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Experimental investigation of increasing heat transfers inside a double pipe heat exchanger by using Al_2O_3 nanofluid

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Abstract: The aim of the present study is to investigation of increasing of the heat transfer coefficient inside the double tube. This is done by mixing water with aluminum oxide nanoparticles (Al_2O_3), the study was carried out experimentally. In this study, the effects of nanofluids at different volume concentrations from 0.05% to 0.4%, different mass flow rates of the nanofluids inside the tube, and different mass flow rates of the water flow through the annulus were tested. Experiments done with different nanoparticles and without nanoparticles under the same operating conditions. The experiment was designed, and built in the laboratory according to the international specifications and standards of the tubular exchanger manufacturers association (TEMA). By collecting and analyzing the results of the experiments, it was found that the nanoparticles have a significant improvement in the heat transfer coefficient inside the double tube. The heat transfer coefficient inside the tube increases with the increase the Reynolds number of the tube flow. The maximum value of the Nusselt number is when the volume concentration of Al_2O_3 nanoparticles is 0.1%.

Keywords: Double pipe heat exchanger, enhance the heat transfer rate, heat transfer double pipe with Al_2O_3 nanofluid.

التحقيق العملي لزيادة انتقال الحرارة داخل مبادل حراري مزدوج الأنبوب باستخدام سائل النانو لأكسيد Al_2O_3الألمنيوم

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المستخلص: الهدف من الدراسة الحالية هو تحسين معامل انتقال الحرارة داخل الأنبوب المزدوج. تم ذلك عن طريق خلط الماء بالجسيمات النانوية من أكسيد الألومنيوم (Al_2O_3)، تم إجراء هذه الدراسة عملياً. في هذه الدراسة، تم فحص تأثيرات السوائل النانوية بتركيزات حجمية مختلفة من 0.05% إلى 0.4%، ومعدلات مختلفة من التدفق للسوائل النانوية داخل الأنبوب الداخلي، ومعدلات مختلفة من التدفق لتدفق المياه من خلال الأنبوب الخارجي. تم إجراء التجارب بإضافة تراكيز حجمية مختلفة من جزيئات النانو وبدون جسيمات النانو في نفس الظروف التشغيلية. تم تصميم التجربة، وتم بناء التجربة في المعمل وفق المواصفات والمعايير الدولية لجمعية مصنعي المبادلات الأنبوبية (TEMA). من خلال تحليل نتائج التجارب وجد أن الجسيمات النانوية حدث لها تحسين كبير في معامل انتقال الحرارة داخل الأنبوب المزدوج. يزداد معامل انتقال الحرارة داخل الأنبوب مع زيادة رقم رينولدز، القيمة المثلى لرقم النوزلت عندما يكون التركيز الحجمي للجسيمات النانوية Al_2O_3 هو 0.1%.

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الكلمات المفتاحية: المبادل الحراري مزدوج الأنبوب، تحسين معدل انتقال الحرارة، انتقال الحرارة في الأنبوب المزدوج مع مائع النانو Al_2O_3.

1- INTRODUCTION.

Due to its small size, non-manufacturing difficulties, and compactness, the double pipe heat exchanger is one of the most common heat exchangers used in commercial and industrial applications. Ethylene glycol, propylene glycol, engine oil, etc. are the main fluids used in heat exchanger equipment. Cho [1] and his team developed nanofluids called high thermal conductivity fluids, which are prepared by dispersing solid metallic particles of a nanometer in the fluids. In normal life and different industries, water heating is indispensable, with the availability of many different heating methods that contain many problems, among which are the high construction cost, high maintenance cost, and environmental pollution resulting from some of these methods. Therefore, this study will focus on finding a method to heat water at a low cost and without pollution to preserve the environment. We will use nanoparticles for different materials; these materials will be of high purity, and they will be added to hot water to speed up the heating process. Experiments will be conducted by mixing nanoparticles with hot water at different percentages from (0.05% to 0.4%), then the experimental data will be collected and the amount of thermal conductivity, heat transfer rate, Reynolds Number, Nusselt Number, and effectiveness will be found, then the data will be analyzed and compared to each other and also compared to the water heating process without nanoparticles.

Nomenclature:

A	Area of inner tube, m^2
A_i	Surface area of the inner tube, m^2
A_o	Surface area of the outer tube, m^2
Al_2O_3	Aluminium oxide
C_{bf}	Specific heat at constant pressure of hot water in the tube, J/kg.K
C_p	Specific heat at constant pressure of nanoparticles, J/kg.K
$C_{p,nf}$	Specific heat at constant pressure of nanofluids in the tube, J/kg.K
$C_{p,c}$	Specific heat at constant pressure of cold water in the annulus, J/kg.K
D_h	Hydraulic diameter, $= (D_i - d_o)$, m
D_i	Diameter of inner annulus, m
D_T	Thermal diameter, $= \frac{{D_i}^2 - {d_o}^2}{d_o}$, m
F	Fraction factor of nanofluid in the tube, -
L	Length of the heat exchanger, m
NTU	Number of transfer units of the nanofluid in the tube, -

