UNIVERSITI PUTRA MALAYSIA

NEW METHOD OF MEASURE THERMAL CONDUCTIVITY OF NANOFLUIDS

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By

SEYED SHARAFALDIN HOSSEINI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science

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To whom their true love and support are behind my success

Almighty God

And

My parents

Abstract of thesis presented to the Senate of University Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

NEW METHOD OF MEASURE THERMAL CONDUCTIVITY OF NANOFLUIDS

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SEYED SHARAFALDIN HOSSEINI

August 2009

Chairman: Associate Professor Nor Mariah Adam, PhD

Faculty: Engineering

Work on applications of nanofluids can be restricted due to unavailable conductivity meter for nanofluids in the market. This study is concerned with design and development of a conductivity meter for nanofluids for temperature range of 20˚C – 50 ˚C for copper oxide and alumina with distilled water as base fluid. This temperature range is in accordance with ordinary thermal applications and our empirical limitations. The meter is comprised of the components such as a plastic water bath, an electrical heater, some thermometers, an electrical motor, a fan, an electrical transformer, and a 100 ml Pyrex beaker. In this method both conduction and convection were considered to measure the thermal conductivity of moving fluids.

Calibration and verification of the equipment by using distilled water showed a significant agreement to conductivity standard value of ASTM standard.

Results showed that CuO-distilled water has higher thermal properties than alumina-distilled water, and that means particles with higher thermal conductivity make higher conductive nanofluids. For example percentage of thermal conductivity rising for 2%mass CuO-distilled water in 45˚C is equal to 33.5% but this value for alumina is equal to 26%. Among our nanofluids 4% mass particle concentration of CuO-distilled water gave the highest conductivity value and least is 1 mass% particle concentration of alumina-distilled water. Result also showed that this meter can give the conductivity value of 0.001 decimal places.

Finally it can be concluded that nanofluids can consider as new generation of thermal fluid with higher thermal conductivity than traditional thermal fluids. They also can increase the efficiency of thermal equipments.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KAEDAH BARU PENGUKURAN PENGALIR TERMAL BAGI CECAIR NANO

Oleh

Seyed Sharaf Aldin Hosseini

Ogos 2009

Penyelia: Profesor Madya Nor Mariah Adam, PhD

Fakulti: Kejuruteraan

Penggunaan cecair nano menjadi terbatas disebabkan tidak tersedianya meter pengaliran di pasaran. Kajian ini mengenai rekabentuk dan pembangunan meter pengaliran bagi cecair nano untuk julat suhu 20˚C – 50 ˚C bagi kuprum oksida dan alumina dengan air suling sebagai cecair asas. Julat suhu ini adalah bersesuaian dengan penggunaan kepanasan biasa dan juga kenyataan yang terhad. Meter ini terdiri dari komponen-komponen berikut:

Plastic perendaman, Pemanas elektrik, Meter suhu, Motor elektrik, Kipas, transformer elektrik, Kaca bikar yang boleh mengisi cecair 100ml

Pengujian peralatan dengan menggunakan air suling menunjukkan kesesuaian yang penting bagi panduan nilai piawaian pengaliran pemanasan.

Keputusan menunjukkan yang kuprum dioksida-air suling mempunyai kelebihan yang tinggi dibandingkan alumina-air suling, ini bermakna unsur dengan pengaliran pemanasan yang tinggi membuatkan cecair nano lebih berpengalir. Sebagai contoh peratusan pengaliran permanasan meningkat untuk jisim 2% CuO air suling dalam suhu 45˚C adalah sama dengan 33.5% tetapi nilai ini bagi alumina adalah 26%. Di antara cecair nano jisim 4% kepekatan unsur CuO-air suling memberi nilai pengaliran tertinggi dan ianya kurang bagi jisim 1% kepekatan bagi unsur alumina-air suling. Keputusan ini juga menunjukkan meter ini boleh memberi nilai pengaliran pada nilai decimal 0.001.

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I certify that a Thesis Examination Committee has met on 14th August 2009 to conduct the final examination of Seyed Sharaf Aldin Hosseini on his thesis entitled "New Method to Measure Thermal Conductivity of Nanofluids" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.
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This thesis was submitted to Senate of Universiti Putra Malaysia and has been accepted as fulfillment on the requirement for the degree of Master of Science. The members of the supervisory committee were as follows:

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Date:16 October 2009

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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SEYED SHARAF ALDIN HOSSEINI

Date: 4/9/2009

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CHAPTER 1

INTRODUCTION

1.1 Background

Due to the vast applications of heat transfer in various industries, increasing the efficiency of thermal equipments becomes the main purpose of the designers of industrial units. In recent years, researchers have attempted to enhance heat transfer by creating the different approaches. Increase the efficiency and improvement of the output of thermal devices cause energy savings and indirectly decrease the equipment sizes and initial and operation costs (Xuan and Li, 2000a). Unfortunately, most used approaches to achieve this aim is by increasing the equipment surface area per volume unit and therefore increase the equipment size which leads to increase in pressure loss. Consequently, more powerful pumps are required and this leads to higher energy consumption.

