STUDY OF HEAT TRANSFER AND FRICTION LOSS OF NANOFLUID SUSPENSION FLOW IN SQUARE PIPE HEAT EXCHANGER

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Field of Study: Fluid Mechanics & Heat Transfer

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ABSTRACT

An experimentational analysis was done to evaluate heat transfer features of graphene oxide (GO) nanofluid inside the cross section of square cross tube that was exposed to a uniform constant heat flux of the test segments. Lately huge figures of researches have been are proceeded out to examine the outcome of nanofluid in augmentation of the heat transfer rate in numerous heat exchangers particularly using hummer method to attain GO. In this case, advanced hummer method was used to obtain GO and further analyses the effect of the nanofluids. The viscosity and thermal conductivity for the (GO) nanofluids at the concentrations of 0.025%, 0.05%, 0.075%, and 0.1 wt % fixed similarly together with distilled water or known as distilled water before proceeding to the experiments. The heat transfer analysis of the flowing distilled water was compared with (GO) nanofluids using advanced hummer methods. The convective heat transfer coefficient of (GO)-distilled water nanofluid is greater than the base fluid by roughly from 9.7% to 32.7%. Furthermore, the heat transfer coefficient of the (GO)-distilled water enlarged as the flowrate rises. The increase in the pressure drop valued from 13.43% to 36.55%. The friction factor also surges as the values verified from 0.71% to 2.3%. The analysis reveals that more concentration leads to greater heat transfer coefficient, pressure drop and including friction factor.

Keywords: Heat transfer coefficient, concentration, GO-distilled water, friction factor

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ABSTRAK

Analisis eksperimen dilakukan untuk menilai ciri pemindahan haba nanofluida graphene oxide (GO) dalam keratan rentas tiub persegi yang terdedah kepada fluks seragam segmen ujian. Sejak kebelakangan ini, sejumlah besar penelitian telah dilakukan untuk memeriksa hasil nanofluid dalam menilai kadar pemindahan haba di banyak penukar haba terutama menggunakan hummer method untuk mencapai GO. Dalam kes ini, advance hummer method digunakan untuk memperoleh GO dan menganalisis lebih lanjut kesan nanofluid. Kekonduksian terma dan kelikatan (GO) nanofluid pada kepekatan 0,025%, 0,05%, 0,075%, dan 0,1% berat tetap sama bersama dengan basa asas (air suling) sebelum meneruskan eksperimen. Analisis pemindahan haba cecair asas mengalir (air suling) dibandingkan dengan (GO) bendalir nano menggunakan advance hummer method. Pekali pemindahan haba konvektif bendalir nano air suling (GO) lebih tinggi daripada cecair asas dengan kira-kira dari 9.7% hingga 32.7%. Tambahan pula, pekali pemindahan haba air suling (GO) diperbesar ketika laju aliran meningkat. Peningkatan penurunan tekanan tertakluk antara 13.43% hingga 36.55%. Faktor geseran juga melonjak ketika nilai disahkan dari 0.71% hingga 2.3%. Analisis menunjukkan bahawa kepekatan yang lebih tinggi membawa kepada pekali pemindahan haba yang lebih besar, penurunan tekanan dan juga faktor geseran.

Keywords: Kekonduksian terma, kelikatan, kadar geseran, GO bendalir nano

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LIST OF SYMBOLS AND ABBREVIATIONS

GO	:	Graphene Oxide
h	:	Heat Transfer Coefficient (W/m^2 K)
Pa	:	Pressure Drop
Nu	:	Nusselt Number
Re	:	Reynolds Number
Cu	:	Copper
Al_2O_3	:	Aluminium Oxide
CuO	:	Copper Oxide
Si	:	Silicon
CNT	:	Carbon Nanotubes
nm	:	Nanometer
Ag	:	Silver
Au	:	Gold
Al	:	Aluminium
PVD	:	Physical vapor deposition
$CuSO_4.5H_2O$	:	Copper sulfate pentahydrate
PVPK30	:	Polyvinylpyrrolidone
$NaH_2PO_2 \cdot H_2O$	:	Sodium hypophosphite
(Fe)	:	Iron
mV	:	millivolt
$AgNO_3$	:	Silver nitrate
EG	:	ethylene glycol
H_20	:	water
(k_{nf} / k_f)	:	Thermal conductivity ratio

wt	:	Weight percentage
g	:	gram
$	:	Dollar sign
PV/T	:	Photovoltaic/thermal
MNPs	:	Magnetic nanoparticle
MPa	:	Mega pressure
H_2SO_4	:	Sulphuric Acid
$NaNO_3$	:	Sodium nitrite powder
q	:	Heat Flux (W/m^2)
D	:	Diameter (m)
$KMnO_4$	:	Potassium permanganate
f	:	Friction factor
ρ	:	Density
Al_3O_2/dw	:	Aluminium oxide based distilled water
H_2O_2	:	Hydrogen peroxide
$NaNO_3$	:	Sodium nitrite powder
L/min	:	Liter/minutes
ml	:	Milliliter
UM	:	Univerity Of Malaya

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

Due to the fast-paced progression of science and the increasing needs of industries to obtain rates of high heat transfer, many efforts have been gone through to grasp for authentic methods to upgrade the rate of heat transfer. Even though that various approaches have been used efficiently such as utilizing electric or magnetic fields shifting the geometry and rising the heat transfer surface, but they are still powerless to accomplish the current requirements of heat transfer and heat dissipation. Nanofluids are experimented in various ways to study the efficiency of their thermal properties on heat transfer.

1.1 Background Study

Nanofluids is portion of nanoparticles within a mutual working liquid such as water or ethylene glycol which is created in order to shape an active another working fluid intended for augmenting heat transfer (Choi, 1995). Nanofluids can be altered in many circumstances to satisfy a specific demand and it can be shown as pliant cooling technique through its skill to familiarize the necessity of specific system. Usually, nanofluids have the aptitude to be the major modifiable coolant in the world, as in numerous conditions, they can execute the role of variable cooling method owe to the fact that they can be developed to accomplish a specific requirement. Base fluids and nanoparticles are generally analyzed using metal oxide, carbon-based, and metal and distilled water.

Thermo physical distinctiveness of the nanofluids are crucial to forecast their heat transfer performance. It is tremendously significant acting as a controller for the industrial and energy saving perspectives. Industrialization are showing their interest in nanofluids to enhance their performances. Nanoparticles have great prospective to ameliorate the thermal transport distinctiveness assessed to conventional elements fluids suspension, micrometer shaped particles and millimeter. Nanofluids have been center of the attention due to its boosted thermal properties. For the past few years, experimental analysis demonstrates that its thermal conductivity hinges on many aspects such as temperature, base fluid particle, volume fraction, and particles which can be categorized into material, size, and shape. Thermal conductivity enhancement was also largely influenced by the quantity and different kinds of additives and the acidity of the nanofluids.

1.2 Problem Statement

Heat Exchangers are utilized for regeneration of energy and transportation which makes it more demanding from all sectors throughout the world. Researchers had to develop an enhanced heat exchanger performance to meet the supply and demand. The present work had been stressed on properties of nanofluids especially on the heat transfer to elevate the heat coefficient and assess its performance on test rig. Newly, many studies have been conducted to explore the formulation of nanofluids by using carbon-based nanostructures by using hummer method. It has been studied extensively for synthesis of the carbon based nanofluids and its usage as the heat exchanger liquid that leads to a greater advantage in terms of preserving energy, boosting the performance of heat exchanger, and economic merits. Currently, hummer method had been researched and thoroughly experimented in such a way by enhancing the method. More conventional hummer methods had been replaced with advanced or modified method to improve the method and finding out the chemistry of the GO.

1.3 Objectives

1. To evaluate the heat transfer and friction loss of the nanofluid in square pipe cross section for enhancement of heat transfer performance.
2. To analyze the effect of carbon-based nanofluids on the heat transfer.

1.4 Research Project Outline

The research project starts with a glimpse at general overview of nanofluids which includes previous synopsis of literature review on nanofluids in terms of physical characteristics and heat transfers. Chapter 2 displays an inclusive literature review of the nanofluids and their performance of heat transfer. The source of the materials and methodology were showcased in chapter 3. Details of experimental set-up and mathematical formulation were also briefed in this chapter. Then it is followed by results and discussions in chapter 4. This chapter emphases on articulating the important results gotten from contrasting analytical ways being utilized in test rig validation, heat transfer of validations and comparison of different nanofluids from previous literature review. The conclusions associated in this project are determined in chapter 5. Recommendation for future work is also included at the closure of this chapter.

CHAPTER 2: LITERATURE REVIEW

2.1 Nano-fluid types and properties

Nano-fluids is nano-sized solid particles which is mixed in fluids. Basically, to produce nano-fluid there must be one or more nano-sized material and a base fluid. Nano sized material is generally defined at dimension smaller the 150nm. However, the definition of size is not confined to the previous statement where much bigger particles may be used. In relation to that, particle size which is too big may result in abrasion, erosion, and reduction in material. Thus, its best to use smaller size nano material for the application of nano-fluid be practical for industrial application. Whereas base fluid which are used is distilled water, ethylene glycol and oil (Pryazhnikov, Minakov, Rudyak, & Guzei, 2016). Base fluids chosen are generally fluids that have been or still being used for heat transfer application in various industries and day to day application such as in automobiles.

Preparation of nano-fluid which is done mechanically is done by mixing nano material powders into base fluids. Nano materials that are available in powder form can be classified as polymer, non-metallic and metallic types (Yimin & Qiang, 1999). Type of nano materials for metallic and non-metallic types will be stated in the table below.

Table 2.1: Metallic types of nano material

No.	Material	Type
1	Copper (Cu)	Metallic
2	Aluminum (Al)	Metallic
3	Silver (Ag)	Metallic
4	Gold (Au)	Metallic

Table 2.2: Non-metallic types of nano material

No.	Material	Type
1	Aluminum oxide (Al_2O_3)	Non-Metallic
2	Copper oxide (CuO)	Non-Metallic
3	Silicone (Si)	Non-Metallic
4	Carbon Nanotubes (CNT)	Non-Metallic

Table 2.1 shows list of nano materials used in the literatures for metallic type powders. Table 2.2 shows list of nano materials used in literatures for non-metallic powders.

Preparation of nano-fluid can be done chemically also which will be discussed in the nano-fluid preparation part of the review.

Properties of nano-fluid will vary with the type of nano materials used. In general terms, important properties of heat transfer application for nano-fluid application will be stable, durable, and even suspension, proper dispersion and prepared nano-fluid should not have chemical variation in the fluid over time.

2.2 Thermal properties of Water, Ethylene Glycol & Engine Oil

Thermal properties of water, ethylene glycol and engine oil are worth discussing because of its existing useful application in heat transfer. As discussed in the journal these fluids are commonly used as base fluid with nanoparticles mixture to produce nanofluids.

Thermal conductivity is of one the essential parameter in analysing heat transfer. Therefore, thermal conductivity of water, ethylene glycol and engine oil is 0.613 W/mK, 0.253 W/mK and 0.145 W/mK respectively (Sadik & Anchasa, 2009).

2.3 Nano-fluid preparation

There are two methods used in preparing nano-fluids. In layman terms it can be termed as chemical method and mechanical method. Methods found in the literatures is a one-step method and including two-step method, the former to be chemical and mechanical method, respectively.

2.3.1 One-step method

A one-step method to prepare nano-fluids is where the production nanoparticles and preparing of nano-fluid is done concurrently. The technique used to prepare the nano-fluid is called Physical vapor deposition (PVD). Nano-fluids prepared by this method has better dispersion of nanoparticles which also results in more stable mixture. High vapor pressure fluids are not compatible with this method to produce nano-fluids (Devendiran & Amirtham, 2016).

Copper nano-fluid was prepared using the one-step method as stated in one of the literatures. Procedure to prepare the copper-based nano-fluid is as follows:

1. 25ml ethylene glycol solution of copper sulfate pentahydrate ($CuSO_4. 5H_2O$) with 5ml ethylene glycol solution of polyvinylpyrrolidone (PVP-K30).
2. Magnetic stirring performed for 30 minutes.
3. 25 ml of ethylene glycol solution of sodium hypophosphite ($NaH_2PO_2 \cdot H_2O$) added into solution number 1.
4. Magnetic stirring performed for 15 minutes.
5. The solution was put into a microwave oven for 5 minutes to react.
6. After reaction, color of mixture turned from blue to dark red.
7. When mixture was cooled to room temperature nano fluid was obtained.

