SYNTHESIS OF COOLANT BASED CARBON NANOTUBE

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SUPERVISOR DECLARATION

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

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This thesis is submitted as partial requirement for the completion of

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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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DEDICATION

I dedicated this thesis to my beloved parents.

ACKNOWLEDGEMENT

I would like to express my appreciation for those who participate directly or indirectly to guide me for completing this thesis. A special gratitude I dedicate to my supervisor Mr. Imran Syakir Mohamad to whose have invested his full effort in guiding me to complete my final year project especially in writing this thesis. Deepest appreciation for my parent who always be behind and keep support me in most crucial time.

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ABSTRACT

Nanofluids are suspensions of nanoparticles in base liquids with enhanced thermal physical properties as compared to conventional fluid such as water and ethylene glycol as the current commercial coolant nowadays. However in unstable condition nanofluid may cause clogging in operational system due to the sedimentation of the nanoparticles. The agglomeration of nanoparticles may also create a disturbance in heat transfer and thermal conductivity of nanofluid. This research focus on formulating stable nanofluid by various ratio of Nanoamor carbon nanotube and dispersing agent known as Polyvivylpyrrolidone (PVP) with commercial coolant as the basefluid. The nanofluid will be homogenized by mechanical homogenizer at 10000 rpm and ultrasonication at room temperature for five minutes. The pH value of the nanofluid will be maintained at nine during the formulation process. Stable sample will be tested with thermal conductivity test at 3 °C, 6 °C, 25 °C, 45 °C and 60 °C where the best enhancement were observed at 0.3 wt% at 60 °C with 64.5%. As for heat transfer test which is conducted in 6 °C, 25 °C and 45 °C, the best enhancement observed at 0.3 wt% at 25°C with 158.95% followed by 0.5 wt% and 1.0 wt% with 129.47% 93% and.68% respectively. Meanwhile all samples show reduction in comparison to the standard coolant in term of specific heat capacity where 0.3 wt% of CNT shows the lowest reduction followed by 0.5 wt% and 1.0 wt% with -2.31%, -4.7% and -5.34% respectively. Overall results show that 0.3 wt% has the best enhancement and efficient nanofluid. The nanofluid with greater enhancement is potentially highly preferable in cooling industry.

ABSTRAK

Bendalir nano adalah cecair asas yang mengandungi zarah-zarah nano yang mempunyai peningkatan ciri-ciri fizikal haba berbanding cecair konvensional seperti air dan etilena glikol sebagai penyejuk komersil pada masa kini. Bagaimanapun bendalir nano yang tidak stabil akan menyebabkan sistem operasi akan tersumbat disebabkan pemendapan zarah-zarah nano. Tambahan pula pemendapan zarah-zarah nano akan memberi kesan dalam pemindahan haba dan peraliran haba bendalir nano. Fokus kajian ini adalah menghasilkan bendalir nano yang stabil dengan kepelbagaian nisbah CNT Nanoamor serta ejen bersurai yang dikenali sebagai polivinilpirolidon (PVP) bersama penyejuk komersil sebagai bendalir asas. Bendalir nano akan dihomogenkan dengan homogenisi mekanikal pada 10000 rpm dan ultrasonikasi pada suhu bilik selama lima minit. Nilai pH bendalir nano dikekalkan pada nilai sembilan semasa penghasilan bendalir nano. Sampel yang stabil akan menjalani eksperimen terhadap kekonduksi terma pada 3 °C, 6 °C, 25 °C, 45 °C dan 60 °C dimana peningkatan yang terbaik dilihat pada peratusan berat 0.3 wt% pada suhu 60 °C dengan 64.5% peningkatan. Eksperimen pengaliran haba pula dijalankan pada suhu 6 °C, 25 °C dan 45 °C. Peningkatan yang terbaik adalah 0.3 wt% CNT pada suhu 25 °C dengan 158.9% diikuti 0.5 wt% CNT yang mempunyai 129.47% serta 68% kenaikan pada 1.0 wt%. Sementara itu, kesemua sampel mengalami penurunan dari segi muatan haba dimana 0.3 wt% mempunyai penurunan paling sedikit diikuti 0.5 wt% dan 1.0 wt% dimana masing-masing mempunyai -2.31%, -4.7% dan -5.34%. Keseluruhanya 0.3 wt% mempunyai peningkatan bendalir nano yang terbaik dan cekap. Bendalir nano yang mempunyai peningkatan yang terbanyak berpotensi dan disyorkan didalam industri penyejukan.