Nu_{nf}	Nusselt number of the nanofluid in the tube, -
Nu_o	Nusselt number of the cold water in the annulus, -
P_i	Pressure inlet of the nanofluid in the tube, Pa
P_o	Pressure outlet of the nanofluid in the tube, Pa
Pr	Prandtl number, -
Pr_{nf}	Prandtl number of the nanofluid in the tube, -
Q	Average of heat transfer rate, W
Q_c	Heat transfer rate of the cold water in the annulus, W
Q_{nf}	Heat transfer rate of the nanofluid in the tube, W
Re	Reynolds Number for annulus fluid, -
Re_{nf}	Reynolds Number of the nanofluid in the tube, -
$T_{c,i}$	Inlet temperatures of the cold water in the annulus, K
$T_{c,o}$	Outlet temperatures of the cold water in the annulus, K
$T_{h,i}$	Inlet temperatures of the nanofluid in the tube, K
$T_{h,o}$	Outlet temperatures of the nanofluid in the tube, K
U_i	Overall heat transfer coefficient of nanofluid in the tube, $W/m^2.K$
U_o	Overall heat transfer coefficient of the cold water in the annulus, $W/m^2.K$
W_{nf}	Weight of nanofluids, kg
W_{water}	Weight of water, kg
d_i	Diameter of inner tube, m
d_o	Diameter of outer tube, m
f	Friction coefficient, -
h_i	Heat transfer coefficient of nanofluid in the tube, $W/m^2.K$
h_o	Heat transfer coefficient of the cold water in the annulus, $W/m^2.K$
k_{bf}	Thermal conductivity of hot water in the tube, W/m.K
k_m	Thermal conductivity of the tube material, W/m.K
k_{nf}	Thermal conductivity of nanofluids, W/m.K
k_o	Thermal conductivity of the cold water in the annulus, W/m.K
k_p	Thermal conductivity of nanoparticles, W/m.K
u_{nf}	Velocity of nanofluid in the tube, m/s

Greek symbol:

ρ_{bf}	Density of hot water in the tube, kg/m^3
ρ_{nf}	Density of nanofluids in the tube, kg/m^3
ρ_p	Density of nanoparticles, kg/m^3

ρ_{water}	Density of cold water in the annulus, kg/m^3
μ_{bf}	Viscosity of hot water in the tube, kg/s.m
μ_{nf}	Viscosity of nanofluid, kg/s.m
μ_o	Viscosity of the cold water in the annulus, kg/s.m
$\dot{m}_c$	Mass flow rate of cold water in the annulus, kg/s
$\dot{m}_h$	Mass flow rate of nanofluid in the tube, kg/s
ΔP	Pressure drop of the nanofluid in the tube, Pa
ϵ	Effectiveness of the nanofluid in the tube, -
ϕ	Volume concentration, -

1.1 Research Problem:

In many uses we need to heat water, there are many options for heating water but they have problems. As for example; if we use solar cells for heat the water the cost will be high. In addition, if we use electricity for heat the water the cost will be high and pollution comes from it. Also if we use traditional heating methods this leads to more pollution for the environment. Therefore, we want to find a method with low-cost heating and does not pollute the environment.

1.2 Research Objectives:

The aim of this study is to improve the heat exchange rates in the double pipe heat exchanger. Improving the heat exchange rates shall reduce heat exchange size, capital and may be operational costs.

1.3 Importance of the Research:

The importance of this study in finding a method to heat water using nanoparticles. To get a method that reduces the amount of energy used. Improve the efficiency of the system that used it. Increase the speed of processes within the system. Improve the physical characteristics by using nanoparticles and protect the environment from pollution resulting from other heating processes.

2- LITERATURE REVIEW.

Nanofluid is the term used to suspend solid, nanometer-sized particles in traditional fluids; improved heat characteristics, such as convective heat transfer coefficient, are the most prominent characteristics of such fluids in contrast to the base fluid without major alterations in physical and chemical properties. In this study, aluminium oxide nanofluids and copper oxide were prepared separately from ethylene glycol. Using a double pipe and plate heat exchangers, the effect of forced convective heat transfer coefficient in turbulent flow was calculated. Besides, to compare the findings with the experimental data, we calculated the forced convective heat transfer coefficient of the nanofluids using theoretical correlations. The effects of particle concentration and operating temperature on the nanofluids' forced convective heat transfer coefficient were also calculated to evaluate the effects. The results show a large improvement in the nanofluids' convective heat transfer coefficient relative to the base fluid, varying from 2 percent to 50 percent. Also, the results show that the convective heat transfer coefficient of nanofluid increases with increased concentration of nanoparticles and nanofluid temperature. Our studies showed that the theoretical and experimental findings coincided at lower temperatures; however, the two sets of results appear to have growing discrepancies at higher temperatures and with increased concentrations of the nanoparticles in ethylene glycol, Zamzamian et al [2].

In this study, both parallel and counter flow double pipe heat exchanger heat transfer and turbulent flow of water/alumina nanofluid were investigated. The governing equations, based on the finite volume method, were solved by using an in-house FORTRAN code. For nano fluid and turbulent modelling, single-phase and stander k-ϵ models were used. The internal fluid was known to be hot fluid (nanofluid) and cold fluid (outer fluid) (base fluid). The effects of volume fraction, flow direction and Reynolds number of nanoparticles on base fluid, nanofluid and wall temperatures, thermal efficiency, Nusselt number, and coefficient of convection heat transfer were studied. The findings showed that increasing the volume fraction of nanoparticles or the amount of Reynolds causes Nusselt number and convection heat transfer coefficient to be increased. 32.7% and 30% are the highest levels of average Nusselt number and thermal efficiency, respectively. Also, by increasing the volume fraction of nanoparticles, the fluid outlet temperature and wall temperature will increase. The analysis of the minimum temperature in the solid heat exchanger wall shows that the minimum temperature in the counter flow has decreased substantially compared with the parallel flow rate. However, the slope of thermal efficiency enhancement of the heat exchanger gradually tends to a constant value by increasing the number of Reynolds. This behaviour is more apparent in heat exchangers with the parallel flow. For higher Reynolds numbers, Bahmani et al [3] found that the counter flow in heat exchangers enhanced the heat transfer of the heat exchangers.

Experimental research was performed to estimate the convective heat transfer and friction factor of the flow of CuO nanofluids under turbulent flow conditions in a double pipe U-bend heat exchanger. The CuO nanofluid was circulated at different mass flow rates (8,10, 12, and 14 LPM) and different volume concentrations through the inner tube of the U-bend heat exchanger. At a fixed mass flow rate of 8 LPM, the hot water was flowing through the annulus tube. The results show that the number of nanofluids in Nusselt increases with increasing concentrations of Reynolds number and particle volume. As compared to base fluid with a pumping penalty, the Nusselt number increase is around 18.6% at 0.06% volume concentration, Rao and Sankar [4].

