coefficient compared to the base fluid. Nano fluid is used as a cold fluid in heat exchanger which considered as a three phase fluid i.e. solid phase (nanoparticles), liquid phase (base fluid), and interfacial phase therefore it increases the rate of heat transfer and efficiency of heat exchanger as well. Nanofluid is prepared either by one-step or two-step method. In one-step method nanoparticles are synthesized in base fluid by using chemical methods. In case of two step method nanoparticles are firstly prepared in powder form by physical or chemical methods like laser ablation and sol- gel processing. Nano fluid stability and concentrations are characterized for best results.

Argonne National Laboratory of USA by Choi in 1995 [1] which showed that thermal performance of conventional liquid could be remarkably improved using nanoparticles .Albadr et al. [2] experimentally studied horizontal shell and tube heat exchanger for forced convective heat transfer and flow characteristics of a counter flow under turbulent flow conditions for water as base fluid and different volume concentrations of Al_2O_3 nano fluid. Nitin Jaju et.al[3] proposed the research and practical work done on tube heat exchanger by using nanofluids which is a heat transfer augmentation technique. Glimpses are given on methods of preparation of nanofluid as well as parameters that affect nanofluids .V.Santhosh Cibi, et al., [4] studied on convective heat transfer increment with graphite nanofluids by the use of shell and tube heat exchanger. They mainly focus during their research study the graphite nanofluids performed great in shell and tube heat exchanger for laminar. They used Graphite nano powders for the experimentation and stirrer with the base water by varying its concentration in the range of 0.025, 0.05, and 0.075 (in percent) by volume. During the experimentation they observed that when the concentration of the graphite was rises with different concentrations, the heat-transfer-co-efficient rises gradually with the concentrations. They also concluded that the performance of graphite on thermal conductivity value of nano fluids was much best than heat transfer-coefficient of nano fluids, and also with graphite rise concentration and flow performance of the coldest fluid. V. Murali Krishna et.al. [5] conducted experiments to study the heat transfer rates of Al_2O_3–water nanofluids for different flow rates and volume concentrations in a concentric tube heat exchanger. Dharmalingam et.al.[6] carried out experimental study on heat transfer characteristics of water based Aluminum oxide nano fluid in a counter, parallel flow direction in a shell and tube heat exchanger in this the overall heat transfer coefficient increases with increase in mass flow rate of the nano fluid Nitheesh Krishnan et.al[7] the effect of the heat transfer characteristics in shell and tube heat exchangers using Nano fluids Heat transfer rate increases with increasing concentration of nano particle. Nanofluids are more efficient as compare to other base fluids. Efficiency of heat exchanger is varies by factors like temperature flow rate, concentration of nano fluid, size of heat exchanger. P.V.Durga Prasad et.al. [8] carried out experimental investigation to enhance the heat transfer by using Aluminum oxide nano fluids at low volume concentrations and trapezoidal cut twisted tapes. K.P.V. Krishna Varma et.al carried out experimental investigation on Enhancement of Heat Transfer Using Fe_3O_4/Water Nanofluid with Varying Cut-Radius Twisted Tape Inserts and showed that the average Nusselt numbers increase with an increase of Reynolds number and the nano particle volume concentration Convective heat transfer, friction factor as well as thermal performance factor associated with the simultaneous application of nano fluid and variable cut-radius inserts are higher than those associated with the individual techniques. Raei et.al.[10] Measured overall heat transfer coefficient and friction factors of water based γ-Al_2O_3 nano fluid in a double pipe heat exchanger and results are demonstrated that increasing the concentration of nano fluid, flow rate and inlet temperatures increase the overall heat transfer coefficient and heat transfer rate.

In this present paper CuO nano particle is selected with transformer oil as base fluid. The experimentation is conducted for varied volume concentration and different temperatures to study the effect of nano fluid on heat transfer rate and overall heat transfer coefficient.