A single-step approach to produce nano-fluid is much simple to perform and cheaper to produce. However, limitation is found where only low vapor pressure fluid types can be used to produce nano-fluids using the one-step method (Zhu, Lin, & Yin, 2004).

2.3.2 Two-step method

Two-step method is where nanoparticles are available in powder form purchased or produced separately. Subsequently, the nanoparticles will be mixed with a base fluid and dispersed in a mechanical process. Dispersing of nano-fluid is done using ultrasonic vibration equipment. Dispersing is done to prevent agglomeration and sedimentation.

In this method, nanoparticles are commercially purchased where it is readily available in the market. Even though, it is readily available in the market it is still worth our time to discuss on few methods of how the nanoparticles are produced. Three methods which are found and displayed in figure 2.1, figure 2.2., and including figure 2.3 as follows:

i. Inert gas condensation.

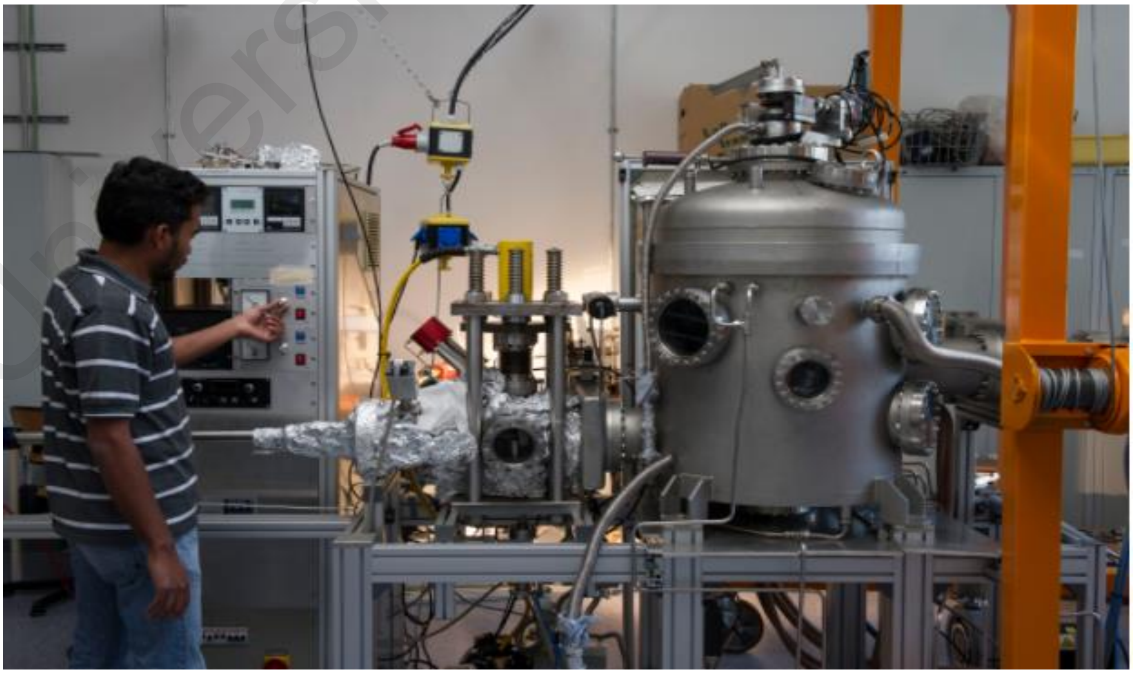

Figure 2.1: Image of Inert Gas Condensation

ii. Chemical vapor deposition.

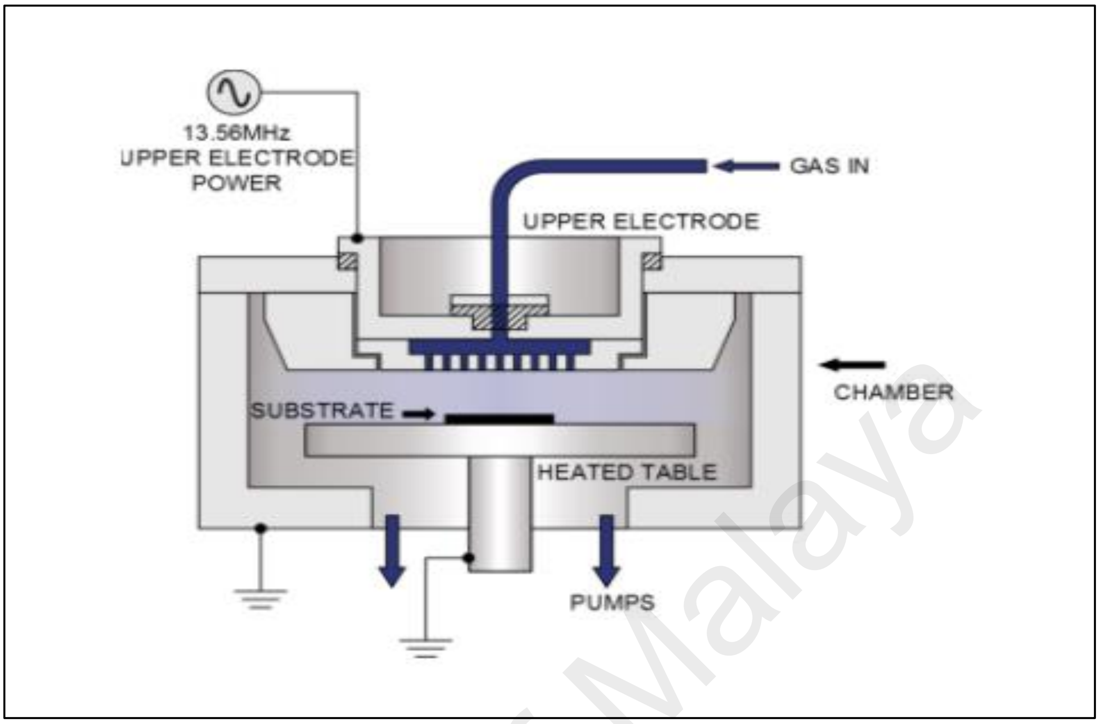

Figure 2.2: Chemical Vapor Deposition (Oxford Instrument, 1995)

iii. Mechanical alloying.

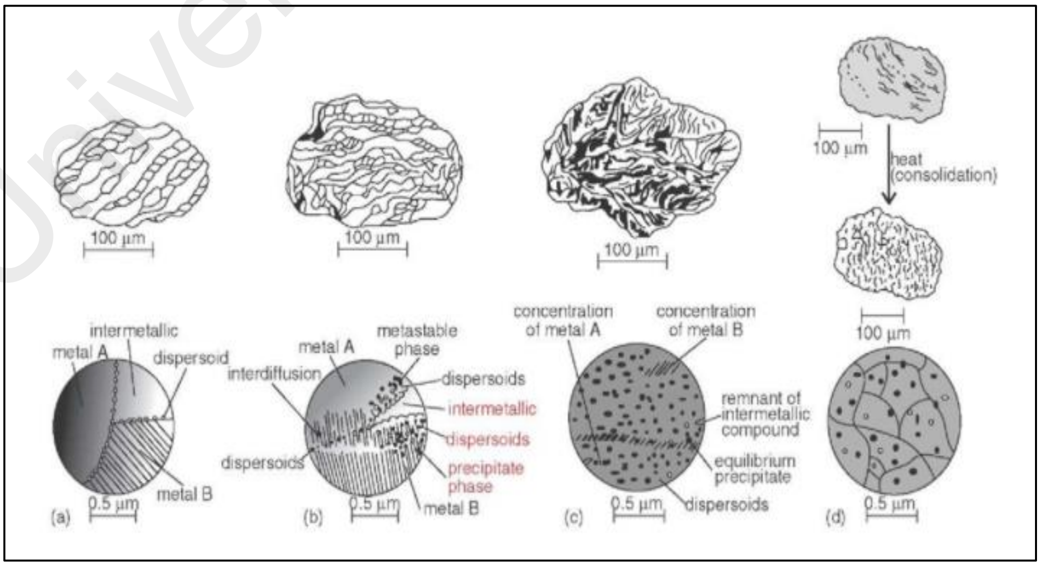

Figure 2.3 : Illustration of Mechanical Alloying

After nanoparticles being produced in the above method, the particles will be dried and stored accordingly. Based on demand the nanoparticles will be transported to any establishment requiring it. Then, nano-fluid will be produced by dispersing the nanoparticles into the respective base fluids (Li, Zhou, Tung, Schneider, & Xi, 2009).

In the case where it is found that agglomeration and sedimentation is occurring even after long process of ultrasonic vibration. Researchers have suggested the use of a surfactant to improve rate of agglomeration and sedimentation. Since agglomeration and sedimentation indicates poor stability of nano-fluid the use of surfactant can be considered to improve stability of the nano-fluid. Common surfactants that have been stated in one journal is laurate salts, oleic acids & thiols (Yimin & Qiang, 1999). Based on reading related journals common surfactants are mostly acid based solution. Discussing stability, another method used to improve stability in nano-fluid suspension is by changing the pH value of the suspension.

Acid based solution are commonly known to be corrosive especially in the heat transfer application area. Heat exchangers which are commonly made of aluminium or copper may be affected by corrosion. When preparing the nano-fluid the pH value of the nano-fluid must be carefully observed to determine suitability in heat transfer application.

Preparation of nano-fluids will vary by type of nano-fluids and base fluids. In some case the use of surfactant may be required. Method of preparing a few nano-fluids using the two-step method will be discussed below.

Iron (Fe) nanofluids was prepared by one of the researchers with the method below. Nano material used was Iron (Fe) nanocrystalline powder and base fluid was ethylene glycol. Size of nanoparticle was 10nm and formed by chemical vapor condensation process. Iron (Fe) nanocrystalline powder was mixed in ethylene glycol base fluid. Then, an ultrasonic disruptor was used to disperse the nanoparticles into the base fluid to stabilise the suspension if the nanoparticles.

Copper (Cu) nanofluids was prepared with almost similar method as the Iron (Fe) nanoparticle discussed before. The difference is that to prepare Copper (Cu) nanofluid, the use of surfactant was applied by the researcher. Two types of Copper (Cu) nanofluid was prepared, one with distilled water (H_2O) as base fluid and another with oil as base fluid. Similarly, after mixing the Copper (Cu) nanoparticles and surfactant into the respective base fluids namely water and oil. Then, the mixture did undergo an ultrasonic agitation process.

2.4 Test Method for Nano-fluid

Nanofluid is can be known as mixture of one or beyond more nanoparticles with a base fluid. When fluid and particles of different characteristics are mixed there is an assumption made that a nanofluid will act like a fluid somewhat than a mixture of solid fluid. With the assumption of fluid behavior is considered for nanofluids but it cannot be neglected that a nanofluid is mixed of solid and fluid. Thus, nanofluids have the tendency to aggregate with time which might make cause the fluid to have reduced effect of heat transfer. Therefore, test method has been developed by various researchers to assess the performance of the nanofluid. The focal aspect of evaluation focusses on the stability of the nanofluid.

