UNIVERSITI PUTRA MALAYSIA

HEAT TRANSFER PERFORMANCE OF ALUMINIUM OXIDE NANOFLUIDS FLOW IN A CIRCULAR TUBE

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By

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HEAT TRANSFER PERFORMANCE OF ALUMINIUM OXIDE NANOFLUIDS FLOW IN A CIRCULAR TUBE.

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January 2017

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Nanofluid is a stable mixture of nanoparticles with less than 100 nm which is dispersed into base fluids such as ethylene glycol (EG), water (W) and engine oil with relatively low thermal conductivity when compared with metal particles. The suspension of nanoparticles into base fluids is introduced as one of the passive methods to enhance thermal performance. The engineered coolant namely, the nanofluids are developed by various researchers with the aim to meet the challenges of improving the efficiency of cooling systems and subsequently, reduce the energy waste of the system. Consequently, this reduces the costs and emissions of greenhouse gases, which have become one of the major tasks for the industry. However, the study of forced convection heat transfer in different base mixtures is yet to be compared based on their performance under similar operating conditions. Therefore, this study endeavours to investigate the properties of Al_2O_3 (aluminium oxide) nanoparticles dispersed in different bases with volume ratios of 40:60, 50:50 and 60:40 (W:EG) and their ability in optimizing the performance of heat transfer in forced convection systems in circular pipes by simulation due to their properties such as high resistance for corrosion and wear with good thermal conductivity. In this research, the heat transfer performance of nanofluids is analyzed through a numerical method using the CFD (computational fluids dynamic) software. Initially, the Al_2O_3 nanofluids are formulated by the two-step method for volume concentrations of up to 2.0% at three different volume ratios of (W:EG). The thermo-physical properties of Al_2O_3 nanofluids namely, the thermal conductivity and viscosity are measured using the KD2 Pro thermal analyzer and Brookfield LVDV-III Ultra Rheometer respectively for a temperature range of 30 to 70 °C. The thermo-physical properties measurement of nanofluids is evaluated as part of the input parameters for the simulation work. The heat transfer coefficient, Nusselt number, friction factor and wall shear stress are collected by simulation using the realizable (k-ε) method to analyze the effects of volume concentration, working temperature and base volume ratio towards the heat transfer performance of Al_2O_3 nanofluids. The highest thermal conductivity enhancement of 12.6% were obtained at 2.0% volume concentration when compared to 50:50 (W:EG) base mixture. Whereas the highest viscosity enhancement of 248.8% were obtained at 2.0% volume

concentration and 40:60 (W:EG) base mixture. The highest enhancement ratio for the heat transfer coefficient and the Nusselt number of Al_2O_3 nanofluids are 76.5% and 61.6% respectively at 60:40 (W:EG), 2.0% volume concentration and 30 °C. An enhancement ratio of 16.1 times is shown for wall shear stress for Al_2O_3 nanoparticles dispersed in 40:60 (W:EG) at 2.0% volume concentration and 70 °C. The Al_2O_3 nanofluids in 60:40 (W:EG) base fluid with 2.0% volume concentration have lower wall shear stress and higher heat transfer coefficient enhancement compared to 50:50 and 40:60 (W:EG) base nanofluids. Hence, it is recommended for various applications in the engineering field.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