II. PREPARATION OF NANO-FLUIDS

In this work, nano fluids with different volume concentrations are prepared using two step techniques. The commercially available Nano powders obtained from different mechanical, physical and chemical routes such as milling, grinding, and sol-gel and vapor phase methods were used. The CuO nanoparticles with average size of 20-50 nm are uniformly distributed into the base fluid Transformer oil for making stable nano fluids of different volume concentration of 0.05 %, 0.1%, 0.5%, 1.0% and 1.5%

Table 1: Specifications of Base fluid (Transformer oil)

Sl. No.	Properties	Base fluid (Transformer Oil)
1	Density	900 kg/m^3
2	Thermal conductivity	0.157 W/ mK
3	Specific heat	1860 J/kg K
4	Viscosity	0.013350 Pa-s

A. Characterization of Nano fluids

Thermo physical properties of Nanofluid

1. The effective properties of nanofluids like density, specific heat, thermal conductivity, and viscosity are to be calculated according to the mixing theory.
2. The density of Nanofluid is calculated using Pak and Cho correlations.

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

where, ρ_{nf} is the density of nano fluids, ρ_{bf} is the density of base fluid (Transformer oil),ρ_p is the density nanoparticles (Al_2O_3 and CuO),φ is the volume concentration.

3. The specific heat of Nanofluid is calculated from Xuan and Roetzelcorrelation .

$$\rho_{nf}Cp_{nf} = (1-\varphi)\,\rho_{bf}Cp_{bf} + \varphi\,(Cp)p\,\rho_p$$

where, Cp_{nf} is the specific heat of Nanofluid, Cp_{bf} is the specific heat of base fluid (transformer oil),Cp_p is the specific heat of nanoparticles (Al_2O_3 and CuO).

4.The thermal conductivity of Nanofluid is calculated from Maxwell formula

$$k_{nf} = \frac{k_p + 2k_{bf} + 2\varphi(k_p - k_{bf})}{k_p + 2k_{bf} - \varphi(k_p - k_{bf})} k_{bf}$$

where, K_{nf} is the thermal conductivity of Nanofluid, K_{bf} is the thermal conductivity of base fluid (transformer oil), Kp is the thermal conductivity of nanoparticles (Al_2O_3 and CuO).

5. The viscosity of nanofluids is calculated using Drew and Pass man correlation.

$$\mu_{nf} = (1 + 2.5\,\varphi + 6.2\varphi^2)\mu_{bf}$$

Where, μ_{nf} is the viscosity of Nanofluid, μ_{bf} is the viscosity of transformer oil.