One of the methods used by researchers is called the sedimentation method. Difference of particle size and concentration is evaluated with sediment time. The results are obtained by a special apparatus. A stable nanofluid is considered when particle size and concentration keep constant. Similarly, nano-fluids samples are kept in test tubes with respect to their type and concentration. Photographs of the samples are taken over a period to observe stability. Figure 2.4 illustrates the sedimentation process

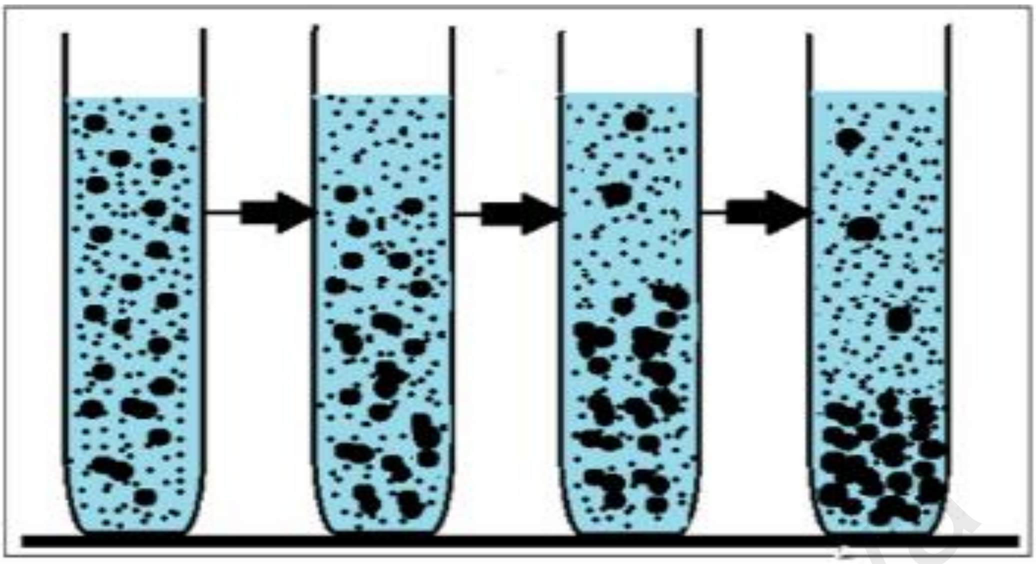

Figure 2.4 : Sedimentation Process

Another method used is zeta potential analysis for nanofluids stability measurement. Zeta Potential values shown is less than -25 mV or more than +25 mV normally have high level of stability (Nurettin Sezer , Muataz A. Atieh, & Muammer Koç, 2019). It is shown in Figure 2.5

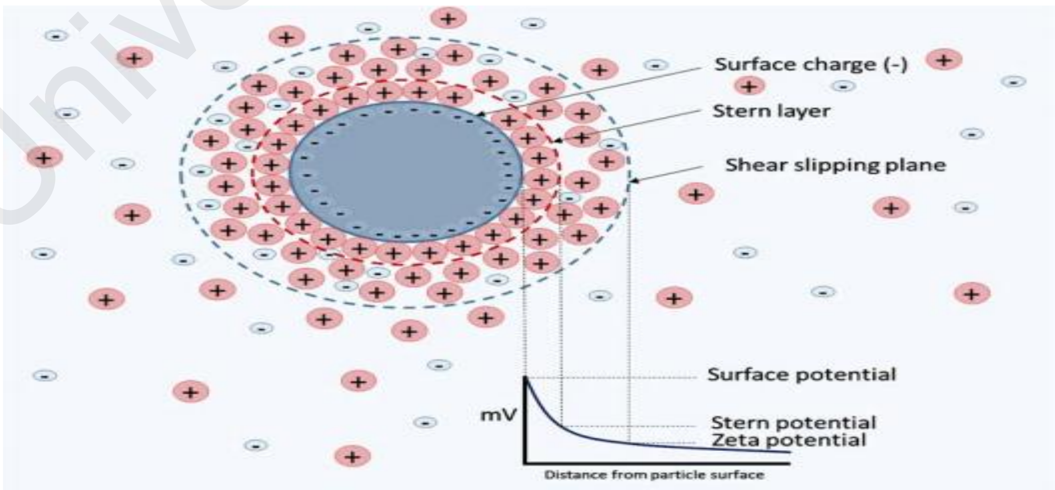

Figure 2.5 : Zeta Potential Diagram

Furthermore, a UV-vis spectrophotometer can be used to measure stability of nanofluids. Absorption of nanofluids is measured through the apparatus. Nanoparticle concentration and absorbance are directly proportional to each other. Figure 2.6 shows the function of the UV-vis spectrophotometer.

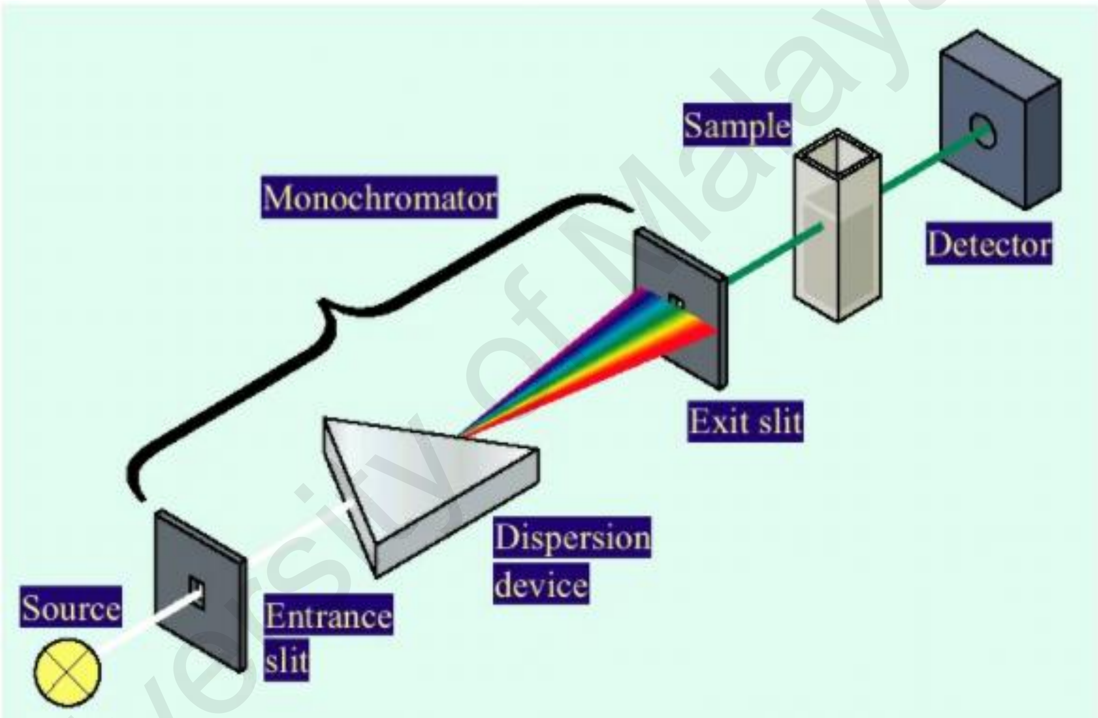

Figure 2.6 : Function of UV-vis spectrophotometer

Centrifugation method is another alternative method practiced for the evaluation of stability. It was evolved due time-consuming technique of sedimentation. This process was utilized to access the stability of silver nanofluid equipped by reducing $AgNO_3$ and selecting PVP representing the stabilizer (A. K. Singh and V. S. Raykar, 2008). Figure 2.7 displays that representation centrifugation.

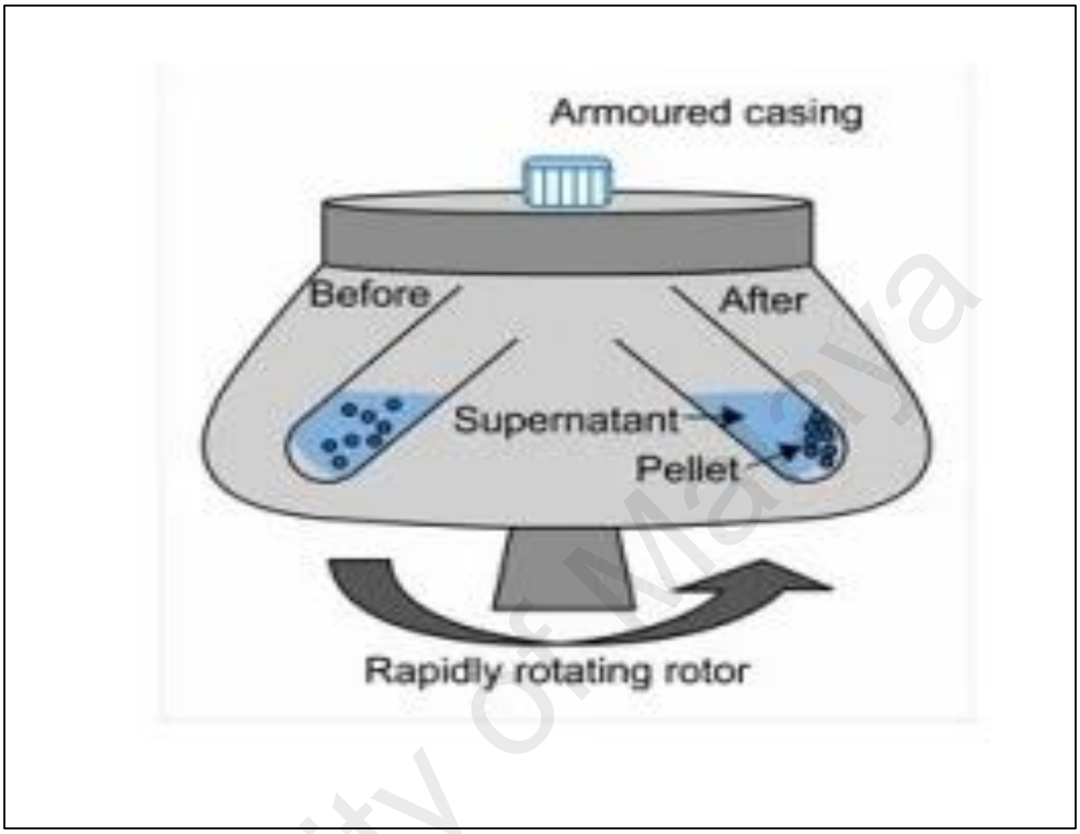

Figure 2.7: Outline of Centrifugation

The pH value of the nanofluid is also said to affect the stability of the fluid due to the formidable repulsive forces which links to electro-kinetic characteristics. Numerous pH results for Al_20_3 nanofluid had been examined and found out that changing its pH value impacts the agglomeration. The results prove optimized pH value differs from each of the sample (Y. Fovet, J. Y. Gal, & F. Toumelin-Chemla, 2001).

2.5 Thermal Properties & Analysis for Nano-fluid

The integration of the nanoparticles here in the base fluid proceeds to modify in the properties of thermophysical parameters just as density, viscosity, and thermal conductivity that impacts the convective heat transfer. Nanomaterials which are different alters their requirements to different range.

2.5.1 Thermal conductivity Of Nanofluids

The thermal conductivity was found to expand with concentration following experiments undertaken with Cu, Al_2O_3. Nanoparticles which are diffused in ethylene glycol (EG), water (H_2O) and oil have shown surge in the thermal conductivity ratio (k_{nf} / k_f) with a reduction in the thermal conductivity results consisting base fluid (Lee S, Choi, & S. U. S., 1996). Regarding the volume concentrations and scale of particle-particle contact which were impacted by pH, surfactant additives, and particle magnitude and form, agglomeration equilibrium is applicable in nanoparticles suspension. The base fluid effect, was detected with diverse nanofluid structures, is most likely linked to the lower results of the thermal resistance inside the EG/water than in the water-based nanofluids. Together thermal conductivity and viscosity are associated powerfully to the nanofluid microstructure.

The nanoparticles diffused in the base fluid were in sprawling motion under the actions of the forces such as Brownian motion, intermolecular van-der-Waals interaction, and electrostatic relations between ions and dipoles (A.M. Hussein, K.V. Sharma, R.A. Bakar , & K.Kadirgama, June 2013). There are many strategies to determine the thermal conductivity of nanofluids specifically; transient hot-wire, temperature oscillation, 3-omega and many more.

