

ANALYSIS OF THERMAL PERFORMANCE OF COUNTER FLOW DOUBLE PIPE HEAT EXCHANGER USING TITANIUM OXIDE (TiO₂) AND ZINC OXIDE (ZnO) NANOFLUIDS

Submitted in partial fulfillment of the requirements for the award
of Bachelor of Engineering degree in mechanical engineering

By

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**DEPARTMENT OF MECHANICAL ENGINEERING
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **Rishi Kumar R (38150092)** and **S.V. Puneeth Reddy (38150084)**, who carried out the project entitled "**Analysis of thermal performance of counter flow double pipe heat exchanger using Titanium Oxide (TiO₂) and Zinc Oxide (ZnO) Nanofluids**" under my supervision from September 2021 to April 2022.

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ABSTRACT

In a nanofluid, metals, oxides, or carbides with a diameter of less than 20 nanometers are combined as one with a base liquid, like water or an oil. Many examinations have recently been completed to inspect the effect of nanofluid on the speed increase of hotness move rates in various hotness exchangers, including the ones referenced previously. Heat transfer improvement using nanofluid is dependent on a variety of factors, among them the kind of nanoparticles, their size, shape, and concentration in the base fluid. It was studied experimentally how a twin pipe heat exchanger with counter flow arrangements and two kinds of nanofluid cooling fluid performed. Zinc and Titanium oxides (TiO_2) are used as a base fluid with ethylene glycol (EG)-alkaline water. This study looked at the heat transfer capabilities of a two-pipe heat exchanger with a counter-flow configuration when various quantities of TiO_2 and ZnO nanoparticles were combined with EG-alkaline water. Alkaline water and nanofluid nanoparticle volume concentration was (0.5, 0.75, 1.25) and flow rate (0.6, 1.0, 1.4) The constant intake temperatures of 60°C for water and 30°C for Nanofluid in a heat exchanger result in two fluids running at constant inflow velocity. Researchers found that nanofluid had higher heat absorption at low flow rates than EG-alkaline water and so improves heat exchanger thermal performance. It is also shown that when the concentration of nanoparticles increases, the heat transmission rate increases.

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CHAPTER 1

INTRODUCTION

Alternative and effective heat dissipation solutions for microelectronic systems and packages have been developed as a consequence of recent trends in device downsizing and process intensification. It has been observed that conventional heat removal technologies are unable to deal effectively with large levels of heat fluxes. The efficiency of heat transfer systems has been improved through a variety of methods offered by researchers. SEMs, TEMs, and other ultra-accurate microscopes have made it possible for scientists to create nanometer-sized materials. Researchers are now working to make these materials. A tremendous rise in nanotechnology interest among scientists and engineers has taken place during the last couple decades. The National Nanotechnology Initiatives get around \$1 billion in federal funding each year (NNI). One trillion dollars is expected to be spent on nanotechnology goods in the US alone by 2015.

1.1 DOUBLE PIPE HEAT EXCHANGER

In a twin pipe heat exchanger, a mechanical seal separates the pipes in a concentric configuration. As the name of this heat exchanger represents that it uses two pipes to exchange heat between two fluids. One pipe has hot fluid while the other pipe has cold fluid. The jacketed u-tube, jacketed tube, hairpin, and pipe-in-pipe heat exchanger all refer to the same device. The two-pipe heat exchanger features a small pipe enclosed by a larger pipe. In the little pipe, one fluid flows, while different streams through the annulus between the two lines. The hotness move surface is situated within the minuscule line. The big tube serves as the primary conduit for the transport of heat. Thus, the inner pipe acts as an insulator between the wires. The external side contains fluid flow through the tube side or inside.

1.1.1 Types of double pipe heat exchanger

Based on the flow direction, two-pipe heat exchangers may be classed. Exchanges may be used with parallel or counter flow, depending on where inlets and outputs are located. Heat transfer and pressure drop may be affected by the

choice between parallel and counter flow, however in certain cases it is better to choose one over the other.

1) Counter Flow Double Pipe Heat Exchangers

As illustrated in Fig 1.1, counter stream heat exchangers have the best heat move coefficient and might be utilized to cool or heat the results as wanted. This is the ideal design for twin pipe heat exchangers.

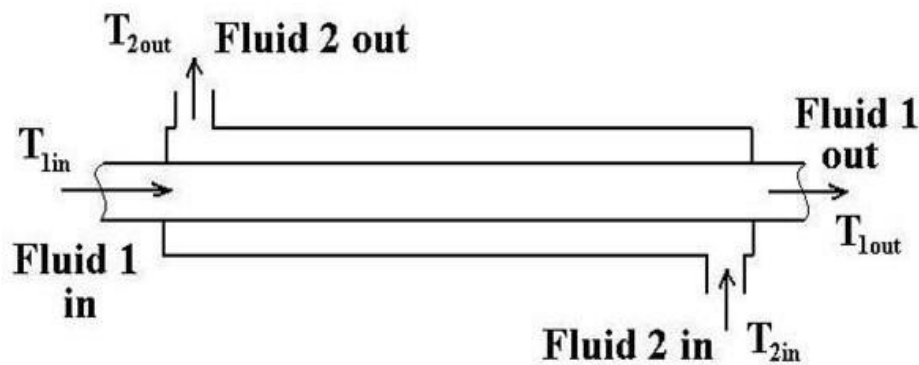


Fig: 1.1: Counter Flow Double Pipe Heat Exchanger

2) Parallel Flow Double Pipe Heat Exchangers

There are no separate inlets and exits for parallel flow. Although the efficiency is poor, this sort of flow should be used in certain situations, as illustrated in Fig. 1.2.

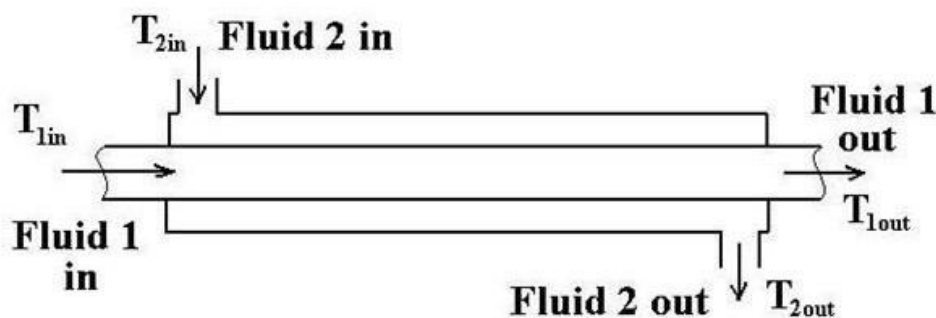


Fig: 1.2: Parallel Flow Double Pipe Heat Exchanger

1.1.2 Advantages of Double Pipe Heat Exchanger

Many industries, including petrochemicals and others, continue to employ this kind of heat exchanger because of its many benefits.

1. It is easy to adjust the heat transmission area, and the construction is simple. During installation, there is no need for further processing since it is made up of standard components.
2. High heat transfer efficiency. As a pure counter flow heat exchanger, it has a high heat transfer coefficient and may be configured with a cross-sectional dimension that increases both fluid velocity and heat transfer coefficient. High-pressure, low-flow fluids with a poor heat transfer coefficient, in particular, benefit greatly from this kind of heat exchange.
3. The framework is basic, but the scope of labour is extensive. The liquid stream speed on the two sides of the hotness move surface might be raised, bringing about a bigger hotness move coefficient on the two sides of the hotness move surface. It is possible to add fins to the outside wall of the inner tube and a scraping film perturbation device to the interior tube in order to promote heat transmission and expand the heat transfer area.
4. The form may be altered according on the installation location, making it easier to get the device installed.

1.1.3 Disadvantages of Double Pipe Heat Exchanger

Due to the enormous surface area, the double-pipe heat exchanger has one major drawback: inefficiency. At the same time, the metal consumption per unit heat transfer surface is much higher than that of the shell-and-tube heat exchanger, which is around five times more. As a result, there are many pipe junctions with high flow resistance and a high risk of leakage.

1. To begin with, disassembly is a pain, and the removable connection is vulnerable to leaking.
2. There are various limitations on the kind of materials that may be used in manufacture. Welding causes thermal expansion and cracking in pipe-in-tube heat

exchangers because the inner tube cannot be welded. Most double-pipe heat exchangers bend and twist into serpentine shapes, which necessitates the use of specialised corrosion-resistant materials not generally available.

3. Each firm in China has its own unique way of welding a double-pipe heat exchanger, based on its own expertise with other heat exchange goods. Because of this, the welding of the double-pipe heat exchanger will need to be inspected and maintained on a regular basis.

1.1.4 Applications of Double pipe Heat exchanger

It is common for heat exchangers to be used in a variety of technical applications ranging from automobile manufacturing to the thermal power plant to waste heat recovery to air conditioning and refrigeration. In order to reduce the size and cost of these devices, a number of strategies have been developed to enhance their thermal-hydraulic performance. Techniques that need external power, such as electrical or acoustic fields, and surface vibrations, may be categorised as either active or passive. Passive methods, on the other hand, use specific surfaces like fins and baffles to increase heat transfer.

1.2 NANOFLUIDS

Choi [1] is credited with coining the term "Nanofluid". Many scientists have studied the thermal conductivity of various Nano fluids and their results have been published. The warm conductivity of nanofluids has been accounted for to be better than that of base liquids in earlier examinations. Different metal and metal oxide nanoparticles have been suspended in various base liquids by Choi et al [2, 3].

One technique to improve heat transmission is to add additives to liquids. The primary goal of improving the heat transfer characteristics of liquids is to increase the fluid's thermal conductivity. Temperature transmission between working fluid and heated surface is facilitated by their thermal conductivity. Nano-sized particles with high warm conductivity might be suspended in a liquid with a low warm conductivity to build the warm conductivity of the liquid. Nanofluids have been demonstrated to be better heat transfer agents over traditional fluids in recent years.

Heat is removed from mechanical systems by means of the usual heat transfer fluids such water and ethylene/propylene glycol, etc. However, heat transmission is an issue with normal liquids. Analysts have shown an interest in growing new kinds of hotness move liquids to work on the productivity of frameworks in light of these unfortunate hotness move properties. They are alluded to as "Nano liquids" in light of their tiny size. As an original sort of liquid, nanofluids are contained nanometer-sized particles suspended in the fundamental liquids like water and different hydrocarbons. For his "Progressed liquid program" at Argonne National Laboratory, researcher S.U.S. Choi made another sort of liquid in 1993 by scattering particles with a width of 1100nm in base liquids (ANL).

Even though it has long been known that adding solid particles to heat transfer media is an effective way to improve heat transfer, it is important to keep in mind that using suspended millimetre or micrometre sized particles can result in serious issues like clogging, high pressure drop, and particle sedimentation. The use of nanoparticles in fluids has greater heat transmission capabilities than the use of big particles dispersed in the fluids. Due to their small size and low concentration, nanoparticles are often employed at very low quantities. These characteristics prevent debris from clogging the canal.

1.2.1 Types of Nanoparticles

Size, chemical, thermal, and morphological characteristics are used to categorise nanoparticles into distinct groupings. A few well-known classes of nanoparticles are based on their chemical and physical features.

1) Carbon-Based Nanoparticles:

It is important to note that two of the most important groups in nanoparticle chemistry are carbon nanotubes (CNTs) and Fullerenes. Fullerenes are a kind of globular hollow cage nanomaterial, like allotropic carbon. These materials are made up of Sp^2 carbon units organised in hexagonal and pentagonal patterns. Carbon nanotubes have a tubular, elongated shape with a diameter of 1-2 nm. Depending on the diameter telicity, they may be projected as either semiconducting or metallic. These are physically similar when rolled on a graphite sheet. For their single, double, or multiple rolled sheets of carbon nanotubes, they were referred to as SWCNTs, DWCNTs, or MWCNTs.

2) Metal Nanoparticles:

In order to create metallic nanoparticles, one must start with a pure metal precursor. These nanoparticles have unique optoelectronic features due to their localised Surface Plasmon Resonance characteristics. A wide assimilation band in the apparent area of the electromagnetic range is given by nanoparticles of soluble base and honourable metals, like Cu, Ag, and Au.

3) Ceramics Nanoparticles:

Heat and subsequent cooling are used to create ceramic nanoparticles, which are inorganic, non-metallic solids. They might be indistinct, polycrystalline, thick, permeable, or empty. Subsequently, specialists are giving close consideration to these nanoparticles on account of their likely purposes in catalysis, photocatalysis, color debasement, and imaging.

4) Semiconductor Nanoparticles:

Semiconductor nanoparticles have broad bandgaps, therefore adjusting the bandgap has a substantial effect on their characteristics, as do semiconductor materials, which have properties that lie between metals and non-metals. This makes them vital components in both photocatalysis and optical and electrical applications.

5) Polymeric Nanoparticles:

Most of these nanoparticles are non-capsular or nano-spherical in form, and they are synthesised from organic components. Molecular adsorption occurs at the spherical surface's outer margins, where matrix particles' mass is mostly made up of solids.

6) Lipid-Based Nanoparticles:

Many biological applications may benefit from nanoparticles containing lipid moieties. Lipid nanoparticles are normally round in structure and have a breadth of somewhere in the range of 10 and 1000 nm. Lipid nanoparticles, as polymeric nanoparticles, have a lipid center and a framework comprised of lipophilic atoms that disintegrate in water. RNA release in cancer treatment and medication

delivery are two uses of lipid nanotechnology that are currently under development. Lipid nanoparticles are designed and synthesised specifically for these purposes.

1.2.2 Properties of Nanofluid

Nanoparticles have a profound effect on the properties of solutions, and a number of factors, counting the sort of material, the size and state of the nanoparticles utilized, the volume centralization of the suspended particles, and the conductivity of the base liquid, all assume a part in this alteration. Liquids with different characteristics, for example, thickness, heat limit, warm conductivity and convective hotness move have been made.

1) Thermal Conductivity

The limit of a substance to convey or ship heat is known as warm conductivity. It is the most basic element for improving a hotness move liquid's warm exhibition. The value of a nanofluid's thermal conductivity has been estimated via a number of theoretical and experimental research. The size, shape, Brownian movement, and volume part of suspended particles all assume a part in this component, which is subject to various factors. The warm conductivity of nanofluids might be estimated utilizing an assortment of strategies, including the transient hot-wire, the consistent state equal plate, the round and hollow cell, the temperature swaying, and the 3w technique.

2) Viscosity

In thermal applications using fluids, viscosity is a critical consideration. Viscosity affects convectional heat transport as well. As a consequence, due to the importance of viscosity in heat transmission, it must be given the same consideration as thermal conductivity. As the grouping of nanoparticles develops, the thickness of nanofluids increments, and as the temperature climbs, it brings down. There have been an assortment of viscometer types used to check the thickness of nanofluids, including the slender cylinder viscometer, the Vibro-viscometer, the turning rotor rheometer, the drop/fall ball, the cylinder viscometer, and the cup viscometer.

3) Specific Heat

The thermal transfer rate of nanofluids is strongly influenced by the specific heat of the fluid. To grow the temperature of one gram of nanofluid one degree Celsius, one gram of hotness should be applied.

1.2.3 Advantages of Nanofluid

1. Increased thermal conductivity results in a higher single-phase heat transfer coefficient in laminar flow.
2. Nanofluids have higher thermal conductivities compared to suspended particles of millimetre or micrometre dimensions, which were used in base fluids to enhance heat transfer.
3. Fluids may be made nanofluids by mixing in a variety of particles, both metallic and nonmetallic.
4. Particles in suspension that are millimetres or even micrometres in size might pose serious issues. Particles with such an abrasive action can clog flow channels, erode pipelines and cause other issues that do not arise as frequently with nanofluids.
5. Particles smaller than millimetres tend to settle quickly. Nanoparticles, on the other hand, may stay suspended in aqueous solutions for a longer period of time.
6. Nanoparticles have a substantially higher surface area than regular particles, which enhances heat transmission.

1.2.4 Disadvantages of Nanofluid

1. Increased wall temperature axial increase owing to lower specific heat capacity.
2. As a result, pumping power is increased.
3. This may lead to long-term fluid settling and possible flow route obstruction.
4. Erosion damage to flow loop components is a possibility.
5. Boiling can't be sustained.

6. Nanoparticle suspensions are quite expensive.
7. The expense of processing is significant.
8. The capacity of the particle to overcome the thermal energy barrier leads to an increase in van der Waals forces, resulting in a reduction in conductivity, at higher pH values and higher temperatures.
9. The creation of a thermal boundary layer surrounding the particles as a consequence of the use of surfactants reduces conductivity.

1.2.5 Applications of Nanofluid

High heat motion gadgets like high power microwave cylinders and high-power laser diodes might be cooled utilizing nanofluid. In order to boost efficiency, nanofluid might be pumped via a small slit in the machinery. It's not uncommon for nanofluids to be used in a variety of applications, such as engine cooling, transmission oil and boiler exhaust flue gas recovery. They can also be used in a variety of other industries, such as defence and space, thermal storage and bio-medical.

CHAPTER 2

LITERATURE SURVEY

Choi is credited with coining the term "Nanofluid" [1]. The thermal conductivity of several Nano fluids has been measured by many studies. As recently expressed, the warm conductivity of Nanofluids not entirely settled to be higher than that of essential liquids.