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND

Nanofluids are stable colloidal mixtures of nanoparticles such as nanotubes, nanofibers and functional nanocomposites in fluids which have a potential to meet the ever growing need for thermal management and high performance cooling media. Metallic nanoparticles or carbon nanotubes in the nanofluids were observeed to have shown superior thermal conductivity which could be exploited as an alternative for conventional heat transfer fluids. Therefore, nanoparticles seem to have a better chance in developing nanofluids containing conductive fillers which can be well dispersed in fluid. Heat transfer through fluid is essentially by convection which depends highly on the thermal conductivity of the fluid. Thus, thermal conductivity is an extremely important factor in the development of energy-efficient heat transfer. Suspensions of nanoparticles in nanofluids are proven to be improving the thermal conductivity and heat transfer. Nanofluids were first innovated at the Argonne National Laboratory, USA (Choi and Eastman 1995)

1.2 PROBLEM STATEMENT

The challenge of this study is to obtain the ratio of stability and dispersion of nanofluids between Nanoamor CNT and also PVP in commercial coolant as the base fluid. This is important to obtain high thermal conductivity and heat transfer coefficient without causing agglomeration and instability condition (Saidur et al. 2011). Thermal conductivity and heat transfer coefficient of the commercial coolant is limited. Thus the using of nanofluid is to enhance the percentage in term of thermal conductivity and heat transfer coefficient.

1.3 OBJECTIVE

To formulate highly efficient carbon based nano-coolant using Nanoamor carbon nanotube, dispersing agent and commercial coolant.

1.4 SCOPE

i. To formulate a stable nano-coolant from Nanoamor carbon nanotube
ii. To find the suitable ratio of the amount of carbon nanotube and the amount of the dispersing agent to be mix with certain amount of water.
iii. To analyze the performance of nano-coolant: thermal conductivity, heat capacity and heat transfer efficiency.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

Nanotechnology is the art of controlling matter at atomic scale and holds the guarantee of giving critical enhancements in innovations in technologies for ensuring nature's turf. Nanotechnology is therefore the amazing innovation in small size. One nm is characterized as one billionth of a meter. Nanotechnology is generally utilized these days as a part of commercial ventures consistent with their extensive gainful to numerous distinctive fields, for example, electric and electronic, coolant or even in telecommunication fields. Taniguchi N. (1974), initially utilized the expression nanotechnology with respect to a particle sputter machine, to allude the processing engineering to get the additional high precision and ultra-fine sizes. It implies that with nanotechnology, rate of precision and additionally the proficiency of advances these days can be expand to the best execution. Notwithstanding, all the researchers and designers concurred that nanotechnology thinks of loads of concerns with the toxicity and ecological impact of nano parts issue. That is the reason analysts continue doing its tests and investigates on their special properties which are exceptionally helpful in the cooling framework businesses. Their thermal conductivity is far past any fluid incorporating water or significantly copper. Actually, this engineering is still new and a considerable measure of exploration and advancement need to be carried out with a specific end goal to accomplished primary objective for improvement of nanotechnology and have the ability to vanquish all industries.

2.2 NANOFLUID

2.2.1 Definition of Nanofluid

Nanofluid is a weaken suspension with complex thermo-chemical properties. Even in low concentration, the particles are easily agglomerated that are reliant on surface charges and Brownian motion of the nanoparticles (Weitz et al. 1984; Weitz et al. 1985). Better dispersion conduct attained where there is less stopping up and bigger add up to surface region (Yang et al. 2005) when nanoparticles suspended in a fluid. Nanoparticle which have surface area much bigger contrasted with microparticles, furnish essentially more high heat transfer at same volume. Furthermore, particles more modest than 20 nm have more than 20% of molecules on their surface (Choi et al. 2004) making them momentarily accessible for thermal cooperation with liquid atoms.