The deposition of nanoparticles is one of the main challenges in the industrial use of nanofluids. Due to vibrating walls, the heat transfer enhancement of Multi Wall Carbon Nano Tube, MWCNT-water nanofluid is examined for various mass fractions in a double pipe heat exchanger. A compact double pipe heat exchanger made of PVDFF conducts this function. Forced vibration is imposed by electro-dynamic vibrators on the outer surface of the heat exchanger. Results show that the imposition of vibrations increase the heat transfer coefficient, thus decrease the deposition of nanoparticles. By increasing the temperature of the nanofluid, mass flow rate, nanofluid mass fraction and vibration frequency, heat transfer increases. In the test of the lowest mass fraction 0.04% with the highest vibration level 9 m/s^2 in the experiment range will get the highest increase in the heat transfer coefficient is 100%, Hosseinian et al [5].

The lack of response of heat devices at higher capacities is one of the obstacles to increasing the capability of different industries. Furthermore, increasing capacity leads to an increase in the drop in pressure, and this is one of the main constraints on large industries. Conventional methods of increasing heat transfer greatly increase the drop in pressure. According to results of previous studies, the thermal efficiency of the heat exchanger can be significantly improved using special nanofluids, which is one of the most thermal devices in the industry. In this study, first an analysis of nanofluid studies and the introduction of nanofluids is presented, then their simulation methods are investigated, and finally, studies have been investigated on the used heat exchanger tubes, and studies have been examined on the plate heat exchanger, helical heat exchanger, shell and tube heat exchanger, and double tube heat exchanger. In terms of energy conversion, improving the thermal and hydraulic efficiency of heat exchangers is very important and also important for the economic recovery of systems by savings. This paper summarizes prior work on heat exchangers and their use of nanofluids. The aim of the paper is not only to explain the previous studies, but also to understand the mechanisms of heat transfer in the heat exchanger application of nanofluids, as well as to evaluate and compare the various techniques of heat transfer. Finally, it can be concluded that in most situations, nanofluids increase the transfer of heat, which decreases the amount of heat exchangers, thereby saving energy, water consumption and industrial waste, Pordanjani, et al [6].

Heat transfer, friction factor, and effectiveness-number of heat transfer units in the inner tube of a double pipe U-bend heat exchanger with different pitch ratios (p/d) of wire coil with core-rod (WCCR) inserts were experimentally estimated for different volume concentrations of Fe_3O_4 nanofluid flow. The experiments were performed at varying concentrations of particle volume (0.005%, 0.01%, 0.03% and 0.06%), various Reynolds numbers (16000-29000) and different WCCR insert pitch ratios (p/d = 1, 1.34 and 1.79). In compared water data with a pumping penalty of 10%, the Nusselt number for a 0.06% volume concentration of nanofluid, is increased by 9.76% and 14.76% in Reynolds number of 16545 and 28954, respectively. Likewise, for 0.06% nanofluid with wire coil with a core-rod insert of (p/d=1) at Reynolds numbers 16545 and28954, the Nusselt number is further increased by 25.39% and 37.90% respectively, compared to water. Based on the experimental data, Nusselt number and friction factor correlations were suggested. For water/nanofluid flow in a tube with WCCR inserts, the effectiveness-number of transfer units (NTU) was determined, Sundar et al [7].

3- EXPERIMENTAL WORK.

Figure (1) displays the experimental setup's schematic diagram. At the beginning of the experiment, the heater is turned on in the hot water tank to raise the water temperature to the required degree. After that, the temperature of the water inside the hot and cold water tank is measured to ensure its desired degree of temperature. After that, nanoparticles of aluminum oxide (Al_2O_3) are added inside the hot tank, and then the water is mixed with nanoparticle well. After that, the valves of the water path of the two tanks are opened, then the pump is turned on to raise the water flow rater in the pipes, the tube and shell flowmeter is calibrated at the required flow rate, the experiment begins to work, and the results are collected and recorded by the fluke device connected to the computer, which takes temperature readings from the thermocouples installed inside the tubes. The experiment is running for 20 to 30 minutes according to the specified time, after that the experiment is stopped, the data is saved, the pump is stopped and the valves are closed. The heater is restarted to raise the temperature of the hot tank, then repeat the same steps with a change in the flow rate and the concentration of nanoparticle, this is done all experiments are completed.

