SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal-Fluids) with honours"

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EXPERIMENTAL INVESTIGATION OF THERMAL CONDUCTIVITY, VISCOSITY, SPECIFIC HEAT AND HEAT TRANSFER PROPERTIES OF CNF-BASED NANOFLUIDS

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DECLARATION

"I hereby declare that the work in this thesis is my own except for summaries and quotations which have been duly acknowledged."

Signature : .....
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Special tribute for my beloved father, mother, siblings and friends.

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All praise is due to Allah. We praise Him and seek His aid and forgiveness. We seek refuge in Allah from the evil which is within ourselves and from the evil in our actions.

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ABSTRACT

Nanofluids are combination of nanoparticles and base fluid with/without the presence of chemical substances to obtain a completely stable solution. Nanofluids are one of the potential fluids for heat transfer with an enhanced thermal properties and heat transfer performance to be use especially for cooling purpose. The major problem face in existing coolant is the addition of bigger size solid particles which can cause clogging and lowered the thermal conductivity. This research is proposed to formulate an efficient nanofluid of carbon nanofiber (CNF) in ethylene glycol based and investigate the thermal properties to be used as a better coolant compared to the existing coolant. This research is focusing on synthesizing a stable nanofluid from Pyrograf III HHT24 carbon nanofiber at the ratio of 0.1wt% to 1.0 wt% CNF with the usage of ethylene glycol and the presence of polyvinylpyrrolidone (PVP) as the dispersing agent. The nanofluid undergo process of homogenization at 10000 rpm in 5 minutes and ultrasonication for 60 minutes. The pH of the solution is controlled at 9 throughout the formulation process. Stable samples are tested for thermal conductivity where the best enhancement were observed for sample NFP14 at 6 ^{o}C. The viscosity is reduced as the temperature decrease where the value fluctuates with different weight percentage. As for heat transfer test, the best result were shown by sample NFP15 at 6 ^{o}C and 25 ^{o}C which is 31.16% and 61.54% respectively whereas sample NFP14 shows best enhancement at 40 ^{o}C which is 14.93%. Meanwhile, only sample NFP14 experienced increment about 0.794% in specific heat while sample NFP12 and NFP15 undergo reduction about -2.951% and -0.479% respectively as opposed to the based fluid. Overall results shows that all samples show improvement in thermal properties and NFP14 are considered as the best sample.

ABSTRAK

Bendalir nano adalah gabungan zarah–zarah nano dan bendalir asas dengan/atau tanpa kehadiran bahan kimia untuk memperoleh satu larutan yang stabil. Bendalir nano adalah larutan yang berpotensi sebagai medium dengan sifat–sifat termal dan pemindah haba yang lebih baik untuk tujuan penyejukan. Masalah utama dalam pendingin sedia ada adalah apabila zarah pepejal yang bersaiz besar ditambah, sistem akan tersumbat dan mengurangkan kekonduksian termal. Kajian ini dijalankan bertujuan untuk menghasilkan bendalir nano yang cekap dalam larutan etilena glikol dan mengenalpasti ciri–ciri termal untuk digunakan sebagai bahan pendingin yang lebih baik berbanding yang sedia ada. Kajian ini menumpukan proses mensintesis zarah–zarah nano yang stabil dari nisbah 0.1 wt% hingga 1.0 wt% Pyrograf III HHT24 karbon nanofiber dengan penggunaan etilena glikol dan kehadiran polivinilpirolidon sebagai agen dispersi. Bendalir nano menjalani proses penghomogenan pada 10000 rpm selama 5 minit dan ultrasonikasi selama 60 minit. Bacaan pH 9 perlu dikawal sepanjang proses penyediaan bendalir nano. Sampel yang stabil diuji untuk kekonduksian termal dan peningkatan terbaik dilihat pada sampel NFP14 pada 6 ^{o}C. Kelikatan berkurang apabila suhu bertambah di mana nilai turun–naik dengan peratusan berat yang berbeza. Bagi ujian pemindahan haba, keputusan terbaik ditunjukkan oleh sampel NFP15 pada 6 ^{o}C dan 25 ^{o}C masing-masing sebanyak 31.16% dan 61.54% manakala sampel NFP15 menunjukkan peratusan peningkatan terbaik pada 40 ^{o}C iaitu sebanyak 14.93%. Hanya sampel NFP14 menunjukkan peningkatan sebanyak 0.794% dalam ujian kapasiti haba manakala sampel NFP12 dan NFP15 menunjukkan pengurangan sebanyak -2.951% dan -0.477%. Keseluruhannya semua sampel menunjukkan peningkatan dalam sifat – sifat terma dan sampel terbaik adalah sampel NFP14.

