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Improve Performance of Double Pipe Heat Exchanger by Using Zno/Water Nanofluid

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Abstract

The heat transfer of double tube heat exchanger under counter flow is experimentally investigated. Nanofluid and the pure water are used as cold and hot fluids respectively. ZnO nanoparticles of 30 nm diameter are dispersed in water to prepare nanofluid with mass concentrations of 0.5 and 1%. Cold nanofluid is flowing through the inner tube heat exchanger with 20°C temperature under 2, 4 and 6 lpm volume flow rate. The hot water enters the annular space of the heat exchanger at a temperature of 65°C and 4 lpm volume flow rate. To improve the performance of the heat exchanger, the experimental findings achieved using this sort of nanofluid will be compared to those obtained using pure water. The outcomes showed that employing nanofluid as the working fluid improved performance. When employing nanofluid, the highest heat exchanger effectiveness is 40 % for nanoparticles concentration of 0.5 % per mass and 54 % (with a mass concentration of 1 %) with a volume flow rate of 2 lpm.

Keywords: Effectiveness, nanofluid, Double pipe heat exchanger, Nusselt number.

1. Introduction:

A heat exchanger is the most efficient way to transfer heat across two fluids without combining them, so long as there is a temperature difference between them. However, increasing the size of the heat exchanger will increase both its volume and its cost. If you want to evenly heat your material throughout, you need to use a heat exchanger procedure [1, 2]. Nanofluids have become used in many practical applications in all areas of heat transfer, and these applications include air conditioning, ventilation, refrigeration, heating, automobile cooling system, devices of electronic, renewable energy systems, nuclear systems, biomedical applications, automobile cooling and

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transformer cooling oils. Therefore, many researchers and scholars focused their efforts on studying these fluids and the change they cause in the effectiveness of the systems when they are added to the traditional fluids used [3].

By reviewing previous experimental research related to enhancing the heat transfer of nanofluids and comparing the results obtained with conventional fluids. The researchers identified the most important factors that affect nanofluids, including the concentration of particles, the type of material, the basic fluid material, and temperature, and they found that there is an enhancement of heat transfer process using nanofluids [4].

The experimental conducted investigations of a double pipe heat exchanger with cold and hot fluids. It was considered that the cold and hot water were flowing through outer and inner tube respectively. The coefficient of heat transfers and energy generated were estimated for various velocity for cold water while keeping constant velocity. Repeated the tests for volumetric concentrations 0.1 and 0.05 percentage of CuO, MgO and (ZnO) nanofluids. It was comparison of heat transfer and efficiency between nanofluids and pure water results. It was concluded that CuO nanofluid is the best for heat transfer as compared to ZnO and MgO nanofluids [5]. Experimental study on a double-tube heat exchanger was conducted by [6]. Hot water passes through the inner tube while the nanofluid passes through the space between the two tubes. CuO nanofluid was used with different volumetric concentrations. It was concluded that there is an increase in the coefficient of. The total heat transfer is 22% at a volume concentration of 0.5% compared to water as a base liquid [6]. The researcher carried out an experimental study using nanofluid in a double-tube heat exchanger (Al_2O_3, TiO_2) with volumetric concentrations (0.2-1.5) %. The results showed a significant improvement in the performance of the system that uses nanofluid compared to the system that uses water as a base fluid [7]. reviewed the research published during the past five years, which was concerned with studying the use of nanofluids and their impact on the performance of different heat transfer systems, and the researchers concluded that there is a wide range to improve heat transfer rates [8]. An experimental study to measure the total heat transfer coefficient and the amount of heat transferred in a double-tube heat exchanger using a nanofluid Al_2O_3 with a diameter of 20 and with volume concentrations (0.001-0.002) and the flow was opposite and turbulent. With water as a base fluid [9]. The researcher carried out an experimental study; To find out the effect of the concentration of Al_2O_3 nanoparticles mixed in water as a base liquid on the performance of a double-tube heat exchanger and for two types of flow (parallel and opposite), the researchers used different volumetric

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concentrations ranging from (0.001 - 0.01) and concluded from the study that the total heat transfer coefficient increases. By increasing the volumetric concentration of nanoparticles in water, this increase continues until the volume concentration reaches 0.008 and then begins to decrease [10]. Summarization of number of researchers have been indicated in Table 1 shown below.