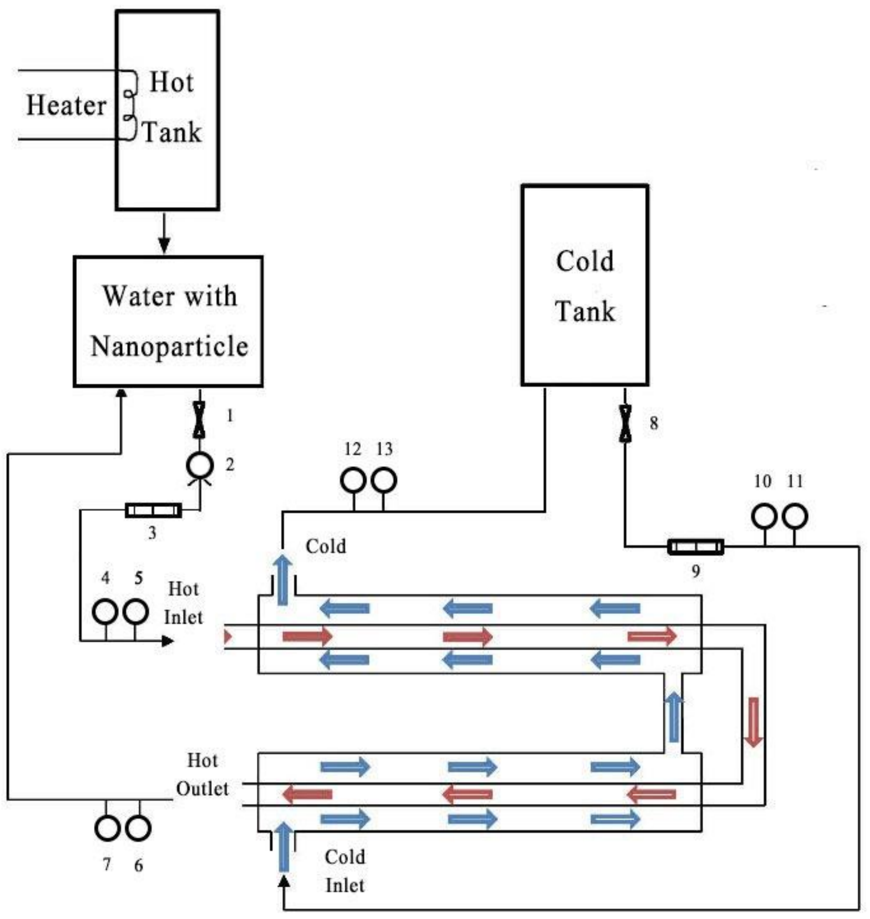


Figure (1) displays the experimental setup's schematic diagram.

Where:

1. Valve of nanofluid tank.
2. Valve of cold tank.
3. Pump of nanofluid.
4. Flowmeter of cold tank.
5. Flowmeter of nanofluid.
6. Pressure gage of inlet annulus.
7. Pressure gauge of inlet nanofluid in the tube.
8. Thermocouple of inlet annulus.
9. Thermocouple of inlet nanofluid in the tube.
10. Pressure gage of outlet annulus.
11. Pressure gauge of outlet nanofluid in the tube.
12. Thermocouple for outlet annulus.
13. Thermocouple of outlet nanofluid in the tube.

4- METHODOLOGY.

The volume concentration of nanofluid:

$$\phi = \frac{\frac{W_{nf}}{\rho_{nf}}}{\frac{W_{nf}}{\rho_{nf}}+\frac{W_{water}}{\rho_{water}}} \qquad (1)$$

The viscosity of nanofluid:

$$\mu_{nf} = \mu_{bf}(1 + 2.5\phi) \qquad (2)$$

The density of nanofluid:

$$\rho_{nf} = \phi\rho_p(1 - \phi)\ \rho_{bf} \qquad (3)$$

The specific heat at constant pressure of nanofluid:

$$C_{p,nf} = \phi C_p(1 - \phi)\ C_{bf} \qquad (4)$$

The thermal conductivity of nanofluid:

$$k_{nf} = k_{bf}\left[\frac{k_p+2k_{bf}+2\emptyset(k_p-k_{bf})}{k_p+2k_{bf}-\emptyset(k_p-k_{bf})}\right] \qquad (5)$$

The heat transfer rate of annulus:

$$Q_c = \dot{m}_c\, C_{p,c}\left(T_{c,o} - T_{c,i}\right) \qquad (6)$$

The heat transfer rate of the nanofluid:

$$\boldsymbol{Q_{nf} = \dot{m}_h\, C_{p_{,nf}}\left(T_{h,i} - T_{h,o}\right)} \qquad \mathbf{(7)}$$

The overall heat transfer coefficient:

$$\boldsymbol{U_i = \frac{Q}{A_i \Delta T_{LM}}\ ,\ U_o = \frac{Q}{A_o \Delta T_{LM}}} \qquad \mathbf{(8)}$$

Where: $A_i = \pi d_i L$

$$A_o = \pi d_o L$$

$$\boldsymbol{\Delta T_{LM} = \frac{\Delta T_a - \Delta T_b}{\ln\left(\frac{\Delta T_a}{\Delta T_b}\right)}} \qquad \mathbf{(9)}$$

Where:

$$\boldsymbol{\Delta T_a = T_{h,i} - T_{c,o}}$$

$$\boldsymbol{\Delta T_b = T_{h,o} - T_{c,i}}$$

The Reynolds Number of the annulus:

$$\mathrm{Re} = \frac{4\dot{m}_c}{\pi D_h \mu_o} \qquad (10)$$

Where: $D_h = D_i - d_o$

The Nusselt number Nu_o of the annulus:

$$Nu_o = \frac{(f/2)(Re-1000)(Pr)}{1.07+12.7(f/2)^{0.5}(Pr^{2/3}-1)} \quad (11)$$

$$f = (3.64 ln Re - 3.28)^{-2}, \; Re \; at \; Tm \quad (12)$$

Where: $T_m = \frac{T_{C,i}+T_{C,o}+T_{h,i}+T_{h,o}}{4}$

The heat transfer coefficient of annulus:

$$\mathbf{h}_{\boldsymbol{o}} = \frac{\boldsymbol{Nu_o K_o}}{\boldsymbol{D_T}} \quad \mathbf{(13)}$$

Where: $D_T = \frac{{D_i}^2-{d_o}^2}{d_o}$

The heat transfer coefficient of nanofluid:

$$\frac{1}{U_i A_i} = \frac{1}{h_i A_i} + \frac{\ln(d_o/d_i)}{2\pi K_m L} + \frac{1}{h_o A_o} \quad (14)$$

The Nusselt number of the nanofluid:

$$\mathrm{Nu}_{nf} = \frac{h_i d_i}{k_{nf}} \quad (15)$$

The Reynolds Number of the nanofluid:

$$Re_{nf} = \frac{4\dot{m}_h}{\pi d_i \mu_{nf}} \quad (16)$$

$$u_{nf} = \frac{\dot{m}_h}{\rho_{nf} A} \quad (17)$$

Where: $A = \frac{\pi}{4}{d_i}^2$

The fraction factor:

$$F = \frac{\Delta P}{\frac{L}{di}\left(\frac{\rho_{nf}{u_{nf}}^2}{2}\right)} \quad (18)$$

Where: $\Delta P = P_i - P_o$

The Number of transfer units:

$$\mathrm{NTU} = \frac{UA}{C_{min}} = \frac{Q}{\Delta T_{LM} C_{min}} \quad (19)$$

