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THERMAL EFFICIENCY ANALYSIS OF A DOUBLE PIPE HEATS EXCHANGER USING SILVER NANOPARTICLES SUSPENDED IN PURE WATER

Sohaib Najmaldin Abdullah ALDAMK

Master's Thesis

Supervisor

Asst. Prof. Dr. Yaser ALAIWI

Istanbul, 2023

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The thesis titled THERMAL EFFICIENCY ANALYSIS OF A DOUBLE PIPE HEATS EXCHANGER USING SILVER NANOPARTICLES SUSPENDED IN PURE WATER prepared by SOHAIB NAJMALDIN ABDULLAH ALDAMK and submitted on 27/2/2023 has been **accepted unanimously/by majority of votes** for the degree of Master of Science in Mechanical Engineering.

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ABSTRACT

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The thesis aimed to conduct an experimental study to improve the effectiveness of the double tube heats exchanger with a counter flow of 1 m in length, the outer tube 19 mm in diameter and the inner tube of copper 9.5 mm in diameter, using Nano-fluids as a cold fluid. Silver oxide nanoparticles with a diameter of 40 mm and a volumetric concentration of 0.2 % and 0.1 % were used with a water as a basic liquid. The cold Nano-fluids flows inside the inner tube at a volumetric flux rate of 3Litre/minute, 5Litre/minute and 7Litre/minute, which enter the heats exchanger at 15 °C ±1, while the hot water flows through the space between the two tubes at a volumetric flux rate of 5 L/minute and enters the heats exchanger at a temperature of 60 °C ±1. The experimental results obtained using this type of Nano-fluids were compared with the use of water to obtain a better efficiency of the heats exchanger. The obtained results showed an improvement in the efficiency of using Nano-fluids. The maximum percentage of improving effectiveness when using silver oxide with water was 28 % at a volumetric concentration of 0.2 % at a volumetric flow rate of 3 litres / minutes. This study showed that the "(density, thermals conductivity, and viscosity) of the Nano-fluids increases with the increase in the volumetric ratio of the solid "nanoparticles".

Keywords: Nusselt Number, Tube Heats Exchanger, Nanosilver/Water, The Perform Effectiveness, Heat Transfer.

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LIST OF SYMBOLS

ε	:	The efficiency
ρ	:	Density
v	:	volume
m	:	mass
T_h	:	Temperatures hot
T_c	:	Temperatures cold
$\dot{m}_c$	:	Cold water mass
Q_h	:	The amount of heats transferred
Q_c	:	The amount of heats gained in cold water
Q_{avg}	:	The average amount of heats transferred
A	:	Area
u	:	velocity
DH	:	Hydraulic diameter
Re	:	Reynolds number
$LMTD$	:	The logarithmic mean temperature of the back flow
F	:	Force
Ui	:	Heats transfer coefficient
C_c	:	Heats capacity of cold water
C_h	:	Heats capacity of hot water
NTU	:	Heats capacity of hot water

Nu	:	Nusselt number
P	:	Pressure
f	:	Coefficient of friction
PEC	:	The heats exchanger performance coefficient
k	:	Thermal conductivity
μ	:	viscosity
CP	:	The specific heats

1. INTRODUCTION

1.1 HEATS EXCHANGERS

Because the heats exchanger creates a temperature difference between the two fluids without mixing them, decreasing the temperature difference necessitates having a bigger heats exchanger, which increases both the size and cost of the system. When designing gadgets, it is crucial to consider both of these orientations. Considerations for heats transfer include not only the performance qualities of the exchanger, but also capacity and volume area allotted for this exchanger, and the production cost. Engineers' growing concern for energy use and their pursuit of optimum designs based on thermal analysis and financial returns may be directly attributed to the prevalence of heats exchangers in modern technology. A specific kind of heats exchanger that nests two tubes of varying diameters within one another. One fluids travels via the smaller inner tube, and the other through the interstitial space. This exchanger can be set up either in a parallel-flow configuration, where hot and cold fluids are fed to the same ends and direction and flow, or counter-flow, where fluids are introduced at opposite ends and flow in the opposite direction.

Graph (1.1) demonstrates Different kinds of heats exchangers can transmit far more heats than these two. The compact heats exchanger has a larger surface area for heats transmission per unit volume than the previous kind.

Adding metal plates or fins to the tube walls creates a huge heats transmission area in this sort of exchanger. Both fluids in this sort of exchange flow in a direction that is perpendicular to the other. Air conditioning and refrigeration systems, automobile radiators, and other applications all employ a (cross flow heats exchanger). Still, the most well-known form of heats exchanger is the shell-and-tube design used in so many industrial settings. Researchers continue to be interested in finding new ways to improve heats exchangers. There are two main avenues for doing so: (1) enhancing heats exchanger design, and (2) enhancing working fluids heats conduction [1].

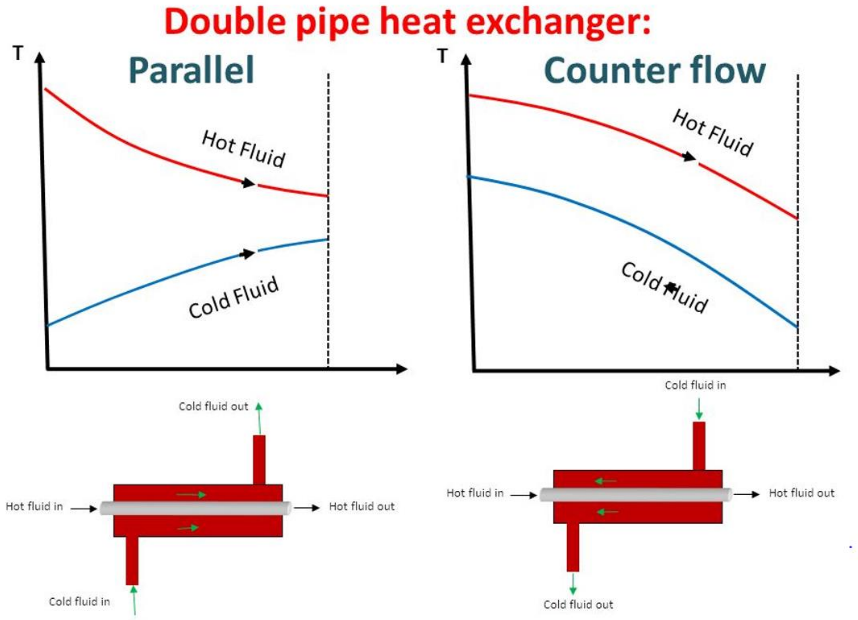

Figure 1.1: Parallel And Counter Current Flow Of A Twin Tube Heats Exchanger [2].

1.2 THE IMPORTANCE OF HEATS EXCHANGERS

One way to achieve thermal homogeneity is for a material's temperature to distribute uniformly over the whole volume. Convection transfers heats from the fluids to the walls of the tubes, and thermal conduction, the transmission of heats energy by the diffusion and small collision of particles or pseudo-particles inside the body as a consequence of the temperature gradient, transfers heats from the tubes to the opposite side. Molecules, electrons, atoms, and photons are all examples of minuscule particles that may scatter and collide. Internal energy (a combination of potential and kinetic energy) is transferred, although it is chaotic on a tiny scale. Finally, convection transfers the heats from the tube interior to the fluids in the heats exchanger's inner tube [2].

A heats exchanger is a device that brings the temperatures of two or more liquids (or gases and vapors) closer together. It is possible to transmit heats from one liquid to another, or from one gas to another, or even between two liquids, by using a solid separator to keep the liquids from mixing or comminuted into direct contact with one another, depending on the kind of heats exchanger used. Heats exchangers may be categorized and subcategorized by their construction materials, components, heats transfer methods, and flow configurations, among other design aspects. Many different heats exchangers are created for a broad range of applications and are used for heating and cooling [3].

1.3 NANOTECHNOLOGY

Today's society benefits greatly from nanotechnology, and Nano-science may be seen across the scientific disciplines. Structures, technologies, it is a group that has rare functions due to the arrangement of its atoms on the scale of size of 1 to 100 nanometers fall within the purview of Nano-science and nanotechnology. It was in the early 2000s that the first commercial applications of nanotechnology emerged, after a period of rising interest in the field and some heated debate. Many fields, including physics, materials science, chemistry, biology, computer science, and engineering, may benefit from nanotechnologies. Applying nanotechnology to human health has shown encouraging results recently, especially in cancer treatment. To fully grasp nanotechnology, it's important to look back at the progression of discoveries that lead to our present knowledge. Nanotechnology in the history of science, from ancient times to the present day, is laid forth in this overview, along with a summary of the most important developments and concepts in the area [4].

It's no exaggeration to say that nanotechnology is at the cutting edge of one of engineering's most consequential and fascinating fields. Since it will affect the development of technology in several different fields, it has stoked hopes for imminent scientific breakthroughs. Therefore, a concise and accessible overview of the method for laypeople is essential. Since 1996–1998 (when remedial studies on this technology and its function in creativity were initiated by the American Center (WTEC) specializing in research), there has been a lot of curiosity in this study area. Nano-science and nanotechnology are the study, application, and management of very tiny objects at the Nano-scale (in fields such as medicine, the military, informatics, electronics, computers, petro chemistry, agriculture, biology, and many more). The unique phenomena made possible by this technology at scales of 1 to 100 nanometers open up new fields of use. At the Nanoscale, matter's physical, chemical, and biological characteristics in any of its three forms may display significant differences from the properties of individual atoms or molecules. Certain nanostructured materials are more robust or exhibit different magnetic properties than bulkier or larger versions of the same material. Still, others have greater ranges and excel in heats or electrical transmission.

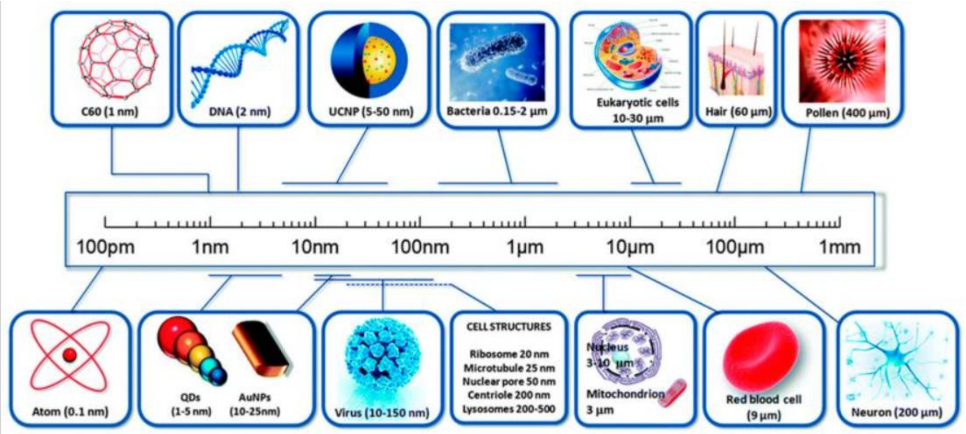

Figure 1.2: The Diameters Of Nano-Materials Are Compared In Figures 1 And 2 [2].

1.4 RESEARCH PROBLEM

Because heats exchangers are used for every process (cooling, heating) in oil facilities, chemical and food labs, and dairy production, the present research is crucial in discovering methods to enhance the performance of the heats exchanger. And there is an immediate need to boost its efficiency by enhancing heats transfer because of its influence on heats exchanger performance, making the most of the time needed to finish the heats exchange process, and cutting down on the expense of producing heats exchangers.

1.5 THE AIM OF THE RESEARCH

With the Add of various nanoparticles to water as a base liquid, the present research hopes to enhance the performance of a double-tube counter-flow type heats exchanger.

a. Selection of nanoparticles of the type of silver oxide nanoparticle (Ago) to mix with water to generate a Nano-fluids with volume concentration ratios (0.5% and 1%).

b. The Nano-fluids thermal conductivity, density, viscosity, and specific heats impact on the heats transfer coefficient, heats exchanger efficiency, and Nusselt number.

c. The experimental results obtained with Nano-fluids were compared to those obtained with water to determinate which provided superior performance in a heats exchanger operating at three different flow rates (3, 5, and 7 L/minute for the Nano-fluids and water as cold fluids, respectively), and one operating at a constant flow rate (5 L/minute) for water hot.

2. LITREATURE REVIEW

2.1 INTRODUCTION

The doubly -tube type heats exchanger is one of the most important and most effective exchangers in many applications, including commercial and industrial. Liquids can travel in the same direction or in opposite directions, making it the simplest [5].

A significant benefit of the double-tube Containing a heats exchanger, items with particles may be processed without the possibility of a blockage. Pasteurization processing, sterilization, reheating, digestion processing and waste treatment [6].

Where heating and cooling are done in many health and pharmaceutical operations with double-tube exchangers in chemicals, in addition to food, oil and gas, renewable energy systems, solar energy, and utilization of waste heats [7].

Exchanger improvements in heats transmission are frequently accompanied by an increase in pressure drop, necessitating more powerful pumps. Any benefits from better heats transmission should thus be weighed against the price of the resulting pressure decrease [8],[9].

The primary goals of a heats exchanger are to save cost and initial space and prevent and prevent significant pressure drop allowing for reduced pumping capacity and lower operating costs [10].

Engine cooling, HVAC, heating, refrigeration, vehicle radiators, electronics, solar and nuclear power systems, therapeutic devices, transformer cooling oils, and many more real-world heats transfer applications use Nano-fluids. Therefore, many academics and researchers have focused on unconventional fluids and the effects of combining them with conventional fluids on system performance [11].

2.2 REVIEW OF EARLIER APPLIED RESEARCH

Many scientists have worked on increasing the efficiency of exchangers that use Nano-fluids as a fluid through which to transfer heats during the past ten years. Improving a two-pipe heats exchanger using aqueous CuO Nano-fluids represented as a heats transfer fluids [12].

Experimental evaluations of the effects of TiO2 and Al2O3 Nano-fluids on heats exchanger performance have shown that they boost performance from 13% to 23% when used in place of conventional fluids [13].

The study conducted experiments on a double-tube heats exchanger using Al_2O_3 aluminium nanoparticles mixed in water as a base liquid and at varying concentrations to improve the efficiency of such heats exchangers. The primary focus of this investigation was finding out how well heats can be conducted through and transferred by the Nano-fluids. The results showed that the total heats transfer coefficient improved when the Nano-fluids was used as the base fluids instead of water. The thermal conductivity coefficient was boosted by 16% when nanoparticles were added to water at a concentration of 3% for the Nano-fluids [14].

Using a Nano-fluids Al_2O_3 with a diameter of 20 and a volumetric concentration of (0.001-0.002) and the opposite flow conditions (turbulent and opposite) [15].

conducted an experimental study to determinate the total heats transfer coefficient and the amount of heats transferred in a double-tube heats exchanger. Measurements showed an increase of 8% in heats transmission and 10% in the overall heats transfer coefficient compared to water as the basic liquid [16].

found That the heats transfer coefficient and the Nusselt number could both be increased by using a Nano-fluids -Al_2O_3 with a volume concentration of 0.1% to 0.3%. The effects of temperature and nanoparticle concentration on the Nusselt number and the heats transfer coefficient were studied in a double-tube heats exchanger with reverse turbulent flow. A satisfactory agreement is shown when contrasting experimental results with reliable theoretical data based on quasi-experimental equations. After the trials, the Nusselt number and heats transfer coefficient reached highs of (19%-24%). the heats transmission coefficient also increases with the operating temperature and the nanoparticle concentration. In addition, conducted an experimental study to determinate the effect of Al_2O_3 nanoparticles mixed in water as a vessel liquid on the performance of a double-tube heats exchanger for two flow directions (parallel and opposite), and the found that the total heats transfer coefficient increases with increasing concentration. Concentrations of nanoparticles in water are rising and will continue to do so until they reach a volume concentration of 0.008 and then begin to fall [17].

