DEVELOPMENT OF REGRESSION EQUATION FOR HEAT CAPACITY AND DENSITY OF NANOFLUIDS PROPERTIES

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Thesis submitted in fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2010

UNIVERSITI MALAYSIA PAHANG

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I certify that the project entitled "*Development of Regression Equation for Heat Capacity and Density of Nanofluids Properties"* is written by *Mohd Taufiq Bin Awang @ Mohammed.* I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering.

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I hereby declare that I have checked this project and in my opinion this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ACKNOWLEDGEMENTS

First I would like to express my grateful to ALLAH s.w.t. as for the blessing given that I can finish my project.

In preparing this paper, I have engaged with many people in helping me completing this project. First, I wish to express my sincere appreciation to my main thesis supervisor Mr. Wan Azmi Wan Hamzah, for encouragement, guidance, advices and motivation. Without his continued support and interest, this thesis would not have been the same as presented here.

I acknowledge my sincere indebtedness and gratitude to my family for their love, dream and sacrifice throughout my life. My father, mother, brother and sisters that always support, motivation and encourage me. There are no appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to attain my goals. Special thanks should be given to my presentation's panel members. I would like to acknowledge their comments and suggestions, which was crucial for the successful completion of this study.

Thank you all.

ABSTRACT

This research focused on the development of regression equation for nanofluids properties. Nanofluid is the mixing fluid with the nanoparticles size material with effective properties to increase the heat transfer process in such cooling system. This is because base fluid such as water and ethylene glycol that is widely used has poor properties. Beside changes the active factors such as fin or temperature different, nanofluids being develop as a passive factor to increase the heat transfer process. Therefore, it can reduce the space of system. The main idea in this pioneered to increase the heat transfer process but before that the properties should be determined first. Moreover, there is no correlation or standardized value for nanofluid properties since it is new technology, developments of regression equation for nanofluid properties were being conducted. In this study, the properties of nanofluids just focus on specific heat and density. The analysis were using nanoparticles that always been used in industries and also that sited by previous researchers, there are alumina (Al_2O_3), titanium dioxide (TiO_2), copper oxide (CuO), silica (SiO_2), zirconium dioxide (ZrO_2), zinc oxide (ZnO), and silicon carbide (SiC). Development of equations is using FORTRAN with the input data were generated from standard mixture equations. The equation was developed with linear regression with a function of bulk temperature (5°C - 70°C) and volume concentration (0% - 4%) of water-based nanofluids. Four linear equations have been developed; there are specific heat of nanofluids, specific heat ratio of nanofluids, density of nanofluids, and density ratio of nanofluids with average deviation of 2.22%, 2.22%, 2.25% and 2.24%, respectively. The equations were verified with various authors in the literatures and showed a good agreement with average deviation less than 3%.

ABSTRAK

Kajian ini difokuskan pada pembentukkan persamaan regresi untuk sifat nanofluids. Nanofluid adalah cecair pencampuran dengan bahan saiz nanopartikel yang bersifat berkesan untuk meningkatkan proses perpindahan haba pada sistem pendingin. Hal ini kerana cecair asas seperti air dan ethylene glycol yang banyak digunakan memiliki sifat kurang berkesan. Selain perubahan faktor aktif seperti sirip atau suhu yang berbeza, nanofluids adalah sebagai faktor pasif untuk meningkatkan proses pemindahan haba. Oleh kerana itu, dapat mengurangkan ruangan sistem. Gagasan utama dalam merintis untuk meningkatkan proses pemindahan haba tetapi sebelum itu sifat nanofluids harus ditentukan terlebih dahulu. Oleh kerana tidak ada korelasi atau nilai standard untuk sifat nanofluid kerana ia merupakan teknologi baru, perbentukkan persamaan regresi untuk sifat nanofluid sedang dilakukan. Dalam kajian ini, sifat-sifat nanofluids hanya fokus pada haba khusus dan kepadatan. Analisis menggunakan nanopartikel yang selalu digunakan dalam industri dan juga yang diletakkan oleh para penyelidik sebelum ini, iaitu alumina (Al_2O_3), titanium dioksida (TiO_2), kuprum oksida (CuO), silika (SiO_2), zirkonium dioksida (ZrO_2), zink oksida (ZnO), dan silikon karbid (SiC). Pembentukkan persamaan menggunakan FORTRAN dengan kemasukkan data yang dihasilkan dari persamaan campuran standard. Persamaan ini dibangunkan dengan regresi linier dengan fungsi suhu bulk (5°C - 70°C) dan konsentrasi kelantangan (0% - 4%) nanofluids berasaskan air. Empat persamaan linier telah dibangunkan, iatiu haba khusus nanofluids, nisbah haba khusus nanofluids, kepadatan nanofluids, dan nisbah kepadatan nanofluids dengan penyimpangan rata-rata 2,22%, 2,22%, 2,25% dan 2,24%. Persamaan tersebut disahkan dengan berbagai penulis dalam penyelidikan dan menunjukkan kesepakatan baik dengan penyimpangan rata-rata kurang dari 3%.