The originality points and the practical applications of this work is the using of ZnO nanofluid with 0.5 to 1% volume fractions in the double pipe heat exchanger. This work is not performed before this time and enhancement of heat exchanger effectiveness is found.

In this work, the heat transfer of pipe tube heat exchanger with different mass concentration of nanofluid is investigated experimentally. ZnO nanofluid is used as the cold fluid and water serving as the base fluid, nanoparticles of 30 nm diameter are utilized, with mass concentrations of 0.5 percent to 1 percent. The volume flow rate range is from 2 liters per minute to 6 liters per minute and hot water enters the shell on the outer pipe at a temperature of 65°C, Table (1).

Table (1) Summarize of literature survey.

	Ref.	Nanofluid	volume fractions	Heat Exchanger	Enhancement
1	[5]	Al_2O_3/water (20nm)	(0.1-0.3)%	mini double-pipe heat exchanger	The heat transfer of nanofluid is substantially higher than 12 percent when compared to water.
2	[6]	Al_2O_3/Water (20 nm)	(0.2-0.3)%	double-pipe heat exchanger	(Al_2O_3/water 0.2%Higher at 0.3% 0.3% Higher at 0.5%.
3	[7]	TiO_2/ water (10-20) nm CuO/water (30-50)nm	(0.1,0.2,0.3)%	double-pipe heat exchanger	(TiO_2/ CuO) /water 0.3%Higher at 5%
4	[8]	Al_2O_3/water (20nm)	0.6%	double-pipe heat exchanger	Al_2O_3/ water 0.6% Higher the heat transfer at 26%
5	[9]	Al_2O_3/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

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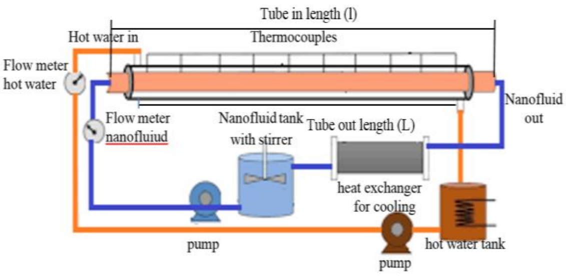
6	[10]	CuO/water 40nm	0.1-0.3-0.5)%(	double-pipe heat exchanger	Increase in the total heat transfer coefficient of 22% at a volume concentration of 0.5% compared with water as a base liquid.

2. Experimental Work:

2.1 Experimental procedure

The test system illustrated in Figure (1) consists of double-tube heat exchangers (two concentric tubes) and two 6-liter thick plastic basins, one of them is to heat the water to 70 degrees Celsius using an electrical coil of 3000 watts before pumping it into the primary heat exchanger. The second basin was used to collect the Nano scale water from the secondary exchanger and continue mixing it with an electric mixer immersed in it to ensure the homogeneous suspension and distribution of the nanoparticles in the water, as well as to maintain the temperature of the nanoparticles at 20°C by cooling it in an airtight plastic container container with ice inside the tank.

(a) Photograph of test rig.



(b) Schematic of experimental work.

Fig. (1): Experimental test rig.