The point when contrasted with the based liquid, changes in physical properties of mixtures happens for example, density, thermal conductivity, thickness and viscosity. Metals, carbides or carbon nanotubes are the nanoparticles that are regularly in the nanofluids. Nanofluids have their own particular properties for example, physical properties (colour, conductivity). Extensive surface region (the particular surface territory of nanoparticles is three requests of size more excellent than microparticles), substantial number of thickness (for a given mass of material there are a more stupendous number of particles as the size diminishes) and surface structure (nanoparticles have ~20% of their molecules close to the surface, permitting them to retain and exchange heat all the more productively) and at long last because of their little estimate they enhance the security of the suspensions (Anwar et al. 2010).

The properties offer profits to assortment of requisitions incorporating microelectronics, heat exchanger, chillers or motor cooling. Nanoparticles of materials, for example, metallic oxides, nitride ceramics, carbide ceramics, metals, semiconductors, single, double or multi walled carbon nanotubes, alloyed nanoparticles and so forth have been utilized for the synthesis of nanofluids. This fluid is based on the amounts of metal or non-metal nanoparticles and also the nanotubes in conventional fluids (Trisakri and Wongwises 2007).

2.2.2 Application of Nanofluids

Nanofluids may be utilized as a part of wide extends of building because of their competence of high temperature transferred and energy effectiveness in a mixed bag of thermal frameworks. This area gives a concise thought of distinctive territories of nanofluid provision dependent upon accessible expositive expressions.

2.2.2.1 Applications in Automotive

In vehicles range, nanofluids have an extraordinary potential requisition as motor coolant, programmed transmission liquid, grease, brake liquid, oil and motor oil. The first provision in cooling programmed force transmission framework which demonstrate that CuO nanofluids have the most minimal temperature appropriation and in like manner the best high temperature exchange execution (Senthilraja et al. 2010).

Automotive cooling systems usually consist of radiator where it was designed to remove heat from an engine block with circulated coolant (Waterloo, 2008). In fact, the coola0nt in radiator which are basically water and ethylene glycol have poor heat transfer properties in nature. It is observed that about 3.8% of heat transfer enhancement with addition of 2% copper particle in a ethylene glycol as basefluid (Leong et al. 2010).

2.2.2.2 Application of Nanofluid in Domestic Refrigerator

These days, HFC134A is utilized as a refrigerant as a part of refrigeration supplies. Commonly mineral oil is stayed away from as lubricant because of the solid synthetic extremity of HFC134A in refrigeration gear. POE (Polyol-ester) oil as a lubricant likewise has the issues of stream stifling and intense rubbing in the compressor. So nanoparticles might be utilized to improve the working liquid properties and effective energy of the refrigerating framework connected with lessening in CO_2 production.

Studies by Bi et al. (2008) found that refrigeration system with the nanorefrigerant worked efficiently and energy consumption reduces by 21.2%. After that they found a remarkable reduction in power consumption and highly improvement in freezing capacity. Jwo (2009) conducted studies on refrigeration system by adding Al_2O_3 nanoparticles into mineral lubricant to improve lubrication and heat transfer performance. Their result shows that 60% R-134a and 0.1 wt % Al_2O_3 nanoparticles were optimal. The power consumption was reduced by 2.4% and the coefficient of performance was enhanced by 4.4%.

Besides, Krishna et al. (2012) conducted an experimental study on the performance of domestic refrigerator using TiO_2 – R12 nanorefrigerant as working fluid. The result shows that freezing capacity increased and heat transfer coefficient increases by 3.6% where the compression work reduced by 11% and also coefficient performance increases by 17% due to addition of nanoparticles in the lubricating oil.

2.2.2.3 Industrial Cooling Applications

In modern cooling, nanofluid has been created and demonstrated incredible low usage of energy and coming about emission decreases (Routbort et al. 2010). They indicated that in place of utilizing water for cooling and warming, nanofluids has the possibility to preserve around the range of 300 million kWh of energy.

Nguyen et al. (2007) used Al_2O_3 nanofluid in electronic liquid cooling system. The concentration of particles was added to 6.8 vol. % and the heat convective coefficient was enhanced by a maximum of 40%.

Firouzfar et al. (2011) used a methanol/Ag nanofluid to fill a thermosyphon heat exchanger and compared the effectiveness and energy saving with pure methanol. Experimental results show that methanol/Ag nanofluid obtained energy savings for about 8.8-31.5% for cooling and 18-100% for reheating the supply air stream in air conditioning system respectively.