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CHAPTER I

INTRODUCTION

1.0 INTRODUCTION

Nanofluids are another type of fluid belong to fluid's family. It can be prepared by dispersing the nanoparticles using dispersing agent in a base fluid. These fluids are stable colloidal suspensions of nanoparticles such as nanotube or nanofiber in base fluid. The special things of the nanotubes arises from its structure and the inherit subtlety in the structure, which is the helicity in the arrangement of the carbon atoms in hexagonal arrays on their surface honeycomb lattices (Mukhopaday, K. *et al.* 2008). Nanofluids were primarily studied by Choi and Eastman at Argonne National Library USA (Choi and Eastman, 1995). Nanoparticles have been studied to have shown superior thermal conductivity which have potential as an alternative for conventional heat transfer fluids. Hence, nanoparticles seems to have better chance in developing nanofluids with higher thermal conductivity especially by utilizing the liquid which have higher thermal conductivity such as water, glycols or oil. Heat transfer through fluid is essentially by convection which depends highly on the thermal conductivity of the fluid. Thus, thermal conductivity is the most important parameter responsible for enhanced heat transfer.

1.1 PROBLEM STATEMENT

Any cooling system existed nowadays usually needs coolant to serves as a medium for heat transfer of the fluid. The common type of coolants use in the era are water, organic chemical and oil as the thermal conductivity is higher. However, with the increase of usage for cooling system, the demand is higher to produce new coolant with higher thermal conductivity as the heat transfer of water is limited. Nanofluids, an emerging and new class of coolants which consist of a carrier liquid, such as water, dispersed with tiny nano-scale particles known as nanoparticles. There are some problems being identified as new coolants are proposed, which is clogging occurs when bigger particles used in a coolant in which may lower their thermal conductivity. The research is done to find the optimum ratio of carbon nanoparticles and the base fluids to produce nanofluids with higher thermal conductivity to be used as future coolant.

1.2 OBJECTIVES

i. To formulate an efficient nanofluid of carbon nanofiber (CNF) in ethylene glycol based.
ii. To investigate the thermal properties of the nanofluids.

1.3 SCOPE OF RESEARCH

i. To formulate a stable nanofluid using carbon nanofiber (Pyrograf HHT24) in ethylene glycol based fluid and Polyvinylpyrrolidone (PVP) as dispersing agent.
ii. To identify the optimum ratio between carbon nanofiber, Polivinylpyrrolidone (PVP) and ethylene glycol in order to achieve good stability.
iii. To obtain carbon nanofluid solution for thermal properties test.
iv. To investigate the thermal conductivity, viscosity, specific heat capacity and heat transfer coefficient of carbon nanofiber (CNF) based nanofluid.