Where: $C_h = \dot{m_h} C_{P_h}$, $C_c = \dot{m_c} C_{P_c}$

C_{min}: The minimum value of C_h and C_c

The effectiveness:

$$\varepsilon = \frac{1-\exp[-NTU(1-Cr)]}{1-\text{Cr}\exp[-NTU(1-Cr)]} \qquad (20)$$

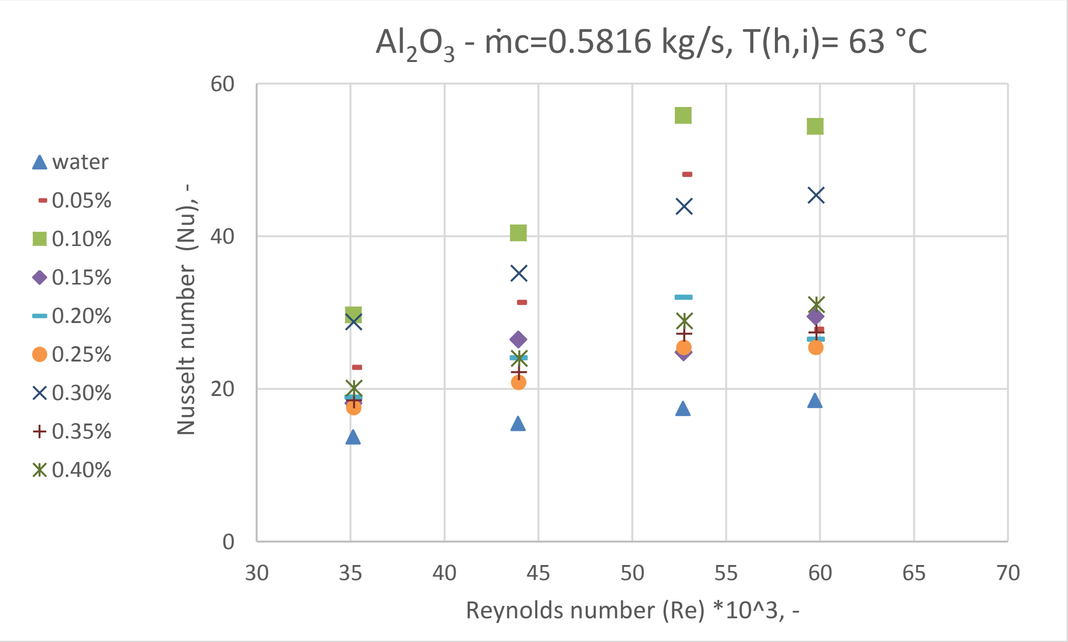
Where: $C_r = \frac{C_{min}}{C_{max}}$

5- RESULTS AND DISCUSSIONS.

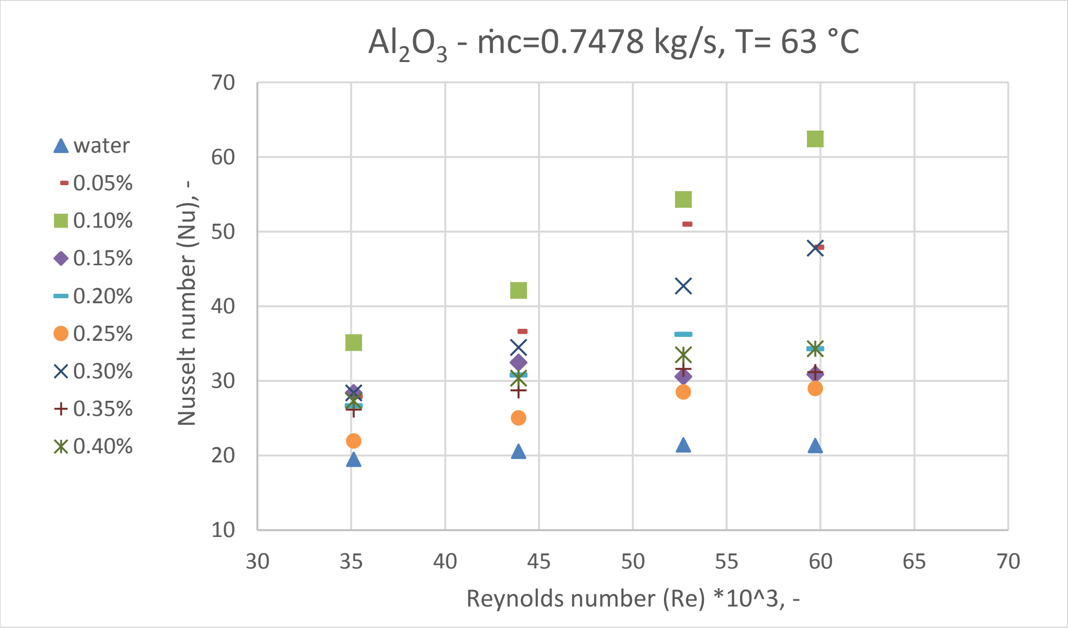
5.1 Effects of Al2O3 nanoparticl on Nusselt number:

From figure (2) can shows the effects of the Al_2O_3 nanoparticle with different volume concertations on the Nusselt number, at temperatures is 63°C and at different mass flow rate of the annulus of about:

(a) is 0. 5816 kg/s and (b) is 0.7478 kg/s respectively. It was showen that the Nusselt number increases as the mass flow rate of annulus increases. As shown in the figure, the Nusselt number increase when the Reynolds number inside the tube increases. The nanoparticle has a huge enhancemet on the Nusselt number when the volume concentration from 0% to 0.1%, the maximum value of the Nusslet number at volume concentration is 0.1%, this increase depend on effect of increase the thermal conductivity and effect of decrease the specific heat at constant pressure. The increasing of the Nusselt number continues until arrive to maximum value at 0.1% then the nanoparticle concentration has a little effect on the Nusselt number this because the nanoparticles make a insulating layer inside the tube.