Researchers from Choi et al [2, 3] have used a variety of different base fluids to suspend various metals and metal oxide nanoparticles. Their research revealed a 40% improvement in thermal conductivity over base fluids using Ethylene glycol + Copper nanofluid (0.3 vol %).

Nayak et al. [4] concentrated on the impact of impinging a TiO₂/water nanofluid on heat move from a warmed steel surface. For volume focuses going from 0.01% percent to 0.07% percent, they conducted out tests when compared to regular

water, the nanofluid spray performed better in dissipating heat (19.34% better). A wide range of thermal engineering areas may benefit from the use of nanofluids, as shown in these studies.

In a turbulent flow within a tube, Azmi et al. [5] studied the heat transfer and friction factor of Al_2O_3 and TiO_2 in 40:60 EG-water at volume concentrations ranging from 0.5%–1.0%. They directed preliminaries at 30°C, 50°C, and 70°C, and noticed greatest hotness move enhancements of 24.2 percent and 23.8 percent comparative with the base liquid for the TiO_2 and Al_2O_3 nanofluids, separately, at a volume convergence of 1%. It has been shown that at a similar temperature and volume fixation, TiO_2 in the 40:60 EG-water nanofluid has a lower heat move coefficient than Al_2O_3 and the base liquid alone. Heat move coefficient of the two liquids rose decisively while working temperature was raised, instead of the base liquid. At higher Reynolds numbers, there was no way to see a distinction in the hotness move coefficients estimated at 50°C and 70°C for one or the other liquid, which was attributed to the overwhelming influence of turbulence over the varying thermo-physical features of the two fluids.

The turbulent forced convection heat transfer of Al_2O_3 /water and TiO_2 /water nanofluids within a circular tube was experimentally observed by Pak et al. [6]. Al_2O_3 particles were shown to have a greater heat transfer enhancement than TiO_2 particles.

The viscosity and heat transfer coefficient of a SiO_2 /60:40 EG-water nanofluid were studied by Kulkarni et al. [7] at volume concentrations ranging from 2% percent to 10% percent and Reynolds numbers ranging from 3000 to 12,000. With increasing particle size, the viscosity dropped, and with increasing volume concentration, it rose. Both the size of the particles and the thickness of the particles were displayed to influence the hotness move coefficient. At a Reynolds number of 10,200, a regular expansion in heat move coefficient of 16% was seen at 10% volume focus for 20-nm-sized particles. Nanofluids' thermo-actual qualities and hotness move coefficient are talked about in the writing around here comparable to working temperature, molecule size, and volume focus.

SiC/deionized water (DIW) nanofluid viscosity and thermal conductivity were concentrated by Lee et al. [8] in the volume fixation scope of 0.001%–3%. Because nanofluids are prone to dissolving, they found that adjusting the pH level of the base fluid to 11 resulted in stable nanofluids, which is consistent with

previous findings. It was found that the nanofluid had a lower viscosity at lower temperatures. Temperature-dependent findings showed that the relative viscosity of 3% percent SiC/DIW rose from 68% to 102% percent. When the volume concentration was 3% percent, the relative thermal conductivity increased by 7.2% percent at 23°C.

High-shear homogenization, sonication, pH adjustment, and surfactant addition were some of the strategies used to create stable nanofluids by Setia et al. [9]. Nanofluid stability was also examined using various approaches.

A ZnO/ethylene glycol nanofluid's thermal conductivity was examined by Kole et al. [10] after extended sonication. They found that the sonication time affects the thermo-physical characteristics.

The thermo-physical characteristics of SiC/40:60 EG-water nanofluid were evaluated experimentally in the temperature range of 10–50°C by Li et al. [11]. A volume concentration of 0.5% percent resulted in a maximum thermal conductivity increase of 53.81% percent above the base fluid at a temperature of 50°C. They found that when temperature rose, agglomeration and Brownian motion increased, explaining the larger volume concentrations' improved thermal conductivity. A volume grouping of 0.5% percent of the SiC/40:60 EG-water nanofluid created viscosities that were 22.46% percent and 18.96% percent more noteworthy than the base liquid, individually, at temperatures of 50°C and 10°C.

Water-based SiC nanofluids with a 3.7% percent volume fixation and a Reynolds number going from 3300 to 13,000 were utilized in investigations conducted by Yu et al. [12] to quantify the hotness move coefficient. As indicated by the discoveries, the hotness move coefficient was worked on by 50-60% contrasted with the base liquid in the concentrated-on Reynolds number reach.

Ag/50:50 percent Ethylene glycol/Water nanofluid stream in a twofold line heat exchanger was shown to increase heat transfer by 67% percent, according to the research of Sarafriz et al. [13].

When Cu/water nanofluids were used in a twin pipe heat exchanger, El-Maghlany et al. [14] found that the efficacy and the number of transfer units (NTUs) had increased.

In a twofold line heat exchanger, Darzi et al. [15] determined the hotness move and tension drop of an Al_2O_3 /water nanofluid at different working liquid temperatures.

The convective heat transfer coefficient for MgO/water nanofluid stream in a twin line heat exchanger was measured by Hemmat Esfe et al. [16] using a heat exchanger with varying particle concentrations and nanoparticle sizes.

An Al₂O₃/water nanofluid stream with a 0.3% percent volume fraction was found to have a heat transfer coefficient by Dittus et al. [17] and Nusselt number of 19% and 24%, individually, in a counterflow two fold line heat exchanger.

It was shown that the heat transfer coefficient of Cu-water nanofluids was a lot higher than that of unadulterated water by Xuan et al. [18] in laminar and turbulent stream systems in constrained convection. Also, it was tracked down that rising the grouping of nanoparticles fundamentally expanded the heat transfer coefficient.

In a twin line counter stream heat exchanger, Vajjha et al. [19] inspected the heat transfer of TiO₂/water nanofluids stream in the volume part scope of 0.002 and 0.02 and the Reynolds number of 8000 to 51000.

Sharma et al. [20] organized hot Al₂O₃/water nanofluid inside tube, while cold water streams annulus tube and surveyed heat transfer coefficient for 0.15% percent, 0.25% percent and 0.5% percent and noticed Nusselt number addition of 40.5% percent contrasted with unadulterated water under 0.5% percent volume fixation.

In a violent stream level twofold cylinder counter stream heat exchanger, Timofeeva et al. [21] observed a 6-11% percent expansion in heat transfer effectiveness at a 0.2% percent volume grouping of TiO₂/water nanofluid stream.

At 0.25% percent TiO₂-water nanofluid stream in a twin line heat exchanger with a Reynolds number of 5000, Zarrinhalam et al. [22] noticed a 22% percent increase in heat transfer.

With increasing particle concentration, a double-tube helical heat exchanger shows a considerable increase in heat transmission, according to a numerical study by Huminic et al. [23].

Fe₃O₄/water nanofluid hydro-thermal properties at 4% volume concentration were explored by Shakiba et al. [24] utilizing a solitary stage model and control volume approach in a counter stream twofold line heat exchanger.

TiO₂ and Al₂O₃ nanofluids flow in a twin pipe heat exchanger was examined numerically by Demir et al. [25].

Return bends may be used to further increase heat transmission in twin pipe heat exchangers. In pipelines with return twists, Hong et al. [26] observed that heat transmission was fundamentally improved, and they reached the resolution that liquid blending, hydrodynamic turn of events, and warm advancement of auxiliary streams promptly downstream of the U-twist were all contributing variables.

For up to 20 line distances across, scientists Clarke et al. [27] quantitatively inspected the hotness move component of auxiliary refrigerant stream in an air chiller U-twists and discovered a 20% percent increase in heat transmission for return bends.

In a two-pipe heat exchanger with a return wind and a Reynolds number of 22000, Prasad et al. [28] observed a 25% percent expansion in heat move productivity at a 0.03% percent volume grouping of Al_2O_3 /water stream. Further heat transfer augmentation is possible by altering the inner tube's geometries, as shown in the previous works.

Brownian motion-induced nano convection was shown to be a key factor in the thermal behaviour of nanofluids by Jang et al [29]. Nanofluids' effective thermal conductivity may be affected by a range of factors, including the proportion of the warm conductivity of nanoparticles to the base fluid, volume part, nanoparticle size, and temperature.

For nanofluids consisting of alumina nanoparticles and transformer oil, Chun et al. [30] studied the convective heat transfer coefficient in the laminar flow regime. It has been shown that alumina-transformer oil nanofluid systems improve heat transmission, and this has been shown experimentally.

It has been shown by Lotfi et al. [31], that the temperature-independent characteristics of Al_2O_3 /Water nanofluid can be displayed utilizing the single-stage, Mixture, and Eulerian two-stage models. As an additional step, they compared the predicted values of the Nusselt number with multiple correlations and one set of actual results at a 1% nanoparticle concentration. They've also looked at how volume concentration affects the temperature of the wall. Utilizing their discoveries, they inferred that the Mixture model is more exact than the other two. Euler-Lagrange technique was utilized to explore the presentation of Mn-Zn ferrite attractive nanofluids in counterflow twofold line heat exchangers under quadrupole attractive fields by Bahiraei et al. [32]. They've looked at the impacts of several

characteristics, including particle concentration, particle size, magnetic field strength, and Reynolds number, among others.

Mohammad Sikindar Baba et al. [33] An exploratory examination of constrained convective hotness move in a counterflow heat exchanger with numerous longitudinal fins using Fe_3O_4 /water nanofluid is presented in this article. Finned tube heat exchangers have a hotness move pace of 80% to 90% percent more noteworthy than plain cylinder heat exchangers when the volumetric centralization of nanofluid is higher. While utilizing 0.4% percent Fe_3O_4 -water nanofluid, the hotness move rate in a finned tube heat exchanger is 90-98% percent more prominent than in a plain cylinder heat exchanger. For 0.4% percent Fe_3O_4 -water nanofluid spilling at a speed of 2 LPM, the grinding variable in finned tube is 3.75 times the plain chamber crushing element.

Han et al. [34] Nanofluids of Al_2O_3 and water will be studied as a means of enhancing double-tube heat exchanger performance when intake temperatures are varied. Nanoparticles of Al_2O_3 with centralizations of 0.25% percent and 0.5% percent by volume have been used at moved input temperatures. As the temperature and volume grouping of nanoparticles rise, so does the hotness transmission. At 50°C input temperature, the maximum Nusselt number increases by up to 24.5%, which is a significant improvement over the water. There is a most extreme expansion in convective hotness move coefficient of 9.7% and 19.6% for volume convergences of 0.25% and 0.50%, separately.

Palanisamy et al. [35] MWCNT/water nanofluids were used to analyse the hotness move and strain drop of a cone helically wound tube heat exchanger. Nanofluids with volume centralizations of 0.1% percent, 0.3% percent, and 0.5% percent have higher Nusselt numbers than water by 28%, 52%, and 68 percent, individually. When contrasted with water, the pressure drop for nanofluids with concentrations of 0.1%, 0.3%, and 0.5% is shown to be 32% larger. At 0.1% percent, 0.3% percent, and 0.5% percent MWCNT/water nanofluid, the increased heat transfer coefficient is 14%, 30%, and 41% higher than water.

Several authors, including Mukesh Kumar et al. [36] The simulation programme ANSYS 14.5 version was used to examine the heat transmission and pressure decline in a twofold helically snaked heat exchanger utilizing MWCNT/water nanofluids. The aftereffects of the reproduction were contrasted with those of the trials. At a Dean number of 1400, the Nusselt number of 0.6% percent

MWCNT/water nanofluids is viewed as 30% higher than water, and the tension drop is 11% more prominent than water. At 0.2% percent, 0.4% percent, and 0.6% percent nanofluids, the Nusselt number is 20%, 24%, and 30% higher than water, separately, at the Dean number of 2000. For nanofluids, the pressure decreases are 4% percent, 6% percent, and 10% percent, respectively, greater than water's pressure drop. This is because the viscosity of nanofluids changes with temperature. After everything was said and done, the experimental and CFD data were compared, and the deviations in CFD Nusselt number and pressure drop were found to be 7.2% percent and 8.75% percent, respectively.

According to Navid Bozorgan et al. [37], in exchangers with a given heat exchange capacity, mass flow rates may be reduced by employing nanofluids. The numerical performance of Al_2O_3 nanoparticles with 7 nm diameters distributed in water at up to 2% volume concentrations is inspected in a level twofold cylinder counterflow heat exchanger under fierce stream conditions. Nanofluid's mass stream rate is generally 24.5% percent lower than that of unadulterated water (the base liquid) under similar conditions. For a volume convergence of 2%, the hotness move coefficient ascends by 64.65% percent, though the warm conductivity increments by under 40%. For a convergence of 2 vol. % percent, the rubbing variable and strain drop ascend by 13.64% percent and 15.66% percent, individually.

Rajput Singh Nitesh [38] et al. TiO_2 /water and CuO /water nanofluids were used in a hotness exchanger (twofold line) to concentrate on the impacts of stream rate and nanoparticle fixation on heat move. The findings show that CuO is a superior nanoparticle than TiO_2 because of its excellent thermo-physical characteristics, which lead to an increase in heat transmission. At 0.3% percent concentration, TiO_2 /water and CuO /water nanofluids improve heat transmission by 5% and 8%, respectively, according to experimental data.

Salman et al. [39] Titanium dioxide (TiO_2) has excellent thermal conductivity and excellent physical and chemical properties, making it an excellent material for improving heat transfer. Three-dimensional simulations are used to examine the thermal analysis of a drafted design (a twin pipe heat exchanger). The concentration of coolant nanoparticles (0-3 vol % percent) is varied. At 0.3% percent volume concentration of TiO_2 nanofluid, modelling findings show an 18% percent expansion in heat move coefficient. When the proportion of TiO_2

increased, the Nusselt number rose significantly. In any case, it very well may be inferred that the improvement of erosion factor is more modest than the increase of heat transmission for volume fractions that are taken into account.

Fule et al. [40] In this research, water-based CuO nanofluids are used to improve heat transmission in a helical coil heat exchanger. The current research evaluated nanofluids containing 0–0.5 volume percent CuO nanoparticles and flow rates ranging from 30–80 LPH (Reynolds numbers range from 812–1895, Laminar flow regime). CuO nanoparticles in nanofluid at a centralization of 0.1 vol% percent expanded the hotness move coefficient by 37.3% contrasted with the base liquid, while at a grouping of 0.5 vol% percent, it expanded by 77.7%. A 37.3% percent increment in heat move coefficient was accomplished at 0.1 vol% percent CuO nanoparticle fixation in nanofluid, contrasted with base liquid, while at 0.5 vol% percent, it was pretty much as high as 77.7% percent, as per the outcomes.

Al₂O₃ nanoparticles conveyed in water stream by means of a fluid cooling arrangement of microchips under tempestuous stream conditions were concentrated by Nguyen et al. [41]. Nanofluid with a molecule width of 36 nm had a greater heat transfer coefficient than its 47 nm particle diameter counterpart, the data showed. The base fluid had a lower heat move coefficient than the nanofluid. For TiO₂-refined water nanofluids moving through an upward line in a vertical bearing under a steady hotness motion limit condition, an exploratory examination was led by He et al. [42] to investigate the hotness move execution and stream qualities in both laminar and tempestuous stream systems.

CHAPTER 3

MATERIALS AND METHODS

3.1 NANOPARTICLES

Particles less than 100 nanometers in diameter are called nanoparticles. When it comes to physical and chemical characteristics, nanoparticles vary greatly from their bigger material counterparts. Engineering may be used to make nanoparticles for specific purposes, or they can be formed naturally or as the by-products of combustion processes. Because of their adaptability, nanoparticles are utilized in an expansive scope of areas, from medical care and beauty care

products to natural safeguarding and air cleansing, in light of their adaptability to be created in exact ways.

3.1.1 ZINC OXIDE NANOPARTICLES

Nanoparticles of zinc oxide (ZnO) with aspects less than 100 nanometers are alluded to as zinc oxide nanoparticles. Despite their small size, they have a lot of surface area for their weight. Zinc oxide nanoparticles have a wide range of physical and chemical characteristics depending on how they are manufactured. In order to create nanoparticles of ZnO, there are a variety of methods, including laser ablation and hydrothermal methods; chemical vapour deposition; thermal decomposition; ultrasound assisted combustion; two-venture mechanochemical-warm combination; anodization; electrophoretic affidavit; and precipitation processes utilizing arrangement fixation and pH.

Among the most studied nanoparticles is zinc oxide, which may be used in a variety of downstream applications. In terms of abundance, zinc oxide nanoparticles are the second most common metal oxide after iron, and they are affordable, safe, and easy to manufacture. Changing the shape of zinc oxide nanoparticles or utilising alternative synthesis techniques, precursors, or materials to make the nanomaterial may readily alter its physical and chemical properties. Analytical sensing uses zinc oxide nanoparticles, a group II-IV semiconductor inorganic chemical. Fig 3.1 shows that zinc oxide nanoparticles emerge as a white powder that is not water-soluble. Its outstanding chemical, electrical, and thermal stabilities are shown in table by the zinc oxide nanoparticle's energy band of 3.37 eV and its holding energy of 60meV. Zinc oxide nanoparticle. It is also capable of optical, electrical, and photocatalytic functions as shown in Table 3.1 Zinc oxide nanoparticles are used in solar cells, photocatalysis, and chemical sensors because of their unique features. For its low toxicity and great UV-absorption properties, zinc oxide nanoparticles are a viable choice for biomedical applications. The strong and stiff structure of zinc oxide nanoparticles makes them helpful in the ceramic industry. Zinc oxide nanoparticles are useful in biomedicine because of their ability to serve as an excellent surface material. It is notable that zinc oxide nanoparticles have a high protection from microorganisms. Therefore, zinc oxide nanoparticles are widely employed in a variety of medical applications, including labelling and sensing of biological systems, transport of therapeutic

drugs and genetic material for gene therapies. Zinc oxide has been authorised by the Food and Drug Administration as a safe material. Zinc oxide may be used as a multifunctional nanocarrier since it can be dissolved in acidic environments, making it easier to carry and release drugs.