2.2.2.4 Biomedical Application

Commercialization of nanodrug delivery devices started in 1990. For examples an electronically activated drug delivery microchip (Shawgo et al. 2002), MEMS-based DNA sequencer developed by Cepheid (2009) and arrays of in-plane and out-plane hollow micro-needles for demal/transdermal drug delivery (Kim et al. 2007) as nanomedicine applications of nanogels or gold-coated nanoparticles (Labhasetwar et al. 2007).

The objective of the advanced implementation in developing micro or nano drug delivery systems is the specialty in easily monitoring and controlling target cell responses to pharmaceutical stimuli, better understanding of biological cell activities and to enable drug development process.

2.3 CARBON NANOTUBE (CNT)

Carbon nanotubes (CNT) are long tube of carbon allotropes, thin fullerences, hexagonal carbon wall of the tubes and has pentagonal rings at the end of the tube cap as in Figure 2.1.

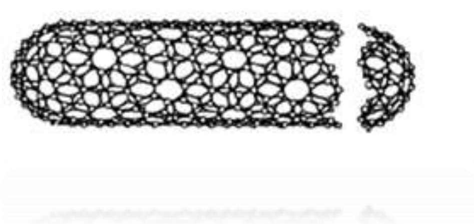

Figure 2.1: Computer-generated images of carbon nanotubes
(Source: Dresselhaus et al. (1995))

CNT were watched first time by Iijima (1991). These round and hollow carbon atoms have extraordinary physical properties and chemical properties which are profitable for nanotechnology (Wang et al. 2003) like optics, electronic and other field of investigation of materials and innovations. One of the physical properties of carbon nanotubes is that it is conceivable to make them just a solitary atomic layer thick. Nanotube could be in size of 1/50,000 the thickness of human hair. Furthermore, all CNT have properties of exceptionally great thermal conductors along the tube which SWNT has a room temperature warm conductivity along its hub around the range of 3500 $W.m^{-1}\ K^{-1}$ contrast with copper which transmit 385 $W.m^{-1}\ K^{-1}$ (Wang et. al. 2005). Plus, CNT has demonstrated that the thermal conductivity of CNT has no less than twice of diamond (Hone J. 2001). This is the reason coolant based from carbon nanotube was recently used now days.

2.3.1 Types of Carbon Nanotube

2.3.1.1 Single –Walled Carbon Nanotube (SWNT)

Single-walled carbon nanotube (SWNT) is nanometer-measurement cylinder comprising of a solitary graphene sheet wrapped up to structure a tube as in Figure 2.2. Since their disclosure was initially reported in 1993, there has been powerful movement investigating the electrical properties of these systems and their potential provisions in cooling commercial enterprises (Iijima et al. 1993). The close arrangement between the single-walled nanotubes structure is because of the van der Waals collaboration. SWNT have distances across on the request of 1 nm while their lengths can compass into the millimetres.

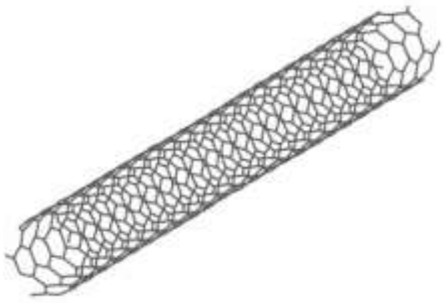

Figure 2.2: Single walled carbon nanotube

(Source**:** Patel, (2008))

Some essential properties of carbon nanotube get the attention of researchers especially in thermal conductivity. Just little measure (<1% volume fraction) of CNT disperse in ethylene glycol upgraded the thermal conductivity of the fluid by 150%. Subsequently Carbon nanotube (round and hollow structure) furnishes higher thermal conductivity upgrade than water based nanofluid (circular particles). CNT have very high thermal conductivity in the longitudinal direction. A single- walled carbon nanotube is able to bend at any angle. Due to their remarkable properties the SWNTs is widely used for nanoelectric devices (Ranakoti et al. 2012).

2.3.1.2 Multi-walled Carbon Nanotube (MWNT)

According to 'Russian Doll Model', different grapheme sheets moved into close concentric cylinder with distance across of the nanometres and length of micrometres as shown in Figure 2.3. Fundamentally MWNT are thicker than SWNT where discovered two years before SWNT (Iijima S. 1991). Each of the singular shell might be portrayed SWNT which could be metallic or semiconducting.