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LIST OF SYMBOLS

μ	Dynamic viscosity of the fluid, (*Pa·s* or *N·s/m²*)
$\dot{m}$	Mass flow rate, (*kg/s*)
$\dot{Q}_{conv}$	Heat convection rate, (*Watt*)
$\dot{Q}_{steady-state}$	Rate of net heat transfer, (*kJ/s*)
ρ_w	Density of water, (kg/m^3)
ρ_{np}	Density of nanoparticles, (kg/m^3)
ρ_{nf}	Density of nanofluids, (kg/m^3)
C_p	Constant pressure specific heat, (*kJ/kg.K*)
Cp_{np}	Constant pressure specific heat for nanoparticles, (*kJ/kg.K*)
Cp_{nf}	Constant pressure specific heat for nanofluids, (*kJ/kg.K*)
ΔT	Temperature different, (*K*)
T_b	Bulk temperatures
ϕ	Concentration of nanofluids

LIST OF ABBREVIATIONS

FKM	Fakulti Kejuruteraan Mekanikal
FYP	Final year project

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Nowadays, numerous industries are using heat transfer fluid such as water, oil, ethylene glycol in its application such as electronic cooling, heat exchanger and thermal system. Enhancement of heat transfer in such systems is very important from the industrial and energy saving perspectives. The low thermal conductivity of heat transfer fluid, such as water is considered a primary limitation in enhancing the performance and the compactness of such thermal system. This was the main problem that occurs to the high effectiveness of the heat exchanger. Heat transfer in cooling process can be found in many industries. There are two methods to increase cooling rate which is expended surface such as fin and increase the flow rate. However, these two methods have their own limitation such as to increase the flow rate, need to increase the pumping power and undesirable to increase the thermal system management's size.

Therefore, many researchers have been trying in order to increase the heat transfer performance in the common fluid and found the new and innovative technique for improvement of heat transfer using nano-scale particle dispersed in a base fluid, known as nanofluid. Due to small sizes and very large specific surface areas of the nanoparticle, nanofluid has superior properties like high thermal conductivity, minimal clogging in flow passages, long-term stability, and homogeneity.

1.2 PROBLEM STATEMENT

All of the research efforts were mostly focused on the characterization of nanofluid thermal/physical properties. An analysis of relevant works has shown an important dispersion of the thermal conductivity data as obtained from various researchers.

Nguyen et al. (2007) is believed to be due to various factors such as the measuring techniques, the particle size and shape, the particle clustering and sedimentation then the measuring data shows the different with theoretical and between other experiments however it is fit with experiment. On the other hand, it was clearly found that the heat transfer of nanofluid is well higher than that of the conventional heat transfer fluids because of their properties.

From the theoretical point of view, a nanofluids represents a attraction and interesting challenge to the researchers in the field of fluid dynamic and heat transfer, because it appears very difficult, to formulate any combine theory that can reasonably predict the nanofluids behavior by considering it as a multi-component fluid. Since a nanofluids is also, by nature, a two-phase fluid, one may then expect that it would possess some common features with the solid–fluid mixtures. The question from Nguyen et al. (2007) regarding the applicability and the limitation of the classical two-phase fluid theory for use to a nanofluids remains widely open.

Duangthongsuk and Wongwises (2010) in opinion, before stating to determine the heat transfer performance of nanofluids, it is necessary to know about their thermophysical properties. However, there is no specific correlation to determine the properties of nanofluids. Because of that, there are needs to determine using the theoretical or conducting the experiment to predict the properties.

In this study, the regression equation for specific heat and density need to be developing because of it is important to predict the value of specific heat and density for nanofluids within the range that has been fixing. Both regression equations variable consist of concentration and temperature of nanofluids.

1.3 RESEARCH OBJECTIVES

The objective of this research is to develop the regression equation of density and specific heat for nanofluids with a function of concentration and temperature.