2.5.2 Viscosity

Rheological distinctiveness of nanofluids were measured by using rheometers (Prasher, R. Song, D, Wang, J, & Phelan, P., 2006).The viscosity has been revealed inversely proportional to the mean diameter size in both EG/water and water-based suspensions. At the identical volume of nanoparticles concentration, the relative viscosity rise was lesser in EG/water than in the water-based nanofluids, particularly in suspensions of minor nanoparticles (Timofeeva, D. M., Singh, & Routbort, J. L., 2010). The viscosity advancement for the different nanofluids are taken from the previous literature reviews was illustrated in the Figure 2.8

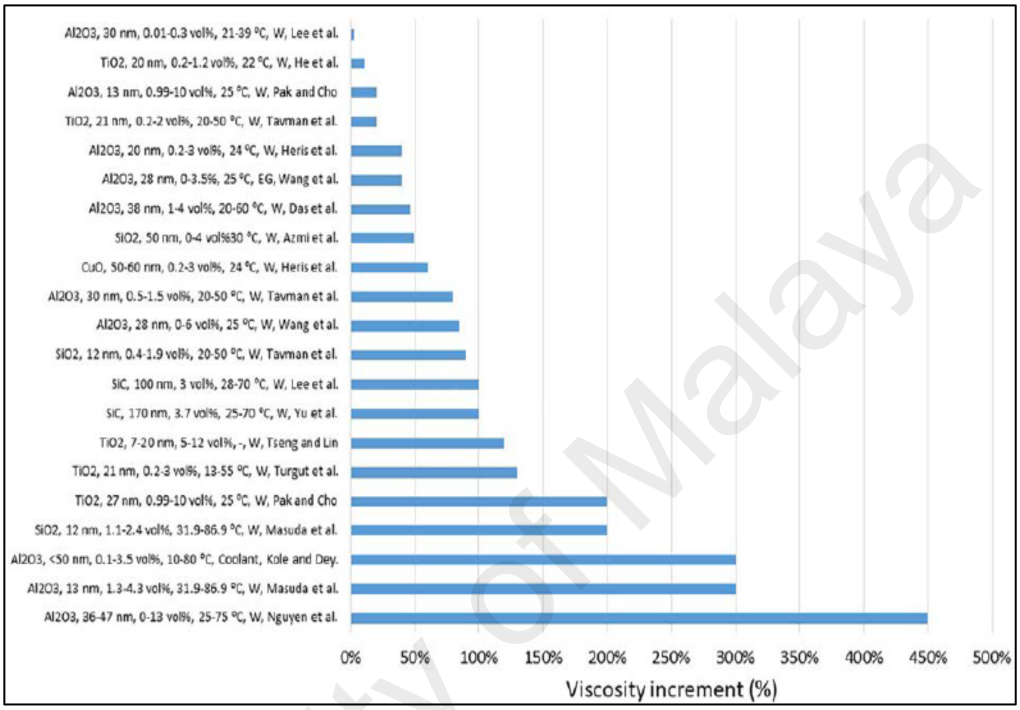

Figure 2.8: Viscosity Increment (A.M. Hussein, K.V. Sharma, R.A. Bakar , & K.Kadirgama, June 2013)

2.5.3 Density

Density is a vital thermo-physical property to evaluate performance of heat transfer for nanofluids. It had effects on some of the parameters such as friction factor, Reynolds number, Nusselt number and pressure loss.

Experimental process was done to identify the density of Nikel-water nanofluid (Riehl, 2012). According to Riehl, the density rises approximately 3.2% and 4.7% for particle concentration growing from 3.5% to 5%. Molecular dynamic simulation was used to inspect the local density of enclosing xenon base fluid together with platinum nanoparticles. They assumed both lognormal size distribution and agglomeration of nanoparticles across the limit of nanoparticles diameters which is (25 – 150nm) (John Shelton, August 1–5, 2010). The author also finds out that the radial distribution function displays surge in the local fluid density. It was increasing due to the development of liquid layers that fully enclose the nanoparticle.

2.6 Square Pipe Heat Exchanger

The study had statistically assessed and make a comparison of the heat transfer performance of coiled tubes against the straight tube which consists of square cross section area and equal distance (J. C. Kurniaa, Agus P. Sasmitob , Saad Akhtarc, & Tariq Shamimc, 2015). Wall temperature of tubes increases directly proportional against rate of heat transfer. The enhancement of convection heat transfer inside a straight tube of various square cross segments were experimented by using platinum nanofluid with a few concentrations ranges from 0.01wt% until 0.06% (Hooman Yarmand, Samira Gharehkhani, Goodarz Ahmadi, S.N. Kazi, & Mahidzal Dahari, August 2015). The authors further stated that friction factor rises about 10%. They described that the convection heat transfer for the entire specimens had a huge enhancement against the base fluid with the highest results of 30% enhanced value at the uppermost concentration of Re which is at 17500.

(Yarmand, H., et al., 2016) analyzed a solution made of water based nanofluid GNP that consist various limits of the weight concentrations of micro nanoparticles which the value is 0.02% and 0.01%. Then the nanofluid was streamed in a stainless-steel tube that was made with cross sectional area placed in horizontal straight tube. The dimensions of the test segments were 1.4m and 0.01m in length and inside diameter accordingly. Rig test experiment was clouded with insulated layer and tape heater for maintaining constant heat flux. Reynold numbers recorded was wide-ranging from 5000 to 17500. Total heat transfer coefficient and Nusselt number logged was 19.68% and 26.5% compared to the host fluid. The enhancement was further raised with the rise in the nanoparticle's concentrations. In addition, pressure drop was noticed to be rise when compared to the base fluid. The values shown was 9.22% at 0.1wt % concentration.

Effects of diffusing a multi walled carbon nanotubes inside the base fluid were reviewed by (I.D.Garbadeen, M. Sharifpur, J.M. Slabber, & J.P.Meyer, November 2017). They detailed that the multi walled carbon nanotubes that are transferred into base liquid experienced a rise around 45% at about 0.1wt nanoparticles concentration when compare to base fluid. Apart from that, pressure drop is also said to be increased for the viscosity from 6% to 15%. Hence, the study revealed that higher concentration attributes to the surge in the density which also influences the enhancement of heat transfer.

(S. Zeinali Heris, Taofik H. Nassan, S.H. Noie, H. Sardarabadi, & M.Sardarabadi, December 2013) conducted a study of Al_2O_3/water nanofluid convective heat transfer through square cross-sectional duct that proceeds under constant heat flux in which it flows in laminar. As they evaluate, they noticed that square cross section duct has the benefit of lesser pressure drop, but it has a reduced heat exchange rate than circular duct. Experimentations demonstrate that substantial enhancement of heat transfer coefficient is accomplished, and it brought up to 27.6% at 2.5% volume portion of nanoparticles comparing to the base fluid which is water. It has been observed that convective heat transfer coefficient rises with the nanoparticle's increment of concentration in nanofluid specifically at large flow rates.

Shahi et al. (Shahi, M, Mahmoudi, A.H, & Talebi, F., February 2010) statistically inspected the efficiency of the laminar convective heat transfer of Copper oxide-water nanofluid which flows through a square cavity underneath a laminar flow regime. The results shown was increased particle concentration influences the average Nusselt number which also rises while the bulk temperature declined rapidly for the nanofluid.

(Hsien-Hung Ting & Shuhn-Shyurng Hou, 2015) examine the convective heat transfer of water based Al2O3 nanofluids running through a square cross-section duct with a state of constant heat flux underneath the condition of laminar flow. The influence of nanoparticle concentration and Peclet number on the heat transfer features of Al_2O_3-water nanofluids are explored. The results demonstrate that heat transfer coefficients and Nusselt numbers of Al_2O_3-water nanofluids surge with rising in the Peclet number and including the escalation of concentration of particle volume. 25.5% of heat transfer coefficient had also increased at a particle volume at concentration of 2.5%. 7500 of Peclet Number is also analyzed with base fluid (pure water). The study shows that similar particle which is 2.5% of volume concentration and the enhancement of the convective heat transfer coefficient 25.5% is were much greater than thermal conductivity (9.98%) for this nanofluid.

2.7 Cost impact of Nano-Fluid Application

Regardless of the hopeful heat transfer enhancement potential detected by many academics, there are numerous boundaries to extensive execution in engineering situations. Most of the understanding on nanofluids mostly depends on marketable obtainable nanoparticles. They were not low-priced and there is no usual amount for these particles as at present (for instance, 100g of the frequently experimented alumina or copper oxide nanoparticles charge $492.00 and $80.00 US dollars, (Nanostructured & Amorphous Materials, Inc., 2002). Moreover, conferring to the industrialist, it seems that the distinctiveness of nanoparticles varies which proceed to the ambiguity of physical property data. Adding to that, roughly some of the nanomaterials are poisonous which lead to preventive actions engaged in preparation amplify the cost of the production.

Mahian et al. (Mahian, O, Kianifar, A., , Kalogirou, S.A., , Pop, I., , & Wongwises, S, February 2013) enlightened that encounters various conundrums such as high price of nanoparticles, unsteadiness and agglomeration, power of the pumping and pressure drop, corrosion of mechanisms create nanofluid commercially unappealing. Higher production cost of nanofluids is one of the reasons that may deter the appliance of nanofluids in industrialization.

Both methods of preparing nanofluids which are one step two step method demanded unconventional and sophisticated equipment. Lee and Mudawar (Lee J & Mudawar I, 2007) and highlighted that extreme rate of nanofluids is amongst the downside of the application of the nanofluids.

(Lv, et al., April 2018) mentioned that even with the remarkable operation of nanoparticles to curb issues, the high cost of nanofluids utilization is continuously becoming one of the most imperative details that may hamper the function of the nanofluids. The total cost of a nanofluid is regulated by the worth of the selected base fluid and the nanoparticles fee. Charges are abnormal when the nanoparticles were more problematic to synthesize or develop for producing the stable colloidal suspension is much more perplexing. Valuation of the worth for some basic known nanoparticles with water as the base fluid as shown in the Figure 2.9.

Type of Nanoparticle	Thermal Conductivity of Particle W/(m-K)	Size of Particle in Solution*	Amount of Solution*	Price of Unit (USD)**
Alumina (Al_2O_3)	30	30-60nm	100.0 mL	$183.50
Copper Oxide (CuO)	401	<50 nm	25.0 g***	$73.10
Gold (Au)	310	10 nm	25.0 mL	$338.00-$362.00
Gold (Au) with Silica Coating	N/A	10 nm	5.0 mL	$318.50
Iron Oxide (Fe_2O3)	0.58	30 nm	5.0 mL	$240.00
Silver (Ag)	429	20 nm	25 mL	$114.50
Titanium Oxide (TiO_2)	22	21 nm	100.0 g	199.50

**All solutions included in table above are in a base fluid of water (H_2O).*
***Prices are from Sigma Aldrich (www.sigmaaldrich.com).*
****Copper oxide nanoparticles are only available in nanopowder form, rather than dispersed in a solution.*

Figure 2.9: Estimation of the price for some common nanoparticles (Azizian, 2017)

However, they settled that the overall appliance of nanofluids is still in its early phases and, therefore, upcoming researches will intensify the prospective applications of the nanofluids.

2.8 Environmental Hazards research and disposal methods of Nano-Fluid

For the past few decades, nanofluids had been the subject of the town for all the industrialization. Its application has been discussed and reviewed from the researchers for the present scenario. Their impact cannot be understated and presently debated for its advantages and disadvantages. There are quite a number of researches had been done on environmental impacts. Nanofluids has been researched for solar energy due to the ever-increasing necessity of heat and electricity, that involves the relative exploitation of Photovoltaic/thermal (PV/T) (Zafar Said, Sahil Arora, & Evangelos Bellos, October 2018). The system has expanded and had assessed to the photovoltaic or solar thermal system without others due to healthier operation of joint PV/T systems when compared to the standard ones. PV/T hybrid systems spawn both together with electrical and thermal energy simultaneously, handing to many other types of applications. In recent times, several types of nanoparticles blended with base fluid which have been utilized in hybrid systems producing in appealing the interest of plentiful scholars. Nanofluid had been operated as an optical filter and competent coolant because of its enhanced thermal conductivity in PV/T systems. Environmentally friendly energy systems had become so vital due to sustainable energy consumption.

The motive is to present the briefing of multiple PV/T technologies at the time collectively with characteristics of their effectiveness, formation of structure, thermal governing expressions and their utilization as well as the up-to-date technologies and constraints which overwhelmingly influence the PV/T collector performance. According to (Zafar Said, Sahil Arora, & Evangelos Bellos, October 2018) there are encouraging impacts and adverse validities on the environmental safety level by operating these solar methods for the energy creation as associated to the conventional energy foundations practices. The adversities that currently present are usage of lands, emissions of pollutants, as well as noise and air pollution which brings a major worry and heavy consequences for the environment.