(a)

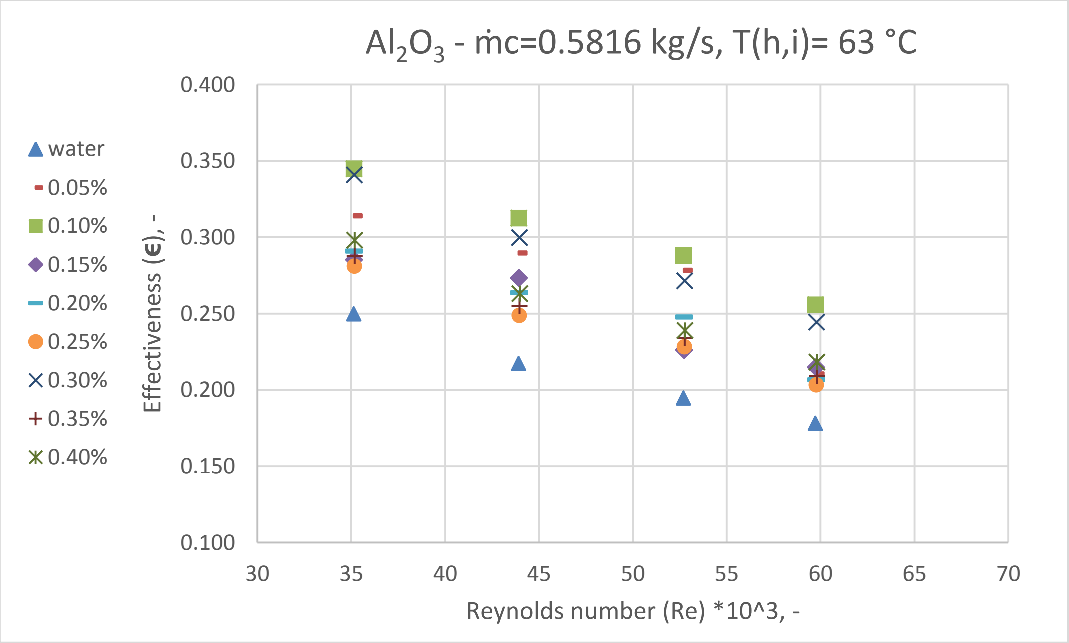


(b)

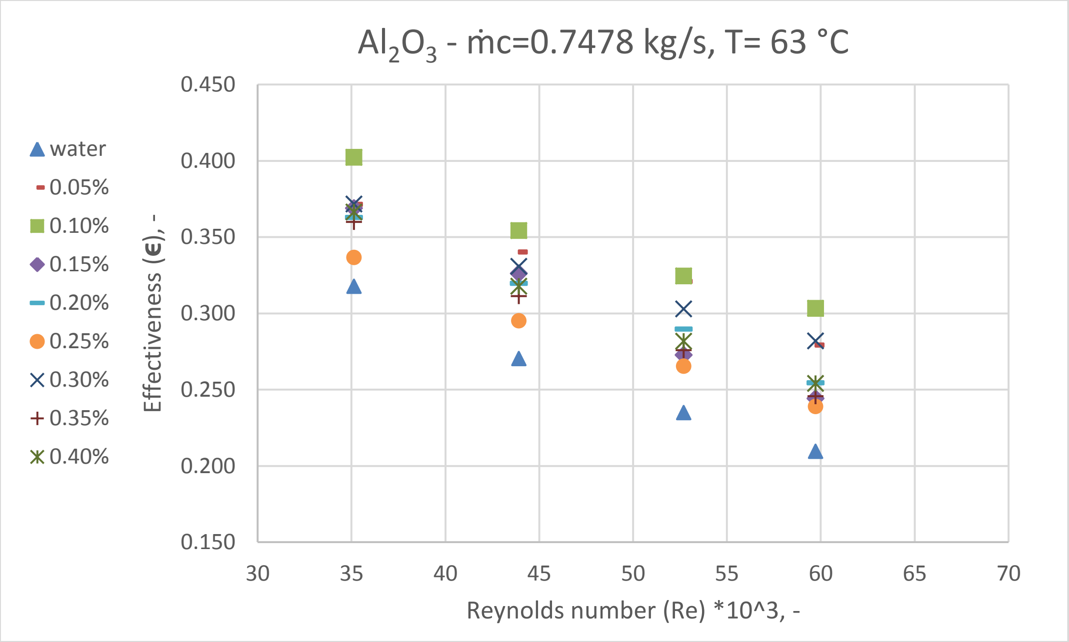
Figure (2) Effects of nanoparticle on the Nusselt number of water and Al_2O_3 nanofluid at different particle concentrations, at temperatures is 63°C, and at different mass flow rate of the annulus of: (a) 0.5816 kg/s and (b) 0.7478 kg/s.

5.2 Effects of Al_2O_3 nanopartícl on effectiveness:

From figure (3) can shows the effects of the Al_2O_3 nanoparticle with different volume concertations on the effectiveness, at temperatures is 63°C and at different mass flow rate of the annulus of about: (a) 0. 5816 kg/s and (b) is 0.7478 kg/s respectively. It was shown that the effectiveness increases as the mass flow rate of annulus increases. As shown in the figure, the effectiveness decrease when the Reynolds number inside the tube increases. The nanoparticle has a big effect on the Nusselt number when the volume concentration from 0% to 0.1%, the maximum value of the effectiveness at volume concentration is 0.1%, then the nanoparticle concentration has a little effect on the effectiveness this because the nanoparticles make a insulating layer inside the tube.