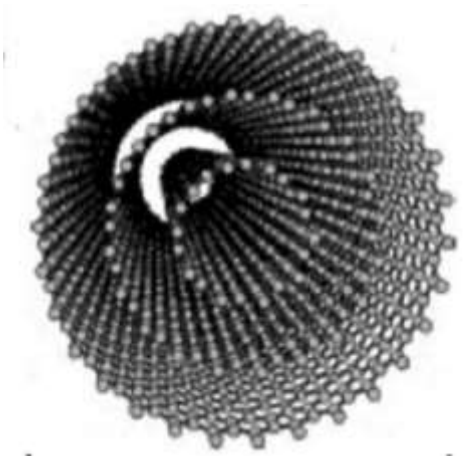

Figure 2.3: Multi-walled Carbon Nanotube
(Source: Ross C, (2008))

The first experimental evidence of CNT was in form of MWNT (Chico 1996). The MWNT is exceedingly popular on their high mechanical quality and its high chemical stability. It appears that MWNT has their nature properties that suitable for field emitters as a sharp tip with nanometer-scale radius, high mechanical stiffness and good electrical conductivity. Furthermore, the one of a kind coaxial shape will upgrade exceptional potential outcomes to be connected to different fields of commercial enterprises.

2.4 DISPERSING AGENT

Surfactant or dispersing agent is compounds that lower the surface tension of a liquid. For this study the surfactant help to disperse CNT in the ethylene glycol as the base fluid. Murshed S.M. (2008) state that dispersing agent is a compound that having polar and a polar groups which adsorb the interface between immiscible bulk phase with their structural characteristic which are polar head group (hydrophilic) and tail group (hydrophobic). It is dependably to control reaction with fine particles, regularly solids or water. Generally they are organic compounds with soluble group chain. The movement of the dispersion is depends on the surface of the molecule. Surfactants stabilize the surface strain as well as avoid the self aggregation of particles in the liquids into supramolecular structures. Although using surfactant as the dispersing agent is an effective way to improve the dispersibility of nanoparticles (Chen et al. 2007).

2.4.1 Polyvinylpyrrolidone

Polyvinylpyrrolidone (PVP) or known as Povidone or Polyvidone is a water soluble polymer that made from monomer N-vinylpyrrolidone. Walter Reppe in year 1939 was the first who synthesized PVP as derivatives of acetylene chemistry. PVP was initially used as a blood plasma substitute and later on been widely used in industrial production. Even the small amounts of PVP may help effectively the stability of emulsion, suspension and dispersion of water. Polyvidone grades can also be used in dry granulates and dry syrups as physical stabilizers. The most important function of these hydrophilic polymers is as a protective colloid. In other words, dispersibility is improved and the sediment volume can be increased. Soluble PVP products are obtained by the radical polymerization of vinylpyrrolidone, giving the structure in Figure 2.4.

Drying is carried out either by spray- or drum-drying. This results in a white-to-yellow-white powder. Soluble PVP in aqueous solution has a very slight taste of its own. Research by (Sahooli et al. 2012) shows that PVP surfactant is more suitable for stabilization of CuO water nano suspension. The advantages of PVP to increase the stability of nanofluid which are good solubility in water, odourless, chemically stable and also non-toxic caused the PVP very famous with other dispersing agents.

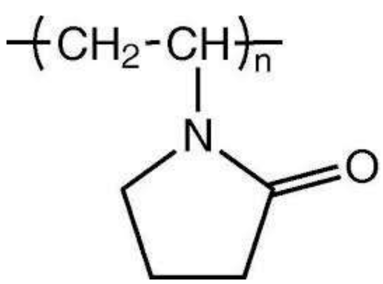

Figure 2.4: Polyvinylpyrrolidone (PVP)

(Source: Simon Michael Kullmann, (2012))

2.5 SYNTHESIS OF NANOFLUID

The first key step in experimental studies with nanofluids is the preparation of the nanofluids. Nanofluids are no ordinary simply liquid-solid mixtures. There are essentially need some special requirements like stable suspension, negligible agglomeration of particles, durable suspension, no chemical change of fluid. Nanofluids are produced from the dispersing of nanometer-scale of solid particles into base liquids such as in this case ethylene glycol and water. Oil also can be used as the liquid base as well. There are mainly two ways of preparation to obtain nanofluids (Mamut 2004).