Using nanotechnology and especially nanofluids can help the researchers make suitable media for heat transfer. This is because nanofluid is a mixture of a base fluid with suspended nanosize metallic or metal oxide particles (Choi, 1995). Common industrial thermal fluids like water, ethylene glycol, and oils have lower thermal conductivity coefficient than metals and metallic oxides. Metallic or metal oxide particles can improve thermal capability of traditional fluid. Using a mixture of solid particles and base fluid has traced back its application to more than a hundred years ago in bigger particle size (Xuan and Roetzel, 2000). However, such suspensions settle rapidly and block the channel way. Besides, it causes erosion in pipe walls and erodes the pumps and other equipments. Because of its ultra thin particle size of nanofluid, those problems are considerably decreased. Increasing the thermal conductivity coefficient and also convection heat transfer coefficient without considerable pressure loss is a benefit of nanofluid compared to traditional mixtures. It is expected that vast use of nanofluid in industries can solve the main problem of equipment and thermal fluids. The main problem is actually the inadequate heat transfer. For example, in some equipment like furnace the fuel consumption is decreased if the heat absorption ability is increased by the fluid that flows inside the pipe and this may lead to decrease in pollution of the environment (Etemad, 2008). Using nanofluid in electrical industries like computer design and production also can be useful. There are some devices such as microprocessors that make a lot of heat. Nanofluid has a great potential to absorb the heat and solve such problems (Nguyen *et al.* 2007b).

1.2 Problem Statement

First step to use thermal fluid in engineering designs is determination of physical properties. There are three types of heat transfer which are conduction, convection and radiation. Conduction is heat transfer between molecules without movement like fluids and solids. Convection is heat transfer due to fluent molecules like fluids. Both of them need the substance to transfer the heat. Last one is radiation which is heat transfer from heat source to cold source by radiance like solar energy. Radiation does not need substance to transfer (Holman, 2002).

In stationary state or laminar flow type, conduction plays a key role of heat transfer. However, there are also convection and radiation but the importance of conduction is more obvious. In this study, the conduction is investigated due to the low velocity, below 2 cm/s, of nanofluid flow from (Yang *et al.* 2005). Thermal conductivity of nanofluids is affected by several factors such as viscosity, pH value of suspension, temperature, particle concentration, surfactants and dispersants, fluid flow type, and material and thermal conductivity of both base fluid and particle. In next chapter we will study effect of each of them (Daungthongsuk and Wongwises, 2007; Namburu *et al.* 2007b; Xuan and Roetzel, 2000).

There are a lot of theoretical formulas or empirical correlations to determine the thermal conductivity of solid or fluids, but none of them could satisfy all nanofluids. Thus, thermal conductivity of nanofluids is needed to measure by experimental methods. There are some methods which are used to measure thermal conductivity of suspensions. However, all of them are designed for stationary state and limited by time and effect of other types of heat transfer. Effectiveness of convection is enhanced by increasing duration of experiment in these methods. The effect of radiation in high temperature gradient should not be forgotten.

1.3 Objective

According to the above mentioned problems, it was attempted to invent the new device to measure thermal conductivity of liquids especially nanofluids. In this device, heat is provided by electrical element and transferred to the sample. The thermal conductivity of moving fluid was calculated by measuring its temperature and putting it in the basic heat transfer formulas. To invent it, we followed the “adaptation of an old principle to an old problem to achieve a new result” principal. This new device is very cheap and is expected to be exact. Experimental run can last up to half hour.

1.4 Scope and Limitation

As it was mentioned above, fluid flow type is one of effective factors in measuring thermal conductivity of nanofluids. In our work, it should be kept on laminar flow and constant velocity (Zeinali Heris *et al.* 2006). Flow type is determined by Reynolds number and it is affected by viscosity. Viscosity relates to density directly. Density is also temperature dependent. Therefore, to measure the thermal conductivity of suspension in given concentration, we have to change the amount of base fluid by increasing the temperature. During the experiment, researcher must care to fix the velocity in each test.

This new device is used only for fluids and suspensions. Because of our experiments were carried out in low temperature between 20 to 50˚C, the effect of radiation heat transfer can be neglected. We also ignore the free convection heat transfer because the free surface of sample liquids is small and covered by aluminum foil (Putra *et al.* 2003).