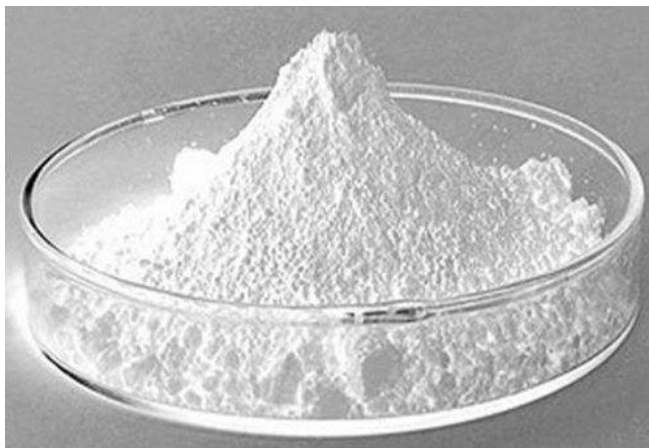


Fig: 3.1: Zinc Oxide Nanoparticles

Table 3.1: Properties of Zinc Oxide Nanoparticles

Properties	ZnO
Appearance	White, Odourless
Crystal Structure	Wurtzite
Chemical Composition	Zinc: 80.34%, Oxygen: 19.6%
Density	5600 kg/m ³
Molar Mass	81.40 g/mol
Melting Point	1975°C
Boiling Point	2360°C

3.1.2 TITANIUM OXIDE NANOPARTICLES

Titanium dioxide has the potential to play a critical role in a wide range of sectors, including photocatalysis, gas sensors that are sensitive to sunlight, cell technology, and biomaterials. In the medical field, titanium's non-poisonous and biocompatible qualities lead to its use in bone tissue construction and pharmaceuticals. Table 3.2 shows that titanium dioxide catalysts are excellent photo catalysts for degrading and hindering a variety of hazardous natural pollutants. Titanium dioxide is used in a variety of ways, counting for water and surface cleaning. Titanium is suggested for desalination offices due to its high consumption protection from sea water. It is because of its nonreactive character

that titanium pins have been chosen for use in restorative applications. Sol-gel, hydrothermal, fire combustion, sol-vothermal, and parasitic-involved biosynthesis are some of the methods used to produce titanium dioxide nanoparticles as shown in Fig 3.2. *Pseudomonas stutzeri*'s periplasmic surface was used to generate titanium dioxide nanoparticles, while *Salmonella typhi* and *Citrus limone* were used to manufacture titanium dioxide nanoparticles. Even in the manufacturing of nanoparticles, plant sources make ideal alternatives. Titanium dioxide nanoparticles have recently been synthesised using microorganisms, for example, *Lactobacillus* sp. also, *Saccharomyces cerevisiae*. Various strategies and arrangements utilizing titanium dioxide nanoparticles have been demonstrated to be more successful than ordinary techniques.



Fig: 3.2: Titanium Oxide nanoparticles

Table 3.2: Properties of Titanium Oxide Nanoparticles

Properties	TiO ₂
Appearance	White, Odourless
Crystal Structure	Rutile
Chemical Composition	Titanium: 59.93%, Oxygen: 40.55%
Density	4230 g/m ³
Molar Mass	79.9378 g/mol
Melting Point	1843°C
Boiling Point	2972°C

3.2 PREPARATION OF NANOFLUID

To create Nanofluid, a base fluid is supplemented with Nanoparticles. Designed colloidal suspensions of nanoparticles in a base liquid are the reason for these liquids. Nanoparticles are microscopic particles with a diameter ranging from 10

nm to 1000 nm. Metals, oxides, carbides, and carbon nanotubes are the most common nanoparticle materials found in nanofluids. Gold (Au), silver (Ag) nanoparticles are examples of metal nanoparticles, whereas zinc oxide, copper oxide, and aluminium oxide are oxide nanoparticles. These include water, ethylene glycol (Ethylene Glycol), and oil as common base fluids.

As previously discussed, the preparation and scattering of nanoparticles in a base liquid is the initial phase in the making of nanofluids. Because of the great van der Waals associations between the nanoparticles, it is undeniably challenging to suspend them equally and stably in the base fluid. As a result, various methods have been employed to ensure proper nanoparticle dispersion in the base fluid. Nanofluid dispersion and stability can be improved by combining ultrasonication, magnetic stirring and surfactant addition with pH adjustment for better dispersion and stability of the nanofluids, as shown in Fig 3.3.

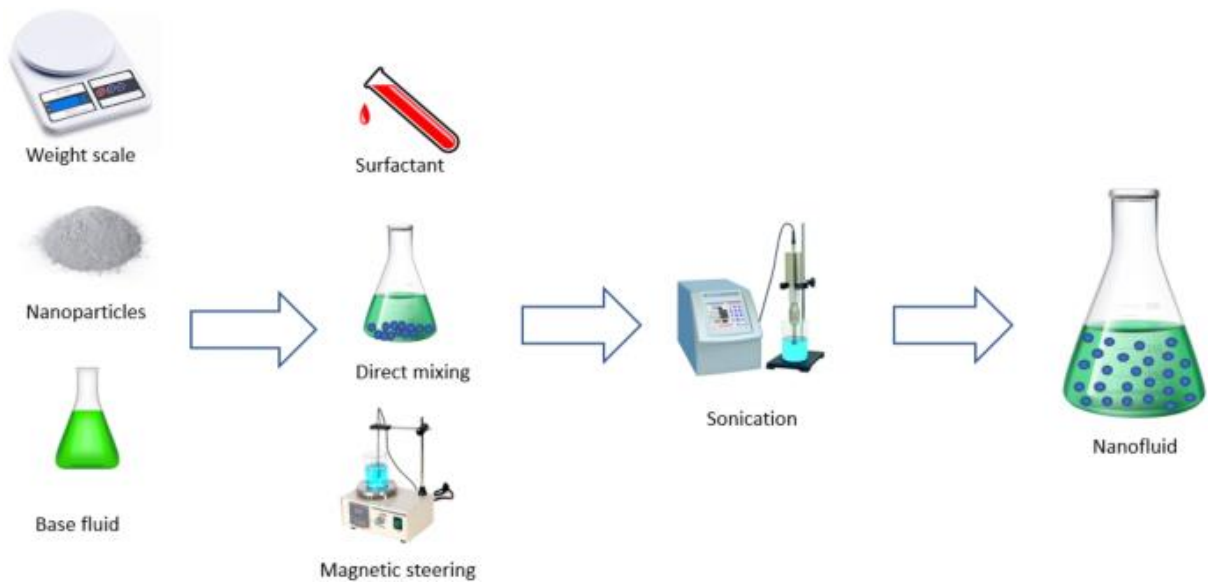


Fig: 3.3: Preparation of Nanofluid

Traditional methods are used to create nanofluids. A single-step technique is distinguished from a two-step method. To make the important nanofluid, the nanoparticles were spread in a base liquid and afterward blended properly. Three common approaches to achieving nanofluid stability have been described so far. Acid treatment, dispersants, and ultrasonic vibration are some of the methods used to stabilise the base fluid. In order to achieve a stable combination, these processes alter the system's surface properties and obscure the resolution. An

ultrasonic vibrator was used to do continuous ultrasonic work on nanoparticles distributed in EG-alkaline water in this study. In order to avoid the aggregation of nanoparticles, this vibrator generates ultrasonic pulses of 100W at 363 kHz for 5 hours. The thermo-physical characteristics of nanofluids are altered by the addition of any surfactant or dispersion. As a result, no additives were used throughout the manufacturing process, keeping the system isolated. Initial materials in this technique include zinc acetate. It was originally agitated with 1m Zinc acetate, and 2m Caustic Soda was smartly added to the new skillfully agitated zinc acetate, which had been agitated. After 18 hours of stirring, the precipitate suspension became a white slurry with a lot of white powder. Ground to a fine powder in a muffle chamber, then calcined at 400°C after being filtered and washed. White and black ash hues shift as the temperature rises beyond 400°C, and the particles disintegrate.

Titanium tetra chloride was used in this (TiCl_4). Water with a pH of 7.4 has been mixed with TiCl_4 50 ml of alkaline water and 200 ml of ice cold water. The beaker is brought to room temperature from an ice-cooled environment. Using a magnetic stirrer, the solution was pushed into a beaker for 30 minutes. At 150°C, the bath will continue until all of the Nano particle matter has been successfully extracted.

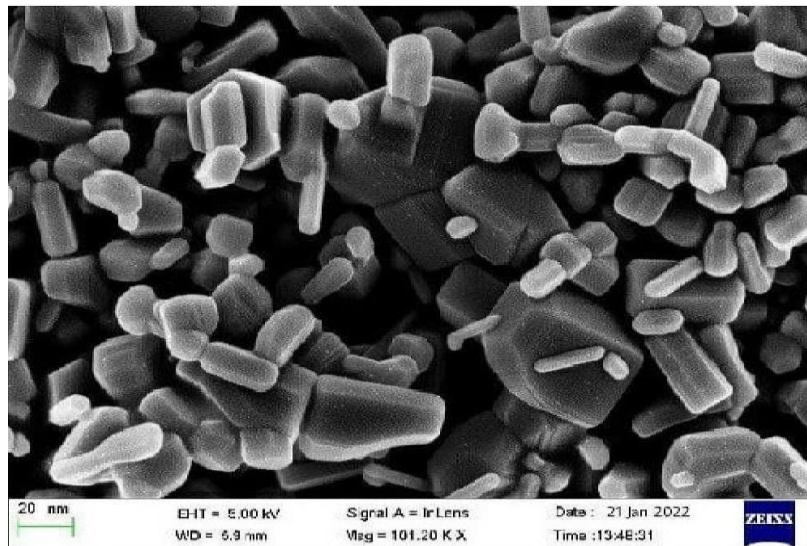


Fig: 3.4: SEM Image of ZnO Nanofluid

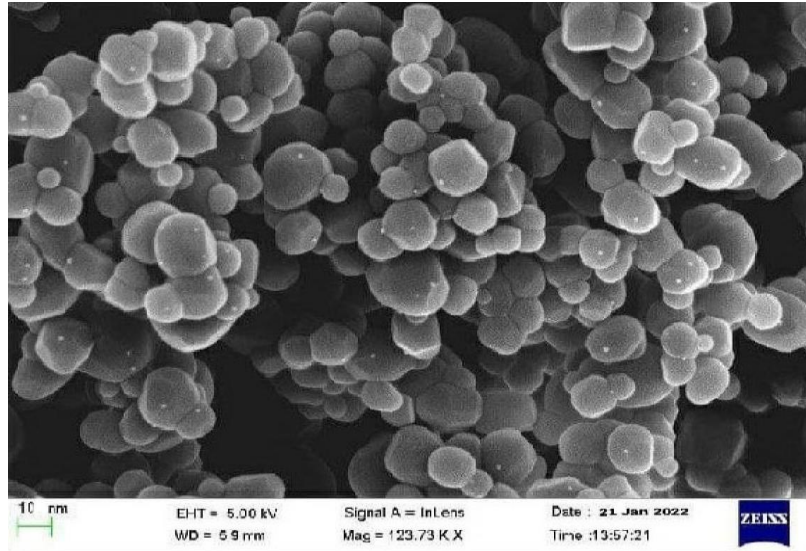


Fig: 3.5: SEM Image of TiO_2 Nanofluid

Scanning Electron Microscope (SEM) images of zinc oxide Nano particles have been obtained using the ZEISS Scanning Electron Microscope. It has a high 2 nm, 3 nm @ 30kV resolution. SEM displays Nano-particles zinc oxide under ZEISS Electron Scanning Microscopy. EHT refers to the high voltage electron which is the electrons' accelerating energy. From the Fig 3.4 and 3.5, the particle size of Nano is clearly visible in the range of Nano metres. Zinc oxide Nano-particulates were collected with a ZEISS Electron Microscope Scanning Microscope (SEM). The resolution is high 2 nm. The SEM image shown in the ZEISS Scanning Electron Microscope reveals Nano-particles of titanium dioxide. The particles are in the meter scale, as can be seen in the Fig 3.4 and 3.5 above.

3.3 EXPERIMENTAL SETUP

The heat exchanger consists of two pipes. The 1.2-meter length of the two-pipe heat exchanger is typical. The outside pipe diameter is 70.2mm, while the inner pipe diameter is 60.2mm. The stainless steel outer pipe has an outside diameter of 90.2mm and an inner diameter of 80.2mm. The heater is controlled by a system board that is heated. The gadget is connected to a computer through a hub board. Temperatures of the hot fluid and nanofluid may be measured using thermocouples. A heater and a hot fluid tank are used to heat and store the hot fluid, respectively. With a 95°C operating temperature, a hot-fluid pumps hot fluid from the hot fluid tank to the double-pipe heat exchanger. Using a cold fluid pump, nanofluid is pumped from the cold fluid tank to the heat exchanger's twin pipes.

The hot fluid and nanofluid flow rates are monitored and recorded using an electronic flow metre. A refrigerator and a tank is used for storing and cooling the nanofluid. Pressure measurement sensors are used to measure the pressure rate and a digital pressure recorder is used to record the pressure of the hot fluid and nanofluid, as shown in Fig 3.6.



Fig: 3.6: Experimental Setup of Double Pipe Heat Exchanger

3.4 EXPERIMENTAL PROCEDURE

- 1) Fill the hot and cold water tanks with water.
- 2) Use the immersion heater in the hot water tank to bring the water temperature to your preferred level.
- 3) Bypass line valves should be completely open and supply valves should be entirely closed to guarantee thorough mixing of water in the water tank to maintain a consistent temperature.
- 4) Operate four valves on the panel in such a way that the heat exchanger runs in a counter flow configuration.
- 5) Allow the hot water to run through the inner pipe side of the piping. Rotate the rotameter to get the required flow rate, as illustrated in Figs. 3.7 and 3.8.

- 6) Turn on the cold water supply from the outside of the pipe. Turn off the cold water supply. Rotameters may be used to fine-tune the flow rate.
- 7) As soon as cold and hot water streams have reached steady state, take note of their input and output temperatures and record them.
- 8) Use rotameters to record the hot and cold water flow rates.
- 9) Re-run steps 6 through 8 for varying flow rates of both cold and hot water.
- 10) The heat exchanger is now operating in a counter flow mode as a result of the adjustment of four valves on the panel.
- 11) After the studies are complete, remove all of the water from both tanks.

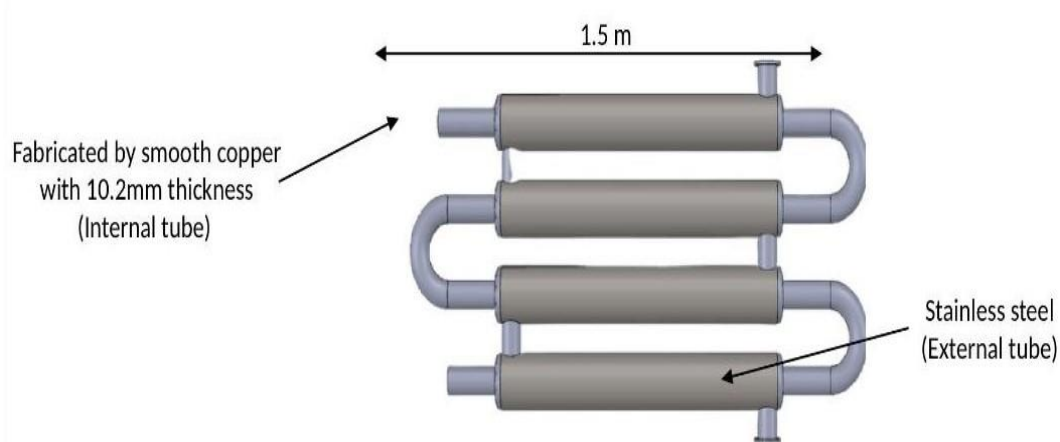


Fig: 3.7: 3D Diagram of Double Pipe Heat Exchanger with U-Bend

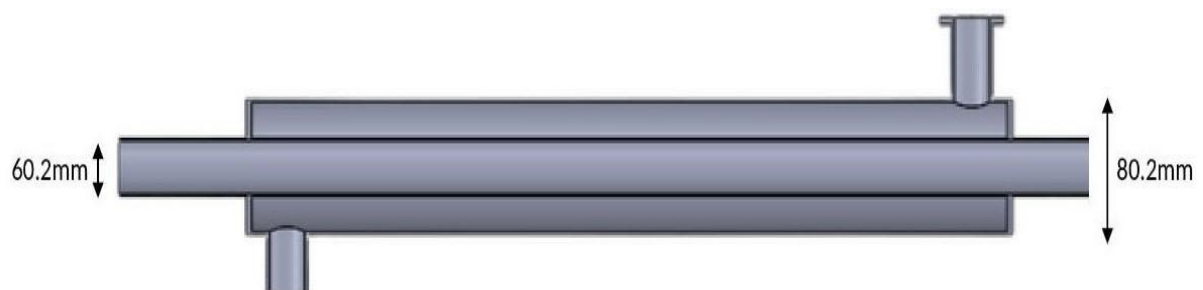


Fig: 3.8: 3D Diagram of Double Pipe Heat Exchanger

3.5 GOVERNING EQUATIONS

It was determined that a certain concentration of nanoparticles had a mass of Eq. (1), provided by Nayak et al. [4]:

$$\phi = \frac{\frac{W_{np}}{\rho_{np}}}{\left(\frac{W_{np}}{\rho_{np}}\right) + \left(\frac{W_{bf}}{\rho_{bf}}\right)} \times 100 \quad (1)$$

where np indicates nanoparticle and bf means base liquid.