CHAPTER II

LITERATURE REVIEW

2.0 INTRODUCTION

Nanotechnology can be said as any research and technology development for characterization and application of material using a length of nanoscale by controlling the shape and size. Nanoscale range from approximately one to one hundred nanometers in any dimension. National Nanotechnology Initialization (NNI) defines nanotechnology as research and technology development at the atomic, molecular, or macromolecular levels using a length scale of approximately one to one hundred nanometers in any dimension; the creation and use of structures, devices and systems that have novel properties and functions because of their small size; and the ability to control or manipulate matter on an atomic scale. The thermal properties of nanofluids have been the subject of an intensive study in nanotechnology applications (Kakac, 2009). Nanotechnology is the using and changing of the usage of matter for particular applications through certain chemical and/or physical processes to make materials with properties required. There are many processes that create nanoscale materials from atoms and molecules to be design as a nanotechnology.

2.1 NANOFLUID

2.1.1 Definition of Nanofluids

Nanofluid is a liquid-solid mixture made from nanometer –scale (<100 nm) of solid particles in a base fluid such as oil, deionized water or ethylene glycol. Nanofluid is a fluid containing nanometer sized particles, called nanoparticles. Nanofluids are engineered nanocolloidal suspension for enhancement specially for thermal conductivity. The modern science of colloids, which dates back to the early studies of Faraday in the mid-eighteen century (Tweney, 2006) is multidisciplinary with overlapping domains in physics and engineering. According to Yu, W. and Xie, H. (2012), nanofluids are a new class of fluids engineered by dispersing nanometer-sized materials such as nanoparticles, nanofibers, nanotubes, nanowires, nanorods, nanosheet, or droplets in base fluids. Nanoparticles such as carbon, copper, aluminium and nickel are suspended in conventional fluids or based fluid and called nanofluids. A research of (Kakac and Pramuanjaroenkij, 2009) proved that the nanolayer works as a thermal bridge between the liquid base fluid and the solid nanoparticles and a nanofluid consists of the liquid base fluid, the solid nanoparticles and the nanolayers as seen in Figure 2.1.

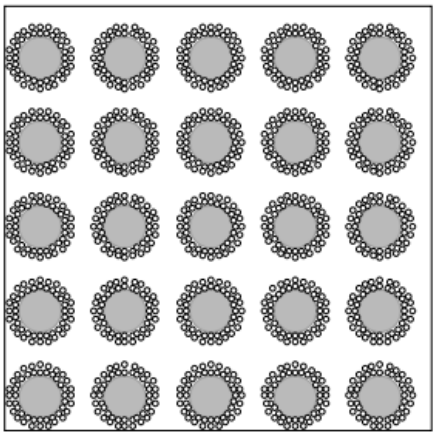

Figure 2.1 : Schematic cross section of nanofluids
(Source : Yu, W. *et al*. 2003)

The concept of nanofluids was first materialized by Choi *et al*. (1995) after performing a series of research at Argonne National Laboratory in USA. According

to Goharshadi, E. K. *et al*. (2013) the first experiments were done to show the extraordinary values of thermal conductivity of nanofluids. However, subsequent research (Lee, S. *et al*. 1999), (Wang, X. *et al*. 1999) showed that the nanofluids exhibit higher thermal conductivity even for low concentration of suspended nanoparticles. For instance, experiments showed an increase in thermal conductivity by dispersion of less than 1% volume fraction of Cu nanoparticles or carbon nanotubes (CNTs) in ethylene glycol or oil by 40% and 150%, respectively (Keblinski, *et al*. 2005).

Research has been done and conclude that the possibility of adding fine substance in base fluid can increase the thermal conductivity compared to the base fluid itself. However, despite the considerable research, adding large size of particles dispersed in the suspension presented several disadvantage such as clogging, rapid settling and the increment of the size of the machine. This major drawback causes researcher to come out with another method of increasing thermal conductivity by introducing the nanoparticles to be added into the base fluid. According to Ding *et al.* (2007) the enhanced thermal behaviour of nanofluids could provide a basis for an enormous innovation for heat transfer intensification, which is of major importance to a number of industrial sectors including transportation, power generation, micro-manufacturing, as well as heating, cooling, ventilation and air-conditioning. Nanofluids are also important for the production of nanostructured materials (Kinloch *et al.* 2002), for the engineering of complex fluids (Tohver *et al.* 2001), as well as for cleaning oil from surfaces due to their excellent wetting and spreading behaviour (Wasan and Nikolov, 2003).