PRESTASI ALIRAN PEMINDAHAN HABA NANOBENDALIR ALUMINIUM OKSIDA DALAM TIUB BULAT

Oleh

CHIAM HUEY WEN

Januari 2017

Pengerusi : Profesor Madya Nor Mariah bt. Adam, PhD, Ir.
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Bendalir nano ialah satu campuran stabil yang mengandungi nanopartikel bersaiz daripada 100 nm yang diserakkan ke dalam bendalir asas seperti etilena glikol (EG), air (W) dan minyak enjin. Pendingin seperti bendalir nano dibangunkan oleh ramai pengkaji dengan sasaran untuk memenuhi cabaran meningkatkan kecekapan sistem pendinginan supaya dapat mengurangkan pembaziran tenaga sistem. Walaubagaimanapun, kajian pemindahan haba perolakan paksa dalam campuran bendalir asas yang berbeza belum dibandingkan berdasarkan prestasi mereka di bawah keadaan kendalian yang serupa. Lantaran itu, kajian ini berusaha menyiasat sifat nanopartikel Al_2O_3 (aluminium oksida) yang disebarkan dalam bendalir asas yang berbeza dari segi nisbah isi padunya iaitu, 40:60, 50:50 dan 60:40 (W:EG), dan juga kemampuan mereka mengoptimumkan prestasi pemindahan haba dalam sistem perolakan paksa menggunakan simulasi. Dalam penyelidikan ini, prestasi pemindahan haba bendalir nano dianalisis melalui satu kaedah berangka yang menggunakan perisian dinamik berkomputer (CFD). Pada mulanya, bendalir nano Al_2O_3 dirumuskan menggunakan metode dua langkah untuk tumpuan jumlah sehingga 2.0% pada tiga nisbah isipadu berbeza. Sifat-sifat termo-fizikal bendalir nano Al_2O_3, iaitu kekonduksian terma dan kelikatan diukur menggunakan KD2 Pro penganalisis terma dan Brookfield LVDV-III Ultra Rheometer untuk julat suhu 30 sehingga 70 °C. Ukuran sifat-sifat termo-fizikal bendalir nano dinilaikan sebagai sebahagian daripada parameter input untuk kerja simulasi menggunakan kaedah "realizable (k-ε)". Pekali perpindahan haba, nombor Nusselt, faktor geseran dan tegasan ricih dinding dihimpun secara simulasi untuk menganalisis kesan kepekatan isipadu, suhu kerja dan jumlah nisbah asas ke atas prestasi pemindahan haba bendalir nano Al_2O_3. Peningkatan kekonduksian terma yang tertinggi ialah 12.6% dari 2.0% kepekatan isipadu berbanding dengan 50:50 (W:EG) campuran asas. Manakala peningkatan kelikatan yang tertinggi ialah 248.8% dari 2.0% kepekatan isipadu adalah dalam nisbah 40:60 (W:EG) campuran asas. Nisbah peningkatan tertinggi bagi pekali perpindahan haba dan nombor Nusselt bendaliran nano Al_2O_3 ialah 76.5% dan 61.6% pada 60:40 (W:EG), 2.0% isipadu kepekatan dan 30 °C. Nisbah tambahan 16.1 kali ditunjukkan oleh tegasan ricih dinding untuk nanopartikel Al_2O_3 yang diserakkan dalam 40:60 (W:EG) dalam 2.0%

isipadu kepekatan dan 70 °C. Bendalir nano Al_2O_3 dalam campuran asas dengan nisbah 60:40 (W:EG) dan 2.0% isipadu kepekatan menunjukkan pengurangan tegasan ricih dinding dan peningkatan pekali permindahan haba yang lebih banyak berbanding dengan 50:50 dan 40:60 (W:EG) nano bendalir asas. Maka, ia disyorkan untuk pelbagai kegunaan dalam bidang kejuruteraan.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF SYMBOLS

q	Local heat flux, W/m^2
k	Thermal conductivity, W/m.K
ΔT	Temperature differences, K
$\emptyset$	Volume concentration,
m_p	Mass of particles, kg
ρ_p	Density of particles, kg/m^3
V_{bf}	Volume of base fluids, m^3
V_p	Volume of particles, m^3
μ_r	Viscosity ratio
k_r	Thermal conductivity ratio
k_{nf}	Thermal conductivity of nanofluids, W/m.K
μ_{nf}	Viscosity of nanofluids, kg/m.s