2.3 Nanofluids preparation

After determining the mass of pure water for volumes of 2 liters, 4 liters, and 6 liters and weight concentration ratios of (0.5 percent and 1 percent), the mass of solid nanoparticles that will be mixed and suspended or dispersed in pure water was calculated using the following [11-13]:

$$\emptyset = \left(\frac{mp}{mp+mf}\right) \times 100 \qquad (1)$$

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To assess the quantity of solid nanoparticles that added to pure water with a weight of (6 liters). Following the determination of the number of solid nanoparticles, they are mixed with pure water in two ways:

The two-step approach for mixing nanoparticles with pure water (and for the two types of particles) is summarized below [14-15]:

1- Preparing the amount of nanoparticles calculated from equation (1), using an electronic balance to obtain the exact weight to mix with (2), (4), and (6) liters of pure water. The image of the scale with accuracy of 0.01g is shown in Figure (2).

Fig. (2): Electronic weighting test.

2- Mixing the produced nanoparticles with 2 liters of pure water with an electric mixer that was left running for 30 - 40 minutes until it became entirely homogenous. Because the mixer could only hold one liter, this operation was completed in four stages.

3-Place the final combination in an ultrasound instrument (Ultrasonic) with accuracy of 0.002 r/s to disperse the nanoparticles and ensure that they are dispersed uniformly in the mixture. Figure (3) depicts the ultrasonic device and the mixer, and the operation of the device was continued for (40-45) minutes. Because the gadget could only hold one liter, the process was divided into four steps. Repeat the same for the remaining weights.

Fig. (3): Mechanical stirrer and ultrasound device.

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A homogenous fluid made from the Nano scale water was poured in the test device's specialized basin and continuously mixed with an electric mixer over the duration of the test to guarantee uniform suspension and distribution of the nanoparticles [16-17].

2.3 Experimental test

The following processes [18] were carried out after the test apparatus had been verified to be ready and the Nano scale water had been prepared and placed in its basin:

It is important to have an electric mixer running in the nan water tank to ensure that nanoparticles disperse throughout the experiment.

2-Starting the electric coil to heat the second basin's water to 65 degrees Celsius. This is done by using a thermostat that has been programmed for this purpose.

3. Calculate the necessary amounts of hot and cold nanoscale water that will pass through the heat exchanger's tubes. Pyloric valves were used to regulate the flow rates, with hot water flowing at a rate of four liters per minute, while nanoscale water flowed at two, four, and six liters per minute. Two flow meters that were installed in the tester were used to measure these flow rates.

4- After confirming the stability, continuing to monitor the temperature gauges at the exchanger's input and exit for both hot and cold fluids and recording temperature data every ten minutes.

2.4 Data reduction

In order to evaluate the Effectiveness and Overall Heat Transfer Coefficient can follow as [19]:

Flow rate of hot water

$$\dot{m}_h = \frac{Q}{60} \times \rho \tag{2}$$

Flow rate of cold water

$$\dot{m}_c = \frac{Q}{60} \times \rho \tag{3}$$

Heat transfers of hot water

$$Q_h = m_h \times Cp_h\,(T_{hi} - T_{ho}) \tag{4}$$

Heat transfers of cold water

$$Q_c = m_c \times Cp_c\,(T_{co} - T_{ci}) \tag{5}$$

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Average Heat Transfer

$$Q_{avg} = \frac{Q_h + Q_c}{2} \tag{6}$$

Inner Pipe Inner Surface Area

$$A_i = \pi \times d_i \times L \tag{7}$$

Difference of mean logarithmic of temperature under counter flow type is [17]:

$$LMTD = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{ln(T_{hi} - T_{co}) \ /(T_{ho} - T_{ci})} \tag{8}$$

The experimental overall heat transfers for the inner pipe can be evaluated as:

$$U_i = \frac{Q_{ave}}{A_i \times LMTD} \tag{9}$$

Heat capacity for flow rate of cold water can be estimated as:

$$C_c = m_c \times Cp_c \tag{10}$$

Heat capacity for flow rate of hot water can be estimated as [18]:

$$C_h = m_h \times Cp_h \tag{11}$$

Capacity of minimum heat flow rate is calculated as:

Cmin. =Minimum Value out of Cc and Ch

Capacity of maximum heat flow rate is calculated as:

Cmax. =Maximum Value out of Cc and Ch

Maximum Heat Transfer can be evaluated as:

$$Q_{max} = C_{min}(T_{hi} - T_{ci}) \tag{12}$$

Effectiveness of the Heat Exchanger

The overall heat transfer coefficient can be evaluated as [19]:

$$UA = \frac{Q_{av}}{\Delta T_m} \tag{13}$$

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Number of Transfer Units is:

$$NTU = \frac{UA}{C_{min}} \quad (14)$$

Effectiveness of a double pipe heat exchanger is:

$$\epsilon = \frac{T_{h1} - T_{h2}}{T_{h1} - T_{c1}} \quad (15)$$

2.5 Assumptions

Any axial heat conduction will be neglected. Potential and kinetic energy are negligible. The fluid specific heat is constant. The heat exchanger system is isolated form the surrounding. The value of heat transfer coefficient was assumed based on fluid assigned in both sides. The system is operating at steady state conditions.

3. Results and Discussion

Nanofluid is the solid nanoparticles suspended in pure water which flowing inside the inner tube to enhanced the temperature differential between the heat exchanger's inlet and outflow for both hot and cold liquids. This is depicted in Figure (4), which depicts the temperature differential variation of pure water and nanofluid cold liquids. It can be seen that the temperature differential reduces as the flow rate increases.

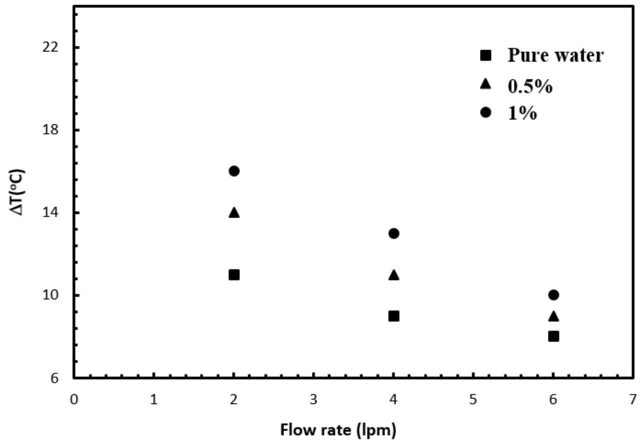

Fig. (4): Inlet and outlet difference temperature of the fluid passing through the inner tube.

Figure (5) depicts the increase in coefficient of nanofluid heat transfer under volumetric flow rates. The reason of this increasing is improving thermophysical properties of the liquid as compared to water.

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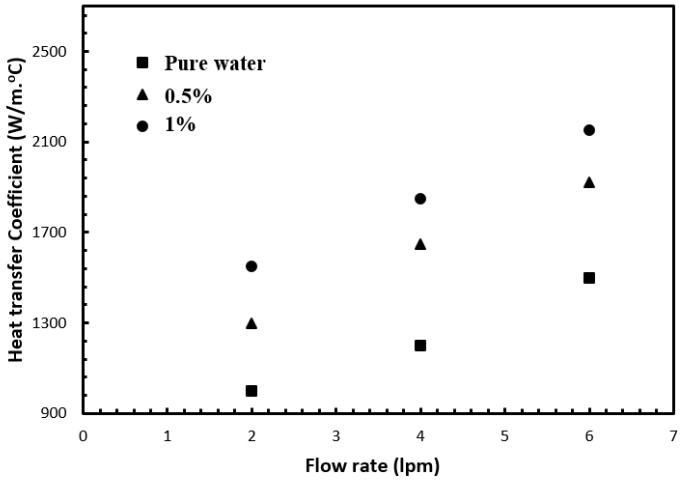

Fig. (5): Heat transfer coefficient with different volume flow rates and mass fractions.