B EXPERIMENTAL SET UP

Schematic View of Experimental Setup

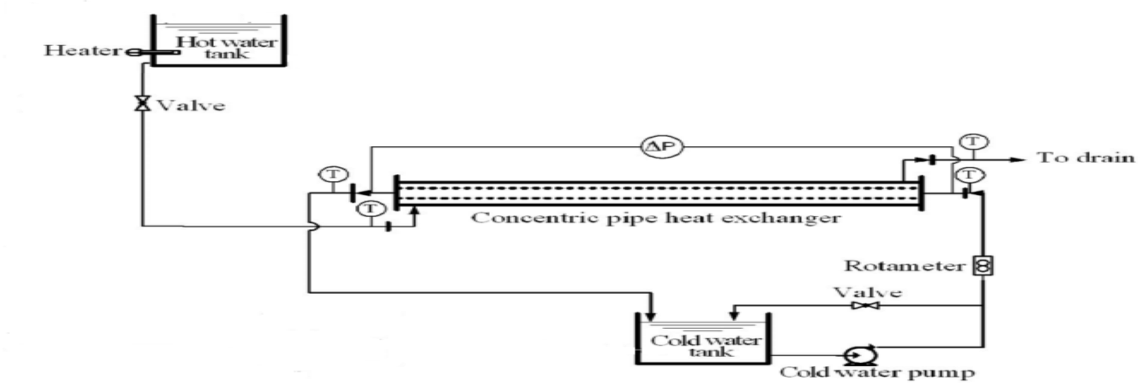

Fig. 1: Schematic View of Experimental Setup

The Fig:1 shows the Schematic view of concentric tube heat exchanger. The setup mainly consists of the following components namely heating element, heat exchanger, reservoir and pump. Concentric tube is considered in the heat exchanger. The outer tube is made up of a galvanized iron (GI) with outer diameter 42mm, inner diameter40mm. The inner pipe is made up of copper with outer diameter 13mm and inner diameter 12mm.The length of the pipe is 1000mm. The reservoir is made up of mild steel, which is coated to avoid corrosion. Here in reservoir nanofluids is stored which is supplied to the test section. The pump with (voltage 160-230V,maximum head 1524mm,discharge 800ltrs/hr) is used to supply working fluid or nanofluids from reservoir to test section .A heater of capacity 0-10 litres is used.

The experimental setup with the above principle components also consist of measuring components such as flow meter having a maximum capacity 350 cc/sec to measure flow rate of working fluid supplied to the test section using the pump. It is fixed in between the reservoir output and entry section of the heating element. To measure the temperature of working fluid at different states of system the thermocouple are fixed at the different points along the flow of working fluid.

C. Analysis of heat Exchanger:

The experiment is conducted by using concentric tube heat exchanger for constant mass flow rate and the flow is parallel. The temperature of hot and cold fluids were noted for different volume concentration 0.05,0.1,0.5,1.0,1.5% for three different temperatures 60^0,70^0,80^0C.From the obtained value heat transfer and overall heat transfer co-efficient is calculated using empirical equations.

From the experimental system, the values that have been measured are the temperatures of the inlet and outlet of the hot fluid and cold fluid for different concentrations of nanofluids at constant mass flow rates.

Hot fluid Heat transfer rate

$Q_h = m_h * C_{ph} * (T_{hi} - T_{ho})$

Cold fluid Heat transfer

$Q_c = m_c * C_{pc} * (T_{co} - T_{ci})$

where, m_h and m_c are the mass flow rate of hot and cold fluid respectively.

C_{ph} and C_{pc} are the specific heat of hot and cold fluid respectively. T_{hi} and T_{ci} are the inlet temperature of thehot and cold fluid and T_{ho} and T_{co} are the outlet temperature of the hot and cold fluid respectively.
The logarithmic mean temperature difference is
LMTD

$$\Delta T_{lm} = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln\left(\frac{T_{hi} - T_{co}}{T_{ho} - T_{ci}}\right)}$$

The overall heat transfer coefficient is

$$Q=UA_s\Delta T_{lm}$$

The experiment is conducted by using concentric tube heat exchanger for constant mass flow rate and the flow is parallel. The temperature of hot and cold fluids were noted for different volume concentration 0.05,0.1,0.5,1.0,1.5% for three different temperatures 60^0,70^0,80^0C.From the obtained value heat transfer and overall heat transfer co-efficient is calculated using empirical equations.

III RESULTS AND DISCUSSION

In this paper a concentric tube heat exchanger is fabricated and experimentation is conducted and results were obtained by using certain equations and the results were plotted for different volume concentrations for different temperatures.