Then, the researcher experimented with calculating the convective heats transfer coefficient while cooling a Nano-fluids composed of AL_2O_3 aluminium particles mixed with water as a base and at varying volumetric concentrations (0.15, 0.25, and 0.5%)%. To do this, they used a copper counter flow double-tube heats exchanger that was 1.25 m in length and had an inner tube diameter of 4.9 mm and an outer tube diameter of 38.5 mm. Convective heats transfer coefficient values for the cooling process were found to be higher than those for the heating process. Using a volume concentration of 0.25 percent for the Nano-fluids, the researchers found that the cooling process was enhanced by 45.2 percent. It was found that a unique formula for laminator flow was needed to calculate the number of Nusselt during the cooling process for volumetric concentrations of 0.15, 0.25, and 0.5%)%. Nun f=0.75Re0.846 Pr-2.28 0.03 [18].

Experimental research was conducted [19].

To calculate the heats, transfer coefficient and the seed concentration for a Nano-fluids consisting of Al2O3 nanoparticles with a volumetric concentration of between 0.3% and 0.1%. The particles are 20 nanometres in size. Heats transfer coefficient and Nusselt number were measured using a double-tube heats exchanger with the turbulent and opposing flow to assess the impact of temperature and nanoparticle concentration. Nusselt number and heats transfer coefficients both saw substantial increases. With an increase in temperature and nanoparticle concentration, the heats transfer coefficient over the base liquid increased by 12%.Then, the researcher [20].

Conducted an experimental inquiry to analyse parallel flow and counter flow utilizing Al2O3 nanoparticles mixed with ordinary fluids (water, ethylene glycol, and oil) that flow through a heats exchanger at different pass rates. The heats exchanger contains icy fluids. Since more heats is transported in the counter flow direction, the results showed that the counter flow exchanger is superior to the parallel-flow exchanger. Increasing the concentration of nanoparticles in the solvent amplifies the effect. performed experimental studies on a double-tube heats exchanger using hot and cold water as the working fluids. The loop is filled with cold water, while the inner tube transports hot water. It is possible to make educated guesses about the Nusselt numbers , the heats transfer coefficient, and the transmission coefficient. The total heats flow rates of different cold water masses may be calculated with the same amount of hot water continuously flowing through. ZnO, MgO, and CuO Nano-fluids with 0.05 and 0.1 percent volumetric concentrations were subjected to similar testing. Nano-fluids were compared to the base fluids of total heats transfers coefficient and Nusselit number, with CuO Nano-fluids having a higher total heats transfer coefficient than ZnO and MgO Nano-fluids [21].

Water was used as the basis liquid, and nanoparticles ranging in size from 15 to 20 nm were created by mixing iron oxide (Fe3O4) with water in a double-tube heats exchanger where the liquid flows turbulently at a Reynolds number (14000Re34600).

Conducted an experimental assessment of a double-tube heats exchanger's thermal performance and flowed. Two kinds of 20 nm Nano forms were added to non-ionized waters create base (Al2O3, TiO2). The inner tube is filled with hot deionized water at 59.3 degrees Celsius, while the outer tube receives a Nano-liquid at 30.7 degrees Celsius. The velocities of both fluids entering the tube are kept constant. Both kinds of nanoparticles were used in both parallel and opposing flows, with and the concentrations are 0.05% to 0.3% and velocities rangings forms 0.015 to 0.3 km/h (0.5, 1, 1.5, and 2). According to the experiments' results, the heats transfer rate improves with increasing nanoparticle concentration in the base liquid. A correlation between particle type and heats transmission rate was also observed. At a concentration of 0.3%, the heats transfer rate was maximum, and the improvement in heats transfer rate was 18.25%. Titanium-particle-laden liquid, in contrast, transferred heats at a rate of 15.5%. It has been shown that the heats transmission rate is higher in the liquid containing aluminium particles than in the liquid containing titanium oxide particles [22].

Experimented using a double-tube heats exchanger made of stainless steel on the outside and copper on the inside. The Nano-fluids can travel across the interstitial space between the two tubes by passing hot water through the inner tube. Concentrations of CuO Nano-fluids in fluids volume were used. It was determined that the total heats transfer coefficient rose by 22% from water 0.5 % [23].

Used 2-tube heats exchangers to study a hybrid Nano-fluids. Ethylene glycol (EG) mixes containing aluminium nitride nanoparticles are favoured for improving heats transfer. Hybrid Nano-fluids with a diameter of 30 nm and a volume fraction of 1% to 4% have been experimentally evaluated for their thermal characteristics. Hydrodynamic and thermal characteristics of EG with scattered AlN nanoparticles have been investigated. Each experiment's flow rate is varied between 0.5 and 4 L/minute, and the Reynolds number is changed from 500 – 1750 . The results showed that friction factor decrease, and the flow rate rises with the flow. Increasing the flow rate and decreasing the volume concentration of Nano-fluids raises the Nusselt number. As much as 160% more heats may be transferred using a hybrid Nano-fluids with low-volume fraction ions as opposed to a regular liquid. The thermal performance of the heats exchanger was shown to be potentially 35% enhanced by the hybrid Nano-fluids compared to the base fluids [24].

Performed an experimental investigation of CuO Nano-particles in water as a vessel liquid and 0.2 % in a counter flow 2-tube heats exchangers add to in a copper inner tube and a length of 1 meter. The efficiency of the heats exchanger was increased by 16 %, while the heats transfer rate increased by 20 %. conducted an experiment using Nano-fluids of varying concentrations. They compared them to pure water to assess the impact of add Al2O3 nanoparticles with a diameter of 47 nm to the base liquid. The investigation results show that increasing both the Reynold numbers and the concentration of Al2O3 Nano particle in water significantly increases the heats transmission efficiency [25].

Conducted an experimental study of heats transfer in a double-tube heats exchanger using different nanoparticle types after combining them in a mixture of water and ethylene as a base liquid at concentrations ranging from (0.2, 0.7, and 1.2) % and rates of flow ranging from 1.5 Litre minute, 1.8 Litre/minute, and 2.1 Litre/minute. At 70 degrees Celsius, 2.1 Litre per minutest, and a concentration of 1.2 percent, the findings showed that the Nusselt number and Reynolds number of the water and ethylene glycol combination were lower than those of ethylene glycol alone. Results showed that the Nusselt number of the Nano-fluids grew with both concentration and flow rate. At 70 degrees Celsius, ethylene glycol improved heats transmission by a maximum of 1.5077 and by a minimum of 0.16844 [26].

Experimented using a Nano-fluids with volumetric concentrations of (0.2-1.5) % of Al2O3 and TiO2 in a double-tube heats exchanger. In comparison to a system utilizing water as a base fluids, the performance of the one using Nano-fluids was far higher, as shown by the results [27].

The researchers focused on forces convection heats transfers This was done experimentally using copper oxide and magnesium oxide Nano-fluids in a laminator flow system within a straight tube maintained at the wall temperature. Fixed. To generate a useful Nano-liquid, propylene glycol and water are mixed as a base liquid, and then a certain quantity of (0.3) CuO / PG-W and 0.7) are added to the mixture. The data indicated that the produced Nano-fluids significantly outperformed the basic liquid in terms of heats transfer efficiency. In regions of maximum volumetric concentration, the Nusselt number rises at a more rapid rate.

Rising values of both the Nusselt number and the heats transfer coefficient are likely due to a synergistic impact of increasing the effective thermal conductivity of the Nano-fluids, the existence of Brownian motion, and the random collision of the liquid particles and the nanoparticles [28].

2.3 REVIEW OF EARLIER EMPIRICAL AND NUMERICAL STUDIES

A heats exchanger with a stainless-steel outer tube and a copper inner tube was subjected to experimental testing [29].

When hot water travels through the inner tube, it forces the Nano-fluids to migrate across the interstitial area between the two tubes. In this experiment, we used CuO Nano-fluids at a range of concentrations in volume. The total heats transfer coefficient rose by 22% from water volume concentre of 0.5 %.

used 2-tube heats exchangers to conduct experiments with a hybrid Nano-fluids. Aluminium nitride nanoparticles dispersed in ethylene glycol (EG) are the favoured method for improving heats transfer. Thermal parameters of the hybrid Nano-fluids have been tested experimentally; its diameter is 30 nm, and its volume fraction is 1-4 percent. AlN nanoparticles dispersed in EG have been studied for their hydrodynamic and thermal characteristics. The investigations vary the flow rates from 0.5 to 4 L/minute and the Reynolds values from 500 to 1750. Based on the results, it is clear that the friction factor decreases, and the flow rate rises with the flow. Increases in both flow rate and Nano-fluids volume concentration result in a higher Nusselt number, whereas reductions in Nano-fluids volume concentration lead to a higher Nusselt number. Increased heats transfer efficiency of up to 160 percent has been seen when using hybrid Nano-fluids with low-volume fraction ions instead of conventional liquids. It was shown that the thermal performance of the heats exchanger might be significantly enhanced by the hybrid Nano-fluids, perhaps by as much as 35% compared to the base fluids [30].

Tested the effects of a 0.2% concentration of CuO nanoparticles in water as the base liquid in a 1-meter-long, copper inner tube counter flow double-tube heats exchanger. There was a 20% increase in the heats transfer rate, and a 16% increase in the efficiency of the heats exchanger [31].

Experimental findings for Nano-fluids at several concentrations were compared with those for pure water to assess the impact of adding 47 nm diameter Al2O3 nanoparticles mixed in water as a base liquid. (et al. As the Reynolds number and nanoparticle concentration increase, the research found that heats transfer may be considerably enhanced by adding Al2O3 nanoparticles to water. conducted an experimental study of heats transfer in a double-tube heats exchanger using different nanoparticle types after combining them in a mixture of water and ethylene as a base liquid with concentrations ranging from (0.2, 0.7, and 1.2) % and rates of flow ranging from 1.5 Litre minute, 1.8 Litre/minute, and 2.1 Litre/minute. According to the data, a combination of water and ethylene glycol has a lower Nusselt number and Reynolds number than ethylene glycol alone at an intake temperature of 70°C, a flow rate of 2.1 L/minute, and a concentration of 1.2%. Results showed that when concentration and flow rate increased, so did the Nano-fluids Nusselt number. At 70 degrees Celsius, ethylene glycol showed a maximum heats transfer increase of 1.5077 and a minimum heats transfer improvement of 0.16844 [32].

Used a Nano-fluids with volumetric concentrations of (0.2-1.5) % of Al2O3 and TiO2 in a double-tube heats exchanger to conduct experimental research. Data shows that utilizing Nano-fluids improves system performance compared to using water as the foundation fluids [33].

The study's primary focus was on examining forced convection heats transfer. Experiments were performed on copper oxide and magnesium oxide Nano-fluids in a laminator flow system within a straight tube at a wall temperature. Fixed. To make a Nano-liquid with useful properties, propylene glycol and water are combined with a certain concentration of (0.3) CuO /PG-W and 0.7). The data indicated that the produced Nano-fluids significantly improved heats transfer efficiency over the basic liquid. Here is where you will see the largest jump in Nusselt number due to the high-volume concentration. This increase in the Nusselt number and the heats transfer coefficient is likely due to the synergistic effects of raising the effective thermal conductivity of the Nano-fluids, the existence of Brownian motion, and the random collision of the liquid particles and the nanoparticles [34].

2.4 ANALYSES OF PRIOR MATHEMATICAL RESEARCH

Used a double-tube heats exchanger to perform a numerical investigation of heats transfer between a pure liquid and a Nano-fluids composed of aluminium oxide Al2O3 coupled with water as a base at different volumetric proportions. The research showed that the heats transfer coefficient At a concentration of 3% in the double-tube heats exchanger, the improvement in total heats transfer coefficient was 22%, and it grows as the volumetric concentration of nanoparticles increases [35].

Used a simplified model of a double-tube heats exchanger with counter flow and turbulent flow to investigate heats transfer when aluminium oxide nanoparticles with a diameter of 20 nm were added to waters bases liquid. After solving a governing equations using the (Mat - Lab) program, the researchers compared their findings to those obtained with only the base liquid. The results showed that using the Nano-fluids improved heats transmission by 26%, leading to an 11% boost in exchanger efficiency [36].

Assessed the efficacy of a 2-tube heats exchangers filled with Al2O3 Nano-fluids for enhancing heats transmission. The average heats transfer coefficient, Nusselt numbers , pressure drop, and friction factor were studied, along with their relationships to concentration and volumetric flow rate. The average heats transfer coefficient and the Nusselt numbers of the main fluids were found to be greatly improved by the incorporation of nanoparticles, by 26% and 12.5%, respectively, at a nanoparticle size concentration of 4%. The boost pressure may be decreased by as much as 10.11 percent if nanoparticles are mixed into the base liquid. The efficiency of the heats exchanger is improved by 16% when aluminium particles (4% by volume) are added to the base fluids [37].

Have conducted a computational study of a double-tube heats exchanger with cold Nano-fluids flowing in the inner tube with helical baffles on its surface and hot water flowing through the outer tubes to ensure the occurrence of turbulent flow. The barriers prevent nanoparticles from depositing and building up along the tube even after extended periods of use. The primary medium was a mixture of water and CuO nanoparticles. The simulation equations were solved using computational fluids dynamics (CFD) software developed by ANSYS (FLUENT) to examine the flow and temperature distribution inside the tube. The heats exchanger's performance and heats transfer rate were found to be enhanced when copper oxide particles were used in a water solution [38].

Heats transfer via Nano-fluids was effective, the study's authors claim, since the properties of Nano-fluids, in particular thermals conductivity, viscosity, were known beforehand. The research found that both the presence liquid and concentration led to improvements in the liquid's thermal conductivity and viscosity. Nano-fluids' heats transmission and friction coefficients were also studied, using several Nanocomposites at varying concentrations and temperatures. raised thermal conductivity coefficient. In contrast, increasing Reynolds number increased the friction and convectional heats transfer coefficients. evaluating and comparing the results of previous experimental work on enhancing the heats transfer of Nano-fluids with those of work employing more conventional fluids [39].

Drew some interesting conclusions. Important factors that affect Nano-fluids include particle concentration, material type, fluids principal ingredient, and temperature. Researchers found that using Nano-fluids enhanced heats transfer significantly. Analysed the Literature around the use of Nano-fluids in heats exchangers, taking into account the many kinds of heats exchangers that exist. The poll found that ethylene glycol was utilized as a base liquid 8 % of the time, whereas water was used 87 % of the time. A few of the most typical After testing solutions containing nanoparticles of aluminium, copper oxide, and carbon with concentrations of 52 %, 20 %, and 11 %, respectively, the study found: Most studies show that using Nano-fluids in heats exchangers, which increases the Reynolds number, results in a considerable improvement in the Nusselt number. In most circumstances, more pumping power is required, and the maximum volumetric concentration results in the best heats transfer [40].