Different amounts of nanofluid are used to determine the thermal conductivity of each. Eq. (2), provided by Azmi et al. [5]:

$$k = 3 \times \left(\frac{N_A}{V_m}\right)^{2/3} \times K \times V \quad (2)$$

Nanofluid molar volume, Boltzmann constant, sound wave velocity, and Avogadro number, are the values of V_m , K , V , and N_A , respectively. At a temperature of 45°C, the viscosity and thermal conductivity of nanofluids were measured at various volume concentrations.

By utilising Eqs. (3) and (4) provided by Pak et al [6], the nanofluid's density and specific heat were calculated:

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

$$c_{p_{nf}} = \frac{(1 - \phi)\rho_{bf}c_{p_{bf}} + \phi\rho_p c_{p_p}}{\rho_{nf}} \quad (4)$$

In this study, Kulkarni et al. [7] gave the equations (5) and (6) for calculating the heat loss of the hot fluid (hf) and heat gain of the cold fluid (cf). The average heat duty of the heat exchanger is given by Equation (7):

$$\dot{Q}_{hf} = \dot{m}_{hf}c_{p_{hf}}(T_{hi} - T_{ho}) \quad (5)$$

$$\dot{Q}_{cf} = \dot{m}_{cf}c_{p_{cf}}(T_{co} - T_{ci}) \quad (6)$$

$$\dot{Q}_{avg} = \frac{\dot{Q}_{hf} + \dot{Q}_{cf}}{2} \quad (7)$$

Logarithmic mean difference (LMTD) was estimated using Eq. (8) based on the reported temperatures, provided by Lee et al. [8]:

$$\text{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} \quad (8)$$

where $\Delta T_1 = T_{hi} - T_{co}$ and $\Delta T_2 = T_{ho} - T_{ci}$.

Eqs. (7) and (8) were utilized to acquire the all-out heat move coefficient in view of the inward line's surface region. Eq. (9) provided by Setia et al. [9]:

$$U_i = \frac{\dot{Q}_{\text{avg}}}{A_{is}(\text{LMTD})} \quad (9)$$

where i is used to designate the inside surface, and $A_{is} = \pi d_i l$ denotes the area of the interior surface. The Reynolds number of the annulus stream is typically in the scope of progress stream. Eq. (10) by Kole et al. [10] correlation was used to obtain the Nusselt number for the annular pipe:

$$\text{Nu}_0 = \frac{\left(\frac{f}{8}\right)(\text{Re} - 1000)\text{Pr}}{1 + 12.7(f/8)^{0.5}\left(\text{Pr}^{\frac{2}{3}} - 1\right)} \quad (10)$$

in which Reynolds's number $\text{Re} = \rho V d_h / \mu$; hydraulic diameter $d_h = d_o - d_i$; and Prandtl number Pr is the Prandtl number. Computations of the grating variable were made utilizing Eq. (11) as given by Li et al. [11]:

$$f = [0.79 \ln(\text{Re}) - 1.64]^{-2} \quad (11)$$

Eq. (12) was utilized to figure the annulus heat move coefficient in light of Eq. (10):

$$h_o = \frac{\text{Nu}_0 \times k_o}{d_h} \quad (12)$$

Condition (9) and (12) are utilized to compute the hot liquid's hotness move coefficient, as shown in Equation (13):

$$\frac{1}{h_i} = \frac{1}{U_i} - \frac{r_i}{k} \ln\left(\frac{r_o}{r_i}\right) - \frac{1}{h_o} \quad (13)$$

k is the inner tube's thermal conductivity; r_i is the inner tube's radius; and r_o is the inner tube's radius.

According to Yu et al. [12], the friction factor of the inner tube was computed using Eq. (14):

$$f = \frac{2\Delta P d}{\rho L V^2} \quad (14)$$

where Inner diameter d , length L , velocity of flow V , and density ρ are some of the variables that may be used to calculate the pressure drop ΔP of an inner pipe.

3.6 COMPUTATIONAL FLUID DYNAMICS (CFD)

Stream investigation using mathematical arrangement methods is known as computational liquid elements (CFD). Fluid-fluid, fluid-solid, and fluid-gas interactions may all be studied using CFD. The domains of aerodynamics and hydrodynamics, for example, typically utilise CFD calculations to decide amounts like lift and drag or field qualities like tensions and speeds. To some degree differential conditions assume a significant part in liquid elements. With the assistance of modern CFD solvers, these rules may be transformed into algebraic equations and then numerically solved.

CFD studies have the potential to save time and money in the design process, making them more cost-effective and speedier than conventional testing strategies. True testing can gauge few factors all at once, yet in a CFD review, all of the relevant variables may be monitored simultaneously and at a high spatial and temporal resolution.

As a result, physical testing cannot be completely excluded from these CFD calculations, which only approach a real-world solution. Tests should still be carried out as a precautionary measure.

In general, the three stages of a CFD study are represented in Fig. 3.9:

1) Pre-processing:

Problem statements are idealised and discretized into computer models at this stage. Phase 2. Assumptions are made about the kind of flow (viscous/inviscid, compressible/incompressible, steady/non-steady) to be simulated. Mesh creation

and the application of starting and boundary conditions are also part of the equation.

2) Solving:

The solver is the one who really does the calculations, and it is at this point that computing power is needed. There are a variety of solutions available, each with various degrees of efficiency and capacity in dealing with certain physical phenomena.

3) Post-processing:

Post-processing involves visualising and analysing the data that has been collected. Analyzers may now check their findings and make inferences based on those findings. Static or animated images, graphs, or tables are all examples of how the findings of your research might be shown.

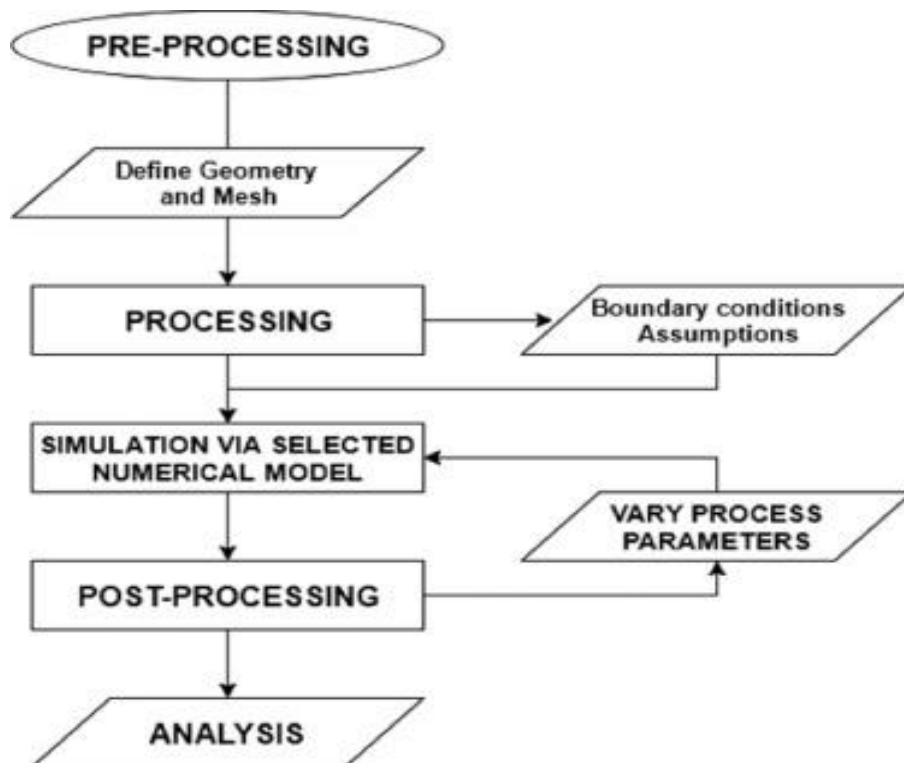


Fig: 3.9: Task Distribution in a CFD Process

3.6.1 MODELLING, MESHING AND ANALYSIS OF DOUBLE PIPE HEAT EXCHANGER

For the purpose of this research, the twin pipe heat exchanger is arranged in alternate orientations, with the cut facing up and the cut facing down. Pre-processing, solving, and post-processing are all components of the CFD analysis. Fig 3.10 shows a 3D model of a heat exchanger created in SolidWorks 15.0, which is used for the geometry modelling.

1) MESHING:

A coarse mesh is formed in free meshing. It consists of both tetrahedral and hexahedral cells with triangular and quadrilateral faces at the borders. Edge sizing is then used to make a tiny mesh. High-pressure and high-temperature zones are well-defined in this model. It was finished utilizing ANSYS' default fitting client, ICEM CFD, for the computational meshing. There are tetrahedral cells in the mesh for the whole model, which will act as main informative elements for temperature and stream all through the mathematical reproduction of this model. Throughout the apparatus, mesh and nodes were dispersed employing a variety of the program's built-in automated meshing algorithms. Control and concentration of the mesh along the wall areas were achieved by the application of face and body selection. The relevance was set at 25, with a coarse curvature sizing centre. Utilizing the relevant value and curvature size from the work of Sarafranz et al. [13], which utilised pure water as a coolant, the outcomes utilizing the thought about conditions (in view of cross section and different boundaries) were contrasted with affirm that they were satisfactory.

2) PROCESSING:

In charge of equations CFD research on shell and cylinder heat exchangers were the essential motivation for the situations, boundaries, and models that will be portrayed in this part. Rejected from the consistent state investigation of DPHE administering conditions are time-subordinate parts of the protection of mass/force/energy preservation (x, y, z planes) indicated in Equations (1) to (6). Dissipation functions are included in the conservation of energy equation (Φ), as seen below (Sarafranz [13]). The equations described in this part are all built-in functions of the ANSYS CFX solver, which is used to execute the simulations.

$$\nabla(\rho\vec{V}) = 0 \quad (1)$$

$$\nabla(\rho u\vec{V}) = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} \quad (2)$$

$$\nabla(\rho v\vec{V}) = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} + \rho g \quad (3)$$

$$\nabla(\rho w\vec{V}) = -\frac{\partial p}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} \quad (4)$$

$$\nabla(\rho e\vec{V}) = -p\nabla(\vec{V}) + \nabla(k\nabla T) + q + \Phi \quad (5)$$

$$\Phi = \mu \left[2 \left[\left(\frac{\partial u}{\partial x} \right)^2 + \left(\frac{\partial v}{\partial y} \right)^2 + \left(\frac{\partial w}{\partial z} \right)^2 \right] + \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \right)^2 + \left(\frac{\partial u}{\partial z} + \frac{\partial w}{\partial x} \right)^2 + \left(\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y} \right)^2 \right] + \lambda (\nabla \vec{V})^2 \quad (6)$$

3) NUMERICAL MODELLING & TURBULENCE MODELS:

According to early models by Sarafriz et al. [13], fluid flow in the DPHE is very turbulent. Consideration must be given to the turbulence models to use for DPHE flows, which have various degrees of velocity, length and temporal instability. Large Eddy Simulation (LES) and a collection of Reynolds-averaged Navier-Stokes (RANS) equations (e.g. the standard k- ϵ , realisable k- ϵ , Spalart-Allmaras, and the standard k- ω models) are used to derive these approximations (El-Maghlany et al. [14]). To complete the flow equations, both models predict turbulent/eddy viscosity, which may then be utilised to represent momentum transfer through eddy diffusivity (Darzi et al. [15]). The RANS equations were employed to construct the time-averaged case model used in the research.

4) BOUNDARY CONDITIONS:

The separate zones were each given their own set of border criteria. Shell-and-tube heat exchangers have two inlets and two outputs since they are made of tubes and shells. Velocity inlets and pressure outlets were specified. The cold fluid's intake velocity was held constant at 0.0787 m/s, while the hot fluid's input velocity was held constant at 1.594 m/s. Atmospheric pressure was used for all of the outlet pressures. The cold fluid was held at 30°C while the hot fluid was kept at 60°C at the input. As a result, the properties of the other walls were also specified. The temperature of the surrounding air was maintained at 30°C.

5) GEOMETRY:

An experimentally confirmed design by Sarfaraz et al. [13] that follows the criteria of the Tubular Exchange Manufacturers Association (TEMA) was used to create the DPHE geometry. Fig 3.10 shows an example of a pilot-scale heat exchanger without the shell covering and flange. An ANSYS Workbench design module was used to import the Rhino 3D model for further processing of the model. The tubes are treated as solid cylinders for a simpler study of the shell-side. The shell-side, where the nanofluid will flow, may be studied using the simplified modelling technique. For validation purposes, Sarfarz et al [13] adopted this modelling technique, which uses a water-based fluid as the basis for initial simulations.



Fig: 3.10: Pilot-Scale Double Pipe Heat Exchanger Geometry

3.6.2 SOLUTION METHODS

The following are the suggested approaches to finding a solution:

Effortless Design Least Squares Cell Based Gradient and Linear Pressure Turbulent Kinetic Energy is the second order upwind momentum. Energy-power law: Second Order Upwind, Turbulent Dissipation Rate.

3.6.3 SOLUTION CONTROL

Relaxation factors have the following parameters:

Pressure = 0.7 pa, Density = 1kg/m^3 , Body forces = $1\text{kg/m}^2\text{s}^2$, Momentum= 0.2 kg-m/s , Turbulent kinetic energy= $1\text{ m}^2/\text{s}^2$

3.6.4 SOLUTION INITIALIZATION

SIMPLEC has decided to use a Pressure Velocity coupling. Slope adjustment was set to zero. Gradient was set to "Least square cell based" in the Spatial Discretization zone. When the wind was "First order Upwind," the pressure was "standard". The "First order Upwind" setting was used for Turbulent Kinetic energy. A "First order Upwind" energy setting was also applied. The solution was started at the intake with a temperature of 30°C, the "conventional approach." Simulation was set to 100 iterations under the conditions of an Above boundary condition and a Solution initialise condition.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 VISCOCITY AND THERMAL CONDUCTIVITY OF TiO₂ AND ZnO NANOFLUIDS

Viscosity changes with volume concentration of TiO₂ EG-alkaline water nanofluid seen in Fig. 4.1(a). Fig 4.1(b) depicts the relationship between volume concentration and the nanofluid viscosity of ZnO EG-alkaline water. With a rise in volume concentration, the TiO₂ nanofluid's viscosity rose because the quantity of nanoparticles per unit volume of the liquid expanded, thereby increasing the flow resistance.

With volume concentrations of 0.5% percent, 0.75% percent, and 1.25% percent, the increase in viscosity for TiO₂ EG-alkaline water nanofluid ranged from 8.98% percent to 36.2% percent and 40.2% percent for ZnO EG-alkaline water nanofluid at an operating temperature of 45°C.

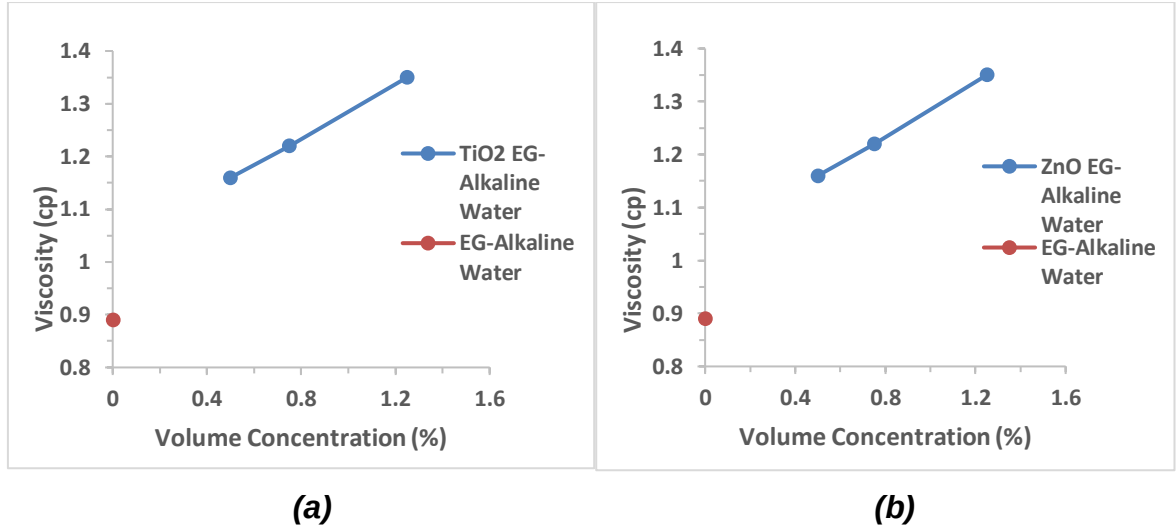


Fig: 4.1: Viscosity of (a) TiO₂ EG-Alkaline Water (b) ZnO EG-Alkaline Water

Figure 4.2(a) shows that the warm conductivity of TiO₂ nanofluid was more significant than that of the base fluid at all volume centers associated with the assessment. At all volume obsessions, the warm conductivity of the ZnO nanofluid was more vital than that of the base fluid, as shown in Fig. 4.2(b). Nanoparticle development extends the warm conductivity of the base fluid for a variety of reasons, as per Hemmat Esfe et al. [16], including fluid interfacial layering, nanoparticle agglomeration, and Brownian movement. The thermal conductivity of 1.25% percent of the TiO₂ EG-alkaline water nanofluid was improved by 38.63% percent.