LIST OF ABBREVATIONS

Nomenclature

Ag	Silver
Al_2Cu	Aluminium Copper Alloy
Ag_2Al	Aluminium Silver Alloy
Al_2O_3	Aluminium Oxide
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Material
BR	Base fluid ratio
C_p	Specific heat, J/kg.K
CFD	Computational Fluids Dynamic
Cu	Copper
CuO	Copper oxide
D_h	Hydraulic diameter, m
EG	Ethylene glycol
Fe_2O_3	Iron Oxide
FVM	Finite Volume Method
G_k	Generation of turbulent kinetic energy
G_b	Generation of turbulent kinetic energy in buoyancy
k	Thermal conductivity, W/m.K
m	Mass, kg
MgO	Magnesium Oxide
M_t	Mach Number
Re	Reynolds number
$\overline{P}$	Time average mean value in pressure, Pa
Q	flow of heat per unit area per unit time,W
RNG	Renormalization Group
SiC	Silicon Carbide
SiO_2	Silicon Oxide
$\overline{T}$	Time average mean value in temperature, K
$\overline{T'}$	Turbulent fluctuation for temperature, K
TiO_2	Titanium Oxide
u_{in}	Inlet velocity, m/s
$\overline{V}$	Time average mean value in velocity, m/s
$\overline{V'}$	Turbulence fluctuation in velocity, m/s
W	Water
Y_M	contribution of the fluctuating dilatation in compressible turbulence to the overall dissipation rate
ZnO	Zinc Oxide

$\rho\overline{V'V'}$	Turbulent shear stress, Pa
$\rho C_P\overline{V'T'}$	Turbulent heat flux,W/m^2

Greek Symbol

∇	Derivative
μ	Dynamic viscosity, kg/m.s
μ_t	Eddy viscosity, kg/m.s
σ_k	Effective turbulent Prandlt number for kinetic energy
σ_ε	Effective turbulent Prandlt number for rate of dissipation
ρ	Density, kg/m^3
ε	Rate of dissipation, J/kg.s
φ	Volume fraction
ϕ	Volume concentration, %

Subscripts

bf	Base fluids
k	Kinetic energy
nf	Nanofluids
p	Particle

CHAPTER 1

INTRODUCTION

1.1 Background study

Thermal energy is an engineering practice that is concerned with the rate of heat transfer either transferring the heat into or out from the system (Y.A Cengel, 2007). A deeper understanding on heat transfer mechanisms is required to design a practical invention involving heat transfer. Due to the wake of the world oil crisis, its price and depletion of resources, fuel consumption need to be reduced. One way to enhance the heat dissipation performance system is to develop and help decrease the weight of the cooling equipment while reducing the fuel consumption in several systems such as radiator (Leong et al., 2010), microelectronic (Daungthongsuk & Wongwises, 2007) nuclear reactor (Hadad et al., 2013) and building heating and cooling system (Kulkarni et al., 2009). For example, increase the heat flow of microprocessors by using nanofluids can reduce the size with more heat transfer rate. The heat exchanger size can be reduced when the thermal heat transfer rate increases. Thus the current and envisioned application in such miniaturized devices call for nanofluids to remove heat as efficiently as possible (Shanthi et al., 2012). For nuclear power industry, by increasing the forced convective heat transfer, it is possible to improve 1% efficiency, it can reduce 320 billion kWh of electricity of the chiller system in a nuclear system (Shinpyo Lee & Choi, 1996). These advanced systems require higher heat fluxes with improved energy efficiency and enhanced heat dissipation. Thus, improvement for heat transfer efficiency of conservative fluid is obligatory to satisfy the necessities of thermal management.

Water, oil and ethylene glycol are the traditional coolants used as thermal fluid in the heat transfer process of a system (Kakac & Pramuanjaroenkij, 2009). However the effectiveness of using traditional coolants in heat transfer needs to be enhanced. This is due to the low thermal ability of these coolant compared to most of the metals with higher thermal conductivity (Ebrahimi et al., 2010). By suspension of the metal particles into traditional coolants, it will enhance the efficiency of thermal conductivity; bringing greater heat transfer coefficient. The concept of adding micro sized metal oxide into the base fluids was introduced by J.C. Maxwell (1881). Numerous mechanical experts like Ahuja and Singh (1975) and A.E. Bergles (1985) evaluated the heat transfer performance by suspending micro sized metal particles into traditional coolants. Results show that there is enhancements in heat transfer but the metal particles have corroded the wall pipe and cause clogging. This required higher pumping power and this is costly and not safe (Das et al., 2007).