As the authors discuss inclusively about the negativity, assessment of financial side and lessening of emissions pertaining nanofluids are recommended. Furthermore, the nanoparticles used in PV/T systems should be wisely monitored because of their poisonous nature. The protocols and legislation regarding nanofluids applications is a critical agenda for the domain’s forthcoming.

(Bapusaheb B. Tambe Patil, 2015) examines the mass population and industrialization ending into the contagion of the reservoirs. Therefore, to purify the wastewater, the usage of nanoparticles for water treatment have received the special attention due to its unique distinctness as an adsorbent and applied for filtration function. Magnetic Nanoparticles

(MNPs) being exploited for the elimination of the heavy toxic materials and facets like Nitrates, natural organic substance and pollutants, biological impurities, Fluoride and Arsenic from the contamination of water. For instance, Nano-structured materials such as magnetic, carbon-iron, photocatalytic Titania nanoparticles, carbon nanotubes, silver-impregnated cyclodextrin Nanocomposites, Nano structured iron zeolite, nanofiltration membranes and functionalized silica are selected in wastewater treatment (Bapusaheb B. Tambe Patil, 2015).

Wastewater treatment that practices nanofluid possess greater benefits in terms of reduction of pesticides, hard water softening, lower energy costs, lessening of heavy metals, fewer wastewater than reverse osmosis and myriads of other benefits. Cellulose acetate Nanofiltration membrane were exploited in the experimentation. Throughout the testing, plenty of different feeds were tried in a range of pressure by altering the concentration ratio to assess the implementation of membranes. The experiment was conducted out at stable pressure which is 1.4 MPa. The specimens from the permeate and the concentrate analyzed at the same time during processes. Metallic ions were decided by the detection of the conductivity and together with ion chromatography. Figure 2.10 shows the schematic diagram of lab NF system.

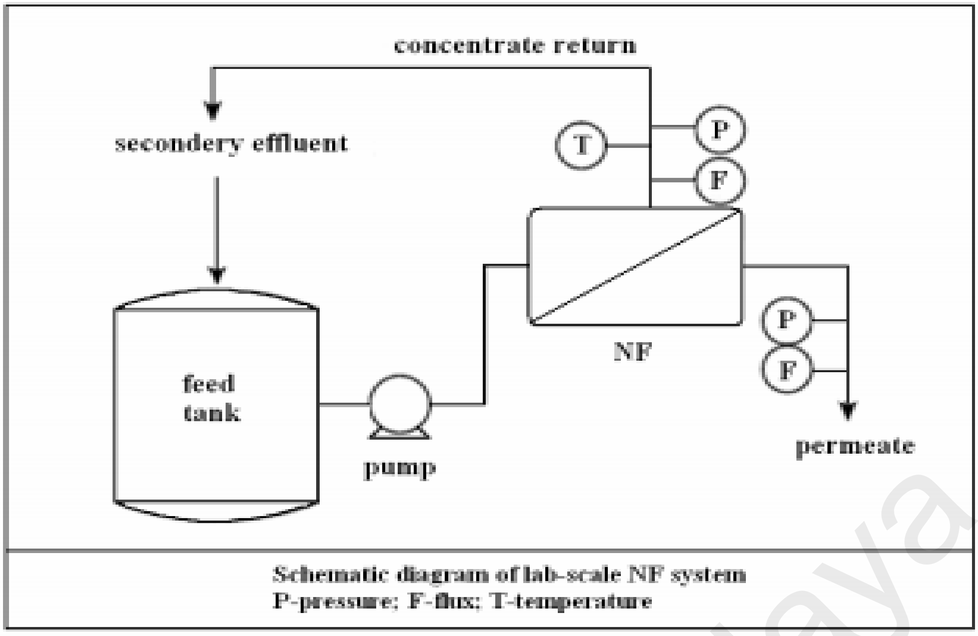

Figure 2.10 : Schematic diagram of lab-scale NF system

While the amount of studies regarding nanofluids have become larger lately, there are currently undecided and have no answer on long-term assessments on how the addition of nanoparticles become more prominent and at the same time reduce the negative impacts and disadvantages created by nanofluid.

2.9 Hummer Method

Hummers method was established (1958), over span of 100 years after the Staudenmaier method. The procedure uses sulphuric acid as the intercalating agent and swaps the fuming nitric acid consumed by Staudenmaier through sodium nitrate. This technique also exchanges potassium dichlorate with potassium permanganate as the oxidant matter. 0.5 weight sameness of sodium nitrate is included to the graphite and sulphuric acid; it is later selected to be of 325 mesh size in traditional arrangements, as this is a minor sufficient size to safeguard tiniest diffusion restrictions as well as extensiveness and consistency of oxidative behavior. 23 ml of sulphuric acid is tallied up together with 1 g graphite. The subsequent mixture is detained at 0˚C and 3 mass weight likenesses of potassium permanganate are inserted which leads the temperature of the mixture never surpasses 20˚C during accumulation. Then the reaction was permitted to happen at 35±3˚C for about 30 minutes. The combination is thereafter monitored to stiffen, progress minor volumes of gas and create a paste which is in grey colour. The mixture is interspersed with water to cool it so that acid is diluted threefold. The reaction effect made the temperature for the time being rises to 98˚C (boiling) and is seized there for about 15 minutes (Sharma, D. Mondal, C. Mukesh, & K. Prasad, 2013). The suspension was diluted to the obliged concentration and diluted hydrogen peroxide was inserted to minimize the residual potassium permanganate, consequential in a solution of bright yellow.

Filtration has been used for product washing which happens to be that pH move toward neutrality, a procedure which could consume times for days, particularly on the way to the latter few washes as the GO can gel and agglomerate at the same moment, blocking up filters. Subsequently, the solid may be dried out in vacuo at the temperature of 40-700C with or without phosphorus pentoxide at about 40˚C, or by freeze-drying. These enhancements presented by Hummers mostly eradicated the poisonous gasses progressed in the Brodie and Staudenmaier methods, exiting this technique a good contender for production of GO (Sharma, D. Mondal, C. Mukesh, & K. Prasad, 2013). Figure 2.11 shows the Hummer synthesis for GO.

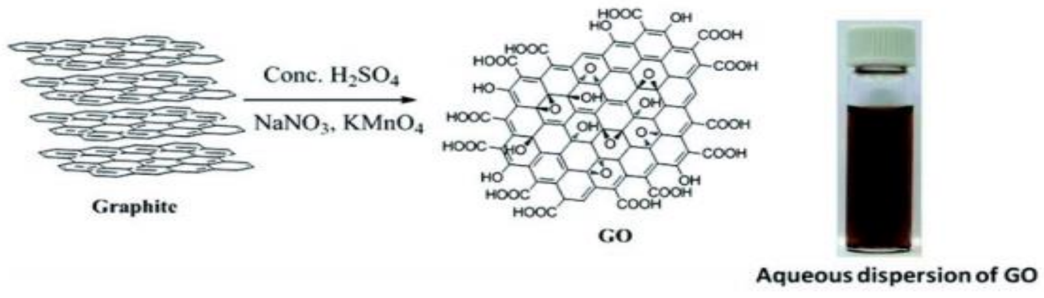

Figure 2.11: Hummer synthesis for GO (Sharma, D. Mondal, C. Mukesh, & K. Prasad, 2013)

2.10 Heat Transfer Analysis of Al3O2/DW

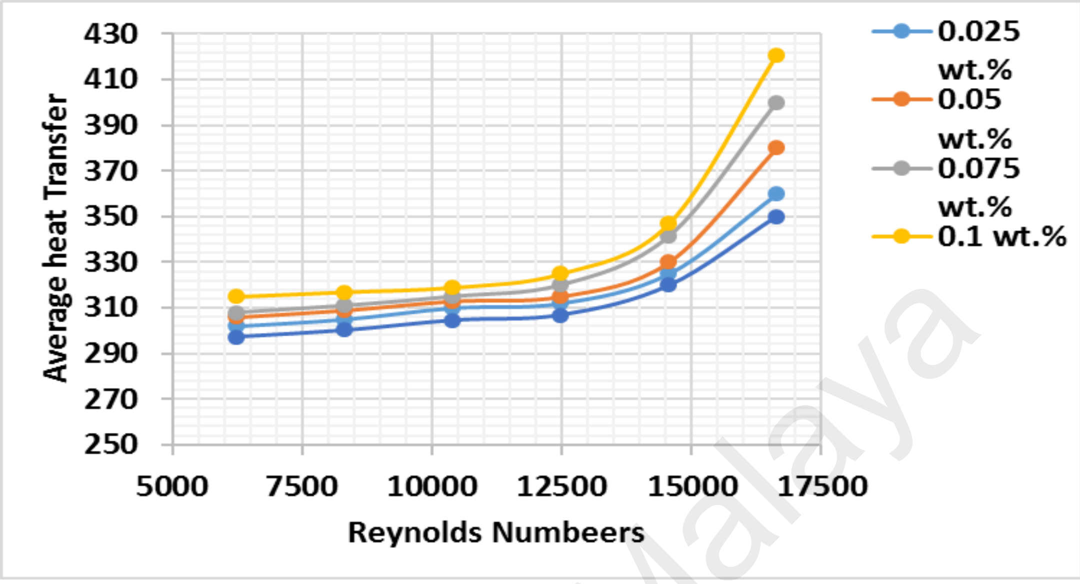

Figure 2.12: Re number against Heat Transfer Coefficient

The current study was also made to do an investigation based on comparison of heat transfer analysis of Al_2O_3/Dw nanofluids which was taken from previous undergrad experiment and compare with GO-distilled water nanofluids. It was set up likewise just like GO-distilled water. As illustrated in the figure 2.12, trend of thermal coefficient for Al_2O_3/Dw nanofluids in the graph is marginally similar to (GO)-distilled water which showcases that 0.1 wt% of the concentration is the highest among the others and distilled water was recorded the smallest in that illustration.

The increased percentage values of heat transfer coefficient in 0.025wt, 0.05wt, 0.075wt and 0.1wt are 2.9%, 8.6%, 14.3% and 20% which indicates the increase in the concentrations as it went higher. Similar to the (GO)-distilled water, the values also show that heat transfer performance in (GO)-distilled water is levels above than the distilled water. It occurs due to greater concentration and strain of fluid motion in inputs of lower heat.

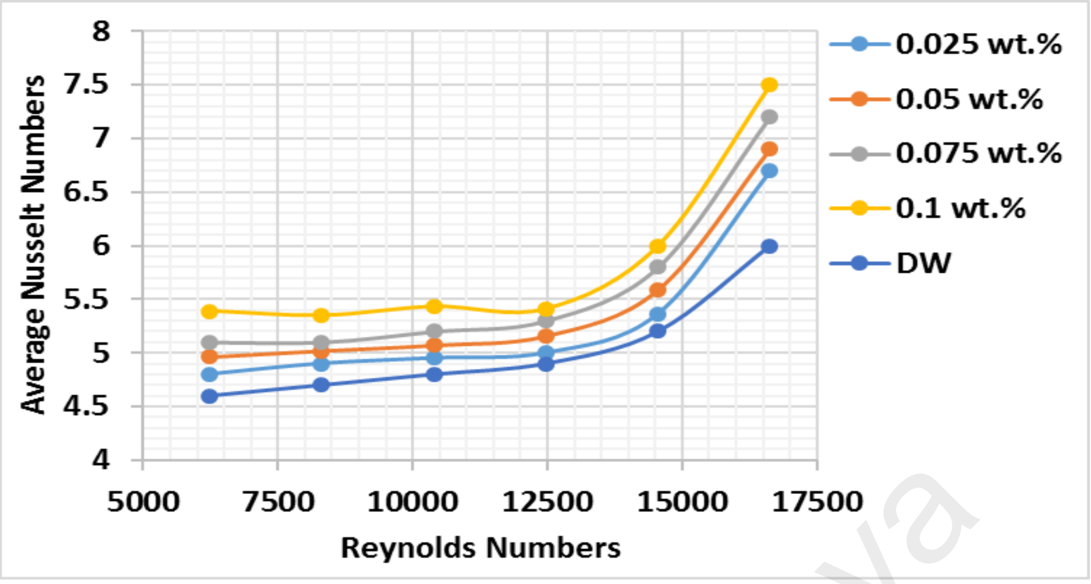

Figure 2.13: Re numbers against Nu numbers

Figure 2.13 specifies the relationship between (Re) and Pressure Drop in the square cross section of the pipe for Al_2O_3/Dw nanofluids. As can be seen in the figure, it displays that (Nu) number raises along with increased numbers of (Re). The maximum concentration that recorded was 0.1wt % where else distilled water was noted the lowest among others.