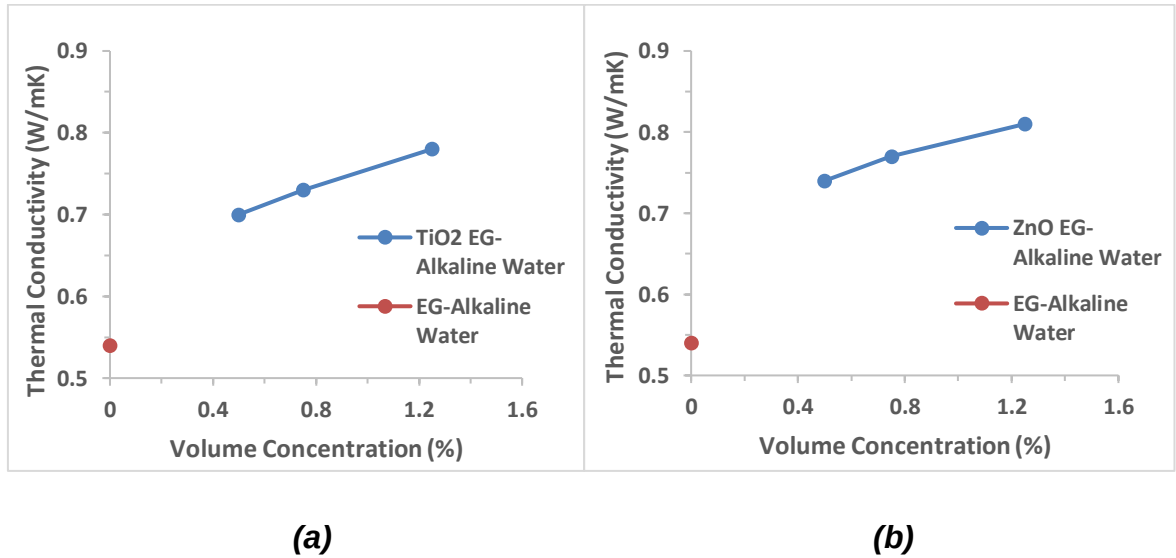


Fig: 4.2: Thermal Conductivity of (a) TiO₂ EG-Alkaline Water (b) ZnO EG-Alkaline Water

The thermal conductivity of the TiO₂ EG-alkaline water nanofluid was dealt with by 24.74% percent even at an extremely low volume grouping of 0.5% percent. The thermal conductivity of 1.25% percent ZnO EG-alkaline water nanofluid was found to have a maximum increase of 42.63% percent. The warm conductivity of the ZnO EG-alkaline water nanofluid was worked on by 28.74% percent even at a generally low volume centralization of 0.5% percent.

4.2 COMPARISON BETWEEN EXPERIMENTAL NUSSELT NUMBER AND THE CORRELATIONS

According to Eqs. (15) – (17), Dittus et al. [17], Pak et al. [6], and Xuan et al. [18] the experimental Nusselt numbers of the TiO₂ and ZnO EG-alkaline water nanofluids were compared to the correlations indicated by Eqs. (15) – (17):

$$Nu = 0.023 Re^{0.8} Pr^{0.4} \quad (15)$$

$$Nu = 0.021 Re^{0.8} Pr^{0.5} \quad (16)$$

$$Nu = 0.059(1.0 + 0.76286\phi_p^{0.6886}Pe^{0.001})Pr_{nf}^{0.9238} \quad (17)$$

Volume concentrations of 0.5%, 0.75% and 1.25% TiO₂ EG-alkaline water nanofluids are shown in Fig. 4.3–4.5, whereas volume concentrations of 0.5%, 0.75% and 1.25% ZnO EG-alkaline water nanofluids are shown in Figs. 4.6–4.8. While the Xuan and Li [18] connection anticipated the exploratory information well at the low volume grouping of 0.5% percent, the Dittus [17], and Pak and Cho [6] relationships anticipated the trial information well as the volume focus expanded.

It was found that the connections of Dittus [17], Pak and Cho [6] and Xuan and Li [18] were 9.97% percent, 11.02% percent, and 12.32% percent different from the experimental results over the range of volume concentrations examined in the study.

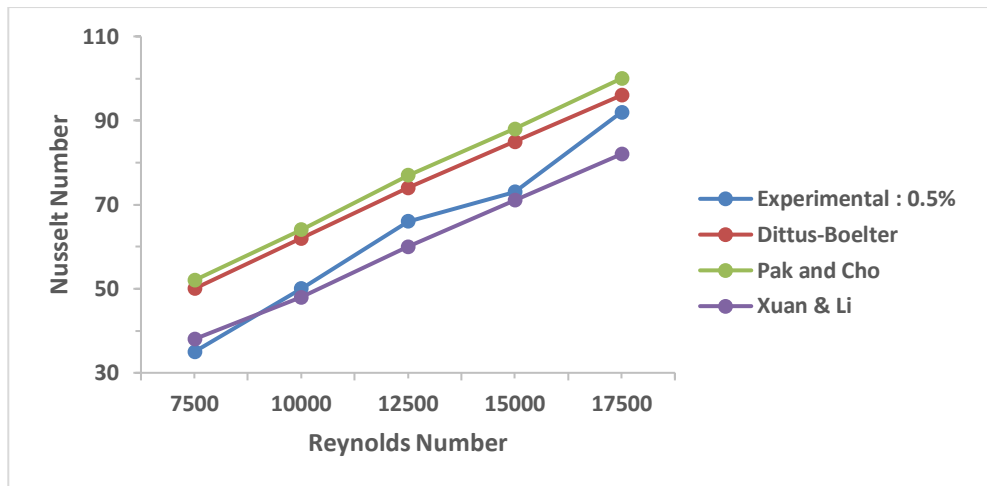


Fig: 4.3: Comparison between the experimental Nusselt number of TiO_2 and the correlations at 0.5%

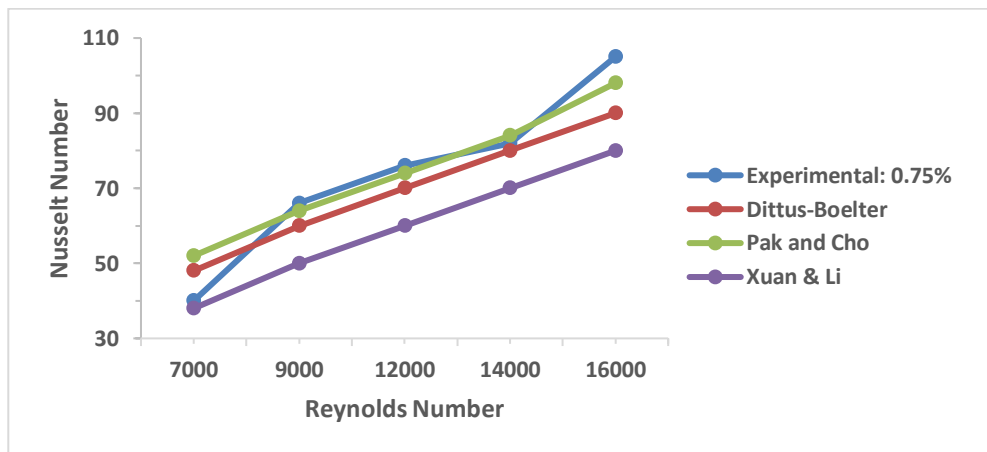


Fig: 4.4: Comparison between the experimental Nusselt number of TiO_2 and the correlations at 0.75%

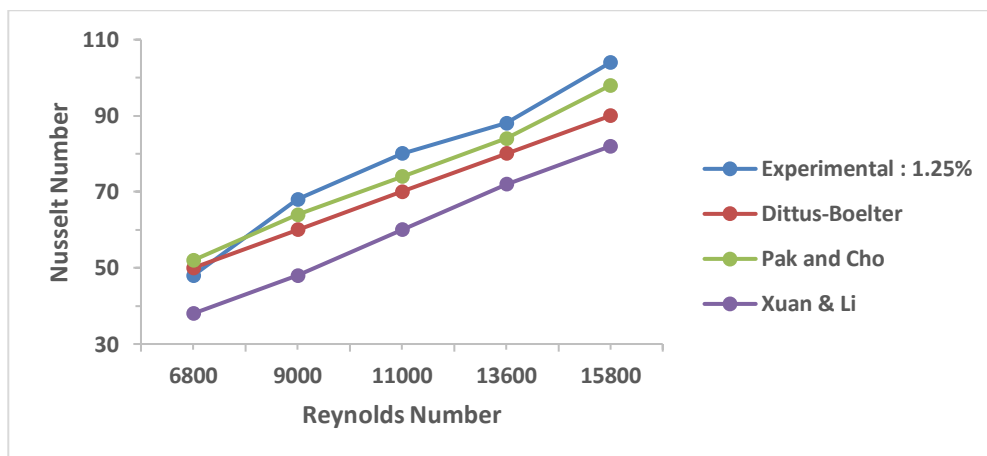


Fig: 4.5: Comparison between the experimental Nusselt number of TiO_2 and the correlations at 1.25%

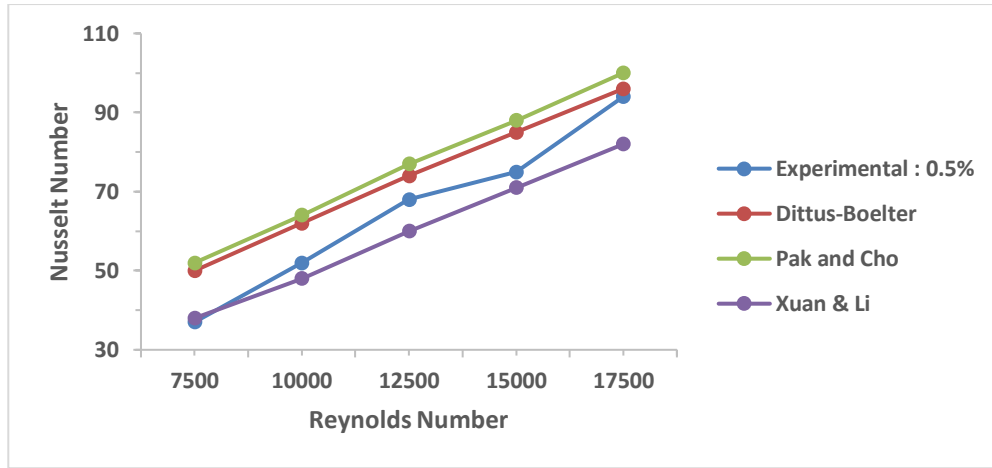


Fig: 4.6: Comparison between the experimental Nusselt number of ZnO and the correlations at 0.5%

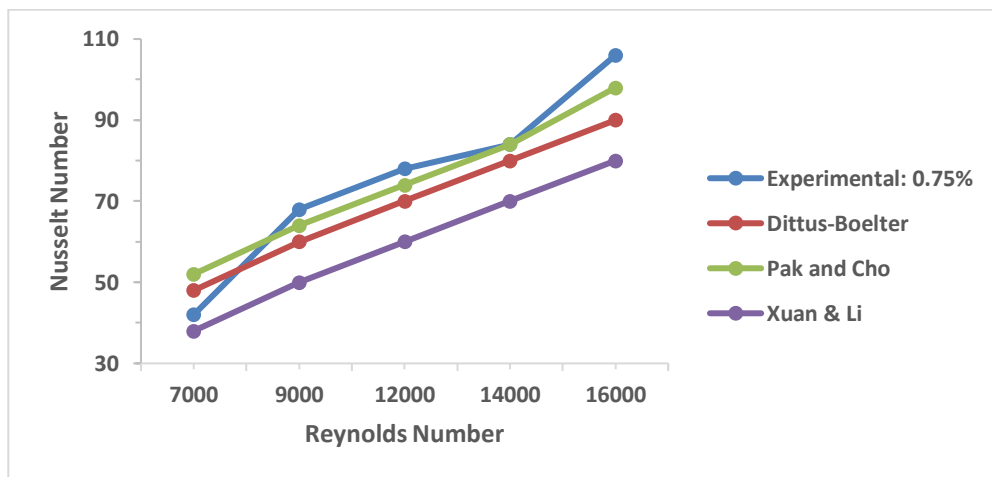


Fig: 4.7: Comparison between the experimental Nusselt number of ZnO and the correlations at 0.75%

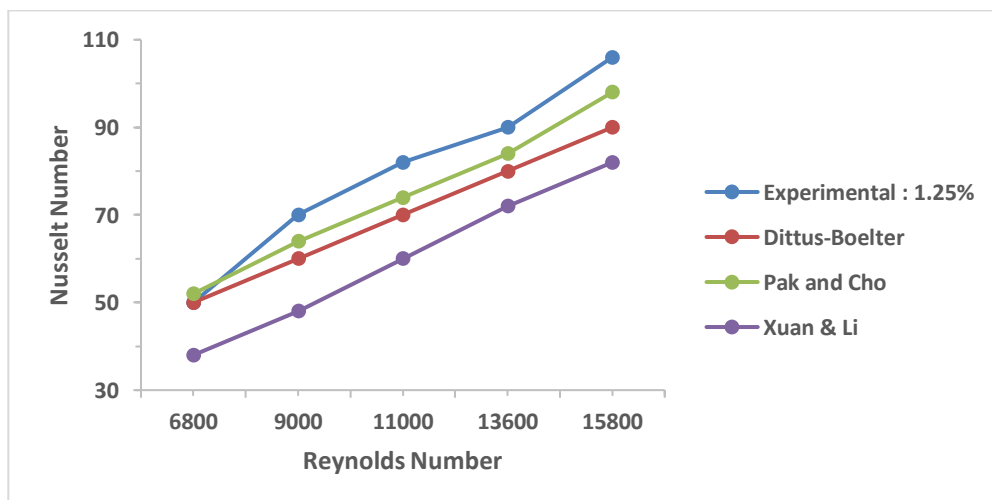


Fig: 4.8: Comparison between the experimental Nusselt number of ZnO and the correlations at 1.25%

4.3 COMPARISON BETWEEN THE FRICTION FACTOR AND THE CORRELATIONS

For the TiO₂ EG-alkaline water nanofluid and ZnO EG-alkaline water nanofluid, we compared their experimental friction factor to that of the correlations provided by Vajjha et al. [19] and Sharma et al. [20], respectively, as shown in Eq. (18) and (19):

$$f_{nf} = f_{bf} \left[\left(\frac{\rho_{nf}}{\rho_{bf}} \right)^{0.797} \left(\frac{\mu_{nf}}{\mu_{bf}} \right)^{0.108} \right] \quad (18)$$

$$f_{nf} = f_{bf} \left[\left(\frac{\rho_{nf}}{\rho_{bf}} \right)^{1.3} \left(\frac{\mu_{nf}}{\mu_{bf}} \right)^{0.3} \right] \quad (19)$$

Figures 4.9-4.11 compare the experimental friction factors of TiO₂ EG-alkaline water nanofluids containing 0.5% percent, 0.75% percent, and 1.25% percent TiO₂ EG-alkaline water. Figures 4.12–4.14 compare the experimental friction factors of ZnO EG-alkaline water nanofluids containing 0.5% percent, 0.75% percent, and 1.25% percent ZnO EG-alkaline water. This demonstrates that the correlations accurately predicted the experimental results for all of the study's volume concentrations. There were 1.73% percent and 6.69% percent variations between the Vajjha et al. [19] and Sharma et al. [20] correlations with the experimental friction factor, respectively. This demonstrates that the correlations accurately predicted the experimental results for all of the study's volume concentrations.