With the invention of nanoparticles, Choi (1995) suspended the nanoparticles in base fluids and named it as nanofluids. Nanofluid is a stable mixture of nanoparticles with less than 100 nm dispersed into the base fluids. The engineered coolant, namely, the nanofluid is developed by various researchers with the aim to meet the challenges of improving the efficiency of the cooling system and subsequently, reduce the energy waste of the system. The result shows that nanofluids enhanced the thermal properties and heat transfer rate compared to the traditional coolants. Similar research was done by S Lee et al. (1999) and found that the 13 nm aluminum oxide (Al_2O_3) nanoparticles dispersed in water have increased thermal conductivity by 30% compared to water at 4.3% volume concentration. Various applications use nanofluids such as transportation (Singh et al., 2006), cooling electronic component (Jang & Choi, 2006) and solar absorption (Otanicar et al., 2010).

The researchers focused the study by reducing the particle size to nano-size and proved its effectiveness in achieving heat transfer enhancements (Xuan & Li, 2000), (Xuan & Li, 2003) and (Khaled & Vafai, 2005). Chopkar et al. (2008) observed that, when the nanoparticle was dispersed in water and ethylene glycol, the thermal conductivity of nanofluid is higher than the base fluid. The solid particles in ultra-fine sizes were able to suspend uniformly in the base fluids thus, improving the thermal conductivity of the liquid. From the review of Azmi et al. (2016) and Godson et al. (2010), the thermo-physical properties such as thermal conductivity and dynamic viscosity of nanofluids is enhanced compared to traditional coolants.

A few studies have reported the convective heat transfer of different nanoparticles dispersed in conventional fluids such as water, oil and ethylene glycol using Computational Fluids Dynamic (CFD). CFD is a method to investigate the fluids flow of the system by using numerical and algorithm analysis, which is a standard implement to design and analyze the engineering problems involving multiphysics phenomena. With the numerical results, the researcher is able to preview the solution of the problem, while improving the system before the experimental stage. For example, Leong et al. (2010) studied heat transfer performance of copper oxide (CuO) dispersed in ethylene glycol flow in flat tubes. The results show that the heat transfer coefficient have increased about 14% at 2% volume concentration compared to base fluids. Mohanrajhu et al. (2015) also analyzed the heat transfer performance of aluminum oxide (Al_2O_3) nanoparticle dispersed in (40:60) W:EG base mixture flow in flat tubes. About 17% increment was found in the heat transfer coefficient at 1% volume fraction. Abdolbaqi et al. (2014) evaluated the heat transfer performance of three different nanoparticles, which included aluminum oxide (Al_2O_3), copper oxide (CuO) and titanium oxide (TiO_2) dispersed in water flow in horizontal ducts. A positive trend was observed in heat transfer coefficient when the volume concentration and Reynolds number increased.

Besides the flat tube and horizontal duct, most of the studies used circular pipes to analyze the heat transfer performance of nanofluids. A flat tube is a light and compact design which can reduce the space usage. It is also less expensive for fabricating (Fraas, 1989). Round tube provides a very strong joint with the header plates due to the low-surface-to-volume ratio (Thulukkanam, 2013). From the review, the heat transfer coefficient of a flat tube is higher than a round tube. From the research of Adnan M Hussein, K V Sharma, et al. (2013), they found that the heat transfer coefficient of titanium oxide (TiO_2) in flat tubes is higher than circular tubes. This result is agreed by the researcher that compared the heat transfer coefficient of the flat tube with circular tube (Adnan M. Hussein et al., 2013; Mohanrajhu et al., 2015). When compared to the pressure drop, Mohanrajhu et al. (2015) found that the pressure drop of the flat tube is much higher compared to the circular tube when Al_2O_3 (aluminum oxide) nanoparticles are dispersed in 40:60 (W:EG) base fluid. While from the research of Safikhani and Abbassi (2014), the heat transfer coefficient and wall shear stress increased when the flattening increased at aluminum oxide (Al_2O_3) nanoparticle dispersed in water in mixture phase with laminar flow. A similar result from Zhao et al. (2016) showed that the heat transfer coefficient and pressure loss have a significant enhancement when the tube flattening is decreased, when aluminum oxide (Al_2O_3) nanoparticles are dispersed in water with laminar flow.