Found several methods to improve heats transfer rates after reviewing the literature from the preceding five years on the usage of Nano-fluids and how they influenced the performance of different heats transfer systems [41].

By simulating TiO2-water Nano-fluids in double-tube exchangers, studies have shown the effectiveness of nanoparticles in heats transfer. [42].

Through the results, it was observed that the thermo physical properties have been improved for the hybrid Nano-fluids by 7 to 13 % when compared to water [43].

The efficiency of the exchanger increases when nanoparticles are used in the base fluids [44].

The study was carried out on various heats exchangers and it was concluded that when using nanoparticles, it reached a significant decrease in the temperature of the contrast fluids [45],[46].

Studies have also concluded that the higher the Nano concentrations in the counter fluids, a significant increase in heats transfer is achieved, and excellent efficiencies are obtained [47].

The studies reached two methods, the first is to increase the percentage and decrease the pressure, and the second is to use spiral wires, as well as the use of porous materials. By using the two methods, noticeable and practical improvements are obtained [48].

Table 2.1: Methods Used To Improve Heats Exchangers Are Double Or Two-Pipe.

Ref	method	Improvement	Result
[49]	Active	Using air bubble injection	The overall heats transfer coefficient undergoes an improvement of 10.30% for 149.50%
[50]	Active	surfaces vibrations	And the heats transfer coefficient undergoes an improvement of 9%
[51]	Active	Using magnetic field	4With lower pressure, the heats transfer rate reaches 320%.
[52]	Active	using ultrasonic vibration	And heats transfer will be improved by 60%.
[53]	passive	porous media	Heats transfer is improved by 44%
[54]	passive	using fins	Enhance heats transfer by about 90-98%.
[55]	Passive	spiral wire	An increase in the Nusselit number by 2.64 we observe.
[56]	Passive	Twisted- tape	Significant 15 % enhancement in heats transfer rate. Frictions factor increased by 10 %
[57]	Passive	Metals foam	Nusselit number enhanced by 57.21%.
[58]	Passive	Nano fluids (MgOethylene Glycol)	heats transfer coefficients enhancements of 27 % for wt. % = 0.3 and 35 % pressures Drop at wt. % = 0.3.

Table 2.2: Using Nano-Fluids Acting on The Corrugated Tube Type Heats Exchanger.

Ref.	Type of nanoparticles	Primary or primary fluids	Rustle
[59]	Al_2O_3/ SiO_2/ CuO	60% ethylene glycol 40 % water	Average heats Transmission has improved by 40 %, 29 % and 43 % and pressure drop has increased by 84 %, 47 % and 100 %.
[60]	TiO_2/Ag/ZnO	Water	An improvement in heats transfer coefficient of 32 %, 21 % and 16 % has been obtained.
[61]	Multi-walled carbon nanotubes (MWCNT)	Glycol solar energy	A heats transfer of 115 % was obtained for a concentration of 0.04 kg/sec and 0.6 %. The increase is 1.56 the pressures drop is 0.08 kg/sec, and the concentration is 0.6 %.
[62]	MgO	50 % water-50 % ethylene glycol	heats transfers enhances by 39 % at wt.% = 0.3 and frictions factors increased by 33.80 %.
[63]	TiO_2	Water	Heats transfer coefficient enhances by 6–11 %. Low penalty of pressures Drop.
[64]	Fe_3O_4	Water	Heats transfer was 115 % for a concentration of 0.04 kg/sec and 0.6 %. The increment is 1.56 the pressures drop is 0.08 kg/sec, and the concentrations is 0.6 %.

Table 2.3: Influence of The Concentrations of Nanoparticle on Nano Fluids Properties.

Ref.	Type of nanoparticles	Base fluids	Rustle
[65]	MWCNT (multi-walled carbon nanotubes)	Ethylene glycol	Thermals Conductivity's Increased by 50 % with a 0.06 % concentration. viscosity increased by 58 % with a 0.1 % concentrations .
[66]	CuO	60% Ethylene glycol/40% water	Thermal conductivity improved by 26 %, density improved by 29 %, and viscosity improved by 27 %.
[67]	Al_2O_3	Water	Increased viscosity by 31 % compared to the base fluids.

Table 2.3: Influence of The Concentrations of Nanoparticle on Nano Fluids Properties "Table Continued",

[68]	MWCNT (multi-walled carbon nanotubes)	Water	Thermals Conductivity Increased by 9.80–15.28 %. Viscosity's increased by 11.489.15 %, and Density's increase's as well.

Found several methods to improve heats transfer rates after reviewing the literature from the preceding five years on the usage of Nano-fluids and how they influenced the performance of different heats transfer systems [69].

2.5 A SUMMARY OF EARLIER STUDIES AND RESEARCH

Previous research and studies have investigated how incorporating nanoparticles into conventional fluids (water, oil, ethylene glycol) can enhance heats transfer performance, as well as how doing so alters the thermals a physical property of the resulting liquid , the performance of various heats exchangers, and the efficiency of the fluids themselves. Copper oxide (CuO), titanium dioxide (TiO2), aluminium oxide (AL2O3), zinc oxide (ZnO), and magnesium oxide (MgO) were the most often used oxides to create nanoparticles, which were then mixed with other liquids (water, ethylene glycol, and oil). Nanoparticles, since the stability of these particles in the base fluids, have a major impact on enhancing heats transmission. Most studies employed nanoparticles with a diameter of 20 nm, and volume ratios typically fell between (0.1%) and (0.3%). Every scientist interviewed for this study agreed that it was difficult to keep nanoparticles dispersed and stable in the base fluids over time. In this research, a heats exchanger was filled with a mixture of copper oxide nanoparticles (diameter: 40 nm) and titanium oxide nanoparticles (diameter: 10-30 nm), with water serving as the base fluids and the volume concentration of the particles being set at 0.5 and 1%, respectively. The Nano-fluids was used in place of water. To improve the efficiency of a heats exchanger, cooling the incoming hot water is recommended. The ratios of optimization may then be compared using these nanoparticles.

3. METHODOLOGY

3.1 EXPERIMENTAL WORK

This chapter includes the construction of the test system consisting of two heats exchangers the first is the main one, as it works to exchange heats between the Nano-fluids that runs in the inner tube of the exchanger and the hot water that flows through the confined space between the two tubes of the exchanger, and this exchanger will be practically identified on the nature of heats transfer between the two fluids in the exchanger and the amount of temperature change.

As for the second exchanger, it is to extract the heats acquired by the Nano-fluids in the primary exchanger and return it to the initial temperature at which it entered the primary exchanger. for this purpose, a cooling system was used to cool the water or the Nano-fluids passing through the inner tube of the secondary exchanger. the work was carried out in two phases.

a. the first stage

it involved testing the primary heats exchanger using water in both tubes and then calculating coefficients and rates of heats transfer between hot water and cold water.

b. the second phase

the same heats exchanger test included replacing the cold water that runs in from tube of the exchanger with a Nano-fluids consisting of silver oxide particles with water at a volume concentration of (0.1% and 0.2%) with a flow rate of (3,5and7 l/minute)

as well as connecting and calibrating measuring devices, as well as preparing the Nano-fluids and checking its stability, as well as the method of conducting the required tests.

3.2 TEST SYSTEM

The test system shown in Figure (3.1) consists of two double-tube heats exchangers , two concentric tubes and two (6) Litre thick plastic (polymethyl methacrylate) tubs, one of which heats the water by means of an electric coil of (3000) watts as shown. Figure (3.2), to a temperature of 60°C ±1 before being forced by a pump to the primary heat's exchanger. The second container is for collecting Nano liquids from the secondary exchanger. Maintaining the temperature of the nanofluids at 15 °C ± 1 and cooling them by means of a refrigeration system installed inside the tank as shown in Figure (3.3).

The flow rate has used one value for hot water (5 l/minute) and three values for cold water or Nano-fluids ((3l/minute) -(5l/minute) -(7l/minute))

The heats exchangers consist of 1-meter-long copper tubes with the following specifications:

Inner diameter of the exchanger inner tube = 9.5 mm, thickness = 1.5 mm

Inner diameter of the outer tube of the exchanger = 19 mm, thickness = 1.7 mm.

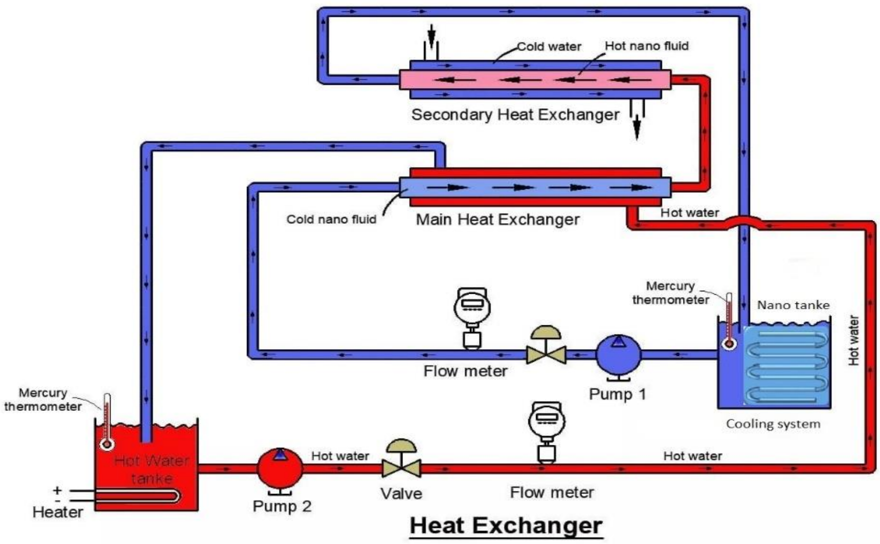

Figure 3.1 Test System Diagram**.**

Figure 3.2: Electron Coil For Heating.

Figure 3.3: Cooling System Inside the Nano-Fluids Tank.

To ensure that heats is not lost from the heats exchangers to the outer periphery, the outer surfaces of the exchangers were insulated with two layers of arm flex insulation, which is used to insulate pipes connecting parts of domestic cooling systems (split units). Figure (3.4) shows a picture of copper tubes and the material used in thermal insulation.

Figure 3.4: Copper Tubes and Insulating Material**.**

The heats exchangers were connected to each other and to the tanks by means of plastic tubes with a diameter of (1/2 inch). Figure (5-3) shows the plastic tubes, connections and valves used to control the flow rate of water and Nano-fluids.

Figure 3.5: Plastic Water Tubes and Fitting.

To circulate the two fluids (water and Nano-fluids) in the system, it contained two centrifugal pumps with a capacity of half a horse as shown in Figure (3.6). One of them is to push the Nano-fluids from the Nano-fluids tank to the primary heats It runs in the inner part of the exchanger, and the second is to push the hot water from the hot water tank to the primary heats exchanger to flow into the confined space between the exchanger tubes.

Figure 3.6: The Pump Used in The Test System.

The parts of the test system were assembled using an iron table, the heats exchangers were fixed on its upper surface, and the tanks and pumps were placed on its lower surface. A plastic plate measuring (2.5 x 1.75) m was installed on which the switches for operating the two pumps, the electric coil, and three light bulbs were installed to indicate whether they were operating, as well as two flow rate measuring devices and digital thermometers used to measure temperatures. Figure (3-7) shows the entire test apparatus and Table (3-1) shows the main parts of the test system.

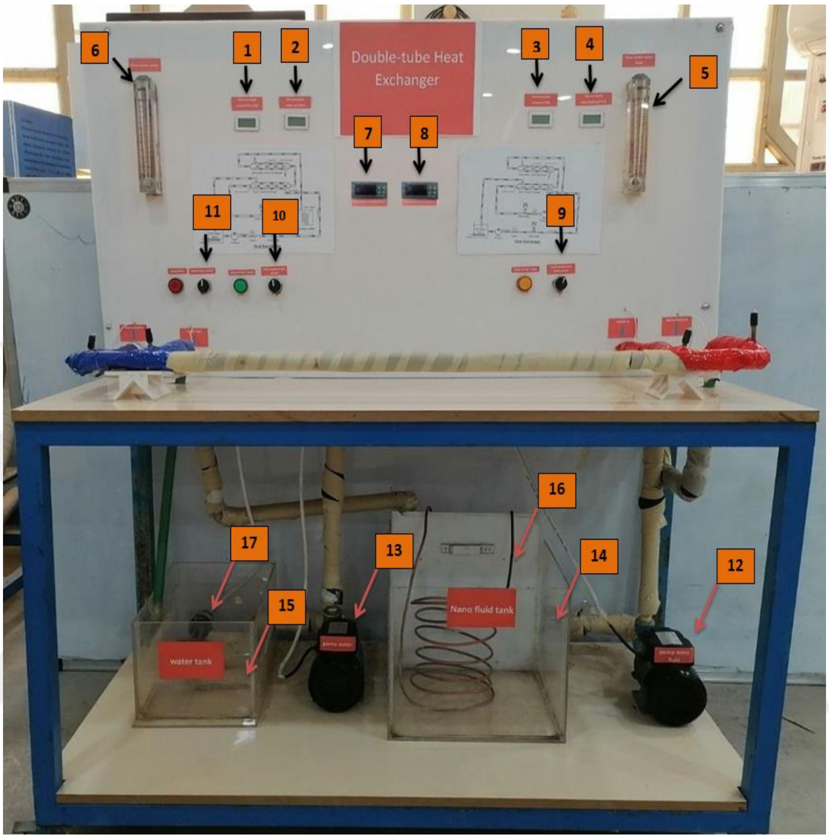

Figure 3.7: Is a Picture of The Test System.

Table 3.1: The Main Parts of The Test System.

Parts of the system	**No.**	**Parts of the system**	**No.**
switch start Nano fluids pump	**9**	Thermocouple to measure the Nano-fluids in (TCi)	**1**
switch start water pump	**10**	Thermocouple to measure the exit temperature of hot water (Tho)	**2**
switch start heater system	**11**	Thermocouple to measure the in temperature of hot water (Thi)	**3**

Table 3.1: The Main Parts of The Test System. "Table Continued",,

Nano fluids pump	**12**	Thermocouple to measure the Nano-fluids out (TCo)	**4**
Water pump	**13**	Volumetric Flow meter (Nano fluids)	**5**
Nano fluids tank	**14**	Volumetric Flow meter (water fluids)	**6**
Water tank	**15**	thermostat cooling system	**7**
Cooling system	**16**	thermostat heater system	**8**
Heater system	**17**		

3.3 MEASURING DEVICES

3.3.1 Thermocouple Measurement

For measuring the temperatures of the two fluids used in the primary and secondary heats exchangers at the entrances and exits of the exchangers. shown in Figure (3-8). These pairs were distributed as follows:

a. Two thermocouples installed on both ends of the base heats exchanger, to measure the temperature of hot water (passing through the space between the exchanger tubes) when entering and leaving the exchanger.

b. Two thermocouples installed on both ends of the base heats exchanger to measure the temperature of water or Nano-fluids (passing through the inner tube of the exchanger) when entering and leaving the exchanger.

