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Enhancement of Double-Pipe Heat Exchanger Effectiveness by Using Water- CuO

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ABSTRACT. This study utilized Nano fluid as a cold fluid in evaluating the counter flow double tube heat exchanger, which will one meter long, an outer diameter of 19 mm, and an inner diameter of 9.5 mm made of copper. Water was the basic fluid, mixed with 40 nm, a volume concentration of (0.5%) and (1%), respectively, of CuO nanoparticles. At 2 L/min , 4 L/min and 6 L/min, Nano fluid flows inside the inner tube. At 20°C, the Nano fluid enters the heat exchanger. The flow of hot water into the heat exchanger is 4 L/min through an annular space with an entry temperature of 65 °C. To achieve better heat exchanger performance. The experimental results will compare to those of pure water. The improvement in performance with Nano fluid as a working fluid was found as (40%) maximum effectiveness obtained at Nano fluid flow rate of 2 L/min with (0.5%) volume concentration and effectiveness (54%) at (1%) a volume concentration.

Keywords: Double tube heat exchanger, Nano fluid, overall heat transfer coefficient, effectiveness of heat exchanger.

Introduction

The heat exchanger is a method in which heat is transferred between two fluids without mixing, therefore a difference in temperature is required. This difference can be reduced by using a larger heat exchanger, but this will lead to an increase in volume and costs. The considerations of these two directions are very important in designing devices Heat transfer is not only in terms of performance characteristics, but also in terms of the capacity or size of the space allocated for this exchanger and the economic cost of manufacturing the exchanger. The heat exchangers played a very important role in the engineers' awareness of energy and their desire to find optimal designs not only in terms of thermal analysis and economic returns ،but also in terms of returns in terms of energy conservation [1-3]. In order to improve the heat transfer process, a change is required in the physical-thermodynamic properties of the fluids used. The conventional liquids have somewhat low thermal conductivity if compared to some non-metallic solids such as copper oxide, alumina, and metallic solids such as copper and aluminum. Therefore, it is necessary to find ways and ideas to enhance the properties of the fluids used by adding solid particles to these fluids. As a result of the development taking place at the present time, it has become possible to manufacture particles of Nano scale sizes easily disperse and suspend in the basic liquid such as water or oil. The new fluids showed better thermal properties without any deposits that might block the channels through which they pass due to the small size of their particles [4].

2.Methodology

1.2 Experimental procedure

The test device shown in Fig. (1) consists of two double-tube heat exchangers (two concentric tubes) and two 6-liter thick plastic basins, one of which is to heat the water by an electrical coil of 3000 watts, to a temperature of 65 ℃ before entering the pump into the primary heat exchanger. The second basin, was used to collect the Nano fluid coming from the secondary exchanger and continue mixing it by an electric mixer to ensure the suspension and spread of the nanoparticles in the water homogeneously, as well as to maintain the temperature of the nanoparticles at 20 ° C by cooling it in an airtight plastic container with ice placed inside the tank.

Table 1: Research review of double-tube heat exchangers with the results of improvement reached by researchers

Sr No	Author Name	Nano fluid Used	% volume concentration of Nano fluid	Type of Heat Exchanger	Enhancement in Heat Transfer Coefficient& Heat transfer rate
1	Aghayari et.al[5] (2015)	Al2O3/water (20nm)	(0.1-0.3)%	mini double-pipe heat exchanger	The heat transfer of the Nano fluid is much higher than 12% compared to the heat transfer of the base fluid
2	Mahrooghi et.al[6] (2015)	Al2O3/Water (20 nm)	(0.2-0.3)%	double-pipe heat exchanger	(Al2O3/water 0.2%Higher at 0.3% 0.3% Higher at 0.5%.
3	Singh et.al[7] (2016)	TiO2/water (10-20)nm CuO/water (30-50)nm	(0.1,0.2,0.3)%	double-pipe heat exchanger	(TiO2/ CuO) /water 0.3%Higher at 5%
4	Talib et.al[8] (2017)	Al2O3/water (20nm)	0.6%	double-pipe heat exchanger	Al2O3/water 0.6%Higher the heat transfer at 26%
5	Aghayari et.al [9] 2014)(	Al2O3/water (20nm)	0.1-0.2)%(	double-pipe heat exchanger	The total heat transfer is 10% and the amount of heat transferred is 8% compared to water as the main liquid
6	Krishna[10] 2017)(	CuO/water 40nm)(	0.1-0.3-0.5)%(	double-pipe heat exchanger	Increase in the total heat transfer coefficient of 22% at a volume concentration of 0.5% compared with water as a base liquid.