Hence, to analyze the fundamental of heat transfer performance of nanofluids that suitable in most of the application, the circular tube is more suitable in this research. This is because the circular cross section can withstand large pressure difference between the inside and the outside of the pipe without undergoing significant distortion. Meanwhile the non-circular pipes are usually applied in the heating and cooling system of buildings as the pressure is relatively small (Yunus A Cengel, 2010). For example, Lotfi et al., (2010) analyzed the heat transfer performance of iron oxide (Fe_2O_3) nanoparticles dispersed in water and found that the mean heat transfer coefficient is about 29% higher compared to the base fluid at 0.6% volume concentration at 20,000 Reynolds number. Youssef et al., (2014) evaluated the heat transfer performance of aluminum oxide (Al_2O_3) nanoparticles dispersed in water and found that the average heat transfer coefficient increases when the volume concentration increase. Naik et al., (2013) had analyzed the heat transfer performance of copper oxide (CuO) dispersed in (70:30) water–propylene glycol mixture base fluids and found that the heat transfer coefficient increases when the volume concentration is increased. However, there are limited studies on the heat transfer performance of nanoparticles dispersed in water-ethylene glycol mixture base fluid. Therefore, a research has to be conducted to fullfil the scope of the thesis. Varied volume concentrations in several flow regions was conducted to analyze and study the aptitude and ability of the nanofluids as a new class of thermal fluid.

1.2 Problem Statement

Energy efficiency has been implemented in many countries worldwide in order to reduce energy consumption, consequently reducing the cost and the emissions of greenhouse gasses which have become one of the major tasks for the industry. Some process is even affected qualitatively by the actions of enhanced heat transfer. In Malaysia, energy efficient products can be applied in many electric appliances such as refrigerants, air conditioners, lightings and televisions with the regulation being governed by the Malaysian Energy Commissioner. Parallel with the technological development in recent years and advanced research approaches, the efficiency of energy consumption has been improved in building systems, automotive systems, industrial process heating, cooling systems in petrochemicals, textiles, pulp and paper, chemical and other processing plants.

Considering the significance of heat transfer in cooling systems, the traditional fluids have been utilized for few centuries to transfer heat out of the system. Hence, enhancement in heat transfer coefficient leads to miniaturization of thermal equipment, which has become more important. To overcome the current heat dissipation problem, two different methods can be used to enhance the ability of the fluids, which are the active and passive method. Traditional coolants such as water, ethylene glycol and engine oil have relatively low thermal conductivity when compared with metal particles. The suspension of nanoparticles into base fluids is introduced as one of the passive methods to enhance the thermal performance. The convective heat transfer coefficient is strongly affected by the surface of the solid, fluid thermal physical properties and the type of flow. Vajjha et al. (2009) found that there is an enhancement in thermal conductivity in the range of 40% to 69% for aluminium oxide (Al_2O_3), copper oxide (CuO) and zinc oxide (ZnO) dispersed in 40:60 (W:EG) base mixture. Elias et al. (2014) mentioned that a positive trend is observed when nanoparticles are suspended in host fluid towards the thermal conductivity and heat transfer performance compared to traditional fluids.

However the long term stability of nanoparticle dispersion, errosion of heat device and increase in pressure dop is one of the main concerns of the industries using nanofluid coolants (Bhogare and Kotahwale 2013). Aluminium Oxide nanoparticles—with its high corrosion, wear resistance and good thermal conductivity that can reduce the thermal shock resistance of the nanoparticles—are able to reduce the issues of nanofluids (Ramsden, 2000). However, the complication of the particle size, material properties and volume concentration on heat transfer coefficient are not completely understood. Hence, to investigate the forced convective heat transfer of aluminium oxide (Al_2O_3) nanofluids, the thermo-physical properties has to be evaluated. To understand the overall heat transfer performance of nanofluids, the particle properties, base fluid properties and the operating condition of nanofluids are evaluated. Limited literature is available on the evaluation of forced convection heat transfer using nanofluids in water-ethylene glycol based mixtures.