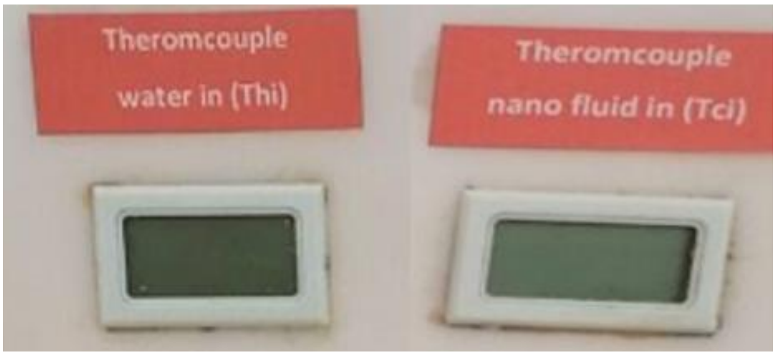

Figure 3.8: Thermocouple Measurement.

3.3.2 Measuring the Flow Rate.

The volumetric flow rate of both hot and cold fluids (hot water and cold Nano-fluids) was measured by two rotameters of the type (Z-3002), which is made of a variable-section glass tube marked with gradations in units (1.8-18) Litre/minute. These two scales are fixed in the specified place shown in Figure (3.9).

Figure 3.9: Volumetric Flow Rate Meter.

3.3.3 Thermostat Measurement

A device used to maintain the temperature of a fluids or a space whose temperature is to be controlled automatically. It contains a sensitive element that changes shape with changes in temperature, resulting in a mechanical force or an electrical signal that works to open or close the electrical circuits that control heats or cold shown in Figure (3.10).

Figure 3.10 Thermostat Measurement.

3.4 PREPARATION OF THE NANO-FLUIDS

Before preparing the Nano-fluids, it is necessary to determinate the amount of water used in the exchanger and the amount of nanoparticles used, which determinates the volume ratio or the concentration of particles in the water. The nanoparticles used in practical experiments to test the efficiency of the heat exchanger are Silver oxide (Ago. Specifications for water are in Annex (A-1), while specifications for silver oxide are written in Annex (A-2). The mass of solid nanoparticles is calculated in Annex (A-3) And by mixing it and then suspending it in water after taking the water mass by volume 6 litres and volumetric concentrations of (0.05% and 0.08%) using the following (1.3) equation [70],[71].

$$m_p = \frac{\emptyset \times \rho_p \times \left(\frac{m_f}{\rho_f}\right)}{(1-\emptyset)} \tag{3.1}$$

Table 3.2: Physical and Thermal Properties of Nanoparticles[72],[73].

Nanomaterial's		Density (kg/m^3)	Thermal conductivity coefficient (W/m.K)	Specific heats (J/kg.K)
silver oxide (Ago)		10490	429	710

The calculated amount of Nanoparticles was prepared for equation (3.1) above using a sensitive balance to obtain the exact weight to mix it with a volume of 6 litres of water. Figure (3.11) shows the image of the sensitive balance.

Figure 3.11: is a Picture of The Sensitive Scale.

By combining nanoparticles with water in two ways, we will explain this in two steps, depending on the type of particles: [74],[16]:

a. The mechanical first step

In order to facilitate the process of mixing nanoparticles with water, the weight of the nanomaterial resulting from the weight ratios (0.1 % - 0.2 %) was divided into three sections, and as the amount of water 6 Litre was divided into three sections, each section (2) litres Mixing the prepared nanoparticles with 2 Litre of water using an electric mixer that continued for 40 minutes until it became completely homogeneous. This process was performed three times to mix the total amount. Figure (3.12 (a)) illustrates the electric mixer.

b. using the ultrasonic machine

We put the resulting mixture from the electric mixer in the ultrasonic device to ensure that it is well mixed in the mixer. The device has been running for 45 minutes. This process took place in three stages because the device does not accommodate more than 2 litters. Figure (3.12 (b)) shows the ultrasound device.

(a) (b)

Figure 3.12: (a) Electric Mixer (b) Ultrasonic.

The Nano-fluids was continuously monitored until the particle separation phase started. It was noted that the maximum time for stabilization of the Nano-fluids consisting of water and silver oxide is approximately (12) hours for the volumetric ratio (0.1 %) and approximately (11) hours for the volume ratio (0.2 %). Therefore, it can be said that the Nano-fluids (silver oxide with water) is stable during the duration of the experiment. Photograph of the process of monitoring Nano-fluids samples.

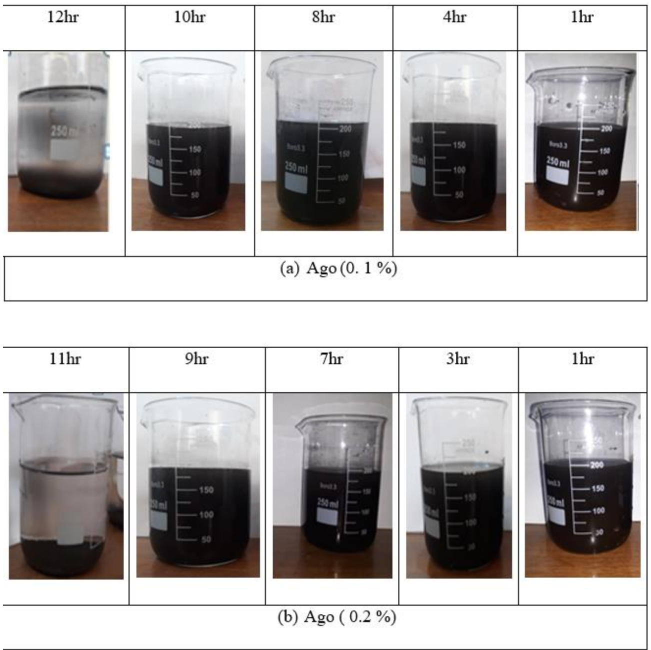

Figure 3.13: (a),(b) Photographs of The Process of Monitoring Silver Oxide Samples With Water**.**

3.5 EXPERIMENTAL MEASUREMENTS

The experimental measurements include the thermo physicals property of the Nano-fluids (density, thermals conductivity, viscosity and specifics heats) as follows:

3.5.1 Density

It represents the mass of the volume unit, which is calculated by equation (3.2) [75]:

$$\rho = \frac{m}{v} \tag{3.2}$$

Note that (m) is the mass that was measured in a sensitive balance, (v) represents the volume of water required, which is measured using a graduated flask as shown in Figure (3.14).

Figure 3.14: Photograph of The Graduated Beaker and Sensitive Scale.

3.5.2 THERMAL CONDUCTIVITY

Thermal conductivity can be defined as the material can get a temperature, which a property of a material. The thermal conductivity of the water and the Nano-fluids was calculated using a (Conductivity Meter) type (TS-51), and the accuracy of the device is approximately (1%). Put the cylindrical part in the water sample and the Nano-fluids sample in the centre of the flask at the required temperature and for all volumetric concentrations and after a period we take the practical reading of those samples as shown in Figure (3.15).

Figure 3.15: Photographs of Measuring Thermal Conductivity.

3.5.3 VISCOSITY

Using the device (Brookfield Digital Viscometer DV-II+ Pro) as shown in Figure (3-16), which works on the principle of torque (shear stress) to calculate the viscosity of the Nano-fluids and the viscosity of water.. The water sample, as well as the Nano-fluids sample, and for each volume concentration, were placed in the graduated flask, where the viscosity is measured by rotating the cylinder at the bottom of the device, which is immersed in the fluids whose viscosity is to be measured, and the calculation model is shown in Annex (B-3).

Figure 3.16: Photographs of Viscosity Measurement.

3.6 ACTION STEPS

Verify that the device is ready to work, the water experiment was started. The water was heated to a temperature of ±1°C by means of a heating coil, and cold water was prepared at a temperature of 15°C°±1 with a determination of the rate of flow for hot water (5 Litre/minute) and for cold water. At (3 Litre / minute) with monitoring of the temperature gauges and when the stability state is reached, the values for the temperature are recorded. Repeat the experiment with hot water stability and cold-water flow rate modification. (5 Litre / minute) and then after that to (7 Litre / minute). minute) and record the temperature values after checking for stability.

* Parallel and opposite flows have been compared, and it has been proven that the opposite is better. Therefore, it was adopted by the study.

After completing the preparation of the Nano-fluids and placing in is own aquarium, By following the steps [37].

a. running electrical Coil ; To heats the water in second vessel and raise its temperature to 60°C ±1°C and this is achieved by Cooling thermostat set the Nano-fluids by means of a cooling system to a temperature of 15°C°.

b. And by determining the required quantities that pass through the exchanger pipes in terms of water hotness and coldness, with a flow of (5) litters / minute, and with the flows taken (3, 5, 7) litters /minute, which are measured with special measuring devices in laboratory equipment

c. Continuous monitoring of the inlet and outlet of the exchanger for hot and cold liquids, checking them every 10 minutes, and ensuring that the condition is stable.

3.7 CALCULATIONS

Calculate the physical properties of hot and cold fluids from the average inlet and outlet temperatures for both fluids.

$$T_{h,m} = \frac{T_{h_i} + T_{h_o}}{2} \quad , \tag{3.3}$$

$$T_{c,m} = \frac{T_{c_i}+T_{c_o}}{2} \qquad (3.4)$$

The total heats transfer coefficient, the amount of heats transferred, and the efficiency of the heat's exchanger were calculated using the following equations.

a. Calculation of the mass flow rate of hot water.

$$m_h = \frac{\dot{V}}{60000} \times \rho \qquad (3.5)$$

b.Calculation of the cold-water mass flow rate.

$$\dot{m}_c = \frac{\dot{V}}{60000} \times \rho \qquad (3.6)$$

c.The amount of heats transferred from hot water to cold water

$$q_h = \dot{m}_h \times Cp_h \times (Th_i - Th_o) \qquad (3.7)$$

d. The amount of heats gained in cold water

$$q_c = \dot{m}_c \times Cp_c \times (Tc_o - Tc_i) \qquad (3.8)$$

e.The average amount of heats transferred

$$q_{avg} = \frac{q_h + q_c}{2} \qquad (3.9)$$

f.The area adopted for calculating the velocity of water or Nano-fluids flowing in the inner tube is the tube cross-sectional area (A_ci), which is:

$$A_{ci} = \frac{\pi}{4} d_i^2 \qquad (3.10)$$

g.The area approved for calculating the velocity of hot water flow in the space between the two pipes (Aan):

$$A_{an}= \frac{\pi}{4}\left(D_i^{2} - d_o^{2}\right) \tag{3.11}$$

h.Calculate the flow velocity of each of the two fluids in the exchanger from the following equation:

for cold fluids

$$u_i=\frac{\dot{m}_c}{\rho\times A_{ci}} \tag{3.12}$$

for hot fluids

$$u_o=\frac{\dot{m}_h}{\rho\times A_{an}} \tag{3.13}$$

i. The hydraulic diameter (DH) in relation to the space between the two tubes (ie, hot water) is calculated from the equation:

$$DH = \frac{4AC}{P} = [Di - \ do] \tag{3.14}$$

j.Calculate the Reynolds number for hot water and cold water based on their respective properties at the average inlet and outlet temperature; In order to find out the flowing linear or turbulent, using the equation:

for cold fluids

$$Re_c = \frac{\rho_i \, u_i \, d_i}{\mu_i} \tag{3.15}$$

for hot fluids

$$Re_h = \frac{\rho_o \ u_o \ DH}{\mu_o} \tag{3.16}$$

k. The amount of space occupied by the inner surface of the inner tube

$$\mathrm{Ai} \ = \pi \times \mathrm{di,ip} \times \mathrm{L} \tag{3.17}$$

l.The amount of space occupied by the outer surface of the inner tube

$$\mathrm{Ao,ip} = \pi \times \mathrm{do,ip} \times \mathrm{L} \quad (3.18$$

m.13-The logarithmic mean temperature of the backflow

$$\mathrm{LMTD} = \frac{(Thi{-}Tc0) - (Th0 - Tci)}{ln\,(\frac{(Thi{-}Tc0)}{Th0 - Tci})} \quad (3.19)$$

n. And the total heats transfer coefficient is relative to the inner surface area of the inner tube. The value of 1 = F in the reverse flow [76].

$$\mathrm{Ui} = \frac{q_{avg}}{A_{i,ip} \times LMTD \times F} \quad (3.20)$$

$$\frac{1}{Ui} = \frac{1}{hi} + \frac{Ai \quad \ln \; do/di}{2\pi kl} + \frac{Ai}{Ao}\,\frac{1}{ho} \quad (3.21)$$

u.Heats capacity of cold water

$$\mathrm{Cc} = \dot{m}\mathrm{C} \times \mathrm{Cp_c} \quad (3.22)$$

o.Heats capacity of hot water

$$\mathrm{Ch} = \dot{m}\mathrm{h} \times \mathrm{Cp_h} \quad (3.23)$$

71-minuteimum heats capacity (Comminute), = Cc) minute value of Cc and Ch

p.The upper limit of the heats capacity (Cmax), = (Ch is the highest value of Cc and Ch

q.Calculation of the heats capacity ratio

.

$$C^* = \frac{C_{min}}{C_{max}} \quad (3.2)$$

r.Calculate the numbers of heats transfers units (NTU) forms the following equations:

$$\mathrm{NTU} = \frac{U_i\,A_i}{C_{min}} \quad (3.25)$$

s.Calculate the efficiency of the heat exchanger from the following equation:

$$\varepsilon = \frac{\Delta T_{min}}{\Delta T_{max}} \quad (3.26)$$

Using Practical Equations, it will be:

$$\varepsilon = \frac{(Tco - Tci)}{(Thi - Tci)} \tag{3.27}$$

Calculations using theoretical equations it will be:

$$\varepsilon = \frac{1 - e - NTU(1 - C*)}{1 - C*e - NTU(1 - C*)} \tag{3.28}$$

t.It is possible to determinate the Nusselt- number inside an inner tube by first determining the temperature of surface of the inner part (tube), which is the same as the outer surface thanks to the temperature scales distributed all around the outer surface of the inner tube, and then determining the inner heats transfer coefficient.:

$$T_{w_c} = \frac{T1 + T2 + T3 + T4 + T5}{5} \tag{3.29}$$

$$T_{c,avg} = \frac{Tc_o + Tc_i}{2} \tag{3.30}$$

.

$$h_i = \frac{q_{avg}}{A_i(T_w - T_{c,avg})} \tag{3.31}$$

$$Nu_c = \frac{h_i\, d_i}{k_i} \tag{3.32}$$

u. Assuming that the surface temperatures of the inner and outer tubes are identical, calculate the Nusselt number in the outer tube from the calculated outer surface temperature of the inner tube and the outer heats transfer coefficient; Because of the small thickness of the tube.:

.

$$T_{w_h} = \frac{T1 + T2 + T3 + T4 + T5}{5} \tag{3.33}$$

$$T_{h,avg} = \frac{Th_i + Th_o}{2} \tag{3.34}$$

$$h_o = \frac{q_{avg}}{A_o\,(T_{h,avg} - T_w)} \tag{3.35}$$

$$Nu_h = \frac{h_o\, DH}{k_o} \tag{3.36}$$

v.Calculate pressure losses from the following equation:

$$\Delta P = \rho \times g \times H \tag{3.37}$$

25- Calculate the coefficient of friction for the inner tube from the following equation [76]:

$$f = \frac{2*\Delta P*gc*d_i}{L*\rho*u^2} \tag{3.38}$$

w.Calculate the heats exchanger performance coefficient at a volume concentration ratio of (0.5 and 1%) from the following equation [77].

$$PEC = \frac{\left(\frac{Nu_{nf}}{Nu_f}\right)}{\left(\frac{f_{nf}}{f_f}\right)^{\frac{1}{3}}} \tag{3.39}$$

3.8 CALCULATE THE PROPERTIES OF NANO-FLUIDS FROM EQUATIONS

a. The density of the Nano-fluids was calculated as in the following equation [78],[79]:

.

$$\rho_n = (1 - \emptyset)\rho_f + \emptyset\rho_P \tag{3.40}$$

Calculations for all volumetric ratios in Annex (A-1)

b. Calculation of the thermal conductivity of the Nano-fluids as follows [80]:

$$k_n = k_f\left(\frac{k_s+2k_f-2\emptyset(k_f-k_s)}{k_s+2k_f+\emptyset(k_f-k_s)}\right) \tag{3.41}$$

Calculations for all ratios are in Appendix A-2.

c. Calculating the viscosity of the Nano-fluids as follows [81]:

$$\mu_{nf} = \mu_{bf}(1 + 2.5\emptyset) \tag{3.42}$$

Calculations for all volumetric ratios in Annex (A-3)

d. Calculation of the specific heats of the Nano-fluids [82].

$$CPnf = \frac{(1-\emptyset)CPbf * \rho bf + \emptyset * \rho p * Cpp}{\rho nf} \quad (3.43)$$

Calculations for all volumetric ratios in Annex (A-4)

There is an error rate generated from practical experiments and measurements, so it must be taken into account [83].

$$\% \, error = \frac{|theoretical \, value - experimental \, value|}{theoretical \, value} \times 100\% \quad (3.44)$$

3.9 COMPUTATIONAL FLUIDS DYNAMICS (CFD) ANALYSIS

The analysis is carried out using the simulation program (ANSYS FLUENT 2022 R1). Through this simulation, the temperature distribution for the heats exchanger is known the fig (3.17).