3.Nano fluids preparation

The mass of the solid nanoparticles that will be mixed and suspended or dispersed in pure water was calculated after determining the mass of pure water for a volume of 2 liters, 4 liters, and 6 liters with a volume concentration ratio of (0.5% and 1%) using equations (1) [3-11]:

$$m_p = \frac{\emptyset \times \rho_p \times \left(\frac{m_f}{\rho_f}\right)}{(1-\emptyset)} \quad ......(1)$$

After calculating the amount of solid nanoparticles, they are combined with pure water in two ways[12]:

The two-step method was used to mix the nanoparticles with pure water and are summarized as follows [13-14]:

1. Preparing the amount of nanoparticles calculated from equation (1) above, using an electronic balance to obtain the specific weight to mix it with a weight of (2) liters, (4) liters and (6) liters of pure water .
2. Mixing the prepared nanoparticles with 2 liters of pure water using an electric mixer that was kept running for a period of time ranging between (30-40) minutes until it became completely homogeneous .
3. Putting the resulting mixture into an ultrasound device (Ultrasonic) for the purpose of dispersing the nanoparticles and ensuring that they are suspended homogeneously in the mixture .

After completing the preparation of the Nano fluid and obtaining a homogeneous fluid, it was placed in the basin dedicated to the Nano fluid in the test device and continued to be mixed during the period of the test by an electric mixer installed in the basin for this purpose to ensure the suspension and spread of the nanoparticles homogeneously [15-16].

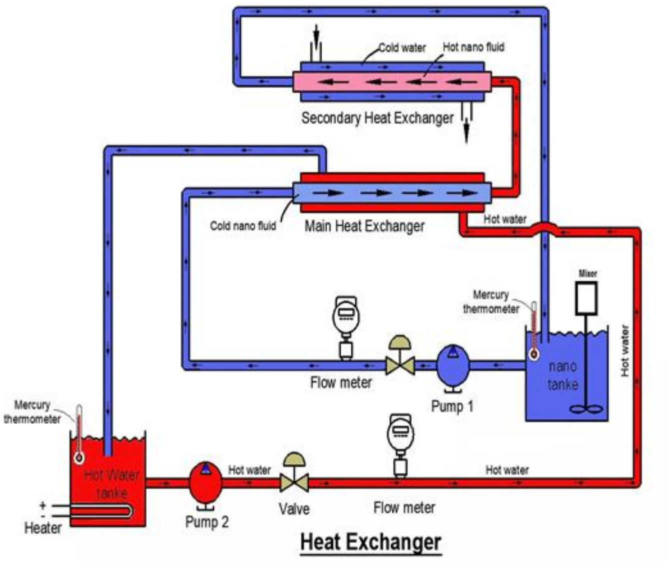

Fig.1: Shows a picture of the test device.

4. Action Steps:

(Procedure)

After making sure that the test device was ready and finished preparing the Nano fluid and placing it in its basin, the following steps were followed [8]:

1. Operating the electric mixer installed in the Nano fluid tank and continuing to operate it throughout the period of the experiment to ensure the dispersion of the nanoparticles in the water.
2. Turning on the electric coil to heat the water in the second basin and raise its temperature to 65 ° C. This is achieved through a thermostat set for this purpose.
3. Determine the required quantities of hot water and cold Nano fluid passing through the tubes of the heat exchanger. The flow rates were controlled by pyloric valves, where the flow rate for hot water was (4) liters minute, while the flow rates for Nano fluid were (2) liters per minute, (4) liters per minute, and (6) liters / minute. These flow rates were measured with two flow meters installed in the tester.
4. Continuing monitoring of temperature gauges at the inlet and outlet of the exchanger for both hot and cold fluids and recording temperature values every ten minutes after checking the state of stability.