2.1.2 Application of Nanofluids

Nanofluid can be used in broad application of engineering application due to their enhancement in thermal conductivity and the efficiency of the energy usage.

2.1.2.1 Application in Transportation

An ethylene glycol and water mixture, the practically universal coolant used automotive coolant, is a relatively poor heat transfer fluid compared to water alone (Wang, X. Q. and Mujumdar, A. S. 2008). Cooling is one of the important challenges facing by numerous industry. The addition of nanoparticles to the standard engine coolant has the ability to improve automotive and heavy duty engine cooling rates. By using nanoparticles, the size of the coolant system can be reduced as it has high ability to remove heat engine. The usage of smaller cooling systems and lighter radiator in an automotive system will be advantage for every aspect of car and the performances. In normal automatize coolant, pure ethylene glycol is used which is a poor heat transfer fluid compared to 50/50 mixture of ethylene glycol and water but the addition of nanoparticles will improve the situation.

The result of nanofluids research applied to the cooling of of automatic transmissions. Tseng *et al.* (2005) dispersed CuO and Al_2O_3 nanoparticles into engine transmission oil. In automative lubrication applications, surface modified nanoparticles stably dispersed in mineral oils are researched to be effective in reducing wear and enhancing load carrying capacity (Zhang and Que, 1997).

2.1.2.2 Application in Electronics Cooling

Electronics application is very sensitive towards humidity and heat. The excessive amount of heat can cause overheat to electrical application and reduced the performance or at worst can destroy the appliances. Nanofluids have been considered as the working fluid for heat pipes in electronic cooling applications. Research by Tsai *et al.* (2004) proved that the usage of water based-nanofluid as a heat spreader for CPU in a notebook or PC decrease the thermal resistance as compared with deionized water. In a related study by Ma *et al.* (2006) shows the decrement in temperature difference for evaporator in an oscillating heat pipe from 40.9 °C to 24.3 °C. Nguyen *et al.* (2007) experimentally study the cooling of micro electronic components which is the behaviour and heat transfer enhancement of an Al_2O_3/water nanofluid flowing inside the closed system.

2.1.2.3 Application in Space and Defense

Any military devices and systems requires high cooling level to ensure the performance of the the weapons. This matter is challenging as cooling with conventional fluids cannot afford to provide high heat transfer for the cooling and heat transfer purpose. Nanofluids have the potential to provide the required cooling as needed. You *et al.* (2003) and Vassalo *et al*. (2004) have reported order of magnitude increases in the critical heat flux in pool boiling with nanofluids compared to use of base fluid alone.

2.1.2.4 Application in Medical

Nanofluids and nanoparticles have a lot of usage in biomedical sector. The cooling system is very crucial especially in operation theatre where the surgery should be conducted. The effective cooling of operation theatre as well as getting fresh air ventilation can enhance the patient's survival chance and reducing the risk of organ damage. In a contrary, nanofluid is also important to be used in cancer treatment which higher temperature is needed around tumours to kill cancerous cell without affecting nearby healthy cells (Jordan *et al*. 1999).

2.2 CARBON NANOTUBE

According to Popov, N. V. (2004) carbon nanotubes are unique tubular structures of nanometer diameter and large length/diameter ratio which the nanotubes may consist of one up to tens and hundreds of concentric shells of carbons with adjacent shells separation of 0.34 nm. The sp^2 hybridization of carbon element can form a variety of amazing structures. The carbon element that for shell is closely related to the arrangement similar to honeycomb arrangement but by the formation of carbon atom in graphite sheets. First such structure to be discovered was the C_{60} molecule then only in 1991 as shown in Figure 2.2, that Ijima (1991) observed for the first time tubular carbon structure eventhough various carbon cages were studied.