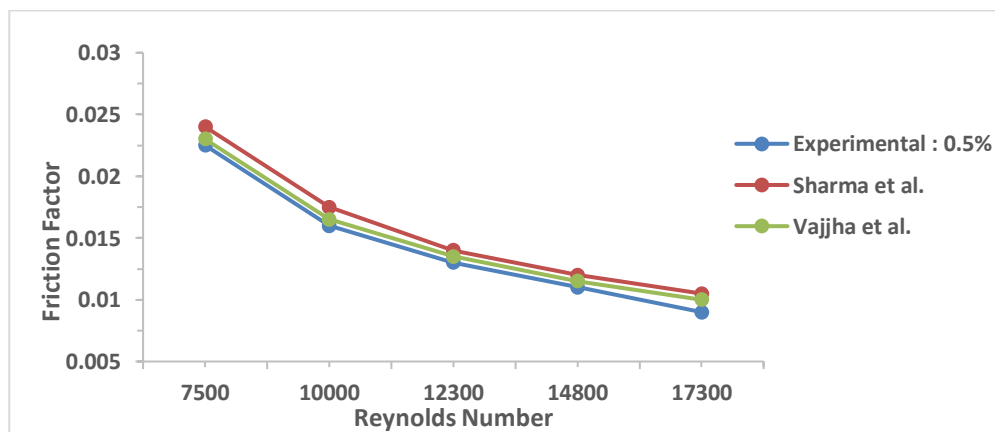


Fig: 4.9: Comparison between the experimental Friction Factor of TiO₂ and the correlations at 0.5%

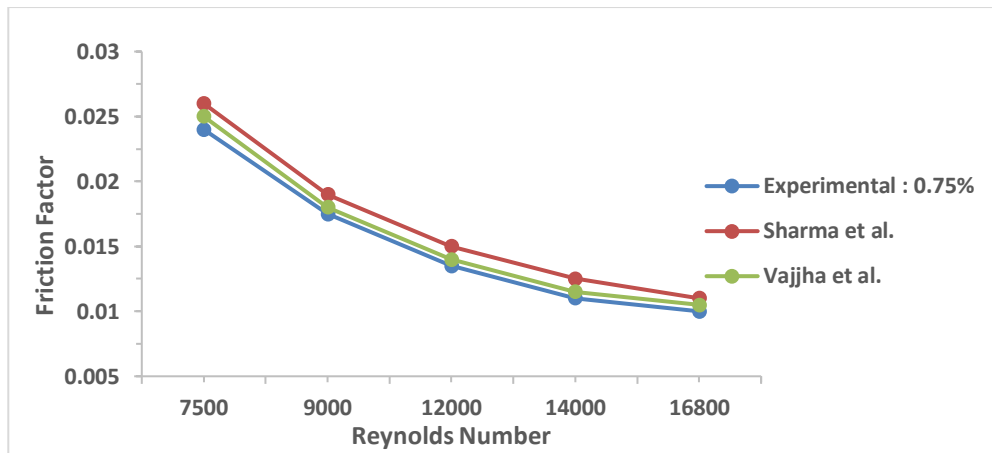


Fig: 4.10: Comparison between the experimental Friction Factor of TiO_2 and the correlations at 0.75%

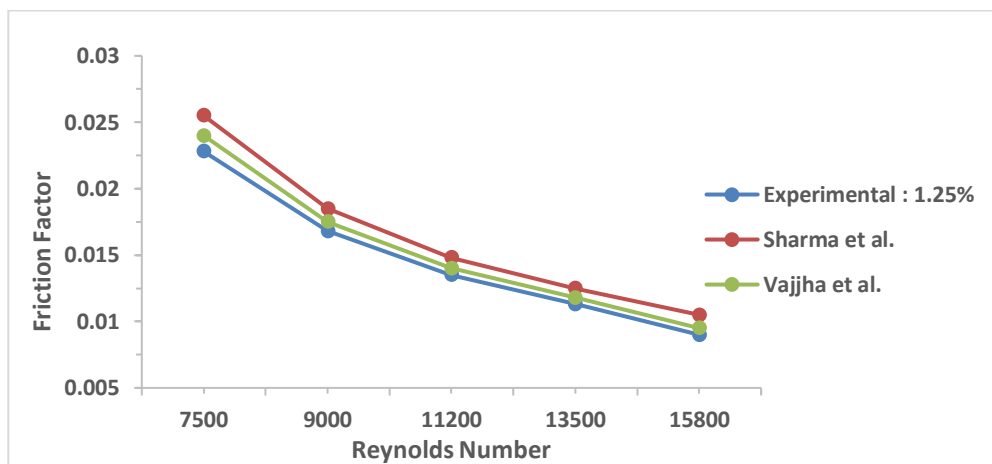


Fig: 4.11: Comparison between the experimental Friction Factor of TiO_2 and the correlations at 1.25%

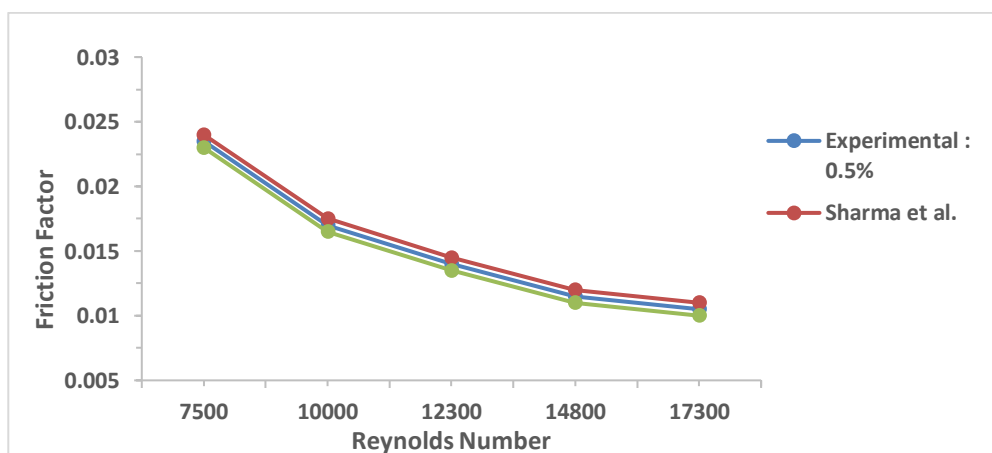


Fig: 4.12: Comparison between the experimental Friction Factor of ZnO and the correlations at 0.5%

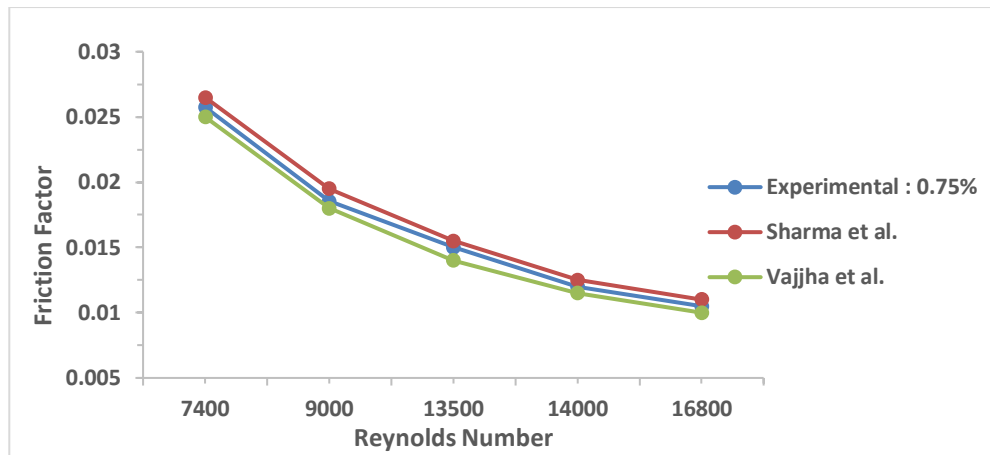


Fig: 4.13: Comparison between the experimental Friction Factor of ZnO and the correlations at 0.75%

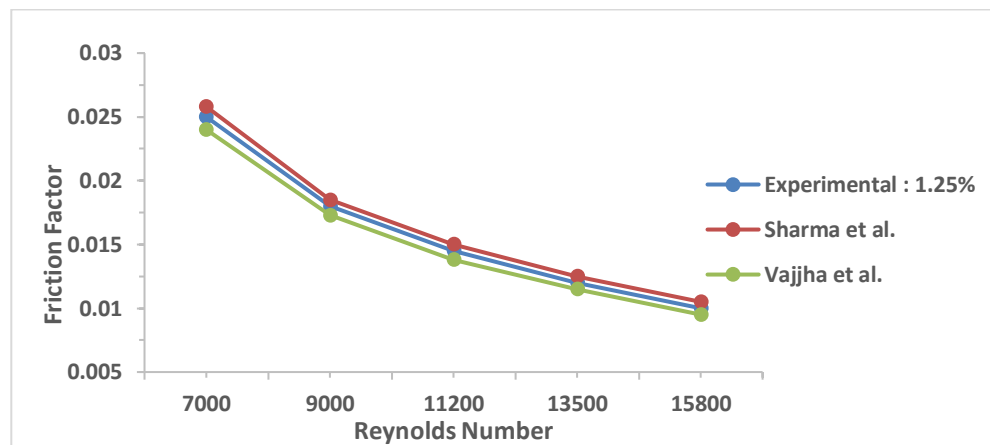


Fig: 4.14: Comparison between the experimental Friction Factor of ZnO and the correlations at 1.25%

4.4 NUSSELT NUMBER AND HEAT TRANSFER COEFFICIENT OF THE TiO₂ EG-ALKALINE WATER AND ZnO EG-ALKALINE WATER NANOFLUIDS

The thermal exhibition of the hotness exchanger was upgraded by the thermo-actual qualities of the TiO₂ EG-alkaline water nanofluid and ZnO EG-alkaline water nanofluid. TiO₂ EG-alkaline water nanofluid Nusselt number change with Reynolds number is displayed in Fig 4.15. The Reynolds number of the TiO₂ EG-antacid water nanofluid was a lot of lower than that of the base liquid at a similar stream rate. This was because the dispersion of TiO₂ nanoparticles increased the viscosity of the EG-alkaline water solution. However, because to the low volume concentrations used in the investigation, the adjustment of Reynolds number with volume focus was generally minor. The normal Nusselt number diminished by

7.87% percent in contrast with the base liquid at volume concentrations as low as 0.5% percent of the TiO_2 EG-alkaline water nanofluid. Nusselt's number began to rise at a modest proportion of 3.82% percent for a volume concentration of TiO_2 EG-alkaline water nanofluid at 0.75% percent and increased to 18.92% percent for the 1.25% percent volume concentration. Due to the movement of the bulk fluid, the Nusselt number mirrors how much times heat move is expanded by convection over conduction. Nanoparticle-actuated Brownian movement and agglomeration of nanoparticles are liable for diminished Nusselt numbers in the TiO_2 EG-soluble water nanofluid contrasted with the base liquid.

Due to the slight rise in the Nusselt number at 0.75% percent of the nanofluid, Brownian movement prompted conduction as opposed to mass smooth movement instigated convection appears to be the predominant method of heat transmission in the TiO_2 EG-alkaline water nanofluid and ZnO EG-alkaline water nanofluid. In addition, the Reynolds number decreased as a result of an increase in viscosity, resulting in a further fall in the Nusselt number.

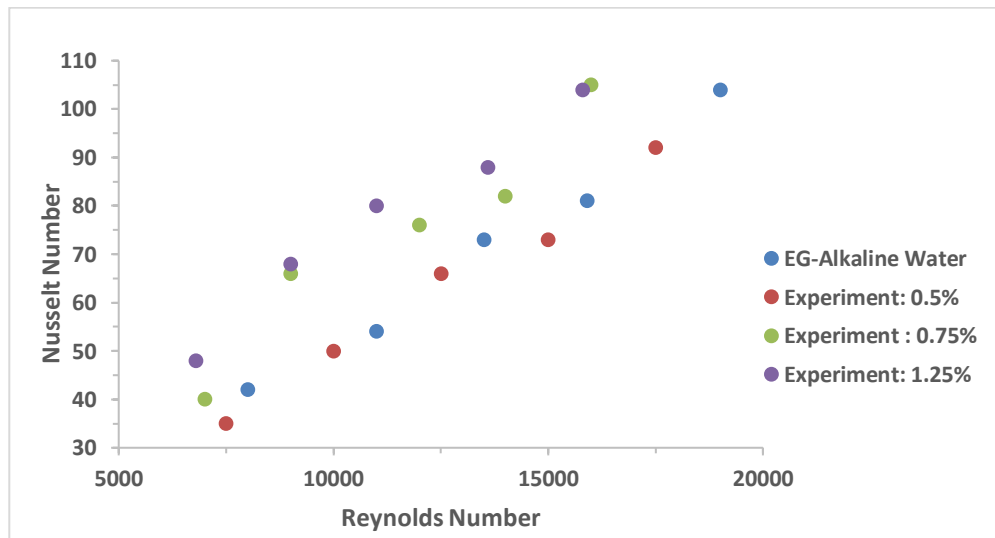


Fig: 4.15: Nusselt Number of TiO_2 EG-Alkaline Water Nanofluid

It is thus possible to use the Nusselt number to estimate how much heat may be transferred by scattered nanoparticles in the base fluid.

The Nusselt number of the ZnO EG-acid neutralizer water nanofluid changes with the Reynolds number found in Fig 4.16. The Reynolds number of the ZnO EG-acid neutralizer water nanofluid was a ton of lower than that of the base fluid at a

comparative stream rate. Because of the dispersion of ZnO nanoparticles in the EG-alkaline water solution, the viscosity of the solution increased. The average Nusselt number decreased by 9.87% percent in comparison to the base fluid at volume concentrations as low as 0.5% percent of the ZnO EG-alkaline water nanofluid. The Nusselt number increased by 5.82% percent at a volume concentration of 0.75% percent of ZnO EG-alkaline water nanofluid and increased to 20.92% percent at a volume concentration of 1.25% percent. There are lower Nusselt numbers in the ZnO EG-alkaline water nanofluid compared to the base fluid because of nanoparticle-induced Brownian motion and the agglomeration of nanoparticles.

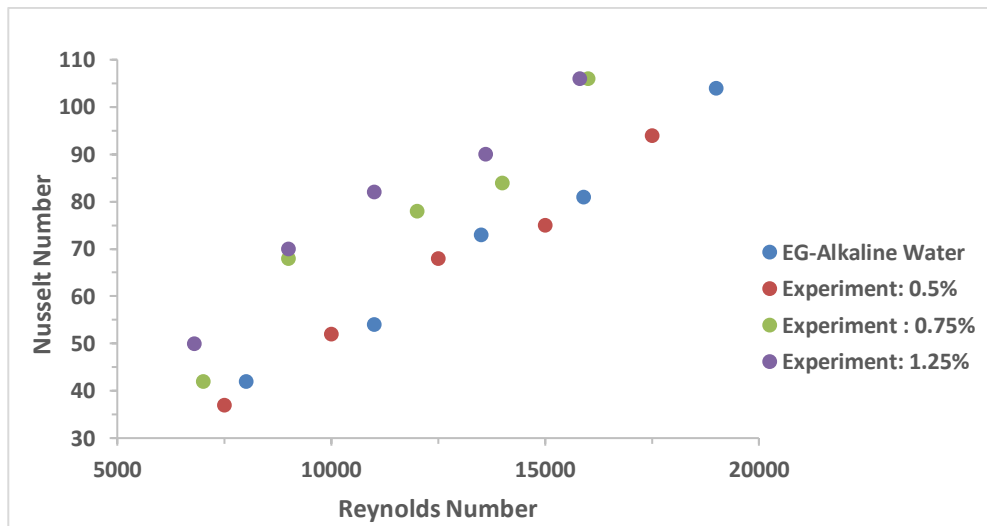


Fig: 4.16: Nusselt Number of ZnO EG-Alkaline Water Nanofluid

Because of this, it is not possible to compare various nanofluids' thermal performance by comparing their variation in the Nusselt number with their Reynolds numbers. Azmi et al. [5] found similar findings, as did Timofeeva et al. [21]. For this reason, the Nusselt number is the optimum method for contrasting trial and expected outcomes for a similar liquid and hotness move coefficient for nanofluids and base liquids with different warm conductivities, according to Timofeeva et al. [21].

Similar hotness move coefficients of the TiO_2 EG-antacid water nanofluid with that of the base liquid are displayed in Fig 4.17, where an expansion in heat move coefficient can be distinguished with an expansion in volume focus and stream rate. The DPHE's hotness obligation ascends with the expansion of nanofluid,

even at a similar admission stream rate and liquid mass temperature. Thus, the all-out heat move coefficient of the hotness exchanger has risen, bringing about a higher hotness move coefficient for the nanofluid. When contrasted with the base liquid at 45°C working temperature, the TiO₂ EG-antacid water nanofluid had normal expansions in heat move coefficient of 15.82% at 0.5% percent, 41.732% at 0.75% percent, and 53.292% at 1.25% percent throughout the range of flow rates included in the study.