3.9.1 Geometry

Figure 3.17: Heat Exchanger Model**.**

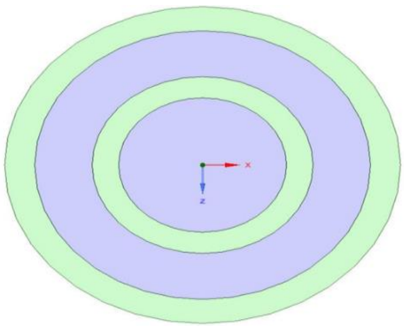

Figure 3.18: The Temperature Distribution for The Heats Exchanger.

3.9.2 Mesh

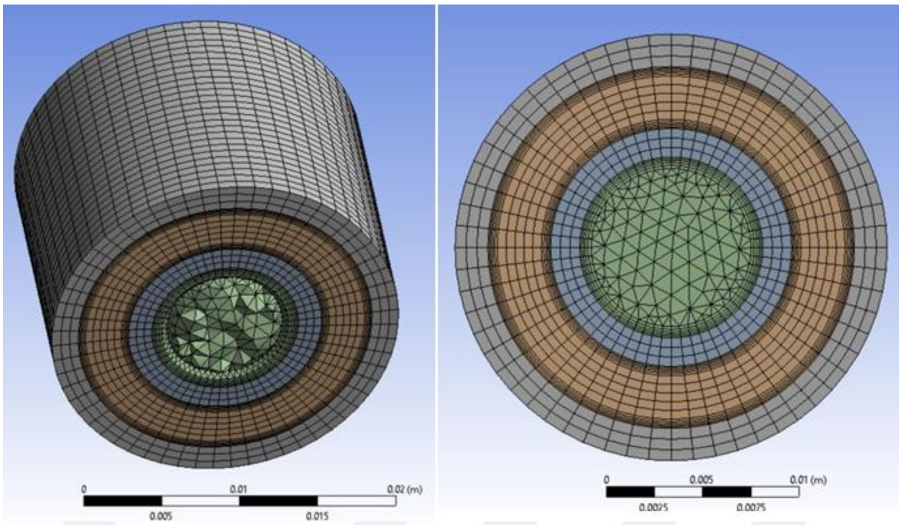

Figure 3.19: The Mesh Results for the Heats Exchanger.

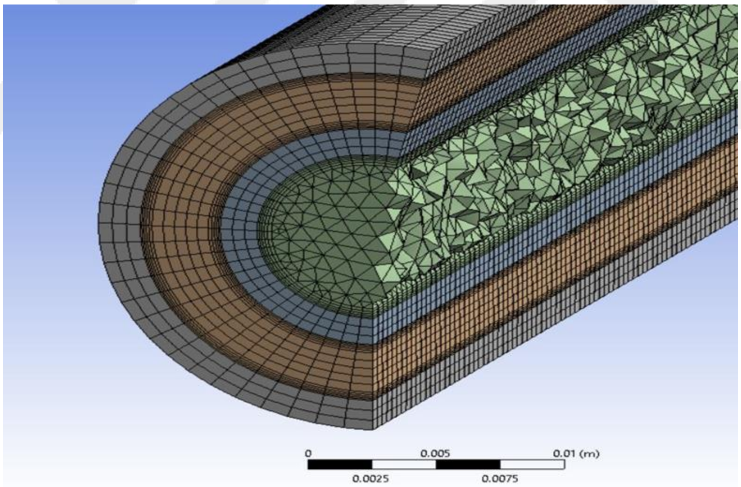

Figure 3.20: The Mesh Results With Section to Show Details for the Heats Exchanger.

3.9.3 Calculations using Fluids Dynamics (CFD) Analysis

a. calculations heats exchanger (water fluids)

a. Hot water (5l/minute)&cold water (3l/minute).

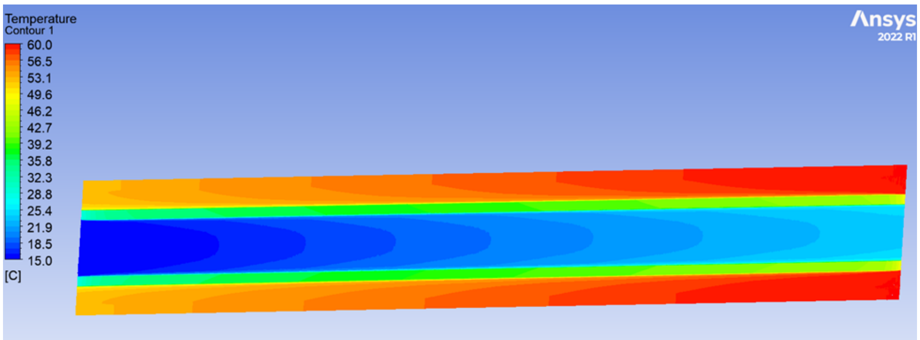

Figure 3.21: Fluids Dynamics Temperature Contours for Hot Water (5l/Minute)&Cold Water (3l/Minute).

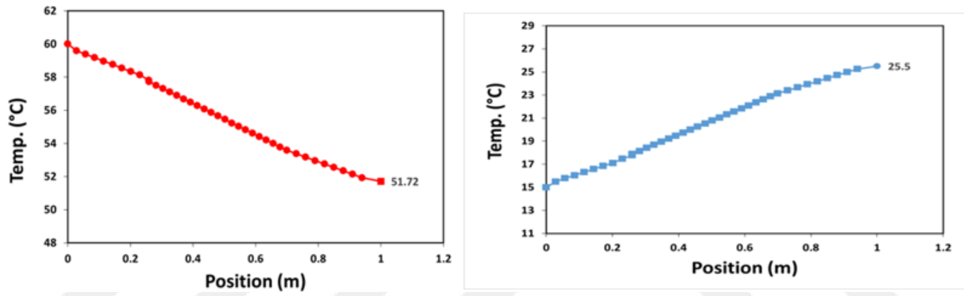

Figure 3.22: Illustrative Graph for Hot Water (5l/minute)&Cold Water (3l/minute).

b. Hot water (5l/minute) &cold water (5 L/minute)

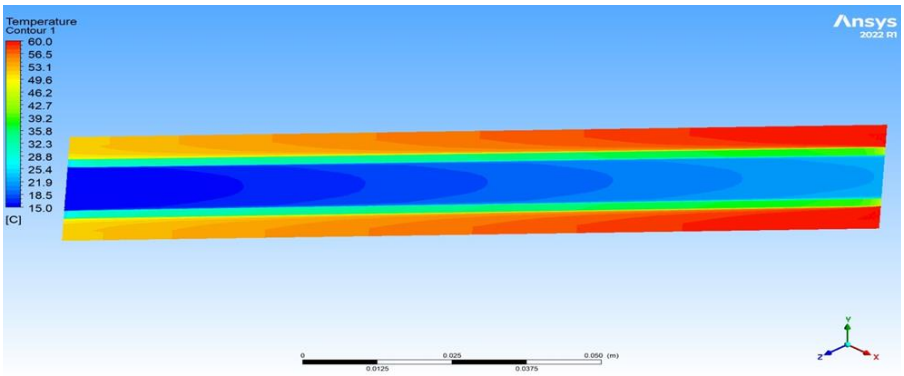

Figure 3.23: Fluids Dynamics Temperature Contours For Hot Water (5l/Minute) &Cold Water (5 L/Minute).

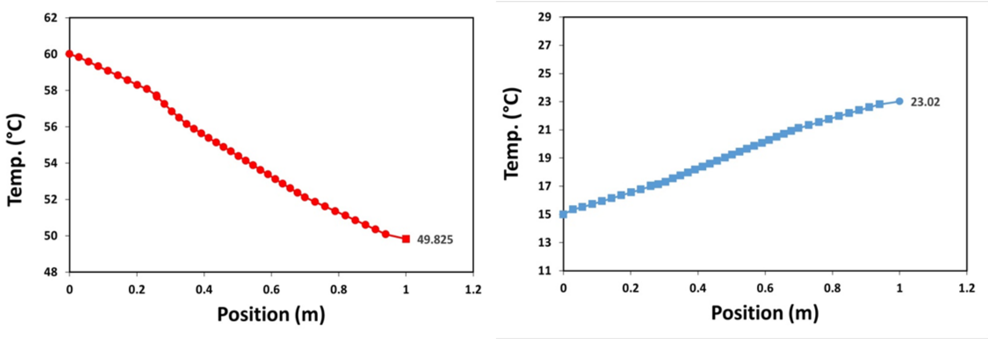

Figure 3.24: Illustrative Graph for Hot Water (5l/minute) &cold water (5 l/minute).

c. Hot water (5l/minute)&cold water (7l/minute)

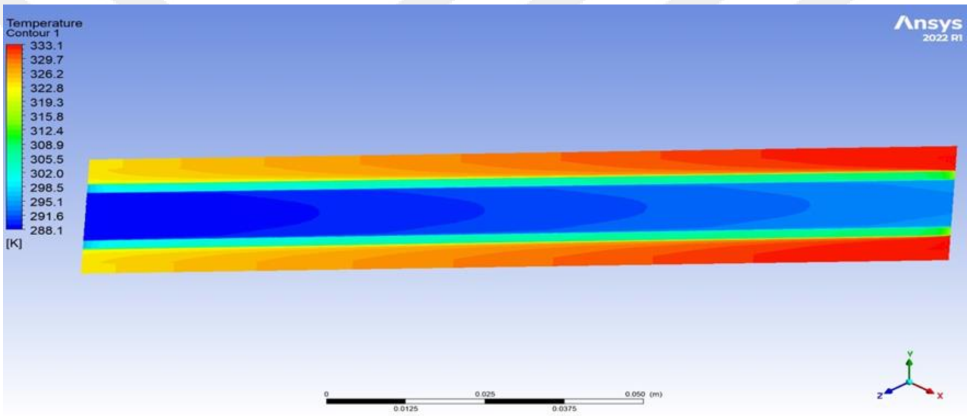

Figure 3.25: Fluids Dynamics Temperature Contours for Hot Water (5l/minute)&cold water (7l/minute).

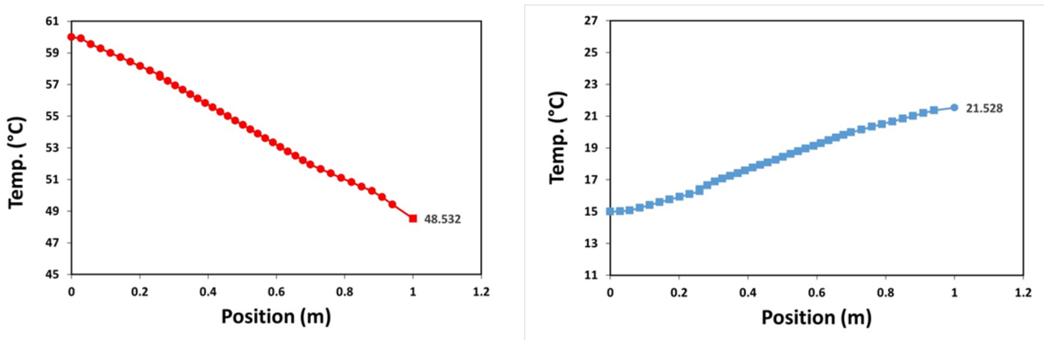

Figure 3.26: Illustrative Graph for Hot Water (5l/minute)&Cold Water (7l/minute).

b. Calculations heats exchanger (Nano fluids/Ago)

a. Hot water (5l/minute) &cold water (3l/minute)/Ago (0. 1%).

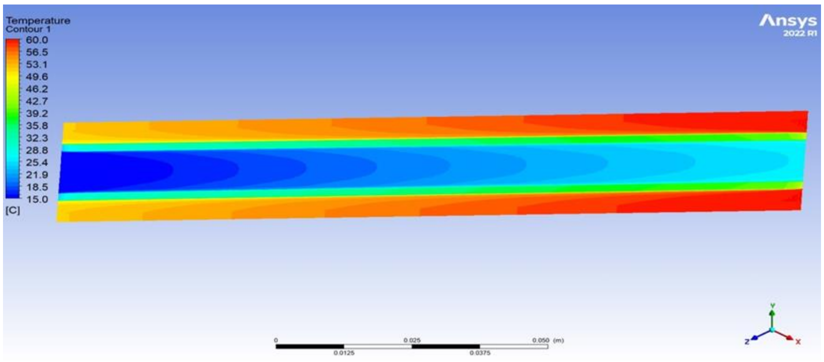

Figure 3.27: Fluids Dynamics Temperature Contours For Hot Water (5l/minute) &cold water (3l/minute)/Ago (0. 1%).