1.4 SCOPE OF THE STUDY

1. Thermophysical study of 2 properties which is specific heat and density.
2. Types of nanoparticles are alumina (Al_2O_3), Titanium dioxide (TiO_2), Silica (SiO_2), Zink oxide (ZnO), Silicon carbide (SiC), Zirconium dioxide (ZrO_2) and Copper oxide (CuO) nanoparticles.
3. Properties for nanoparticles and nanofluids.
4. Properties of water base nanofluids only.
5. Development of regression equation with different concentration and temperature.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Duangthongsuk and Wongsises (2010) stated fluids such as water, oil, and ethylene glycol are poor heat transfer properties and they are widely used in many industries nowadays. Nanofluids are modern heat transfer fluids organized by dispersing metallic or non-metallic nanoparticles into fluid. Many researchers demonstrated that nanofluids have created a variety of advantages, such as better long-term stability, greater thermal conductivity compared with millimeter or even micrometer sized particle.

Nanofluid is a pioneering heat transfer fluid with better potential for enhancing the heat transfer performance. Many pioneers have been made to study its thermophysical properties which is important before determine the heat transfer performance.

Basically, the main idea is to disperse small solid particles in common base liquids in order to enhance their heat transfer properties. However, before starting to determine the heat transfer performance of nanofluids, it is necessary to know about their thermophysical properties.

Know that, viscosity, density and specific heat which are the properties of nanofluids that are important transport properties. From the researcher, Nguyen et al. (2007) stated publications about the viscosity and specific heat of nanofluids are still bare compared with thermal conductivity properties. From the theoretical, Nguyen et.

al, (2007) also stated that a nanofluid represents a fascinating new challenge to researchers in fluid dynamics and heat transfer because of the fact that it appears very difficult, if not practically impossible, to formulate any theory that can reasonably predict behaviors of a nanofluid by considering it as a multi-component fluid.

Chandrasekar et al. (2010) found that, in general, dynamic viscosity of nanofluid increases considerably with particle volume concentration but clearly decreases with a temperature increase. Then, they also state that the hysteresis phenomenon has raised serious doubts regarding the reliability of using nanofluids for heat transfer enhancement purposes.

2.2 PROPERTIES OF FLUIDS

A fluid is any substance which flows because its particles are not rigidly attached to one another. The properties outlines below are general properties of fluids which are of interest in engineering. These properties can readily found at many reference book.

2.2.1 Viscosity

Viscosity is the one of properties that is needed to know to determine heat transfer rate of fluid. Viscosity is a scientific term describing the internal friction of a fluid or gas. Both have adjacent layers, and when pressure is applied, the friction between layers affects how much the substance will respond to external force. Yunus A. Cengel, (2006) said in his book, viscosity, in its simplest form, can be evaluated by the thickness of a substance. A general rule is that gases are less viscous than liquids, and thicker liquids exhibit higher viscosity than thin liquids.

2.2.2 Density

Yunus A. Cengel, (2006) also explicit about a material's density and it is defined as its mass per unit volume. It is, essentially, a measuremement of how tightly matter is crammed together or can also refer to how closely "packed" or "crowded" the material appears to be. For example: A rock is obviously denser than a crumpled piece of paper of the same size. This can simplify to the equation below. The unit of density is kg/m^3.

$$\rho = \frac{m}{v} \tag{2.1}$$

m = mass of the object

ρ = density of the object

V = volume of the object

2.2.3 Specific heat

The other properties that is important to determine before conducted the experiment to predict the heat transfer of fluid as a cooling agent. Specific heat is define as the ratio of the amount of heat required to raise the temperature of a unit mass of a substance by one unit of temperature to the amount of heat required to raise the temperature of a similar mass of a reference material, usually water, by the same amount. Le-Ping Zhou, (2009) said it is also can be define as the amount of heat, measured in calories, required to raise the temperature of one gram of a substance by one Celsius degree.

There are two types of specific heat which are specific heat at constant pressure, c_p and specific heat at constant volume, c_v. Yunus A. Cengel (2006) define the specific heat at constant volume, c_v can be viewed as the energy required to raise the temperature of a unit mass of as substance by one degree as the volume is constant. The energy required to do the same as the pressure is held constant is the specific heat at constant pressure c_p. Common unit is kJ/kg.°C or kJ/kg.K. Notice that $\Delta T(°C) = \Delta T(K)$ and 1°C change in temperate is equivalent to a change of 1K.