2.5.1 Single-Step Approach

Single step process can only be synthesized in small scale due to expensive cost of the preparation. That is why single step process is developed quickly. Zhu et al. (2004) showed a single-step chemical method for preparing copper nanofluids by reducing Copper Sulfate Pentahydrate ($CuSO_45H_2O$) with Sodium Hypophosphite ($NaH_2PO_2H_2O$) in ethylene glycol under microwave irradiation. This process need to constantly making and dispersing the particles in fluid. So the agglomeration between the particles can be reduced thus increase the stability of the fluids. The single-step process consists of simultaneously making and dispersing the particles in the fluid. The process of drying, storage, transportation and dispersion of nanoparticles can be avoided, so the agglomeration of nanoparticles is minimized and thus the stability of the nanofluid is increased (Li. Y et al. 2009). Single-step physical vapour condensation method can reduce the agglomeration of Cu/ethylene glycol nanofluids (Choi et al. 2001).

2.5.2 Two-Step Approach

In this method, nanoparticles was first produced and then dispersed in the base fluids. The two-step methods widely used in the processing of nanofluids as commercial nanopowders by either physical or chemical methods. Generally, ultrasonic equipment is used to intensively disperse the particles and reduce the agglomeration of particles. For example, Eastman et al. (1997), Lee et al. (1999), Wang et al. (1999) use this method to produce Al_2O_3 nanofluids.

Murshed et al. (2005) prepared TiO_2 water nanosuspension by the same method. Xuan et al. (2000) used commercially available Cu nanoparticles to prepare nanofluids of both water and transformer oil. Two-step method also can be used for synthesis of carbon nanotube based nanofluids. SWNT and MWNT cabon nanotube were first produced by pyrolysis method and then suspended in basefluids with or without use of surfactant (Xie et al. 2003).

As compared to the single-step method, the two-step technique works well for oxide nanoparticles, while it is less successful with metallic particles. Plus the two-step method is the most economic method to produce nanofluids in large scale. This is due to nanopowder synthesis technique have already been scaled up to industrial production levels (Yu et al. 2011).

2.6 STABILITY OF NANOFLUID

The agglomeration of nanoparticles in the nanofluid is not only causing the settlement and clogging of microchannels but also the affect the thermal conductivity of nanofluid. So further investigaion on the stability is a key factor that influences the properties of nanofluid for application and it is necessary to study and analyze the influencing factors to the dispersion stability of nanofluid.

2.6.1 Stability Evaluation Method

There are several ways to achieve stability of nanofluid. The simplest method is the sedimentation method (Wei et al. 2010). The stability of nanofluid can be influence by sediment weight or sediment volume of nanoparticles under an external force field. The stability of nanofluid will be considered stable when concentration or particle size keeps constant (Li et al. 2009). Zhu et al. (2007) also used sedimentation balance method to measure stability of graphite suspension where the weight of sediment and suspension fraction of nanoparticles during certain period was measured.

Sedimentation method can only be applied for short period observation. Therefore, centrifugation method is developed to enhance the stability of nanofluid. Singh et al. (2008) used centrifugation method to test the stability of silver nanofluid by using microwave synthesis in ethanol with PVP as the dispersing agent. The result shows that the stability of the nanofluid long lasted more than a month in static state. The experiment was done under 10 hour of centrifugation at 3000 rpm without sedimentation.

2.6.2 Enhancing the Stability of Nanofluid

Surfactant are also called dispersant is a easy and economic way to improve the stability of nanofluid. The dispersant can affect to the surface characteristic of nanofluid in small quantity. Dispersant are responsible to increase the contact of two materials or known as wettability. Although using surfactant to improve the stability of nanoparticles, surfactant also might cause several problems (Chen et al. 2008). For example the addition of surfactant may contaminate the heat transfer media and also might produce foam during heating process of nanofluid.

Besides, stability mechanisms of nanofluid also give an impact on the nanofluid stability. Particles in dispersion may adhere together and form aggregates of increasing in size which may settle out due to gravity. The stability means that the particles inside the nanofluid did not aggregate at a significant rate. The aggregation rate is determined by frequency of collisions and the probability of cohesion during collision (Popa et al. 2010).