The increased heat transfer coefficient values in each of the concentrations are 10%,13.3%, 18.3% and 25% which reveals the surge in the concentrations as it raises higher. As similar to (GO)-distilled water nanofluid, it takes place because the nanofluids was occupied with suspended nanoparticles which possessed a greater conductivity than distilled water.

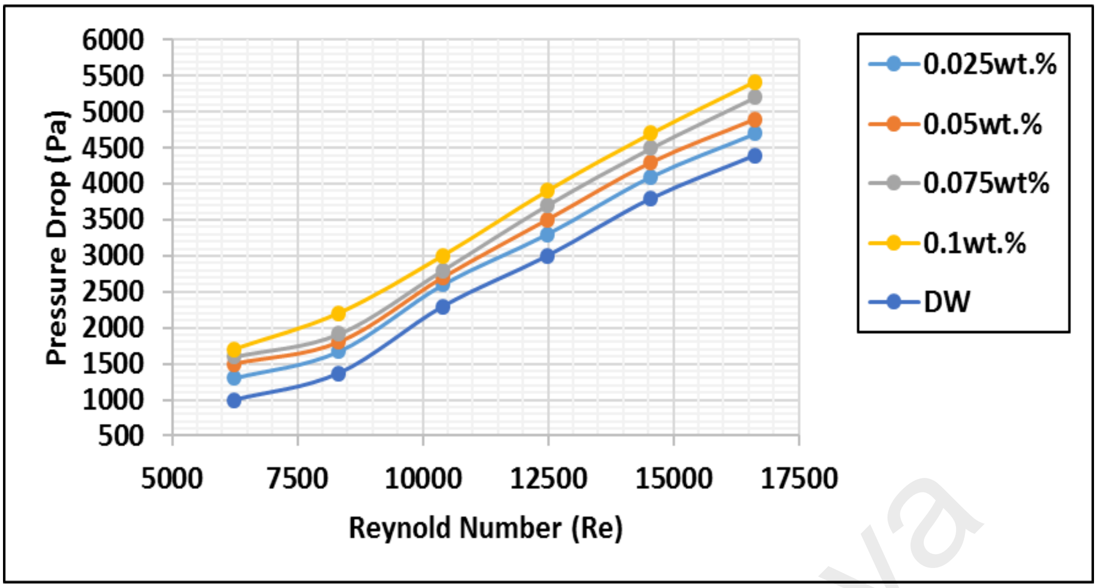

Figure 2.14: Re numbers against Pressure drop

Relationship between (Re) and Pressure Drop of Al_3O_2/dw in the square cross section of the pipe was illustrated in figure 2.14. The trend shows exactly like (GO)-distilled water that if the pressure drops increases, the number of (Re) number also increases. The largest concentration recorded were in 0.1% wt of concentration where else the lowest again is distilled water which is same as (GO)-distilled water.

The density is a huge factor of parameter which leads to the increased pressure drop of the nanofluids. Mean ratio of increasing the pressure drop with increasing (GO) concentrations are 9.3%, 12.8%, 18.6% and 28.6% for each of the concentrations respectively. Friction factor does relate to pressure drop as it also mostly depends on the nanofluids important aspect which is concentration and the velocity. Brownian motion for the particles is of the reason that made the particles to passage with a greater force in the higher concentration of Al_3O_2/dw.

2.11 Summary

Many researches had been done among in scientific community to create a huge enhancement of nanofluids based carbon which is GO that maintain and assess the characteristics of graphene as possible. Great enhancements in the development have been completed since Brodie first printed his paper based on synthesis of GO. A cumulative number of scholars for the past years have been turning to the Hummer method, which uses sulphuric acid as the intercalating agent and swaps the fuming nitric acid consumed by Staudenmaier through sodium nitrate. Besides that, the yearly rate of growth in the numeral of citations which practice the Hummer method is larger than that Staudenmaier method. Hummers method currently had been acting as a future synthetic method for GO.

This growing interest in the Hummer method was enlarged with the number of studies in the square pipe heat exchanger. It was detected to have granted other researchers moderate success to study the efficiency of GO compared to the other methods. Not only that, environmental impact of nanofluids and waste disposal had been studied extensively by number of researchers which had been discussed earlier in this chapter. The study was conducted specially for solar energy due to the ever-increasing necessity of heat and electricity, that involves the relative exploitation of Photovoltaic/thermal (PV/T). The comparisons are also made with Al3O2/DW nanofluids to find out the better enhancement of nanofluids among them.

CHAPTER 3: METHODOLOGY

3.1 Experimental Set-Up

Generally, performance of the heat transfer can be assessed by the heat transfer coefficient (h) in the turf of thermo fluid properties. Heat transfer coefficients carry a substantial weightage in determining the concept of heat transfer in this field. Hydrodynamic and convective heat exchange distinctiveness nanofluids of Graphene Oxide were studied then set-up in the square pipe of test segment of an conjectural test rig (Fig. 3.1) assembled in the innovative and developed CFD Engineering laboratory in the UM.

The parameters were thoroughly inspected, lined up and calibrated for the vales, flow loop, temperature detectors, flow indicators, and DP transmitters before preceding to operate the specimens in the test rig. Wilson plot was integrated where surface temperature of the measured pipe in the bottom thickness of the wall were transmitted to the core temperatures of the surface for the test pipe (Chowdhury, MR. Johan, S. N. Kazi, & Waqar Ahmed, 2020). Figure 3.1 shows a full experimental arrangement for nanofluids testing and the numbers represented were compiled in Table 3.1.

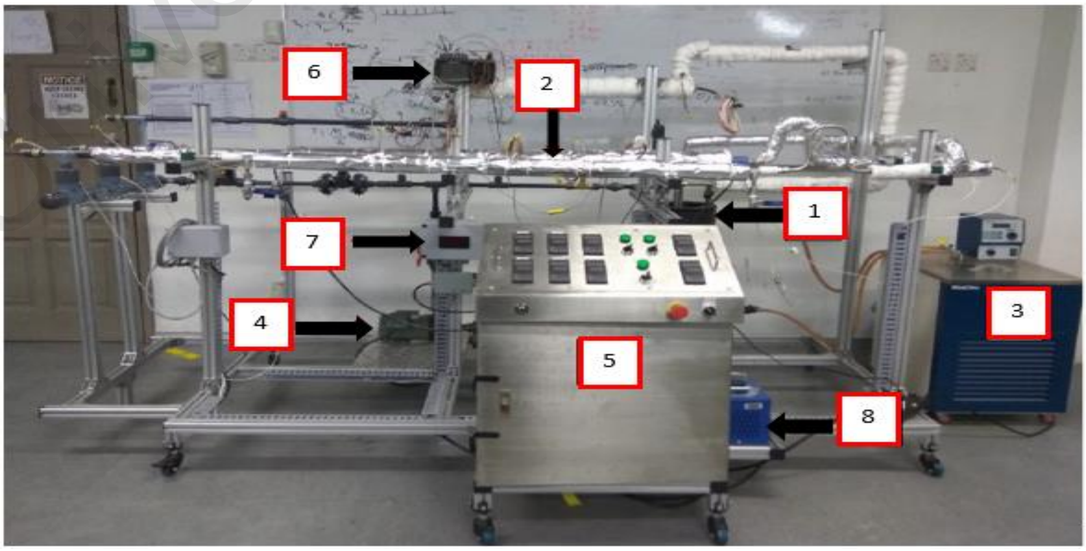

Figure 3.1: Experimental set up

Table 3.1: Experimental Set up parts

Numbers	Experimental Set-Up
1	Storage Tank
2	Test Section
3	Cooling Unit
4	Pump
5	Power Supply
6	Data Logger
7	Differential Pressure Transducer
8	Transformer

The inner diameters and length of the squared cross-section tubes were 0.01m and 1.2m as per recorded for the calculations. The heated sections of the tubes were thermally insulated via enclosing with glass wool at the external layer surface at the cross section of the test segment. The flat wire heating components were also covering the test segments which connected to voltage transformer that constrained the power supply. Heating element was given the utmost power capacity which was 600 W. Pressure loss and flowrate were recorded via an instrument called Foxboro TM differential pressure transmitter and other instruments called Bürkert Contromatic SE 32 or simply called as wheel transmitter with showcasing demonstration.

Power supply and transformer were utilized to transfer uniform heat flux throughout the square pipe. Apart from that, thermal loss to the outer backdrops were insignificant and unimportant in contrast to the heat channeled to the fluids which are flowing inside the tube. Five thermocouples were embedded equivalently at the top of the heated sector tubes to assess the temperatures of the surface section. K-type thermocouples were used and riveted by applying high-epoxy adhesive materials. Average of inlet temperature and outlet temperatures of the testing segment parts were evaluated to measure the bulk temperature of the fluid. Thereby to collect the interpretation of the temperature, two sensors of (PT 100) were placed at the inlet section and outlet segment of the testing parts.

Pump with the highest capacity 80L/min was worked to impulse out the fluid throughout the loop of the flow. 10L of insulated covered reservoir tank was gone through from the flow loop and the fluid inside was swirled to retain at consistent temperature to avoid sedimentation of the molecules in the tank. The fluid which are flowing through the test segment was heated and transfer back to the reservoir where its function was to chill at the earlier state and recirculated back.

3.2 Materials and Method

Graphene Oxide (G0) were synthesized for the nanofluid by succeeding the process of functionalization with advanced hummer method and will be made by operating the two-step method. Base fluid that are going to be used is distilled water that are prepared in the lab.

3.2.1 Preparation Of (GO)

The key materials used in this process are graphite powder, hydrogen peroxide, sodium hydroxide, hydrochloric acid. sodium nitrite, potassium permanganate and sulphuric acid. The processes will be further proceeded with another two stages and enlighten in detail below.

3.2.2 Preparation by Advanced Hummer Method

Initially 1.7g of Graphite powder and 0.7g of sodium nitrite powder ($NaNO_3$) were added inside a 1000ml beaker. Both compounds were amalgamated together. Then 90ml of sulphuric acid (H_2SO_4) were inserted into the combination and preserved inside the beaker under the ice bath with the temperature of (<30°) and nonstop constant stirring for the next 30 minutes. Next is followed by adding 1.7 g of potassium permanganate ($KMnO_4$) into the solution gradually while maintaining the temperature fewer than 30°C to prevent them from explosion as well overheating.

This solution had been mixed constantly for 8 hours straight at measured temperature 30°C. 100 ml water was added into the solution gradually to make sure the solution is diluted and continue blending for about 2 hours at 30°C. Lastly, the solution is again mixed with 40% of hydrogen peroxide (H_2O_2) and carry on stirring for about 2 hours until the colour of the solution transforms to bright yellow. The solution is drenched with 10% of aqueous hydrochloric acid, ethanol and distilled water accordingly numerous times until formation of like a gel substance (pH should be neutral) is detected. The gel like substance is vacuumed and was heated inside the oven for approximately 60°C for 6 hours where eventually (GO) is produced. Figure 3.2 illustrates the formation GO below.