Manufacturers following American Society Technology and Materials (ASTM) International standards (2015) highlighted in ASTM D4985-10 (2015) that the percentage of base fluids should be 60:40, 50:50 and 40:60 (W:EG). This is because when the ethylene glycol concentration is less than 40%, they will be more prone to corrosion protection and freezing as ethylene glycol acts as an anti-freezing agent. Meanwhile, if the ethylene glycol concentration is more than 60%, the heat transfer performance will decrease due to the high viscosity and reduced freeze protection as engine parts could be damaged or not functional in the efficient condition. The ASTM is provided in APPENDIX D for further details. For regions with extreme temperature conditions, the mixture of ethylene glycol and water is more preferably used as the thermal fluid in the heating and cooling systems for buildings and automobile radiators (Sundar et al., 2013b). Thus, the heat transfer performance using nanoparticles dispersed in 60:40, 50:50 and 40:60 (water-ethylene glycol) is evaluated and compared under similar conditions. Therefore, studies of three different ratios of water-ethylene glycol based mixtures are essential to understand the actual forced convection heat transfer of the nanofluids. The forced convective heat transfer of the nanofluids in three different ratios is analyzed for future development of nanofluids in applied engineering fields at different working temperatures.

A numerical method can evaluate the forced convective heat transfer of nanofluids while reducing the time consumed and cost. Computational fluid dynamics is a software that allows users to predict the impact of fluid flow on the product by numerical analysis. By using the algorithm method, the solution of a problem can be previewed and helped to improve the future and existing product and experiment (Kamyar et al., 2012). With the numerical method, the nanofluids in different parameters and conditions can be predicted before the real application. Different base fluid ratios, temperatures, volume concentrations and Reynolds number can be analyzed. For example, M.S Youssef et al. (2014) that were concerned with the heat transfer performance of aluminium oxide (Al_2O_3) nanoparticles dispersed in water, found that the average heat transfer coefficient increases when the volume concentration increase. Vincenzo Bianco (2010) found that the heat transfer coefficient increased by 5% to 30% when volume concentration increased from 1% to 6% as aluminium oxide (Al_2O_3) nanoparticles is dispersed in water. Bayat and Nikseresht (2012) found that the heat transfer coefficient have increased by about 39% compared to base fluids when aluminium oxide (Al_2O_3) nanoparticles are dispersed in 40:60 (W:EG) base fluids at 6% volume concentration and 100,000 Reynolds number. Namburu et al. (2009) compared three different nanoparticles dispersed in (40:60) W:EG and found that the Nusselt number for copper oxide (CuO), aluminium oxide (Al_2O_3) and silicon oxide (SiO_2) increased when the volume concentration increased. Similar research was done by P. Kumar (2011), Naik et al. (2013), Keshavarz Moraveji and Hejazian (2012), P. Kumar and Ganesan (2012) and Hejazian and Moraveji (2013). Due to the advanced pace and breadth of the research, a truly comprehensive review for nanofluids is probably impossible and certainly far from the scope of this thesis. With varying concentrations of nanofluids in different flow regions with the influence of the base fluid, different interesting studies can be conducted to know the capability and ability of nanofluids as a new class of thermal fluid.

The circular pipe is selected in this research because most of the applications used circular pipes as the medium to transfer the coolant in the system. Using circular pipes can lower the friction factor and pressure loss in turbulent flow compared to other non-circular pipes. Several simulations that were studied showed that the flows encountered in engineering practices are turbulent (Heyhat et al., 2012; Vincenzo Bianco et al., 2010). Besides that, turbulent flow will provide an additional mechanism for momentum and energy transfer, which will help in transporting the energy much more rapidly than molecular diffusion, thus, helping enhance the heat transfer. Hence, a single phase with turbulent flow in a circular pipe is analyzed using the CFD software for this research by referring to the methods of Abdolbaqi et al. (2014).

However, limited researchers are concerned with the effects of base fluids and temperature on heat transfer performance of nanofluids. Therefore, the temperature of 30, 50 and 70 °C are adopted, with aluminium oxide (Al_2O_3) nanoparticles dispersed in 60:40, 50:50 and 40:60 (W:EG) base fluids following the Handbook (2005). The heat transfer performance of aluminium oxide (Al_2O_3) nanofluids with volume concentrations in the range of 0 to 2.0% and turbulent flow in a copper circular tube is analyzed using the CFD simulation software for realizable (k-ε) method.

1.3 Objectives of Study

Overall objective is to determine the best performance of aluminum oxide (Al_2O_3) nanofluids in circular tubes through simulation. The specific objectives of this research are as follows:

i. To formulate aluminum oxide (Al_2O_3) nanofluids and evaluate the thermo-physical properties at different ratios of base mixtures and temperatures.
ii. To investigate the forced convection heat transfer for various base mixture nanofluids at different working temperatures by simulation.