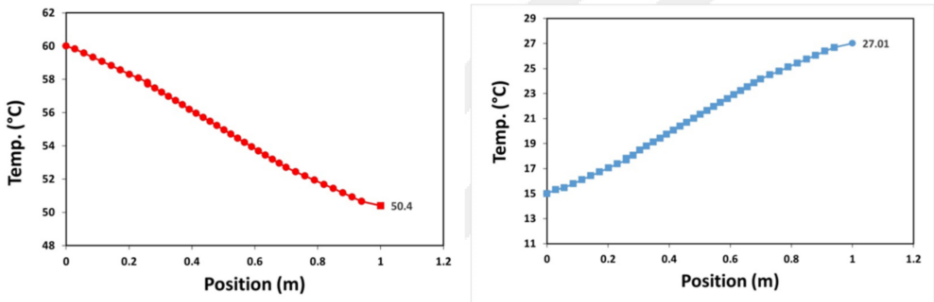

Figure 3.28: Illustrative Graph For Hot Water (5l/Minute) &Cold Water (3l/Minute)/Ago (0. 1%).

b. Hot water (5l/minute)&cold water (5l/minute)/Ago (0. 1%)

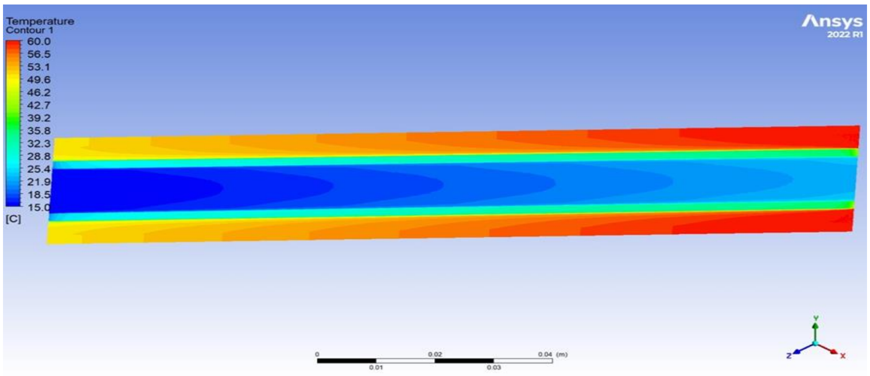

Figure 3.29: Fluids Dynamics Temperature Contours For Hot Water (5l/Minute)&Cold Water (5l/Minute)/Ago (0. 1%)

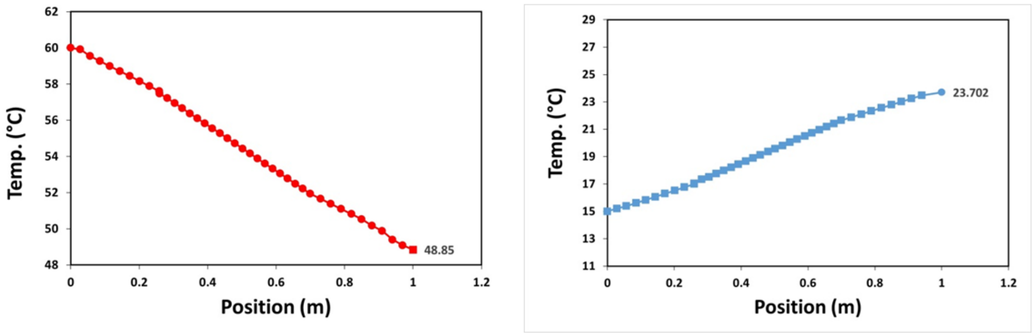

Figure 3.30: Illustrative Graph For Hot Water (5l/Minute)&Cold Water (5l/Minute)/Ago (0. 1%).

c. Hot water (5l/minute)&cold water (7l/minute)/Ago (0. 1%)

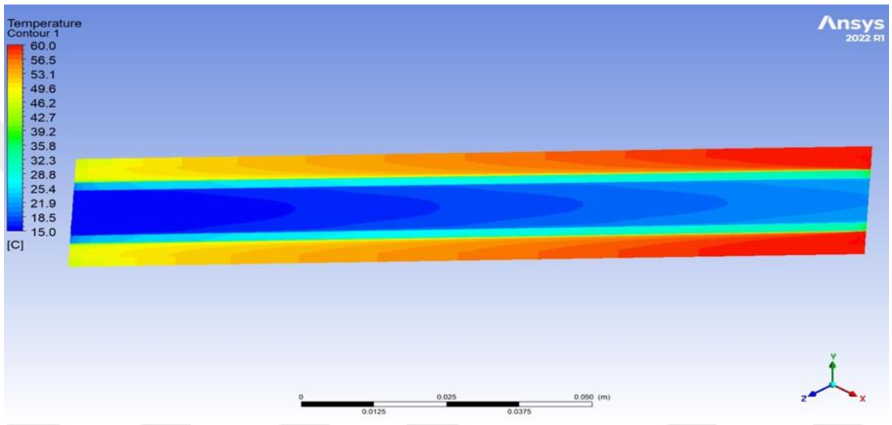

Figure 3.31: Fluids Dynamics Temperature Contours For Hot Water (5l/Minute)&Cold Water (7l/Minute)/Ago (0. 1%).

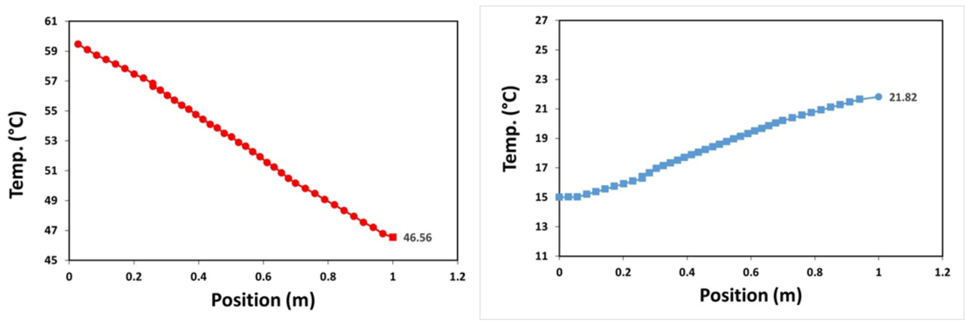

Figure 3.32: Illustrative graph for hot water (5l/minute)&cold water (7l/minute)/ago (0. 1%).

d. Hot water (5l/minute)&cold water (3l/minute)/Ago (0. 2%)

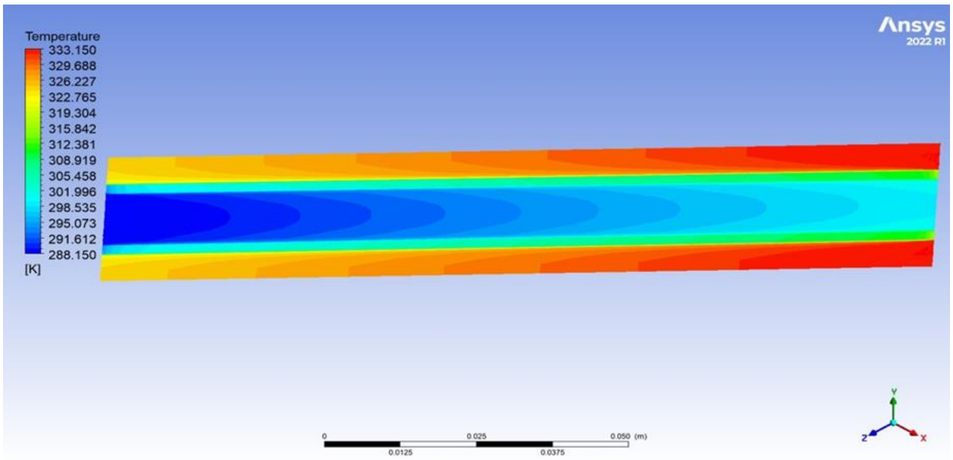

Figure 3.33: Fluids Dynamics Temperature Contours For Hot Water (5l/Minute)&Cold Water (3l/Minute)/Ago (0. 2%).

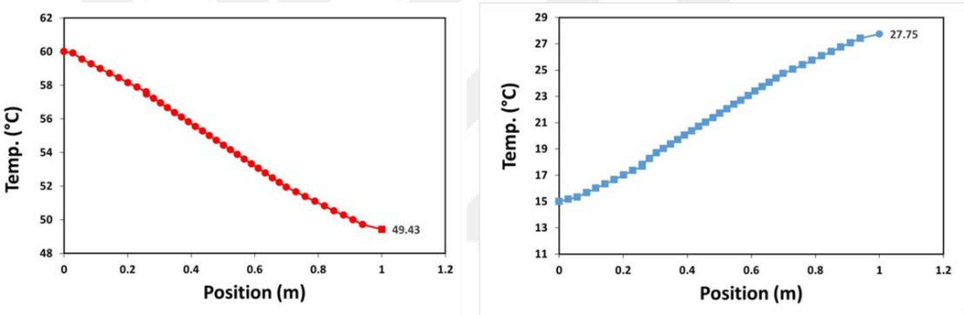

Figure 3.34: Illustrative Graph For Hot Water (5l/Minute)&Cold Water (3l/Minute)/Ago (0. 2%).

e. Hot water (5 L/minute)&cold water (5l/minute)/Ago (0. 2%)

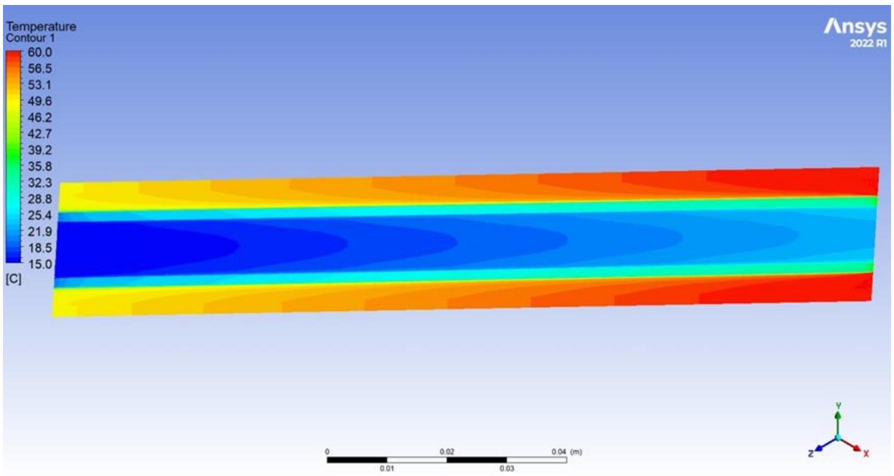

Figure 3.35: Fluids Dynamics Temperature Contours For Hot Water (5 L/Minute)&Cold Water (5l/minute)/Ago (0. 2%).

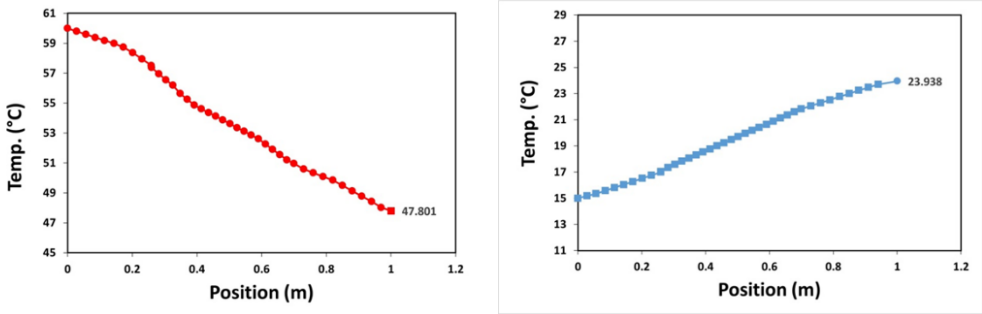

Figure 3.36: Illustrative Graph For Hot Water (5 L/Minute)&Cold Water (5l/Minute)/Ago (0. 2%

f. Hot water (5l/minute)&cold water (7l/minute)/Ago (0. 2%)

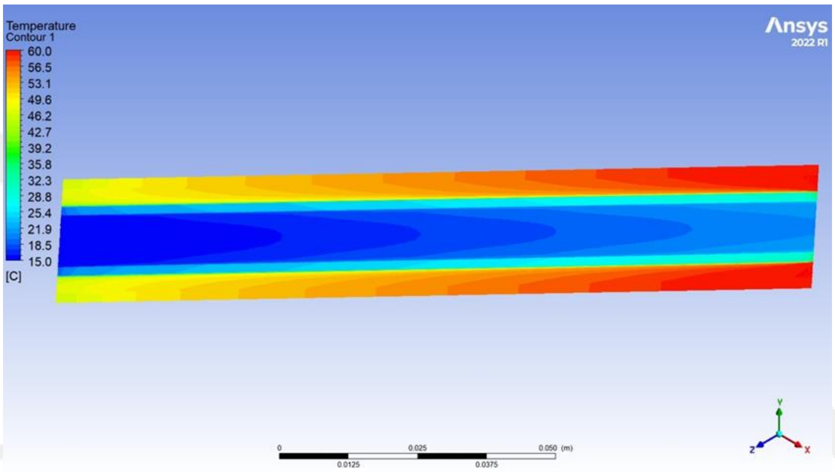

Figure 3.37: Fluids Dynamics temperature contours for Hot water (5l/minute)&cold water (7l/minute)/Ago (0. 2%).

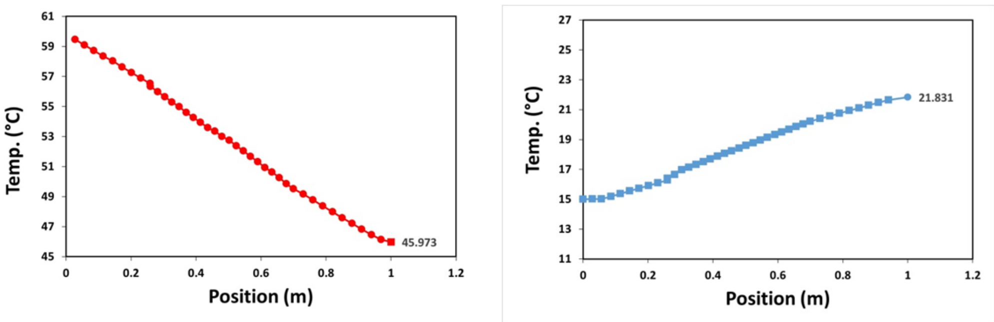

Figure 3.38: Illustrative Graph For Hot Water (5l/Minute)&Cold Water (7l/minute)/Ago (0. 2%).

3.10 CALIBRATION OF THE MEASURING EQUIPMENT USED

a. The temperature gauges were calibrated with a standard mercury thermometer at zero Celsius and boiling point as shown in Figure (3.38 (d))and the readings were close. The error rate ranges between (0.3-0.5) %.

b. The viscometer was calibrated by using Stokes' law experiment as shown in Figure (3.38 (c)) (The error rate is ±1%).

c. The thermal conductivity device was calibrated by examining the thermal conductivity of water, as shown in Figure (3.38 (b)) and the reading was very close. (Error rate ±0.5%)

d. The water flow meter was calibrated as shown in Figure (3.38 (a)), and the reading was very close. (Error percentage ±0.5%).

(a) (b) (c) (d).

Figure 3.39: Equipment Used in The Examinations

4. RESULTS AND DISCUSSION

4.1 INTRODUCTION

In this chapter, the theoretical results that were worked on in the computer program are presented in the ANSYS program for the purpose of determining heats transfer coefficients, heats transfer rate, and heats exchanger efficiency. The chapter also The experimental results were obtained from practical experiments conducted on the manufactured heats exchanger under the same conditions adopted in the theoretical aspect. In addition, the theoretical results were compared with the experimental results to determinate the extent of compatibility and convergence between them.