Steps to Determine the Overall Heat Transfer Coefficient and Effectiveness of an Experiment [17]:

Hot Water Flow Rate

$$\dot{m}_h = \frac{\dot{V}}{60000} \times \rho \qquad \text{....... (2)}$$

Cold Water Flow Rate

$$\dot{m}_c = \frac{\dot{V}}{60000} \times \rho \qquad \text{...... (3)}$$

Hot water heat transfers to cold water.

$$q_h = \dot{m}_h \times \mathrm{Cp_h} \times (\mathrm{Th_i} - \mathrm{Th}_o) \qquad \text{.........(4)}$$

Cold water to hot water heat transfer

$$q_c = \dot{m}_c \times \mathrm{Cp_c} \times (\mathrm{Tc_o} - \mathrm{Tc}_i) \qquad \text{........(5)}$$

Average Heat Transfer

$$q_{avg} = \frac{q_h + q_c}{2} \qquad \text{.........(6)}$$

Inner Pipe Inner Surface Area

$$A_i = \pi \times d_{i,ip} \times L \qquad \text{.........(7)}$$

For Counter Flow Arrangement, Logarithmic Mean Difference In temperature

$$\mathrm{LMTD} = \frac{(\mathrm{Thi} - \mathrm{Tc0}) - (\mathrm{Th0} - \mathrm{Tci})}{\ln(\mathrm{Thi} - \mathrm{Tc0}) / (\mathrm{Th0} - \mathrm{Tci})} \qquad \text{..........(8)}$$

Based on the inner surface area of the inner pipe, the practical overall heat transfer coefficient

$$U_i = \frac{q_{avg}}{A_{i,ip} \times \mathrm{LMTD} \times F} \qquad \text{........(9)}$$

Cold Water Flow Rate Heat Capacity

$$Cc = \dot{m}_c \times Cp_{,c} \qquad \text{.......(10)}$$

Flow Rate of Hot Water Heat Capacity

$$Ch = \dot{m}_h \times Cp_{,h} \qquad \text{...........(11)}$$

Flow Rate of Minimum Heat Capacity

Cmin=Minimum Value out of Cc and Ch ......(12)

Flow Rate of Maximum Heat Capacity

Cmax=Maximum Value out of Cc and Ch .....(13)

Maximum Heat Transfer Possibility

$$q_{max} = C_{min}(Th_i - Tc_i) \qquad \text{..........(14)}$$

Effectiveness of the Heat Exchanger

$$\varepsilon = \frac{\Delta T_{min}}{\Delta T_{max}} \qquad \text{.........(15)}$$

5. Results and Discussion:

It can be seen that the addition of nanoparticles to the cold water flowing inside the inner tube increased the temperature difference between the inlet and outlet of the heat exchanger for both hot and cold fluids. This is indicated in Figure (1) which represents the temperature difference variation of the cold liquid of pure water and Nano fluid. It can be seen that the temperature difference decreases with increasing flow rate. Figure (2) shows the enhancement in the overall heat transfer coefficient when adding nanoparticles to water for both values of the volumetric flow rates. This is due to improving the thermo physical properties of the liquid by adding nanoparticles compared to pure water. Figure (3) shows the same trend for the overall heat transfer coefficient of the heat transfer rate. This is because the heat transfer is directly related to the overall heat transfer coefficient. the enhancement in the overall heat transfer coefficient, where the volume flow rate was (2) liters per minute (25%) at a volume concentration (0.5%) and a strengthening rate of (35.7%) at a volume concentration (1%), while the relative strengthening was (16%) for (4) liters Per minute at a volume concentration of (0.5%) and a boost rate of (17%) at a volume concentration of (1%). When flowing - (6) liters per minute, the rate was (17)% at a volume concentration of (0.5%) and (18%) at a volume concentration of (1%). The effectiveness of the heat exchanger was calculated with the values of the volumetric flow rate of pure water and Nano fluid Figure (4) shows that the effectiveness of both decreases with an increase in the volume flow rate, and there is an improvement in the effectiveness of the heat exchanger when using Nano fluid as a working fluid. The maximum improvement in effectiveness was (54%), for (2) LPM volume flow rate and at volume concentration (1%).

6. Conclusion:

1. The overall heat transfer coefficient increased when using a Nano fluid instead of pure water.
2. The maximum percentage enhancement in overall heat transfer coefficient when using Nano fluid was (35.7%), for a volume flow rate of (2) LPM at a volume concentration (1%).
3. The maximum percentage enhancement in heat transfer rate when using Nano fluid was (55.5%), for a volume flow rate of (2) LPM at a volume concentration (1%).
4. The maximum heat exchanger effectiveness obtained, when using Nano fluid was (54%), for a volume flow rate of (2) LPM at a volume concentration (1%).