The dispersion can be enhanced by ultrasonic agitation and mechanical stirring. The dry powder nanoparticles usually are broken down and separated in the in the process of aggregation of nanopartices. Li et al. (2006) prepared Al_2O_3/water and CuO/water nanofluids by dispersing Al_2O_3 and CuO nanoparticles into water by 3 hours of ultrasonic vibration. As the results the nanofluid had been stable for several days. Generally the time of ultrasonication influence the dispersion effects. Kwak et al. (2005) studied the effect of ultrasonic processing time on the stability of CuO/EG. The studies show that longer time of ultrasonication will lead to aggregation of nanoparticles. Besides (Mohamad et al. 2011) used 10000 rpm of homogenization for five minutes and then nanofluid went through ultrasonification for 60 minutes.

2.7 THERMAL CONDUCTIVITY

Thermal properties of liquids play an important role in heating and cooling applications. Thermal conductivity is a physical property that gives their heat transfer performance. Conventional fluids like water and also ethylene glycol have inherently poor thermal conductivity which makes them inadequate for high cooling applications. Scientists have doing researches to enhance the thermal conductivity of these conventional heat transfer fluid by using solid additives followed by classical effective medium theory (Maxwell 1873) for effective properties of mixtures.

Masuda et al. (1993) have shown that it is possible to break down the limits of conventional solid particle suspensions by conceiving the concept of nanoparticle-fluid suspensions. Shyam et al. (2008) and Choi et al. (2001) found that nanofluid have capability to enhance thermal conductivity and at low concentration of nanoparticles. Even at less than 0.1% of nanoparticles can enhance the thermal conductivity of the fluid up to 40% (Wang et al. 1999).

The percentage of enhancement is found to increase with temperature (Das et al. 2003) which can be shown in Figure 2.5. The bigger size of Al_2O_3 has the higher thermal conductivity with increasing temperature. It proved that the higher the size of nanoparticles, the higher the thermal conductivity of the nanofluid. It was found that the particle sizes of nanoparticles have an important role to test the thermal conductivity. Chopkar et al. (2006) investigated the effect of size of nanoparticles for $Al_{70}Cu_{30}$/EG nanofluid by size ranged from 9 nm to 83 nm.

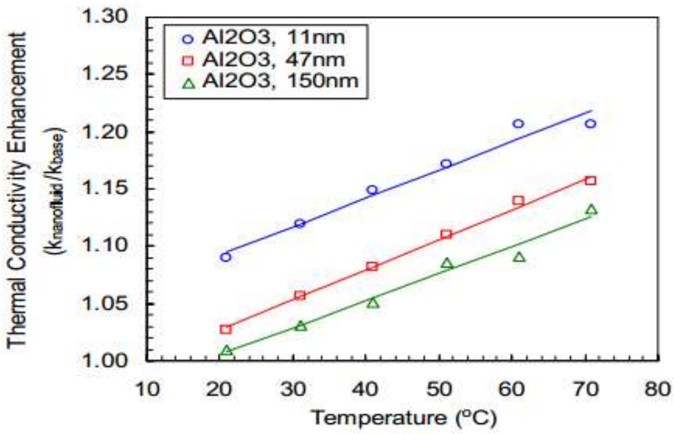

Figure 2.5: Thermal conductivity enhancement of nanofluid with increase of size of nanoparticles

(Source: Chon et al. (2005))

Besides the weight percentage of nanoparticles also influence the thermal conductivity (Mohamad et al. 2011) in as in Figure 2.6. The nanotube that been used is NC300 where 1.0wt% of NC300 showed the highest enhancement thermal conductivity at 45 ˚C compared to the lower volume fraction of NC300. It is due to the collision of nanoparticles or known as brownian motion inside the fluid causing the heat being dissipated and thus influenced the thermal conductivity (Leong et al. 2006). The higher the collision of nanoparticles the higher the heat being dissipated.