It is worth noting that the research dealt with two case studies of the exchanger for theoretical and experimental studies, where pure hot water flows in the space between the exchanger tubes the same Nano fluids is being pumped through the flow rate is 5 L/minute for the inner tube of the exchanger. In the first case, pure water was used, which is the case that was adopted as a basis for comparison to find out the percentage of improvements in the performances of the exchanger. In the second case, Nano water consisting of a mixture of waters with silver oxide particles was used. In these two cases, and for both theoretical and experimental studies, number flow rates were used Two for water or Nano-water that passes inner tube of the exchangers, and the rates are 3 Liter per minutes and 7 Liter per minutes, while the constant volumetric The average hot water flow used is 5 liters per minute.

4.2 EXPERIMENTAL RESULTS

The obtained results of the practical experiments conducted for the heats exchanger are in Figure (4-1), as it shows the change in the difference between the entry and exit temperatures of the fluids passing Through the inner tube of the exchanger used at a rate of 3, 5 and 7 Liter per minutes, with a concentration Volume % (0.2-0.1) silver oxide with water. And nanoparticles play an important role in increasing or decreasing temperatures, and this causes an increase in the rate of heats transfer to the Nano-fluids due to changing the flow model and increasing the (Boundary Layer) due to the rise in temperature of the fluids by adding nanoparticles, which results in enhancing the efficiency of the heats transfer process.

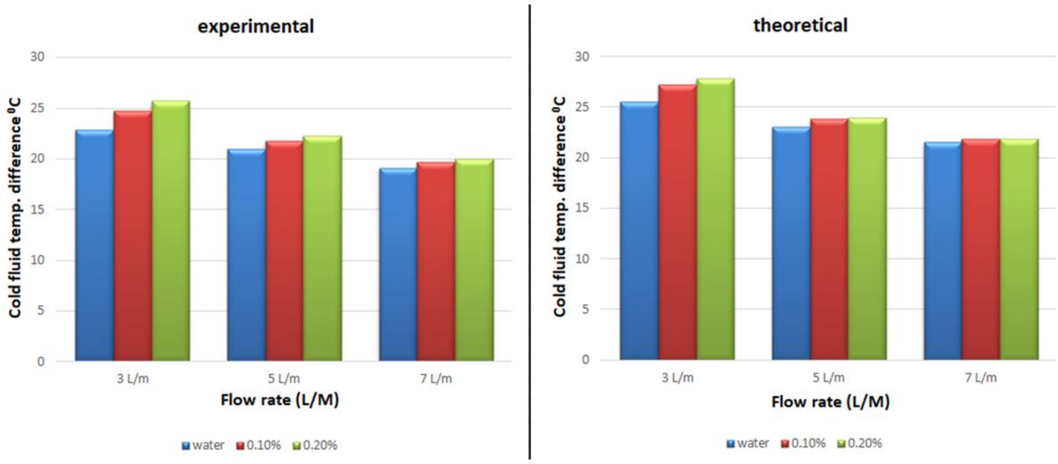

Figure 4.1: Comparison of Liquids Passing Through The Inner Tube With Volumetric Concentrations (0.1% - 0.2%) Of Nanofluids Mixed With Water Compared To Water.

Increasing the flow rate reduces the temperature difference. Still, this decrease in the difference in temperature does not mean that the heats transferred is less in the case of increasing the flow rate, The flow rate, when it is increasing, definitely leads to a higher rate of heats transfer, for the reasons I mentioned earlier, and the flow rate is 7 Liter per minutes higher than that of pure water. This includes the direct relationship between the rate of heats transfer and the flow rate, which is evident in Figure (4-2). The difference in the internal heats transfer coefficient with the type of nanoparticles added to the water as well as the flow rate, the heats transfer coefficient increases with the increase in the flow rate, and the use of silver nanoparticles gives higher values for the heats transfer coefficient. An increase in the internal heats transfer coefficient leads to an increase in the overall heats transfer coefficient.

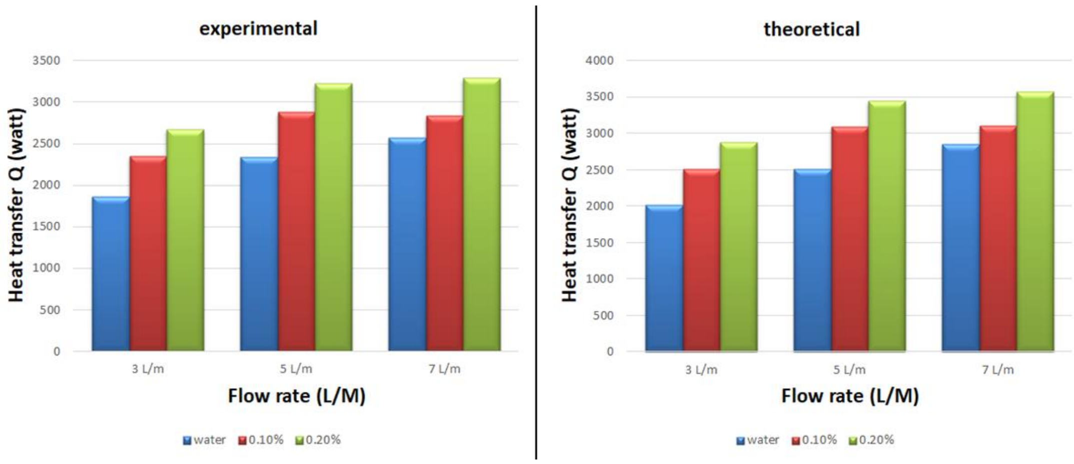

Figure 4.2: The Effect It of Flow Rate and Volumetric Concentrations The Internal Heat Transfers Coefficient of Silver Nanoparticles With Water Compared With Water.

In Figure (4.3) a comparison of the total internal heats transfer coefficient, according to the equations, when the average amount of heats transferred increases, the total heats transfer coefficient certainly increases, as it reached the highest value at a flow of 7 Liter per minutes, as the water had a W / m2. ℃ of 2785.9 and for the silver nanoparticles at a concentration of 0.1 % with water W/m2.℃ 3192.47 and W/m2.℃ 3632.3 at a volumetric concentration of 0.2 %.

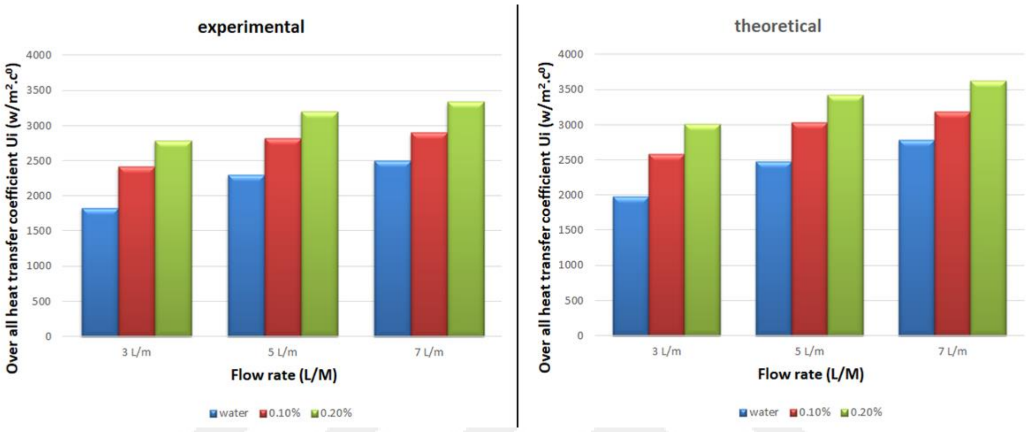

Figure 4.3: The Effect It of Flow Rate and Volumetric Concentrations on The Internal Heat Transfers Coefficient of Silver Nanoparticles With Water Compared With Water**.**

Figure (4.4) It shows the change that occurred in the efficiency of the heats exchanger by using Nano-silver with water in the inner tubes of exchangers and flow rates of the experimental study. The Nano-fluids containing silver nanoparticles at a concentration of 0.2 % recorded the highest exchanger effectiveness values. The highest value of exchanger effectiveness in practical experiments was 0.2824 using silver nanoparticles at a concentration of 0.2 %. It is noted that there is a slight improvement at the flow of 7 L/M compared to the flow of 5 L/M because the heats capacity of the cold fluids is the smallest and, according to the law of Effectiveness, is directly proportional to the temperature, difference, the temperature difference of the cold liquid is small at the flow of 5 L/M, while at The flow is 7 L/M, and the heats capacity of hot water is the smallest, and the temperature difference is greater, so the efficiency increases.

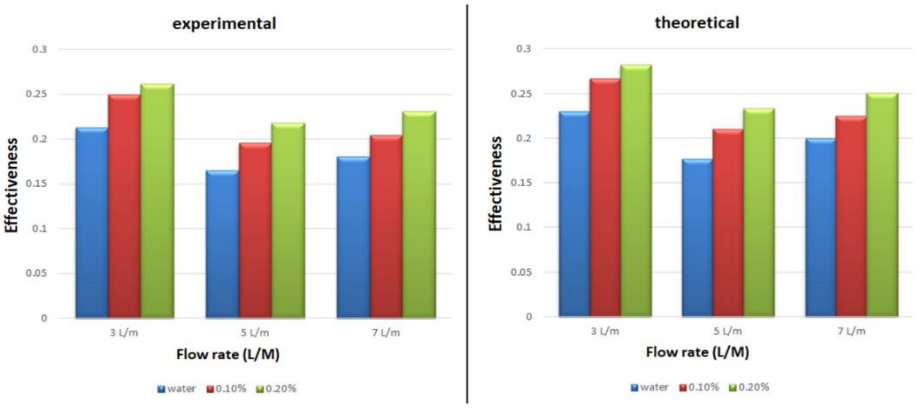

Figure 4.4: Changing The Effectiveness of The Heat Exchanger Using Nanoparticles of Silver With Water.

It is noted in Figure (4.5) that the NTU value increased according to the equations used at the lowest flow rate of 3 L/M, and that the highest value was obtained (0.3722), and thus, the relationship is positive with the Effectiveness of the exchanger.

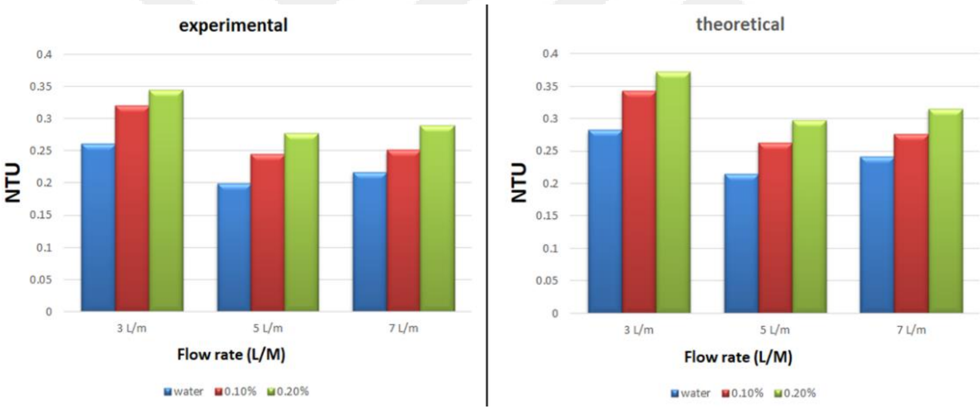

Figure 4.5: Changing The Value of The Numbers of Heats Transfer Units With Changing The Volumetric.

The figure (4.6) shows the increase in the Reynolds number, flow rate, as well as and amount of Nano-fluids density of the according to the equations used and the increase in the amount of heats transferred and the coefficient of internal and total heats transfer from the addition of Nano-materials of silver nanoparticles at volume concentrations (0.2-0.1) %. It is noted that The highest values are volumetric concentration of 0.2 %, and thus the Nusselt, numbers increases, as shown in Figure (4.7). The Nusselt number increases with increasing the volumetric concentration of each silver nanoparticle with water from the rise in the internal heats transfer coefficient in a direct relationship with the Nusselt number. Thus, the Nusselt number for Nano-fluids is greater than water; Because the Nusselt number depends on the heats transfer coefficient and thermal conductivity.

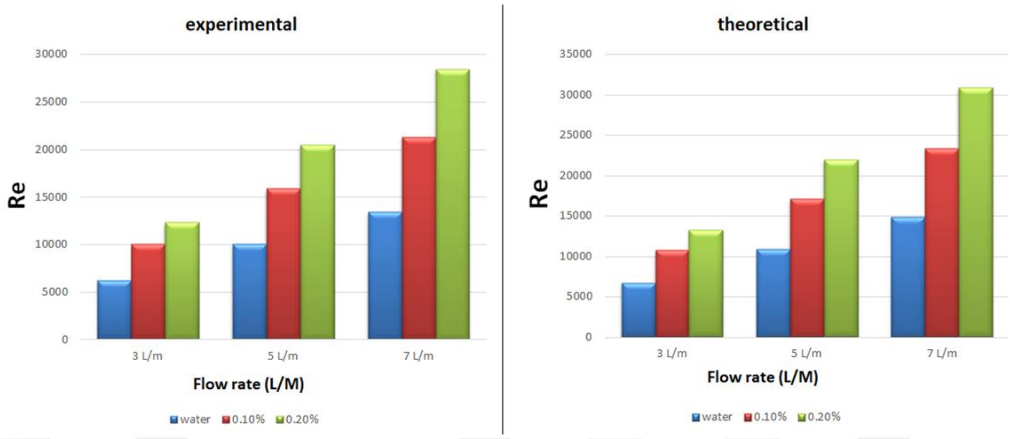

Figure 4.6: Variation of Reynolds Number With Change in Flow Rate.

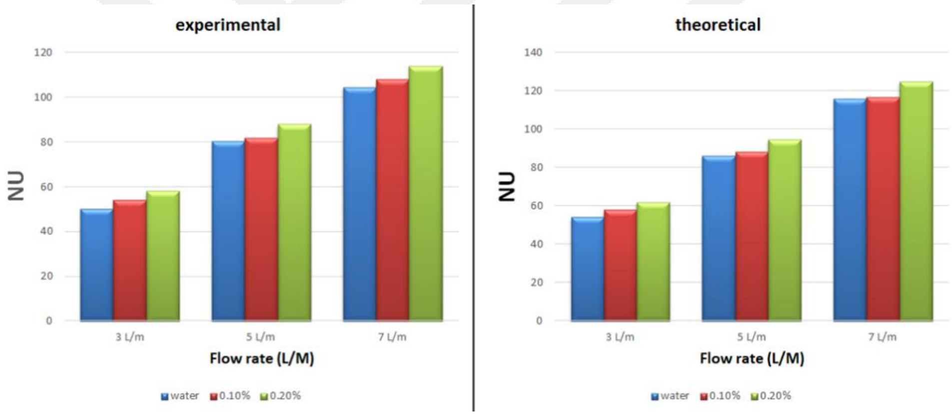

Figure 4.7: Nusselt Varies With A Change Rate and Volumetric Concentrations.