A. Overall heat transfer coefficient

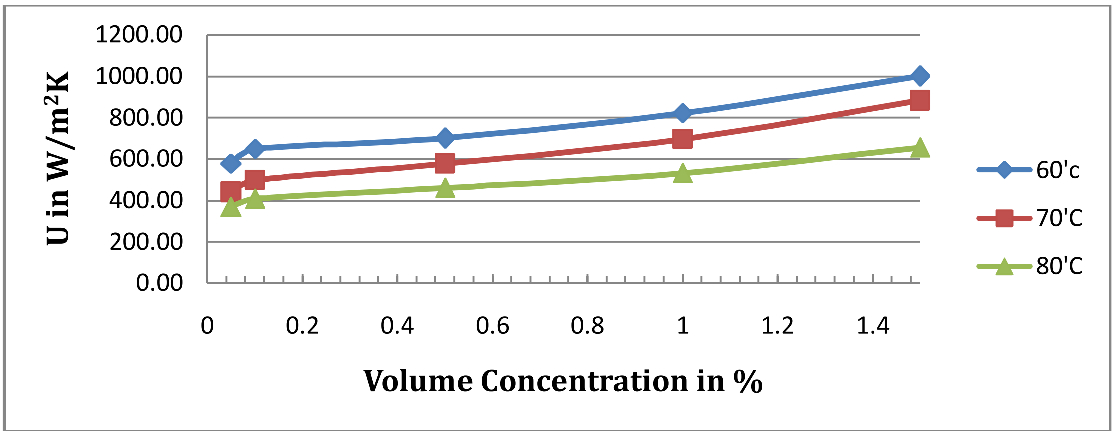

Fig 2:Variation of overall heat transfer co-efficient for different volume concentration at different temperature

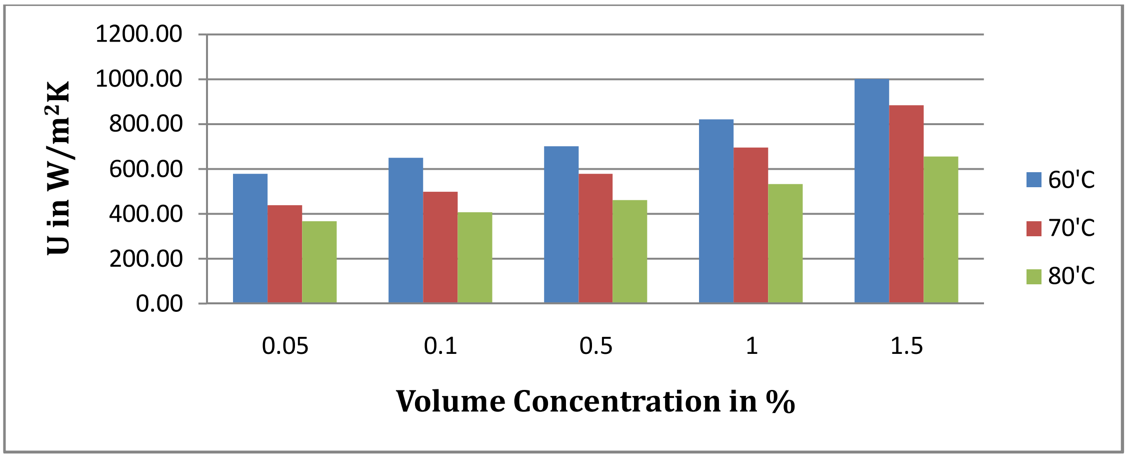

Fig3:Variation of overall heat transfer co-efficient for different volume concentration at different temperature(bar chart)

From the results it is observed that overall heat transfer coefficient increases with increase in volume concentration compared to base fluids. The maximum enhancement of overall heat transfer co-efficient occurs at 1.5% volume concentration for CuO transformer oil nano fluids. This increase of heat transfer co-efficient may be caused by high concentration of nano particles towards the wall side by particle migration and force of attraction.The overall heat transfer coefficient of nano fluids decreases with the increase of temperature since it depends on logarithmic mean temperature difference.