1.5 Thesis layout

The thesis comprises five chapters organized in the following way:

Chapter 1 – Introduction: It introduces the subject related to this research, defines the problem statement, and presents the research objectives. It includes also the scope and limitation for this study

Chapter 2 - Literature Review: It reviews up to date literatures on the subject matter providing the reader with insights of the latest development.

Chapter 3 – Methodology: It describes the theory and method used in this study. The experiment also is described, including preparation of the setup, preparation of samples, and procedure of tests.

Chapter 4 – Result and Discussion: It analyzes and discusses the results of tests which are carried out by our new method, comparing our result by previous results. It also includes some related findings about nanofluid behavior.

Chapter 5 – Conclusions and Recommendations: It concludes the findings of this research and recommends areas for future works.

CHAPTER 2

LITRATURE REVIEW

2.1 Theory

The basis of any design is on recognition of physical properties of materials used. In particular to design the fluid base thermal systems, knowledge of properties of fluid is necessary to predict its behavior. Recently new types of thermal fluids, which are called nanofluids, are applied to improve the efficiency of thermal equipment. Uncertain values of physical properties of these nanofluids are main problems of thermal engineering designs (Behzadmehr *et al.* 2007).

There are some important reactions such as Van Der Vals force, Brownian motion, and interaction between particles in solid/liquid suspensions which are affected on measurement of physical and thermal properties of nanofluids (Daungthongsuk and Wongwises, 2007). Thus, measuring techniques of the physical properties also is important. In this work, the researchers attempt to focus on techniques or methods which are used to measure thermal conductivity of liquids.

There are several methods to measure it like transient hot wire method (Gross and Tran, 2004), hot-strip method (Gustafsson *et al.* 1979), hot needle method (Doug Cobos, 1998), 3ω method (Wang *et al.* 2007b) etc, but the main problems of these techniques were that all of them were performed in stationary state and were restricted by time (Hammerschmidt and Sabuga, 2000). Due to the effect of convection, by increasing the time, traditional devices should be performed in a few seconds. Otherwise, convection heat transfer makes large error in output.

Our new method considers the convection heat transfer and works comparatively to measure the thermal conductivity of moving liquids and suspensions. This method, which will be explained in next chapter, thermal conductivity of nanofluids was measured by consideration of both conduction and convection heat transfer while they were in motion. Due to low temperature range, radiation heat transfer can be neglected (Gross and Tran, 2004).

2.1.1 Physical properties

Every thermal liquid has four main physical properties which are thermal conductivity, viscosity, density, and heat capacity. Among them, thermal conductivity plays the most important role to transfer the heat, especially in stationary state and low velocity of liquid. In physical aspect, thermal conductivity, k, is the property of a substance which shows its ability to conduct heat when is subjected to a temperature gradient (Bejan, 1995). In another statement, conduction is one kind of heat transfer and defined as the transfer of heat by means of molecular agitation within a material without any motion of the bulk material as a whole (Nguyen *et al.* 2007b).

Viscosity is a measure of the resistance of a fluid against deformation by either extensional stress or shear stress (Chen *et al.* 2007). In general terms, it is the resistance of a liquid to flow (Brinkman, 2004). These two components almost affect directly or indirectly on calculations of all dimensionless numbers used in heat transfer.

For example, direct effect of thermal conductivity coefficient in Prandtl (rate of molecular prevalence of momentum on molecular prevalence of heat), Nusselt (rate of convection on conduction heat transfer), Biot (rate of conduction resistance on convection resistance) and Fourier (rate of intensity of heat transfer on heat store in control volume) numbers and indirect effect on Peclet (Reynolds number time Prandtl number), Rayleigh (multiplying Grashof and Prandtl numbers), Stanton (rate of Nusselt number on multiplying Reynolds and Prandtl numbers), Graetz and Luis (rate of molecular prevalence of heat on molecular prevalence of material) numbers are obvious.

Viscosity also has direct effect on Reynolds (rate of inertial force on viscosity force), Prandtl and Grashof (rate of buoyancy force on viscosity force) numbers an indirect effect on Nusselt, Peclet, Rayleigh, Stanton and Graetz numbers.

There are two other physical properties. Materials density defined as their mass per unit volume. Density plays a very important role in heat transfer especially in natural convection. The basis of natural convection is on buoyancy force and density gradient (Bu-Nada *et al.* 2008). Density has inverse effect on natural convection (Roy *et al.* 2004). However, in spite of experimental results, Trisaksri and Wongwises (2007) believed that increasing the density can cause increase the natural convection.