1.4 Scopes and Limitations of Study

For the main purpose of research, the scopes and limitations are as below:

i. The research is only concerned with the simulation study of heat transfer performance of aluminum oxide (Al_2O_3) nanofluids flow in copper circular tubes with turbulence flow.
ii. Thermo-physical properties measured the thermal experimentally are thermal conductivity and dynamic viscosity. Density and specific heat is measured using mixture relation equation.
iii. The measurement of thermal properties of aluminum oxide (Al_2O_3) nanoparticles dispersed in ethylene glycol-water base fluid for volume concentration of 0% to 2% was conducted.
iv. The base fluid of 60:40, 50:50 and 40:60 of water-ethylene glycol was prepared and the thermo-physical properties were measured in temperature range of 30 to 70 °C.
v. The thermo-physical properties of Al_2O_3 nanofluids result is set as the input of the simulation.
vi. The simulation was conducted in temperature range of 30, 50 and 70 °C.
vii. The simulation only concerned with the single phase of forced convective heat transfer.
viii. The flow is limited to the turbulence flow regime (3000-30000) with constant heat flux (8000 W/m^2) flow in a circular pipe.
ix. The simulation used realizable (k-ε) as the turbulence modelling.
x. The circular tube is assumed prefect circular cross-section with smooth surface throughout the 1.5 m pipe.

1.5 Significant Of Study

This study brings positive impacts toward the heat transfer performance of the system by evaluating the properties of the nanofluids in different ratio of Ethylene glycol and water mixture and study the forced convective heat transfer in circular pipes using simulation. Nanofluids can help in reducing heat loss of the system, which will increase the efficiency of the system. Besides that, nanofluids are also able to improve the heat transfer rate, hence, reducing the physical size and weight of the system. Various studies regarding the heat transfer performance of the nanofluids had been done. However, the influence of the base fluids towards the advance heat transfer has not been fully grasped in numerical studies. Before starting the simulation, the thermal physical properties of nanofluids in different ratio of base fluids is studied to understand the properties in various ranges of temperatures and collected the data as the boundary condition in simulation. In applied thermal engineering, the heat transfer performance of nanofluids can be analyzed through simulation by measuring the related parameters that contributed to the forced convection heat transfer studies. To investigate the applicability of the nanofluids, the study covered a wide range of Reynolds number and temperature ranges to fulfill the different conditions in the engineering application. Additionally, there are no establishing literature studies regarding the influence of the ratio of Ethylene glycol and water mixture towards the heat transfer performance in simulation. Although the selected base fluid is studied, no researcher has compared and studied the effects of the ratio of base fluids. Therefore, the study of aluminum oxide (Al_2O_3) nanoparticle dispersed in 40:60, 50:50 and 60:40 EG:W base mixture in simulation is an innovative method to achieve better heat transfer performance. The study is also concerned with the effect of volume concentration and temperature towards the heat transfer performance of the nanofluids to select a suitable combination of nanofluids for the operating system.

1.6 Thesis Overview

First the thesis started with the introduction of the research conducted, which included the background of the nanofluids and the Computational Fluids Dynamic software. Then the reason and purpose of this research was mentioned in this chapter. Next, the chapter discussed about the nanofluids in current heat transfer fields through the established literature. Besides that, the previous experimental and numerical studies regarding nanofluids were also mentioned to help understand the flow and the trend of the heat transfer performance of nanofluids. The following chapter explained the flow and the method of preparation of the nanofluids and the measurement of thermal-physical properties. Then, the simulation process regarding the analysis of the heat transfer performance flow in circular pipes using nanofluids was discussed, which helps to fulfill the objective of this research. After discussion of the methodology, the data was collected and the result and discussion were done in the next chapter. To maintain the accuracy of the results, simple validation was done and the results were discussed to evaluate the effect of volume concentration, temperature and ratio of Ethylene glycol towards the heat transfer performance. Lastly, the thesis ends with the conclusions and summary of the frame of the thesis, which has arisen from this entire research study and suggestion of future work to improve the current research.

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