(a)

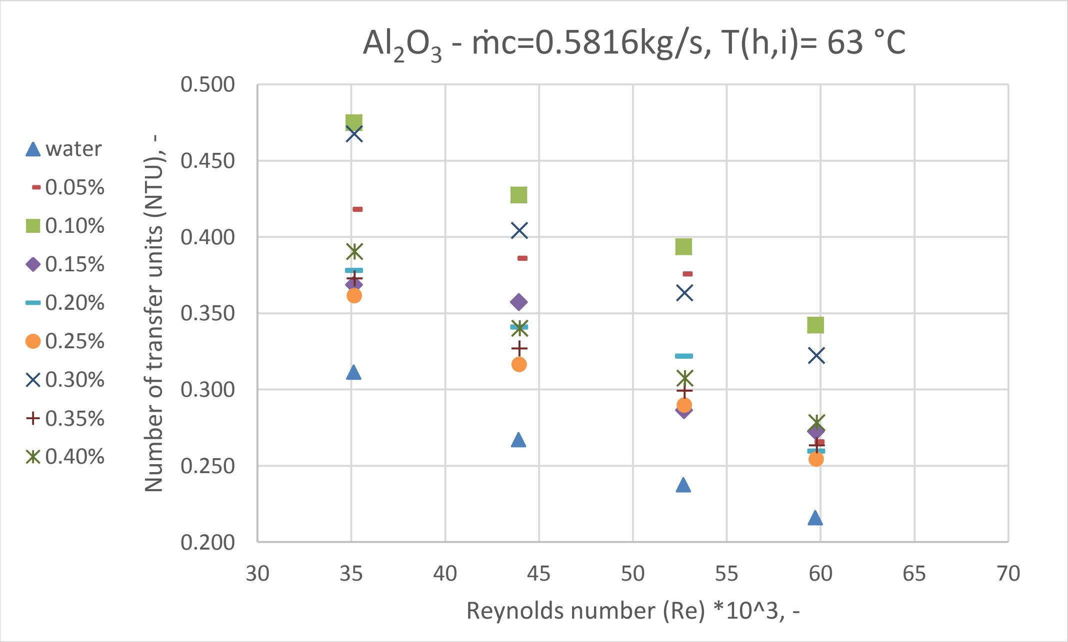


(b)

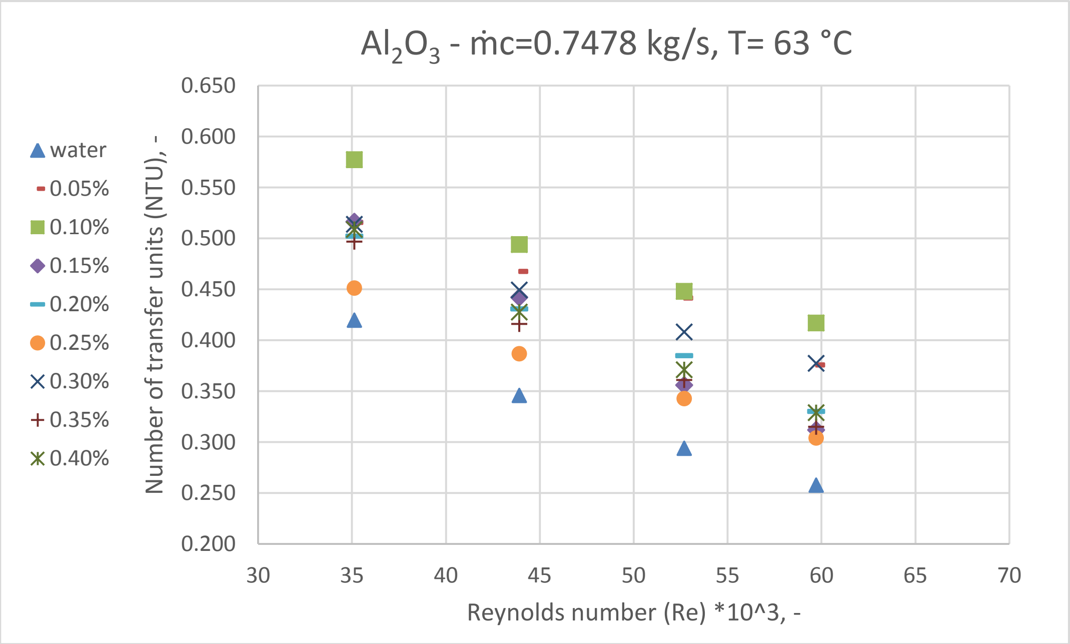
Figure (3) Effects of nanoparticle on the effectiveness of water and Al_2O_3 nanofluid at different particle concentrations, at temperatures is 63°C, and at different mass flow rate of the annulus of: (a) 0.5816 kg/s and (b) 0.7478 kg/s.

5.3 Effects of on Number of transfer units:

From figure (4) can shows the effects of the Al_2O_3 nanoparticle with different volume concertations on the Number of transfer units, at temperatures is 63°C and at different mass flow rate of the annulus of about: (a) is 0. 5816 kg/s and (b) is 0.7478 kg/s respectively. It was showen that the Number of transfer units increases as the mass flow rate of annulus increases. As shown in the figure, the Number of transfer units decrease when the Reynolds number inside the tube increases. The nanoparticle has a big enhancemet on the Number of transfer units when the volume concentration from 0% to 0.1%, the maximum value of the Number of transfer units at volume concentration is 0.1%, this decrease depend on effect of increase of the mass flow rate and effect of increase the specific heat at constant pressure. The increasing of the Nusselt number continues until arrive to maximum value at 0.1%, then the nanoparticle concentration has a little effect on the Number of transfer units this because the nanoparticles make a insulating layer inside the tube.