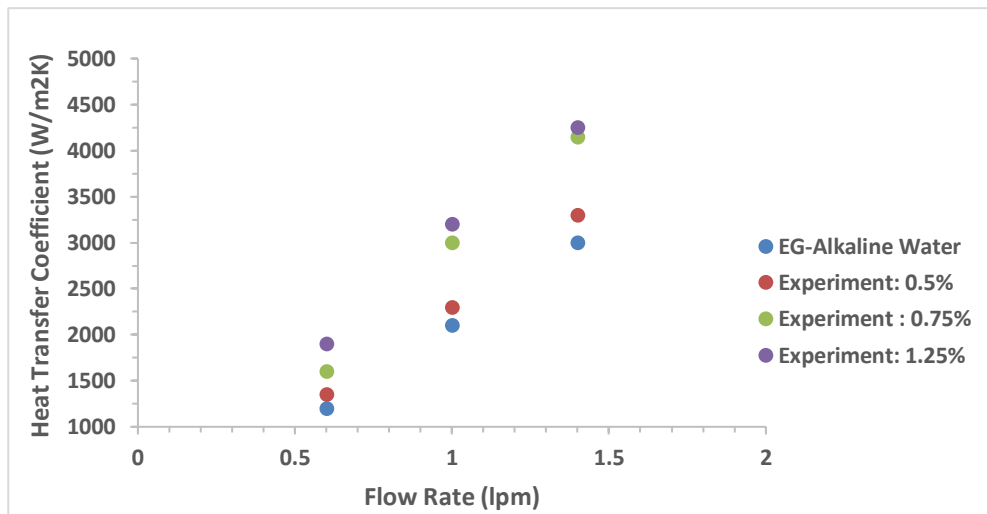


Fig: 4.17: Heat Transfer Coefficient of TiO₂ EG-Alkaline Water Nanofluid with the Flow Rate

Relative hotness move coefficients of the ZnO EG-antacid water nanofluid with that of the base liquid are displayed in Fig 4.18, where a consistent ascent in the hotness move coefficient can be recognized with an expansion in volume focus and volume stream rate.

Heat transfer coefficient increases of 18.65% percent at 0.5% percent, 44.63% percent at 0.75% percent and 56.34% percent at 1.25% percent of ZnO EG-alkaline water nanofluid at 45°C throughout the range of flow rates studied were found in the study.

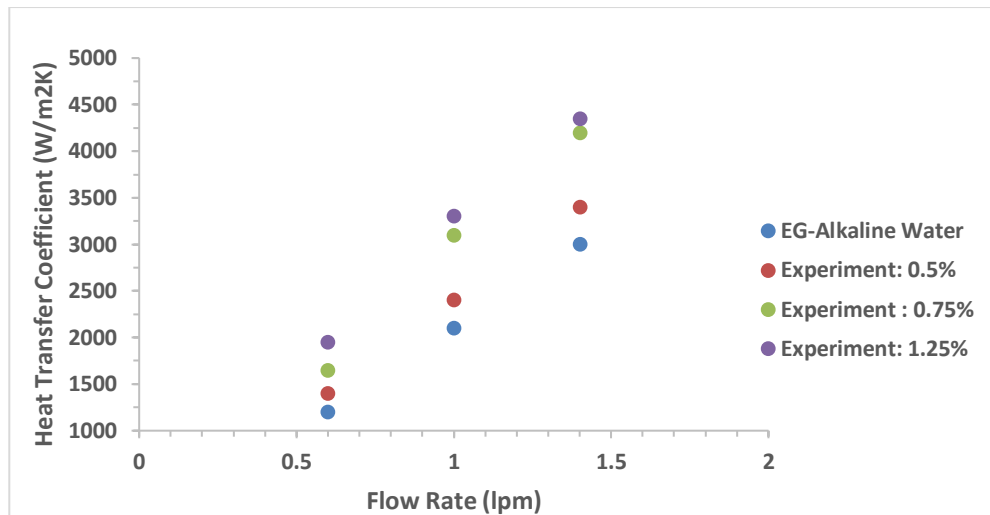


Fig: 4.18: Heat Transfer Coefficient of ZnO EG-Alkaline Water Nanofluid with the Flow Rate

4.5 FRICTION FACTOR OF THE TiO₂ EG-ALKALINE WATER AND ZnO EG-ALKALINE WATER NANOFLUID

Decreasing the Reynolds number brought about a decrease in the erosion element of the TiO₂ EG-soluble water nanofluid and ZnO EG-antacid water nanofluid. The friction factor diminished as the shear pace of the liquid in the limit layer diminished with an expansion in the Reynolds number. Because the viscosity of the TiO₂ EG-alkaline water nanofluid and ZnO EG-alkaline water nanofluid increased as volume concentrations increased, the rubbing component of these nanofluids was more noteworthy than that of their base liquid. Higher Reynolds numbers, on the other hand, showed that the friction factors of both nanofluids were almost identical to those of the base fluid at all concentrations. To determine the friction factor, turbulence is more important than differences in the thermophysical characteristics of nanofluids with differing volume concentrations at higher Reynolds numbers. Using a concentration range between 0.5% and 1.250%, the TiO₂ EG-alkaline water nanofluid increased its friction factor on average by 8.11 to 18.56 percent compared to a base fluid of the same composition.

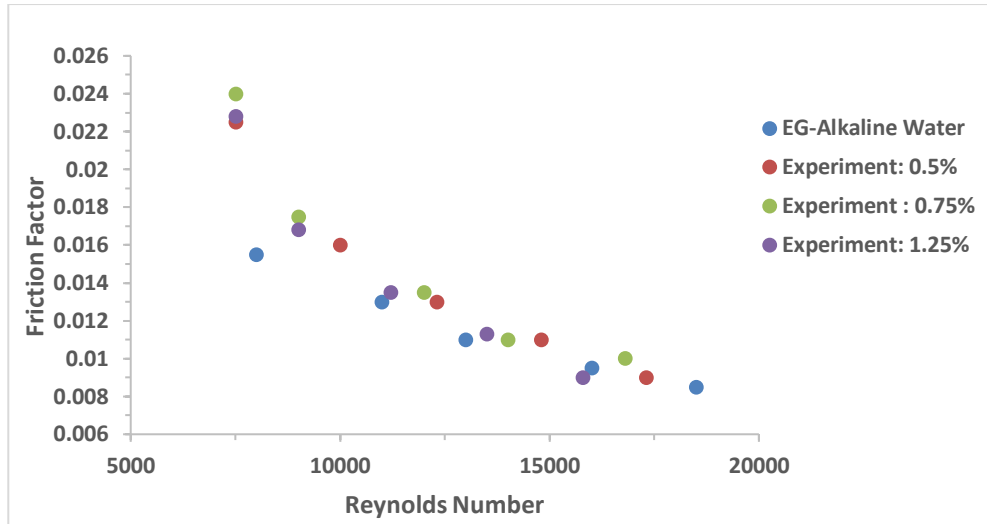


Fig: 4.19: Friction Factor of TiO_2 EG-Alkaline Water Nanofluid with the Reynolds Number

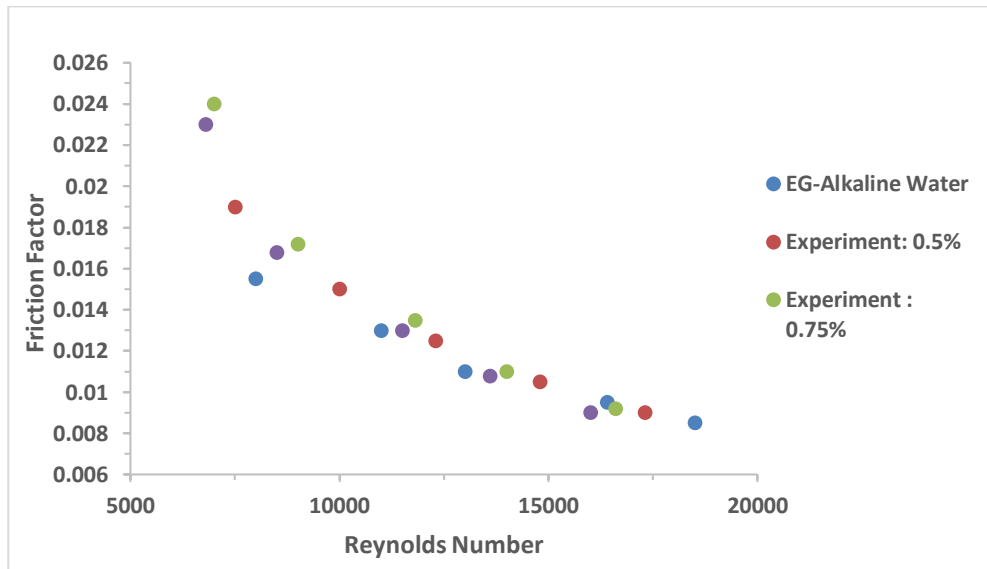


Fig: 4.20: Friction Factor of ZnO EG-Alkaline Water Nanofluid with the Reynolds Number

Whenever the volume focus was expanded from 0.5 percent to 0.75 percent to 1.25 percent, the normal expansion in grinding factor for the ZnO EG-soluble water nanofluid was 11.48 percent to 21.79 percent.

4.6 PRESSURE DROP OF THE TiO₂ EG-ALKALINE WATER AND ZnO EG-ALKALINE WATER NANOFLUID

Figure 4.21 exhibits how the strain drop of the TiO₂ EG-soluble water nanofluid changes with stream rate, which is a direct measure of pumping power. Volume concentration enhanced the pressure drop in the TiO₂ EG-alkaline water nanofluid. TiO₂ EG-alkaline water nanofluid nanofluid had an average pressure decrease of 26.87% at 0.5 percent, 26.35% at 0.75 percent, and 39.44% at 1.25 percent compared to the base fluid.

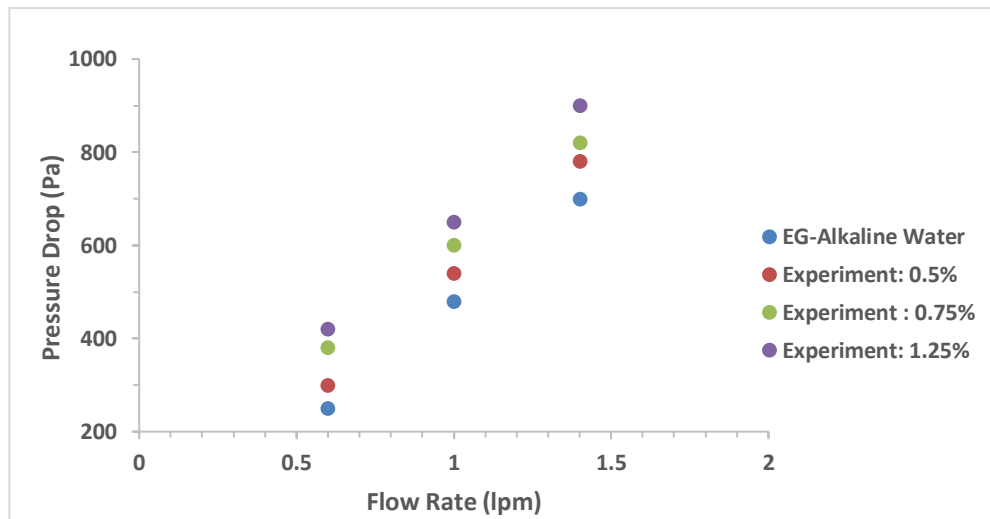


Fig: 4.21: Pressure Drop of TiO₂ EG-Alkaline Water Nanofluid with the Flow Rate

ZnO EG-alkaline water nanofluid pressure drop changes with flow rate because pressure drop is a direct measure of pumping power demand. As the volume concentration grew, so did the pressure decrease of the ZnO EG-alkaline water nanofluid as shown in Figure 4.22. The ZnO EG-alkaline water nanofluid had an average pressure decrease of 29.39 percent at 0.5 percent, 30.81 percent at 0.75 percent, and 43.56 percent at 1.25 percent.

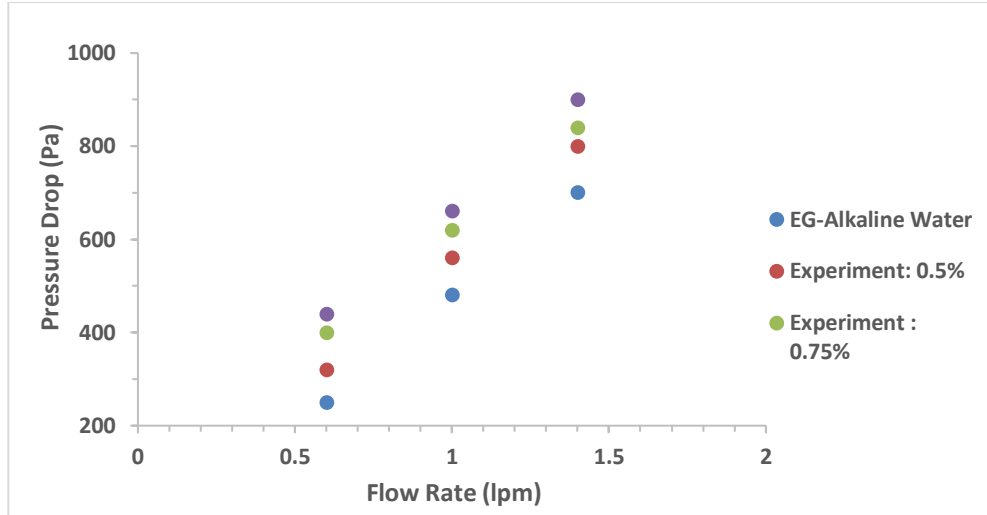


Fig: 4.22: Pressure Drop of ZnO EG-Alkaline Water Nanofluid with the Flow Rate

4.7 THERMAL PERFORMANCE OF THE TiO₂ EG-ALKALINE WATER AND ZnO EG-ALKALINE WATER NANOFLUID

Thermal performance factor (η) was estimated using Eq. (20) from Zarringhalam et al. [22] to assess the proportional impact of heat transfer enhancement and pressure drop penalty.

$$\eta = \frac{Nu_{nf}/Nu_{bf}}{(f_{nf}/f_{bf})^{1/3}} \quad (20)$$

It has been stated that the Thermal Performance Factor (TPF) decides whether the nanofluid can be used in real-world applications. Working fluids with TPFs greater than 1 may transfer heat with just a little loss in pressure throughout the process. As seen in Figure 4.23, the TPF of the TiO₂ EG-alkaline water nanofluid can be seen at various volume concentrations. The TPF was found to rise in proportion to the nanofluid volume concentration. 0.5 percent volume concentration had a TPF below 1, but 0.75 percent and 1.25 percent volume concentrations had TPFs beyond 1. 1.25 percent volume concentration was achieved at a Reynolds number of 9200 with a maximum TPF of 1.125. These findings demonstrate that a volume concentration of 0.75 percent and 1.25 percent of the TiO₂ EG-alkaline water nanofluid is a suitable working fluid. Indeed, even at a volume convergence of 0.5 percent, the TiO₂ EG-soluble water nanofluid had a 15.82 percent improvement in heat transmission.

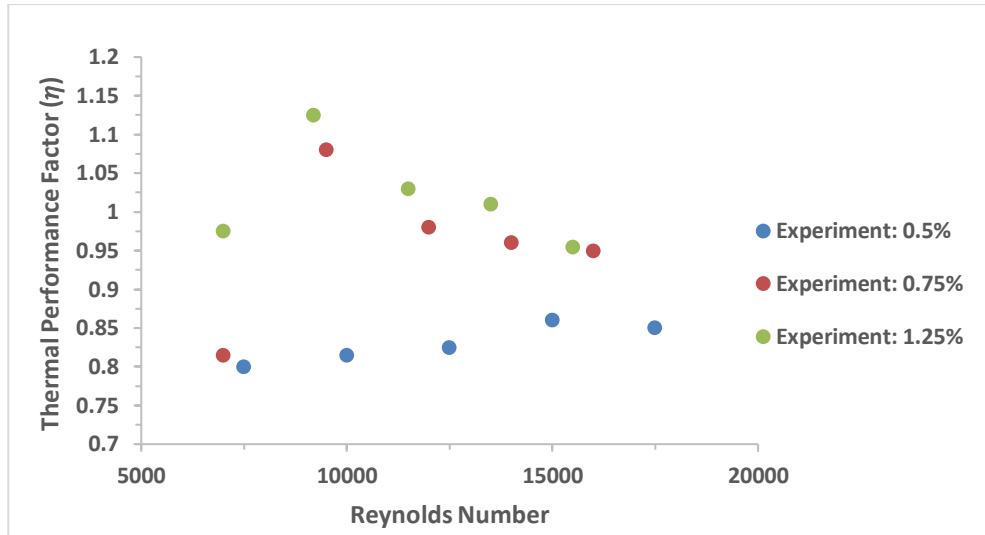


Fig: 4.23: Thermal Performance Factor of TiO_2 EG-Alkaline Water Nanofluid

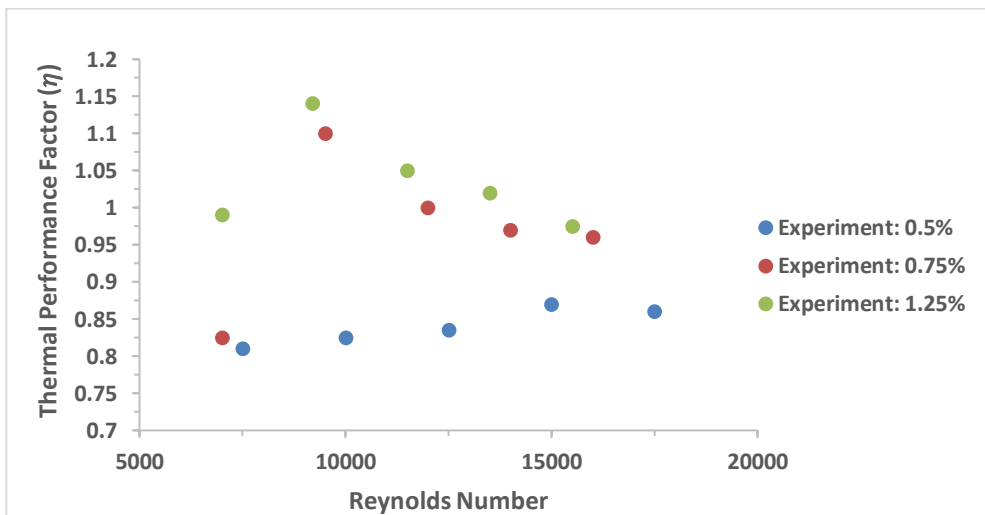


Fig: 4.24: Thermal Performance Factor of ZnO EG-Alkaline Water Nanofluid

TPF of the ZnO EG-alkaline water nanofluid is shown in Fig. 4.24 at various volume concentrations. The TPF was found to rise in proportion to the nanofluid volume concentration. 0.5 percent volume concentration had a TPF below 1, but 0.75 percent and 1.25 percent volume concentrations had TPFs beyond 1. Volume concentration was 1.25 percent at Reynolds number 9200 with a maximum TPF of 1.14. For volume concentrations of 0.75 percent and 1.25 percent, the ZnO EG-alkaline water nanofluid is an excellent working fluid. Indeed, even at a volume convergence of 0.5 percent, the ZnO EG-soluble water nanofluid had a hotness move increase in 18.65 percent.