The same pattern can be seen in Figure (6) for the heat transfer. It was observed that the heat transfer is increasing with volume flow rate and mass concentrations. The reason to this increasing is the increase of thermal conductivity of nanofluid as compared to base fluid. The improvement of the heat transfers where the volume flow rate was (2) liters per minute (25%) at a mass concentration (0.5%) and a strengthening rate of (35%) at a concentration (1%) and the relative strengthening was (16%) for (4) liters per minute at a concentration of (0.5%) and a boost rate of (17%) at a concentration of (1 percent). When flowing - (6) liters per minute, the rate was (17%) at a concentration of (0.5%) and (18%) at a concentration of 1%.

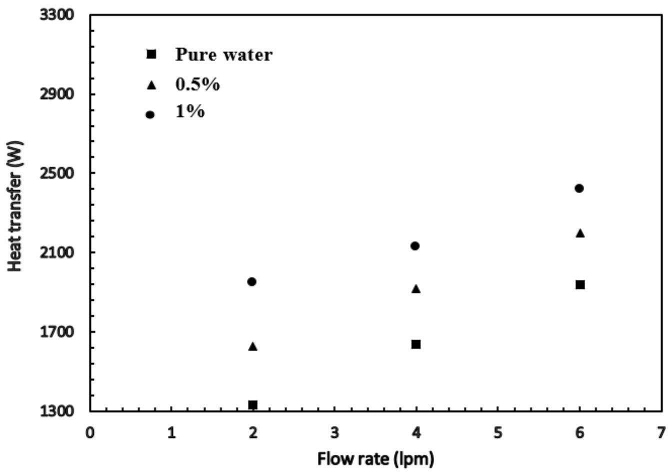

Fig. (6): Heat transfer with different volume flow rates and mass fractions.

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The heat exchanger's effectiveness was determined using the volumetric flow rates of pure water and nanofluid. Figure (7) demonstrates that the effectiveness of both falls as the volume flow rate increases, but the heat exchanger's efficiency improves when nanofluid is used as the working fluid. For (2) LPM volume flow rate and at mass concentration, the largest improvement in efficacy was (54%) (1%).

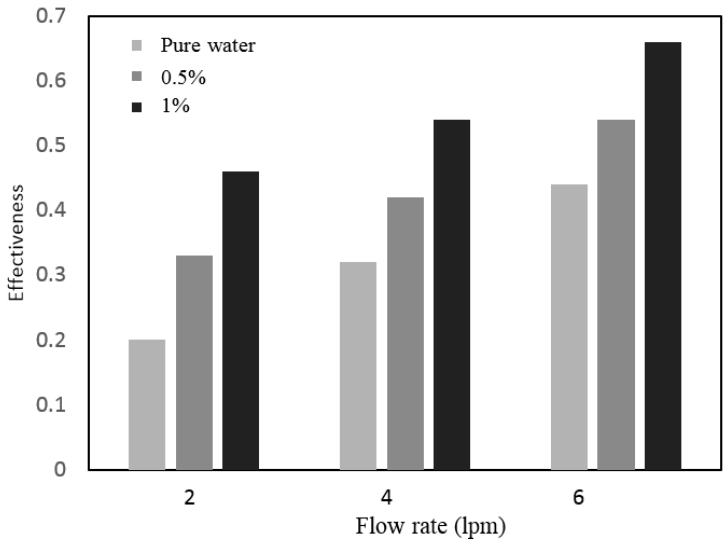

Fig. (7): Effectiveness with flow rates.

4. Conclusion

1. The heat transfer is increasing with increasing of nanofluid volume fraction.
2. The using of 1% nanofluid increase heat transfer by 25%.
3. The maximum heat exchanger efficiency achieved when employing nanofluid was (54%) with a volume flow rate of 2 lpm at a concentration of 1% nanofluid.
4. Effectiveness of heat exchanger is increasing due to increase of flowrate and nanofluid volume concentrations.

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