(a)

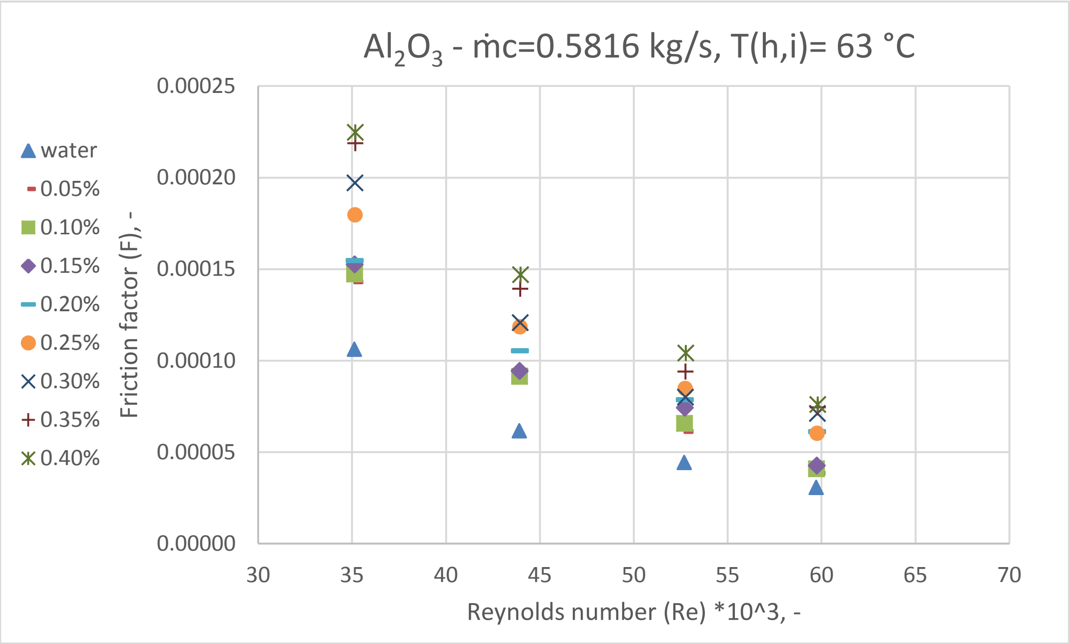


(b)

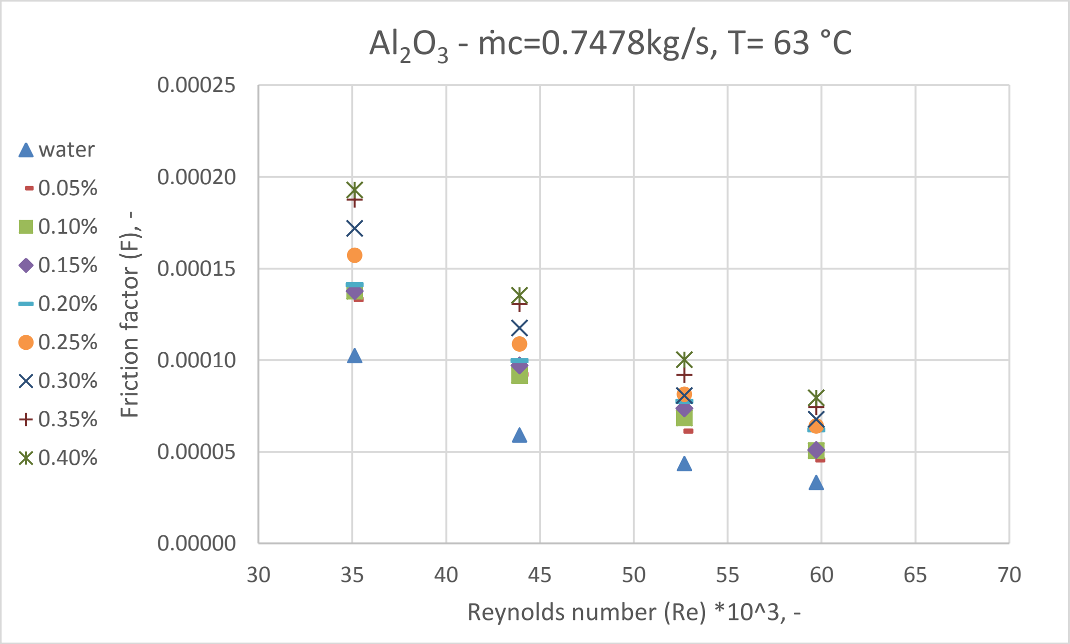
Figure (4) Effects of nanoparticle on the Number of transfer units of water and Al_2O_3 nanofluid at different particle concentrations, at temperatures is 63°C, and at different mass flow rate of the annulus of: (a) 0.5816 kg/s and (b) 0.7478 kg/s.

5.4 Effects of on friction factor:

From figure (5) can shows the effects of the Al_2O_3 nanoparticle with different volume concertations on the friction factor, at temperatures is 63°C and at different mass flow rate of the annulus of about: (a) is 0. 5816 kg/s and (b) is 0.7478 kg/s respectively. It was shown that the friction factor decreases as the mass flow rate of annulus increases. As shown in the figure, the friction factor decrease when the Reynolds number inside the tube increases. The nanoparticle has a significant enhancement on the friction factor when the volume concentration increases the friction factor increase, the maximum value of the friction factor at volume concentration is 0.4%, this increase depend on effect of increase the density and effect of increase the pressure drop between inside the tube.



(a)



(b)

Figure (5) Effects of nanoparticle on the friction factor of water and Al_2O_3 nanofluid at different particle concentrations, at temperatures is 63°C, and at different mass flow rate of the annulus of: (a) 0.5816 kg/s and (b) 0.7478 kg/s.

6- CONCLUSIONS.

In this research, the double tube heat exchanger is designed, and the test device is built. After completing the experiments and analyzing the data, it was found that the nanoparticles have a large improvement in the heat transfer coefficient inside the double tube. The Nusselt number increases when increase of the Reynolds number inside the tube. The Al_2O_3 nanoparticle has a enhancement of the Nusselt number. By increasing the volume concentration, the Nusselt number increases until the maximum value of the Nusselt number is reached when the volume concentration of Al_2O_3 nanoparticle is 0.1%. The increase in the Nusselt number is due to the effects of a increase in thermal conductivity, and a decrease in specific heat at constant pressure, and after the maximum value by increasing the volume concentration, the Nusselt number is slightly affected, because the nanoparticles make a insulating layer that decrease the heat transfer rate.

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