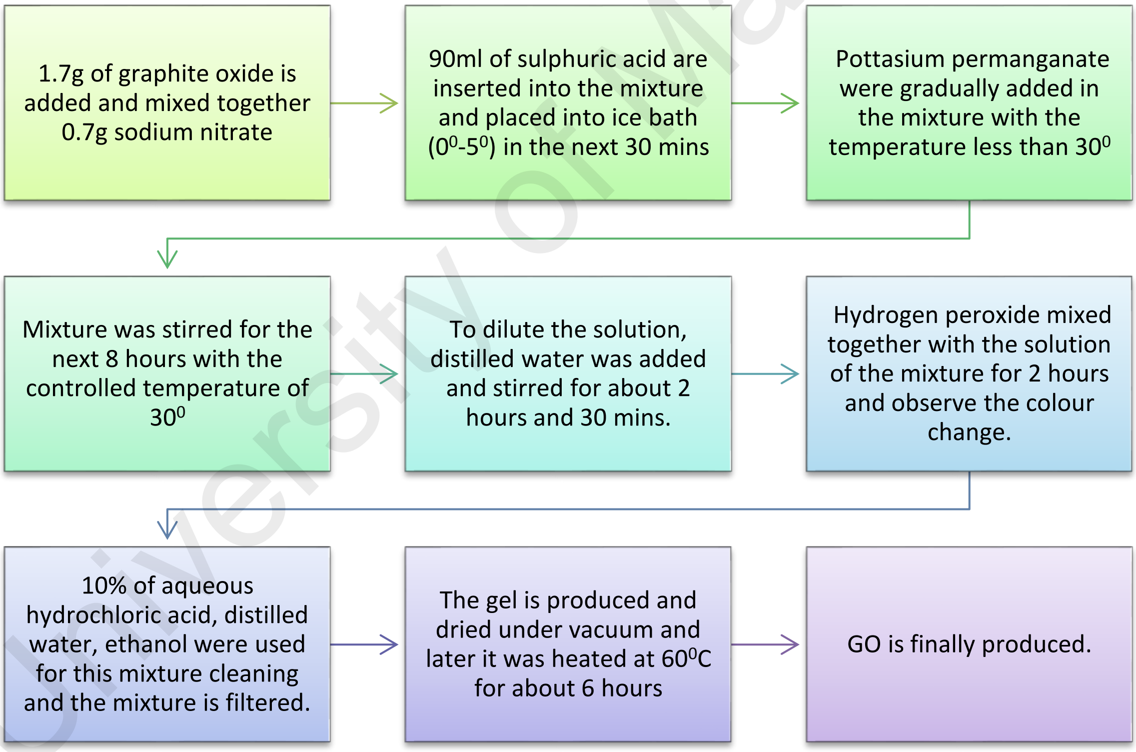

Figure 3.2: Preparation Of GO

3.2.3 Preparation Of GO/Distilled Water

Advanced Hummer method was used earlier for the formation of (GO). Nanofluid will be prepared in four different concentration which are 0.1%, 0.075%, 0.05% and 0.025%.

A total volume of 8L of nanofluid will be prepared for each concentration. Volume of 8L is considered because of the required capacity in the test rig mixer tank to run the experiment. Once the (GO) are included in the distilled water, ultrasonication process had been utilized for 2 hours to disperse the particles inside the mixture and received the (GO) nanofluid according to their concentration. Figure 3.3 shows the two-step process of nanofluid.

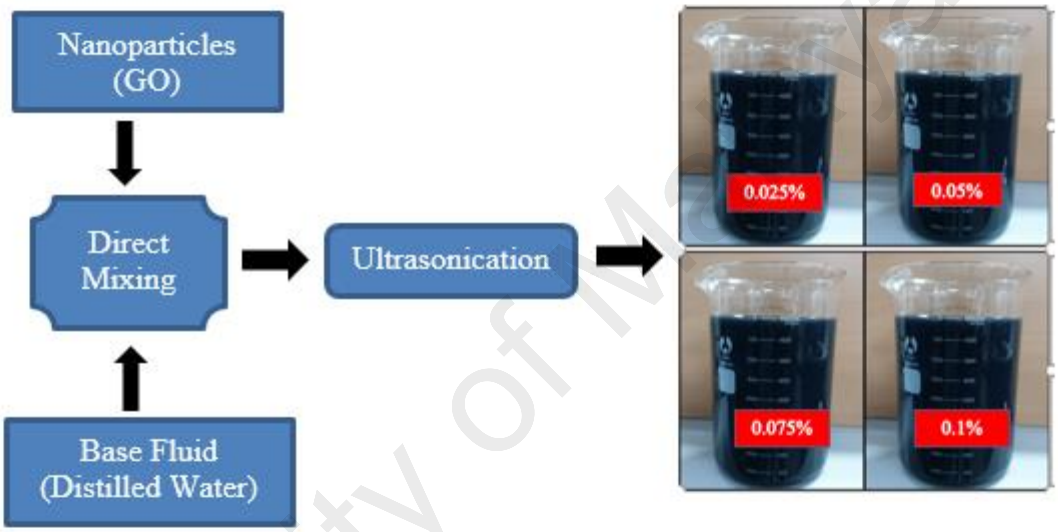

Figure 3.3: Two-Step process of Nanofluid

3.3 Mathematical Formulations

Taw was applied here was Newton's cooling of law which is based on the situations such as bulk of the temperature, temperature of the surface and inlet and outlet temperature assessed from the research. The heat transfer coefficient is specified by the equation 3.1:

$$h = \frac{q''}{Tw - Tb} \tag{3.1}$$

Where T_w, T_b and q'' indicates the wall of the temperature, bulk of the temperature, surface temperature and the thermal flux, particularly T_b is described as $\frac{To+Ti}{2}$ where T_o and T_i represents outlet temperature and inlet temperature for the liquid flow:

The thermal flux was measured in this equation 3.2

$$q'' = \frac{Q}{A} \tag{3.2}$$

In which Q described as the input of the power ($P = VI$) produced by the supply of power and A is known as the surface area of inner of the heated segment of the tube. The formula used for the area is $A=\pi DL$. For further calculations hydraulic diameter, D_h were also used in turbulent flow and internal flow glitches for heat transfer. In this case the D_h formula used in the square pipe is ($D_h = \frac{4a^2}{4a} = a$) where it can be seen that a is the width of the square pipe.

The Nusselt number is a dimensionless specification given in the equation 3.3

$$Nu = \frac{hD_h}{k} \tag{3.3}$$

where D_h, h and K displays hydraulic diameter, convective heat transfer coefficient and thermal conductivity in that order. Reynolds Number was determined utilizing the equation 3.4:

$$Re = \frac{\rho v D}{\mu} \tag{3.4}$$

where μ, v, and ρ depicted as dynamic viscosity of the fluid, velocity, and density accordingly.

Empirical interrelations for Nusselt number proposed (Petukhov, 1970) (Duangthongsuk & Wongwises, 2008) for single-phase fluids were formulated in the equation 3.5 below where *Re* is known as Reynolds number, *Pr* is identified as the Prandlt number and *f* is recognized as the friction factor. Equation can be utilised if $3 \times 10^3 < Re < 5 \times 10^6$ then $0.5 \leq Pr \leq 2000$

$$Nu = \frac{\left(\frac{f}{8}\right)(Re - 1000)Pr}{1 + 12.7\left(\frac{f}{8}\right)^{0.5}\left(Pr^{\frac{2}{3}} - 1\right)} \tag{3.5}$$

Nusselt number can be used in equation 3.6, if $10^4 < Re < 5 \times 10^6$ and $0.5 \leq Pr \leq 2000$

$$Nu = \frac{\left(\frac{f}{8}\right)RePr}{1.07 + 12.7\left(\frac{f}{8}\right)^{0.5}(Pr^{2/3} - 1)} \tag{3.6}$$

Nusselt equation can be utilised as, if $Re > 10^4$ and $0.7 < Pr \leq 160$

$$Nu = 0.023Re^{0.8}Pr^{0.4} \tag{3.7}$$

Friction factor or known as (*f*) were determined in the equation (3.5) and (3.6) using the connection proposed by Petukhov (Petukhov, Heat Transfer and Friction in Turbulent

Pipe Flow with Variable Physical Properties, 1970). The formulation is shown in equation 3.8

$$f = (0.79 LnRe - 1.64)^{-2} \tag{3.8}$$

Nonetheless, If $10^4 < Re < 10^6$, the friction factor for the GO/DW and DW were calculated based on the pressure drop throughout the test segments in the equation 3.9:

$$f = \frac{\Delta P}{\left(\frac{L}{D}\right)\left(\frac{\rho v^2}{2}\right)} \tag{3.9}$$

The experimental connection were exploited to determine the friction factor that were used for base liquid originally designed by Petukhov (B.S.Petukhov, Volume 6, 1970) and Balsius (Blasius, 1908) which is largely used nowadays. It is shown in equation 3.10

$$f = (0.3164 Re^{-0.25}) \tag{3.10}$$

Pumping power which is used for turbulent region can be equated in the equation 3.11:

$$\dot{W} = 0.158\left(\frac{4}{\pi}\right)^{1.74}\left(\frac{L\dot{m}^{2.75}\mu^{0.25}}{\rho^2 D^{4.75}}\right) \tag{3.11}$$

By introducing $\rho = \frac{\dot{m}}{V}$ and $v = \frac{\dot{V}}{A}$ into the equation (3.4) and replacing its outcome into the equation (3.11), the relative pumping power may be used for the constant values of the Reynolds number that where W_{bf} and W_{nf} i the pumping power for the base fluid and also used for (GO) based on distilled water nanofluid, below.:

$$\frac{\dot{W}_{nf}}{\dot{W}_{bf}} = \left(\frac{\rho_{bf}}{\rho_{nf}}\right)^2 \left(\frac{\mu_{nf}}{\mu_{bf}}\right)^3 \quad (3.12)$$

Based on the formula specified, value of Reynolds number, heat transfer coefficient, heat flux, Nusselt number and friction of loss were calculated.

3.3.1 Uncertainties in Experimentation Set-Up

Parameters such as heat transfer measurements, flow rates, velocity, temperature, differential pressure, Reynolds, Russelt numbers were investigated with proper tools. In this Clove treated (GO) experiment. The repeatability displays that all the values are within the limitations of uncertainty. The uncertainties that were happened during the measurement of the parameters were recorded n Table 3.1

Table 3.2: Uncertainties detected during the experimentation of parameters

Criterions	Symbol Indications	Values in percentages %
Temperature of Inlet	T_{in}	± 0.15
Temperature of Outlet	T_{out}	± 0.15
Mass Flow rate	v	± 1.8
Differential of Pressure	h_h	± 2.3
Voltage	V	± 0.16
Current	I	± 0.16

CHAPTER 4: RESULT AND DISCUSSION

4.1 Heat Transfer Analysis Of (GO)-Distilled Water

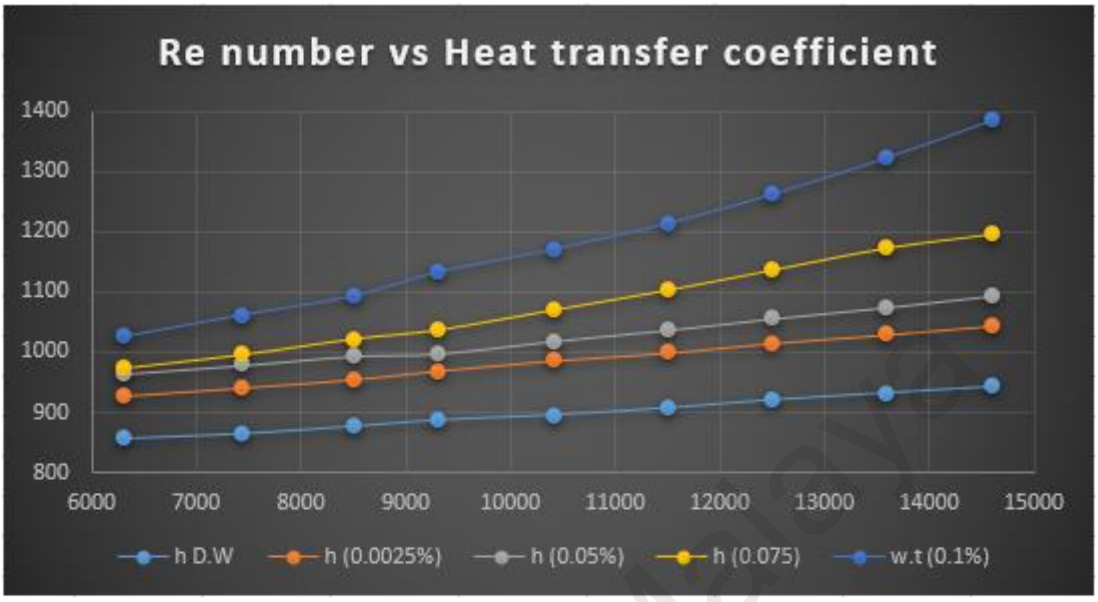

Figure 4.1: Re number against Heat Transfer Coefficient

First of all, recent analysis nanoparticles such as (GO)-distilled water are used in the square pipe cross section. Samples are generally based on distilled water and four different types of concentrations for (GO)-distilled water. Moreover, concentration varies from below 0.025 w% up to 0.1 w%, as be seen in the discussion. As shown in the figure 4.1, heat coefficient for the 0.1%wt concentration were recorded the highest among the other concentrations and distilled water was found out lowest.