Figure (4.8) shows. The effect of adding silver nanoparticles on the friction coefficient of water at different volume flow rates. And for all volumetric concentrations of the Nano-fluids, the volumetric increase the flow rate of the cold liquid leads to a decreases in the friction factor. The coefficient of friction inside the pipe is small in turbulent flow and decreases with increasing volumetric flow rate. The pressure drop is negligible, and the density is greater than the base fluids. It is seen that the coefficient of friction decreases as the Reynolds number increases.

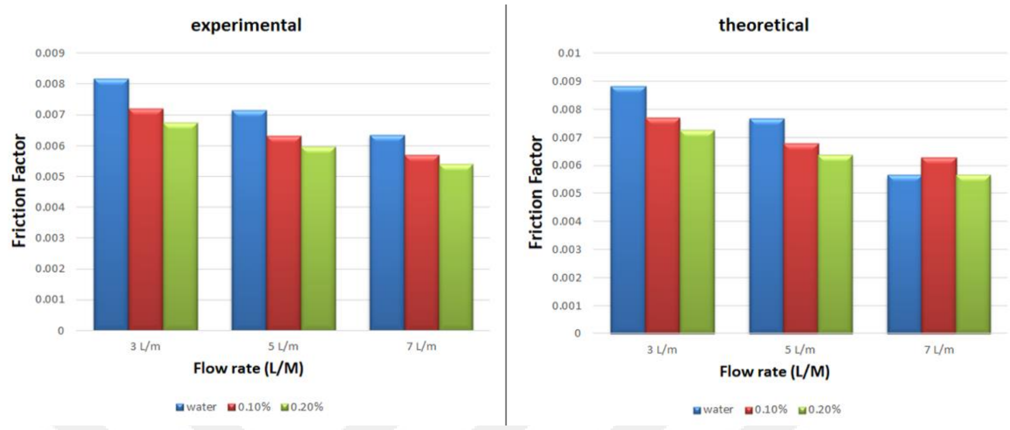

Figure 4.8 Show a Comparison of The Friction Factors of Nano-Fluids and Water at Three Different Flow Rates**.**

Figure (4.9) compares the thermal performance coefficient and flow rates. We note that the performance coefficient increases with the increase in volumetric concentration. decreases when reach to 5 Liter per minute depending on the values of the Nusselt number and coefficient of friction. Heats transfer and heats transfer coefficient are at their highest when the flow is 7 Liter per minute, and therefore the Nusselt number increases, and as a result, we get the highest values for the performance coefficient.

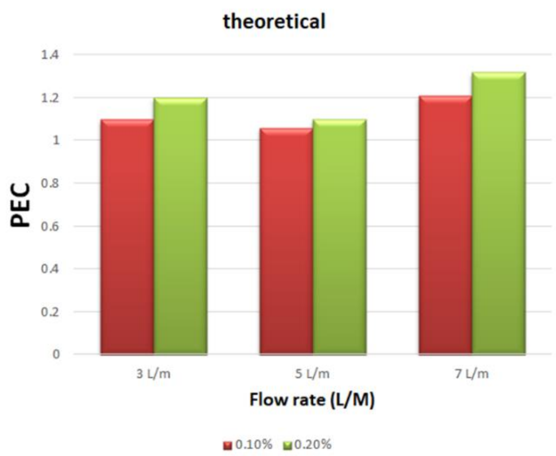

Figure 4.9 Comparison of Thermal Performance Coefficient With Flow Rates and Volumetric Concentrations**.**

4.3: THE EFFECT OF USING NANOPARTICLES ON THE CHARACTERISTIC OF THE BASE FLUIDS

The thermal and physical characteristics of the base fluids are affected when nanoparticles are added, as the results show that they directly affect density, specific heats, thermal conductivity, and viscosity.

4.3.1 Density

The results obtained after the mixing process concluded that. The density of the base fluids increases with the increase in the volumetric concentrations of nanoparticles (Ago And by comparing the density of the Nano-fluids (Ago - Water) with the thickness of the base liquid (water) as shown in Figure (4.10) at volume concentrations (0.1 and 0.2) %, as the density of the Nano-fluids increased compared to the thickness of water; Because the density of nanoparticles is greater than the density of water.

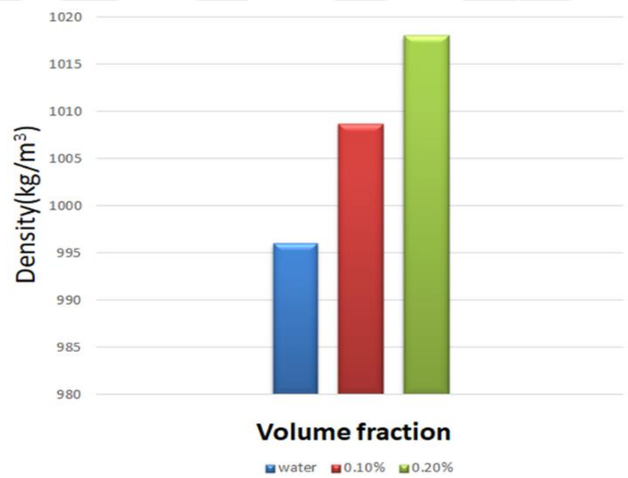

Figure 4.10: Comparison Between The Density of Water and The Density of Nano Fluids**.**

4.3.2 Viscosity

It was concluded from the results obtained after the mixing process that the viscosity increases with increasing volumetric concentrations of (Ago) nanoparticles. If we look at Figure (4-11), we will find the comparison for each of the basic fluids in terms of viscosities with the viscosity of the Nano-fluids (Ago - Water) at volume concentrations (0.1 % and 0.2 %) as the viscosities of the Nano-fluidly increased compared to the viscosity of water; And that the viscosity of the base fluids increases when nanoparticles are added.

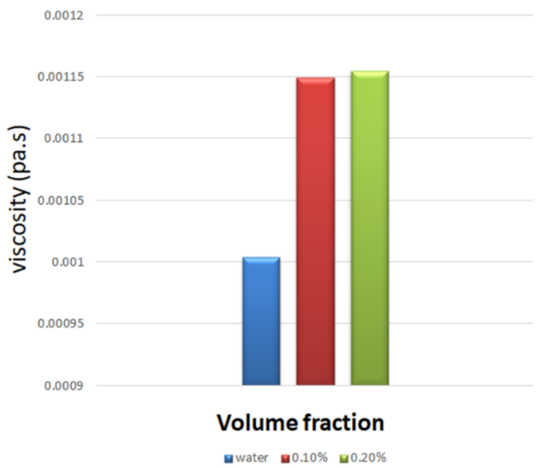

Figure 4.11: Comparison Between The Viscosity of Water and The Viscosity of Nano Fluids**.**

4.3.3. Thermal Conductivity

After the mixing process, the results obtained were summarized that when the volume concentrations of nanoparticles (Ago) increase, the thermals conductivities increases. Figure (4.12) shows the comparison between the thermal conductivities of the nuclear fluids (Ago-Water) and the base fluids in volumetric concentrations (0.1% and 0.2%), as the thermal conductivity of the Nano-fluids increased compared to the thermal conductivity of pure water; This is because the nanoparticles have a higher thermal conductivity than the base fluids, and this has led to an increase in the thermal conductivity of the Nano-fluids.

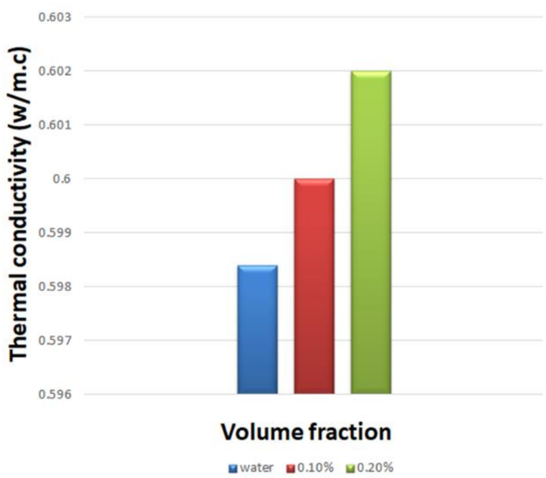

Figure 4.12: Comparison of the Thermal Conductivity of Water And The Thermal Conductivity of Nano Fluids**.**

4.3.4 Specific Heats

The results obtained after the mixing process concluded that the specific heats decrease with increasing volumetric concentrations of the nanoparticles (Ago). Figure (4-13) is interested in comparing each of the basic liquids (water) in terms of specific heats with the specific heats of the Nano-liquid (Ago-Water).at volume concentrations (0.1 and 0.2) %, as the specific heats of the Nano-fluids decreased compared to the specific heats of pure water; Because the specific heats of the nanoparticles is less than the particular heats of the base fluids, which led to a decrease in the value of the specific heats of the Nano-fluids.

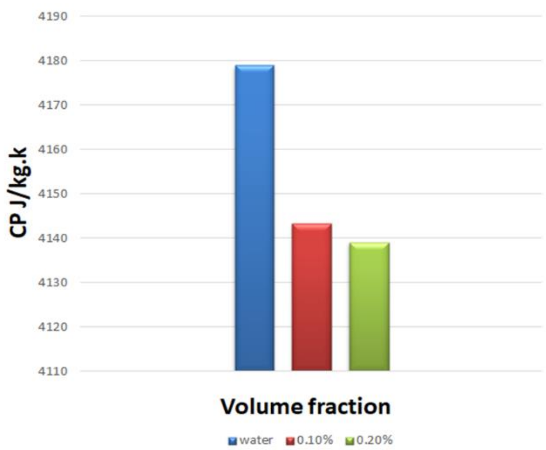

Figure 4.13: Comparison Between The Specific Heat of Water and The Specific Heat of Nano Fluids.

5. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSIONS

There are several conclusions from this experimental study of the effectiveness of the heats exchanger that can be summarized as follows: -

a. The overall heats transfer coefficient and the rate of heats transfer increase in the exchanger using the Nano-fluids instead of water and also increases with the increase in the flow rate of the Nano-fluids

b. The highest percentage of improvement in the total heats transfer coefficient (Ui)was (52%) when using Nano-fluids with at a flow of 3 Liter/minute and with a volumetric concentration of 0.2 %.

c. The highest percentage of improvement in the heats transfer rate(Qc) was (43 %) when using the Nano-fluids a flow of 3 Liter/minute and with a volumetric concentration of 0.2%.

d. The use of Nano-fluids achieved the highest Effectiveness for the heats exchanger at a flow rate of 2 Liter / minute and a volumetric concentration of 0.2 % with an improvement rate of 34.4 %.

e. The highest value of the Nusselt number was at the flow rate of 7 Liter / minute for the Nano-fluids containing Nano silver at a volumetric concentration of 0.2 % by 125, as the improvement rate reached 25 % compared to the water base liquid.

f. The highest value NTU 0.39 with an improvement rate of 38.3 % when using Nano-fluids compared to the water base liquid.

g. The highest value of the Reynolds number was at the flow rate of 7 Liter / minute for the Nano-fluids containing Nano-silver with a volumetric concentration of 0.2 % and with a high improvement rate compared to the water base liquid.

5.2 RECOMMENDATIONS

In order to continue the research on the issue of the effectiveness of heats exchangers, we recommend the following:

a. The use of other types of nanoparticles as well as the use of alcohol or oil and others instead of water as a base.

b. Expanding the study by using wider ranges of flow rates or at laminator flow using multiple concentrations.

c. Studying the effectiveness of the heats exchanger when the Nano-fluids flows in the space between the two tubes instead of flowing into the inner tube.

d. A study to improve the efficiency of the finned heats exchanger using different Nano-materials (iron oxide, magnesium oxide, zinc oxide and aluminum oxide).

e. The use of different diameters and lengths of the tubes used in the device.

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APPENDIX A

Calculations

A.1 DENSITIES CALULATIONS

- The weight of the beaker when empty (m) 91.62
- Weigh the beaker full (m) 276.66

1- Calculating the density of water

M= Weigh the beaker full (m) − The weight of the beaker when empty (m)

M= 276.66 − 91.62

M= 185.04 g

$\rho = \frac{m}{v}$

$\rho = \frac{185.04}{200}$

$\rho = 0.925.2$

$\rho = 925.2\ kg/m2$

1-1 Calculating the density of Nano-fluids (Ago)

$\rho_n = (1-\emptyset)\rho_f + \emptyset\rho_P$

$\rho_n = (1 - \frac{0.1}{100}) \times 999.2 + \frac{0.1}{100} \times 10490$

$\rho_n = 1008.69$

1-2 Calculating the density of Nano-fluids (Ago)

$\rho_n = (1-\emptyset)\rho_f + \emptyset\rho_P$

$\rho_n = (1 - \frac{0.2}{100}) \times 999.1 + \frac{0.2}{100} \times 10490$

$\rho_n = 1008.59$

$\rho_n = 1018.08$

A.2 CONDUCTIVITY CALULATIONS

1. Calculating the conductivity of a Nano-fluids (Ago) at the ratio (0.1)

$$k_n = k_f\left(\frac{k_s+2k_f-2\emptyset(k_f-k_s)}{k_s+2k_f+\emptyset(k_f-k_s)}\right)$$

$$k_n = 0.5984\ (\frac{429+2\times0.5984-2\times\frac{0.1}{100}(0.5984-429)}{429+2\times0.5984+\frac{0.1}{100}(0.5984-429)})$$

$$k_n = 0.600$$

2. at the ratio (0.1)

$$k_n = k_f(\frac{k_s+2k_f-2\emptyset(k_f-k_s)}{k_s+2k_f+\emptyset(k_f-k_s)})$$

$$k_n = 0.5984\ (\frac{429+2\times0.5984-2\times\frac{0.2}{100}(0.5984-429)}{429+2\times0.5984+\frac{0.2}{100}(0.5984-429)})$$

$$k_n = 0.601$$

A.3 VISCOSITY CALCULATIONS

1. Calculating the viscosity of a Nano-fluids (Ago) at the ratio (0.1)

$$\mu_{nf} = 1.148\ \times 10^{-3}\ (1 + 2.5 \times \frac{0.1}{100})$$

$$\mu_{nf} = 1.150 \times 10^{-3}$$

2. at the ratio (0.2)

$$\mu_{nf} = 1.148\ \times 10^{-3}\ (1 + 2.5 \times \frac{0.1}{100})$$

$$\mu_{nf} = 1.154 \times 10^{-3}$$

A.4 SPECIFIC HEATS CALCULATIONS

1. Calculation of the specific heats of a Nano-fluids (Ago) at the ratio (0.1)

$$CPnf = \frac{(1-\emptyset)CPbf*\rho bf+\emptyset*\rho p*Cpp}{\rho nf}$$

$$CPnf = \frac{\left(1-\frac{0.1}{100}\right)4186.8*999.2+\frac{0.1}{100}*10490*\frac{710}{1000}}{1008.69}$$

$CPnf$ =4143.269 KJ/kg. k

2. at the ratio (0.2)

$$CPnf = \frac{(1-\emptyset)CPbf*\rho bf+\emptyset*\rho p*Cpp}{\rho nf}$$

$$CPnf = \frac{\left(1-\frac{0.2}{100}\right)4186.8*999.2+\frac{0.2}{100}*10490*\frac{710}{1000}}{1008.69}$$

$CPnf$ =4139.129 KJ/kg. k