4.8 COMPUTATIONAL FLUID DYNAMICS (CFD):

The current models' flow field and heat transport are numerically simulated using ANSYS FLUENT 15 software. There are a large number of instances being investigated. In the next sections, we'll look at three different situations. Each of the three examples has the same boundary conditions (air velocity of 1 m/s, water input temperature and flow rate of 60°C and (2 lpm) correspondingly).

1) Temperature Contours:

As can be seen in Figure 4.25, a 3D simulation depicts how water circulates in a smooth tube and how same water flows through an integrated finned tube. Temperature differences are readily visible in all situations in this picture, which shows a gradient of temperature distribution along the tube. Figures show that finned tubes have a greater temperature gradient than smooth tubes. A significant increase in the temperature differential inside the test tube may be attributed to fining.

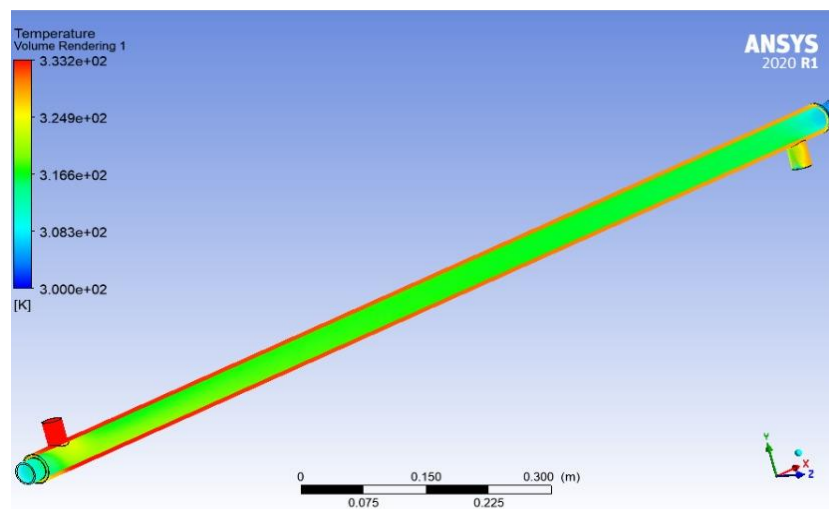


Fig: 4.25: 3D Simulation of Temperature Distribution

2) Velocity and Vectors Contours:

Figure 4.26 depicts a longitudinal section of a velocity contour; as can be seen, the water flow rate within the tube remains stable, but the air flow rate outside the tube increases as the tube passes through it, causing eddies to develop behind the tube and an increase in turbulence.

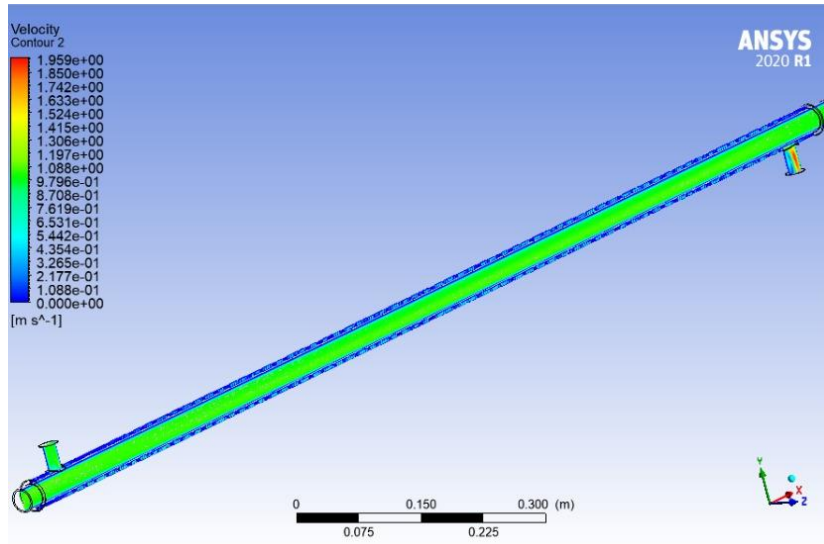


Fig: 4.26: 3D Simulation of Velocity Contour

4.8.1 CFD RESULTS OF TiO_2 EG-ALKALINE WATER NANOFLUID:

On obtaining the CFD results of TiO_2 EG-alkaline water nanofluid, Fig 4.27 demonstrates the residuals vs iterations graph and from Fig 4.28, velocity contour of TiO_2 EG-alkaline water nanofluid is identified. Temperature volume rendering and pressure contour of TiO_2 EG-alkaline water nanofluid is studied through Fig 4.29 and Fig 4.30 respectively.

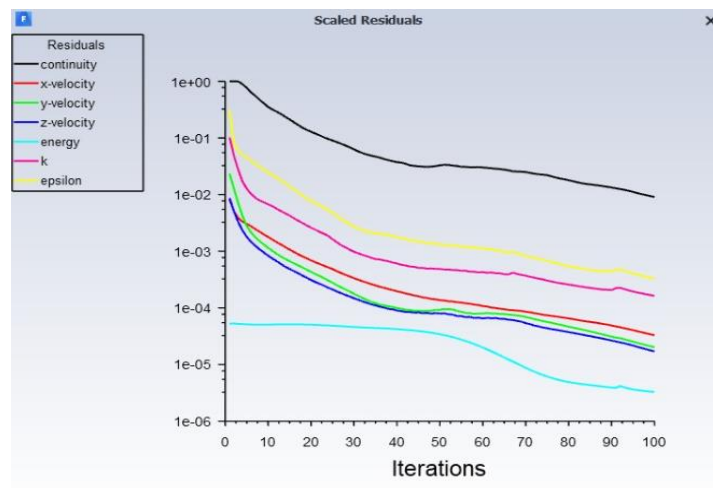


Fig: 4.27: Residuals vs Iterations Graph of TiO_2 EG-Alkaline Water Nanofluid

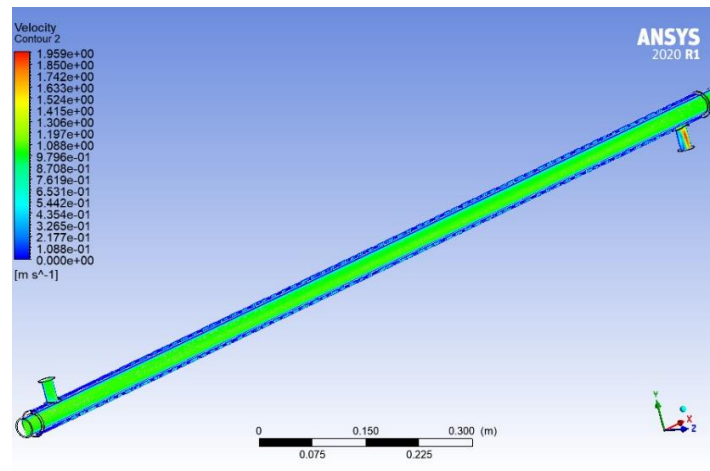


Fig: 4.28: Velocity Contour of TiO_2 EG-Alkaline Water Nanofluid

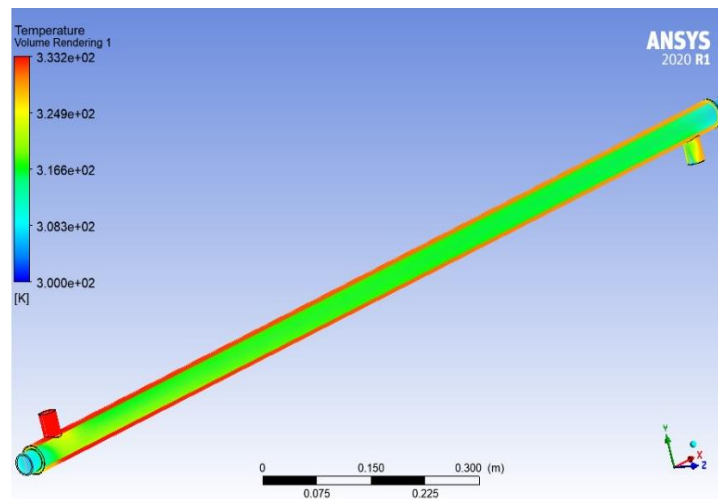


Fig: 4.29: Temperature Volume Rendering of TiO_2 EG-Alkaline Water Nanofluid

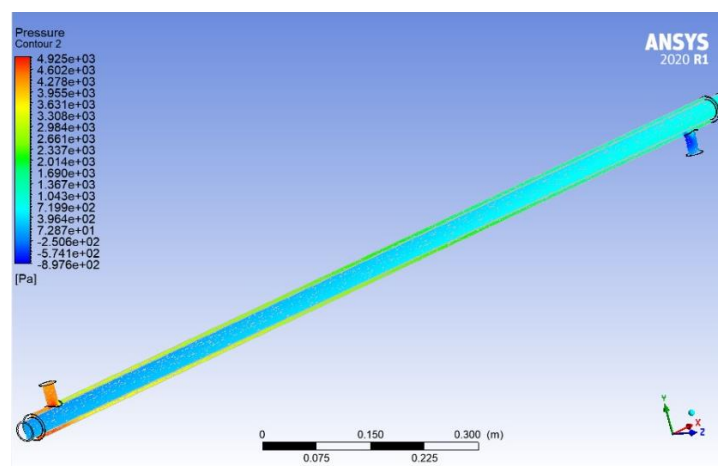


Fig: 4.30: Pressure Contour of TiO_2 EG-Alkaline Water Nanofluid

4.8.2 CFD RESULTS OF ZnO EG-ALKALINE WATER NANOFLUID:

On obtaining the CFD results of ZnO EG-alkaline water nanofluid, Fig 4.31 demonstrates the residuals vs iterations graph and from Fig 4.32, velocity contour of ZnO EG-alkaline water nanofluid is identified. Temperature volume rendering and pressure contour of ZnO EG-alkaline water nanofluid is studied through Fig 4.33 and Fig 4.34 respectively.

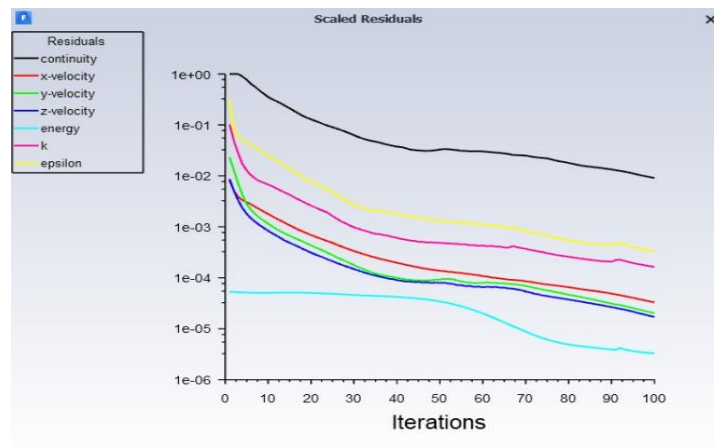


Fig: 4.31: Residuals vs Iterations Graph of ZnO EG-Alkaline Water Nanofluid

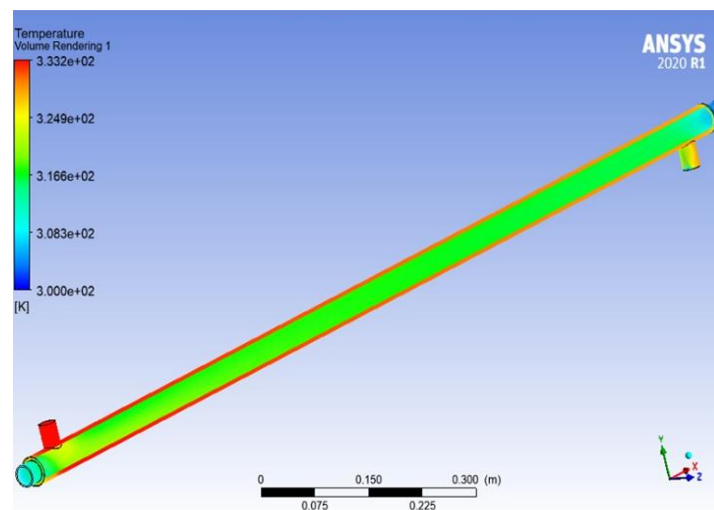


Fig: 4.32: Temperature Volume Rendering ZnO EG-Alkaline Water Nanofluid

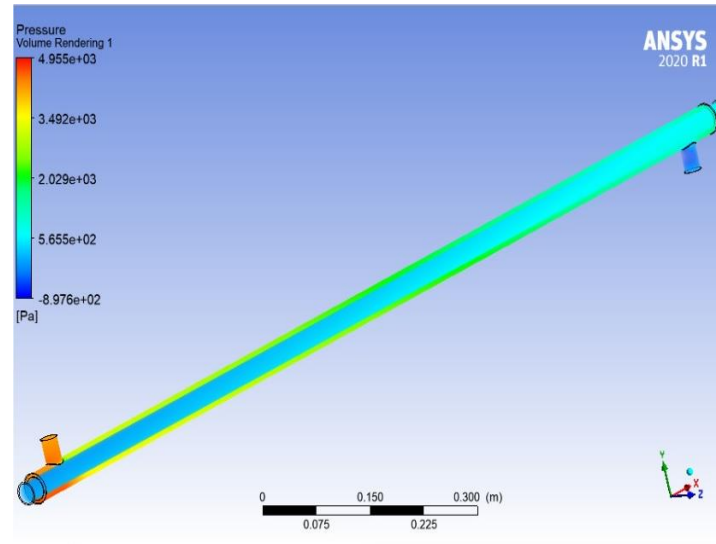


Fig: 4.33: Pressure Volume Rendering of ZnO EG-Alkaline Water Nanofluid

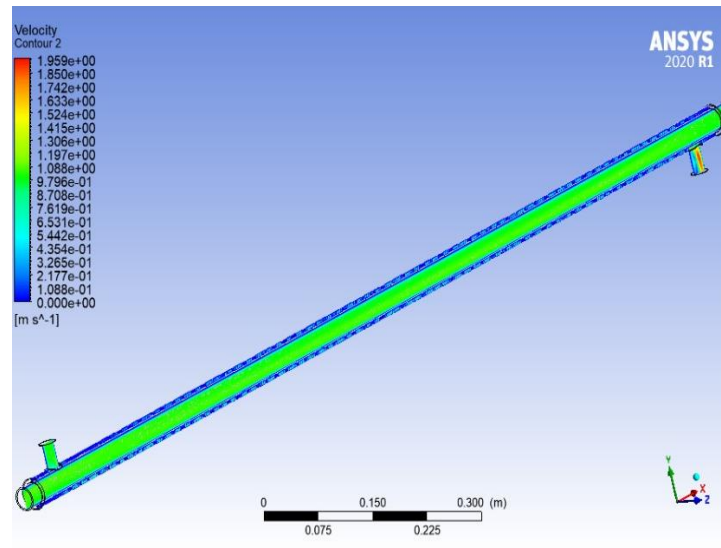


Fig: 4.34: Velocity Contour of ZnO EG-Alkaline Water Nanofluid

CHAPTER 5

SUMMARY & CONCLUSION

Counterflow double pipe heat exchanger performance is improved by employing nanofluid instead of pure fluid as a cooling medium in this experiment. Based on the findings, it may be concluded:

- 1) Counter and parallel flow double pipe heat exchangers become more effective and efficient when nanofluid is used.
- 2) ZnO nanoparticles' better thermal conductivity means they absorb heat more readily from the EG-alkaline water nanofluid than TiO₂ nanoparticles do.
- 3) The counter flow configuration is superior than parallel flow arrangements for all kinds of nanofluids investigated.
- 4) As a result, nanoparticles, which are highly conductive, may be used to improve thermal performance.
- 5) The thermal performance of the heat exchanger improved as the volume concentration rose owing to further heat transfer process enhancements.
- 6) Nanofluids have a greater impact at lower fluid flow rates, whereas their impact diminishes as flow rates increase.
- 7) The thermal performance of ZnO and TiO₂ is improved by 18.5% and 15.5%, respectively.

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