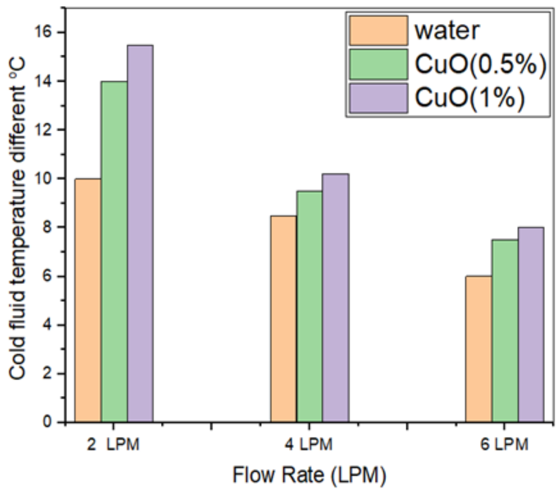

Fig.1: It shows the difference between the entry and exit temperature of the fluid passing through the inner tube, with a volume concentration ratio of (0.5 and 1%) for the nanofluid.

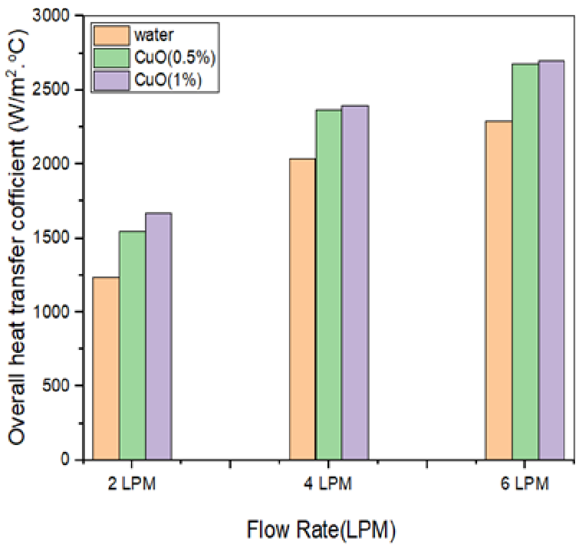

Fig.2: overall heat transfer coefficient with volume flow rates

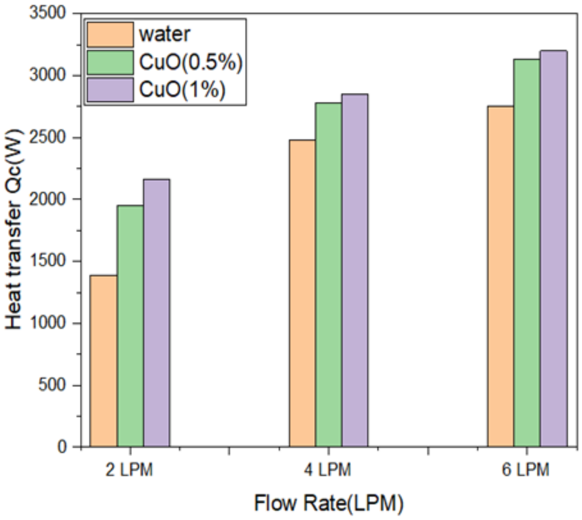

Fig.3: heat transfer with volume flow rates.

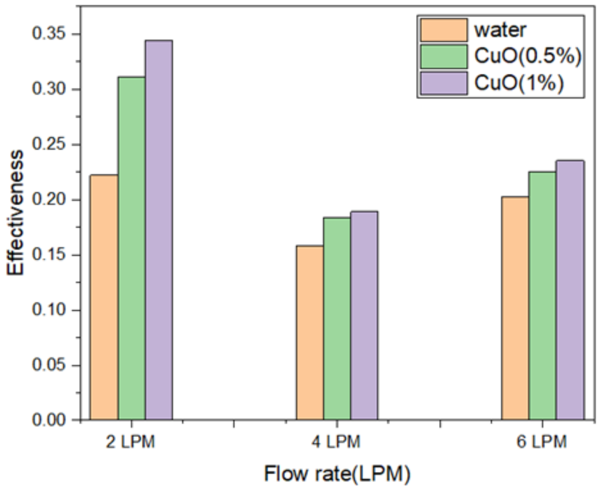

Fig.4: Effectiveness with flow rates.

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