It was due to the greater dynamic (GO)-distilled water nanofluid at the larger concentration and strain of fluid motion in inputs of lower heat. At advanced heat inputs, the propelling force for fluid motion rises and the effect of high dynamic viscosity weakens. As things stand, the convective of the heat transfer coefficient is becoming higher together with the velocity of the fluid and the concentration of the molecules, should specify progression in the heat transfer (GO)-distilled water. The increased percentage values of heat transfer coefficient in each of the concentrations are

9.7%,14.06%, 20.2% and 32.1% which indicates the increase in the concentrations as it went higher.

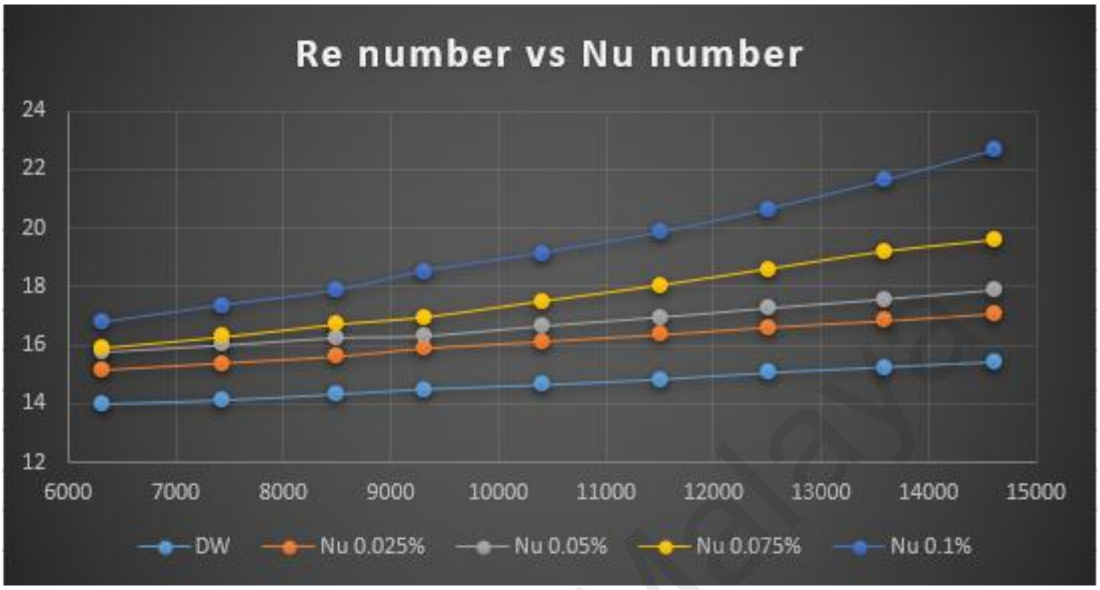

Figure 4.2: Re number against Nu number

The experimental results for the reliance of the Nusselt number (Nu) on the Reynolds number (Re) are shown in Fig. 4.2 for the square cross section pipe. The graph indicates that (Nu) number increases along with increased numbers of (Re). 0.1wt% of concentration had been shown the maximum and the lowest recorded plot was distilled water.

Figure 4.2 shows the increment in all of the concentrations and the graph is moving upwards. The increased heat transfer coefficient value percentages in each of the concentrations are 9.7%,14.06%, 20.2% and 32.1% which indicates the increase in the concentrations as it went higher.

According to the graph, the values shows that heat transfer performance in (GO)-distilled water is levels above than the distilled water. Nusselt number strengthens with an intensification of the fraction of the volume in the nanoparticle. This vogue becomes higher in the large Reynolds number segment. It is documented that the Nusselt number develops with the growth of Reynolds number and also with the increment of weight concentration of nanoparticles. It happens because the nanofluids surrounds with suspended nanoparticles, which hold a higher conductivity in contrast to the base fluid. The Nusselt number of (GO)-distilled based water nanofluid is continuously enriched because of the thermo-physical of nanoparticles distinctiveness and particles of Brownian motion.

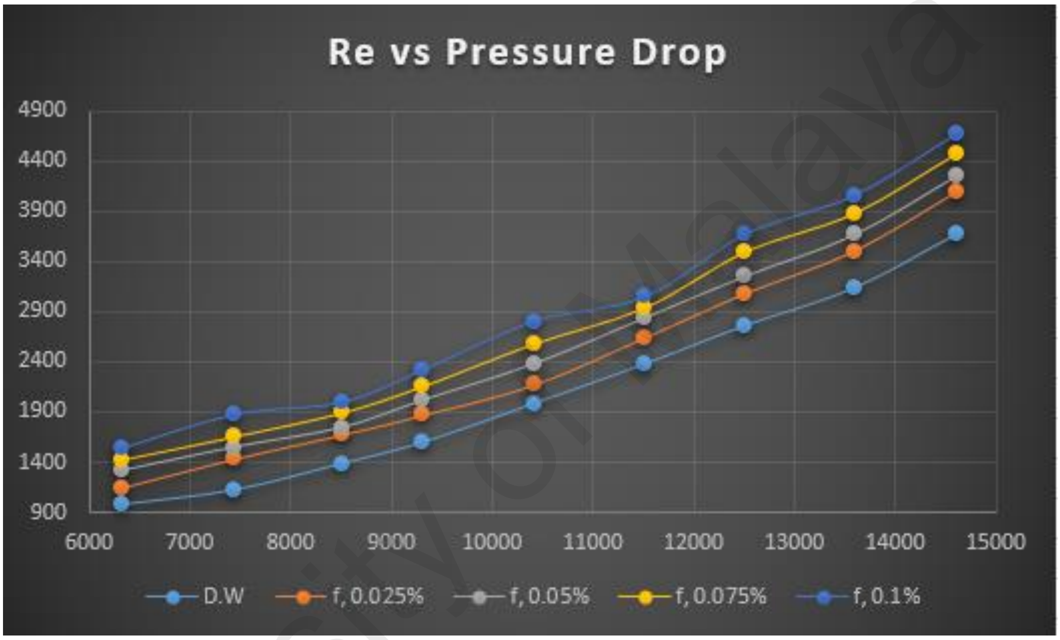

Figure 4.3: Re against Pressure Drop

Figure 4.3 indicates the relationship between (Re) and Pressure Drop in the square cross section of the pipe. It shows that where never the pressure drops increases, the number of (Re) number also increases. The largest data recorded were in 0.1% wt of concentration where else the lowest is distilled water. The density is a significant parameter for the increased pressure drop of the nanofluids. Mean ratio of increasing the pressure drop with increasing (GO) concentrations are 13.4%, 20.9%, 28.6% and 36.5% for each of the concentrations respectively. The comparison shows that there is slightly significant rise in the pressure drop among all the other concentrations and due to the particles of (GO) and viscosity of the nanofluid concentration which leads to a higher rise for increased concentration. The pressure drop also was influenced by friction factor which also hinge on the flow regime and the tube's roughness.

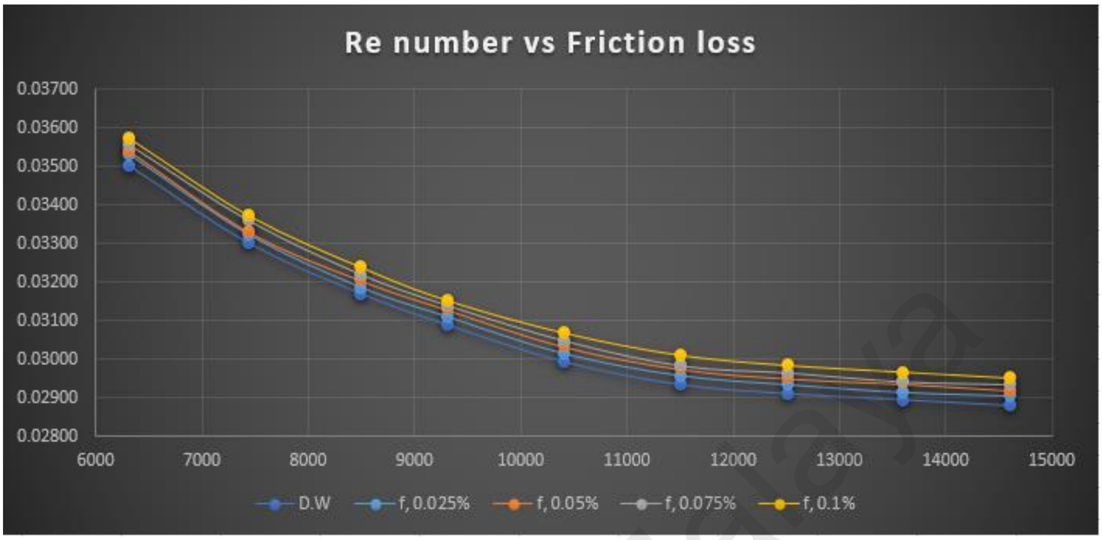

Figure 4.4 : Re number against Friction Loss

Relationship between (Re) number and friction loss in the cross section of square pipe was displayed in the figure 4.4. As shown in the graph, 0.1% wt of (GO)-distilled water was the maximum value recorded among all and lowest was distilled water. But the trend of graphs shows that friction loss is decreasing while Reynolds number is increasing. Friction factor mostly depends on the concentration of the nanofluids and the velocity of the flow. Studies shows that the mixing effects of the particles near the wall, particle migration, particle shape, and the Brownian motion of the particles had a massive impact of on the friction factors.

These are the causes which made the particles to move with a greater force in the higher concentration of nanofluids. It has been found out friction loss for 0.025wt%, 0.05wt%, 0.075wt%, and 0.1wt% concentration was increased by 0.71%, 1.26%,1.72% and 2.3% when compared to the friction factor of distilled water. This happens due to the working fluid velocity which carry a main role in determining the pressure drop and also includes friction factor in heat transfers of this nanofluids.

CHAPTER 5: CONCLUSION

Following this study, graphene oxide through advance/modified hummer method was materialized with better heat transfer and hydrodynamic properties. Preparation of the graphene oxide in distilled water was set at four types of concentrations which are 0.025%, 0.05%, 0.075% and 0.1 wt.%. The study of this preparation was done on the cross section of the square pipe.

Based on the results, comparison was made on the (GO)-distilled water based nanofluids against AL3O2/DW based nanofluids and later found out that (GO)-distilled water in the nanofluids for the cross section of the square pipe displays the largest heat transfer compared at the extreme value of the Reynolds number. The underlying motive behind this upgrading is that the (GO) offers a maximum surface area in the base fluid which could transmit more heat. Beyond that, both (GO)-distilled water and AL3O2/DW nanofluids were producing to maximum heat transfer at the greater weight percentage.

There was a clear expansion in the convective heat transfer coefficient along with Nusselt number for the (GO)-distilled water when the Reynolds number rises from 6300 to 14613 which the flowrate begins from 3/min until 7L/min. It shows that the rise in thermal heat transfer coefficient and Nusselt occurs at a 0.1% wt with an ultimate enhancement. The friction factor of the (GO)-distilled water enlarged by 0.71% to 2.3% as against to the base fluid but it gets lesser when flowrate increases due to fluid hurries into the pipe with soaring velocity that directs to reduce the friction between layer of the fluid and walls of the channel.

In summation, it can be concluded that water-based graphene oxide nanofluid has a wonderful prospect of being using as an alternative heat transfer fluid and slightly better than AL3O2/DW nanofluid for better enhancement of heat transfer.

5.1 Recommendation for Future Work

Vast majority of studies on graphene nanofluid were operated at ambient temperatures. More tests on the physiognomies of graphene nanofluid in high temperatures are obligatory to be completed so that to own a finer comprehension of the behavior and heat transfer of graphene nanofluids. It can be also pursued by performing simulation in more details so that comparisons can be made with different kind of shapes in heat exchanger as well as several types of nanofluids.

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