B. Heat Transfer Rate

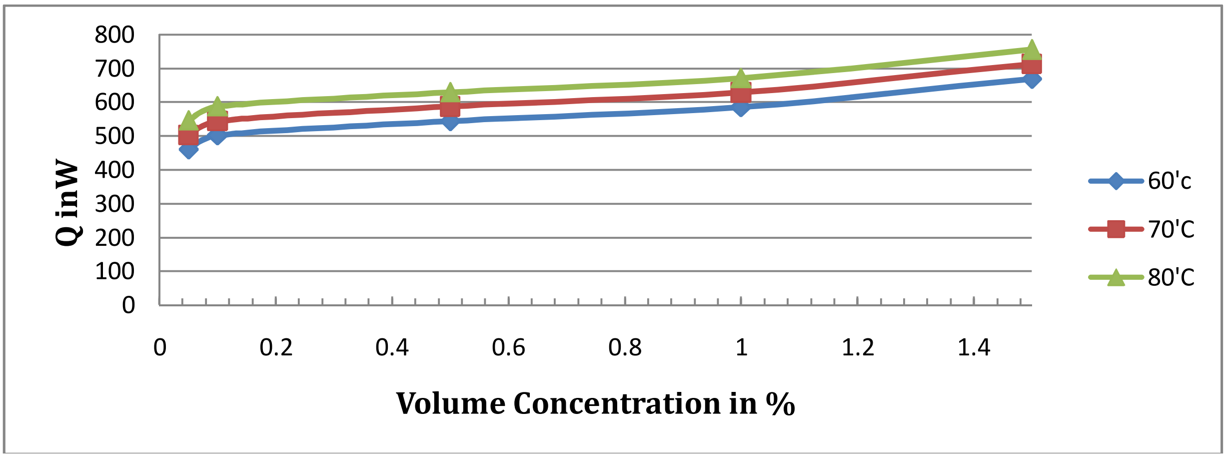

Fig 4:Variation of heat transfer for different volume concentration of CuO Transformer oil nano-fluids for different temperature

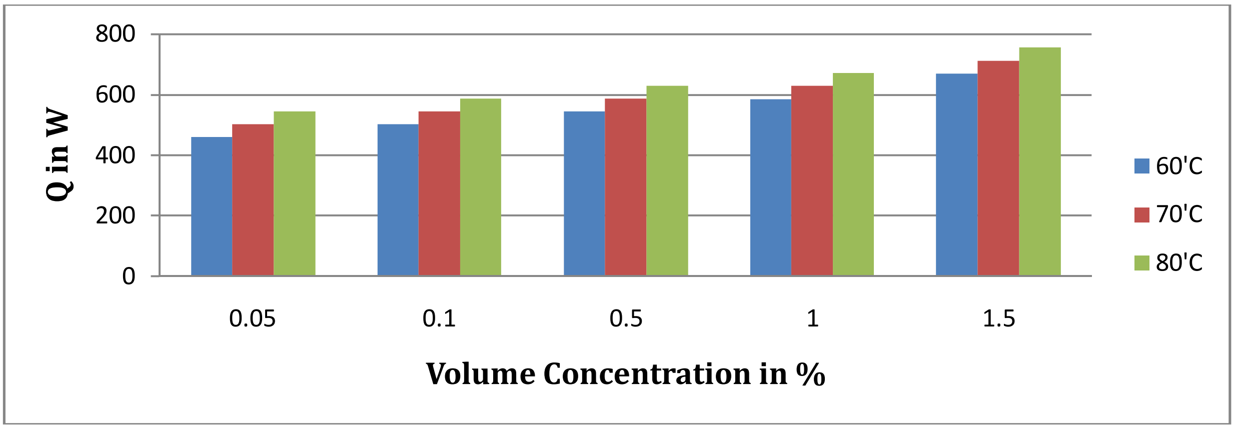

Fig 5: Variation of heat transfer for different volume concentration of CuO Transformer oil nano fluids for different temperature (Bar chart)

Fig: 4 and 5 shows the variation of heat transfer during the process for different volume concentration of CuO transformer oil. Since the heat capacity of nano particles decreases as the concentration of nanoparticles into the base fluid increases which is the reason for nano fluids enhanced heat transfer than conventional fluids.

IV CONCLUSION

In this work concentric tube heat exchanger is fabricated and experimental analysis is carried. Nano particle used is CuO. Nano fluids with different concentration (0.05, 0.1, 0.5, 1.0, and 1.5%) were used for experimental analysis. The following conclusions are drawn

- The heat transfer rate and overall heat transfer coefficient were determined for transformer oil based CuO nano fluids of different volume concentrations.
- Heat transfer rate increases with increasing volume concentration for CuO transformer oil nano-fluids
- Overall heat transfer co-efficient increases with increase in volume concentration for particular temperature. Thus Nanofluids are found to be more efficient as compared to base fluids.

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