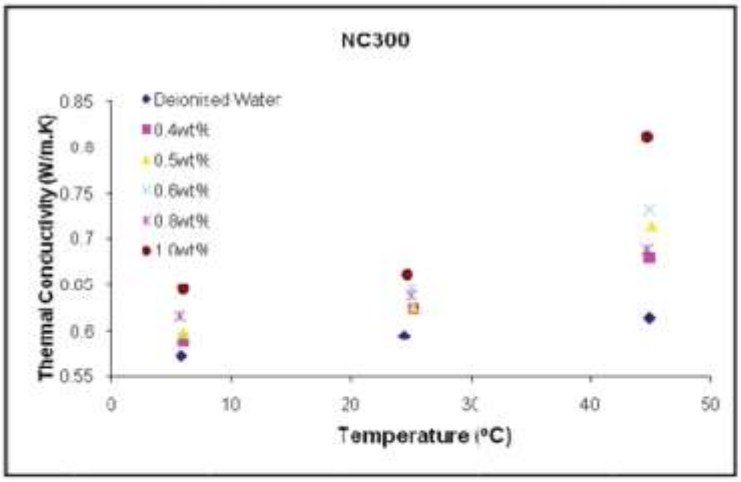

Figure 2.6: Thermal conductivity test of NC300 at various weight percentages (Source: Mohamad et al. (2011))

2.8 HEAT TRANSFER COEFFICIENT

The improvement in term of thermal conductivity does not necessarily prove that the nanofluid has better in term of overall performance. That is why the heat transfer coefficient will take into account. The heat convection is the first form of heat transfer test. The heat transfer enhancement depends on air and basefluid Reynold number which increasing with nanoparticle concentration. Experiment by (Mare T. et al. 2011) proved that the convective heat transfer coefficient of CNT nanofluid was enhanced about 50% in comparison to water for the same Reynolds number. Although some researchers stop from studying the natural convective heat transfer of nanofluid because the suspension of nanoparticles caused higher viscosity and also pressure drop (Calvin et al. 2010).

Based on studies from (Leong et al. 2010), the heat transfer rate and thermal performance of Cu/EG coolant in an automotive radiator which can be improve by increasing the particle volume fraction from 0 % to 2 %. Research by Xuan and Li (2000) stated that the convective heat transfer can be enhanced in nanofluid with Cu nanoparicles in the water based by the range of Reynold number from 10,000 and 25,000.The Nusselt number of the nanofluid increased in 39% with 2% volume fraction of Cu nanoparticles. Dittus-Boelter shows that the higher the volume fraction, the higher the Nusselt number of nanofluid as well as increasing of Reynold number. Unlike the pattern of heat transfer coefficient on which the correlation of Dittus-Boelter cannot explain. However the convection heat transfer coefficient of nanofluid can be decrease by increasing the viscosity of the nanofluid. Pak and Cho (1998) found that the convective heat transfer coefficient of nanofluid at 3% volume fraction of Al_2O_3 has lower than pure water for about 12% reduction for a constant average velocity. It was possibly the suspensions of Al_2O_3 have higher viscosity than pure water especially at high particle volume fractions.

2.9 SPECIFIC HEAT CAPACITY

The specific heat capacity, C (J/kg.K) often called simply specific heat is the heat capacity per unit mass of a material. It is a matter that able to store thermal energy and it is define by evaluating the amount of energy in the form of heat needed to increase the temperature of a unit mass of matter by one degree. Specific heat capacity determine the amount of energy absorbed or released or even the enthalpy change in a body before changes of temperature (Gunn et al. 2005). The concentration of nanofluids can influence the specific heat capacity (Zhou et al. 2008) where the dispersion of Al_2O_3 reduced the specific heat capacity of water.

However addition of nanoparticle on specific heat capacity of fluid does not give any consistant results (Shin et al. 2011). The decreasing of specific heat capacity of nanofluids found by Das et al. (2009) by using zinc oxide and aluminium nanoparticles in mixture of water and ethylene glycol as the basefluid compared to the basefluid itself. Lu and Huang (2013) found that the increasing size of nanoparticles and concentration reduce the specific heat capacity of the nanofluid as shown in Figure 2.7.

In contrast, Zhou et al. (2010) found that there was 6.25% enhancement of specific heat capacity of the ethylene glycol-based CuO nanofluid. Furthermore Shin and Banerjee (2011) got 14.5% and 19% to 24% enhancements of the SHCs in the nanofluids consisting of 1wt.% SiO_2 nanoparticles doped in Li_2CO_3-K_2CO_3 eutectic and chloride eutectic, respectively. Avramov (2008) observed the increment of specific heat capacity with reducing particles size. This could be explained by Debye model of heat capacity of solids where the heat capacity increases as the Debye temperature reduces (Michailov et al. 2010). The reduction of Debye temperature with reducing particle size resulting in increased specific heat capacity.

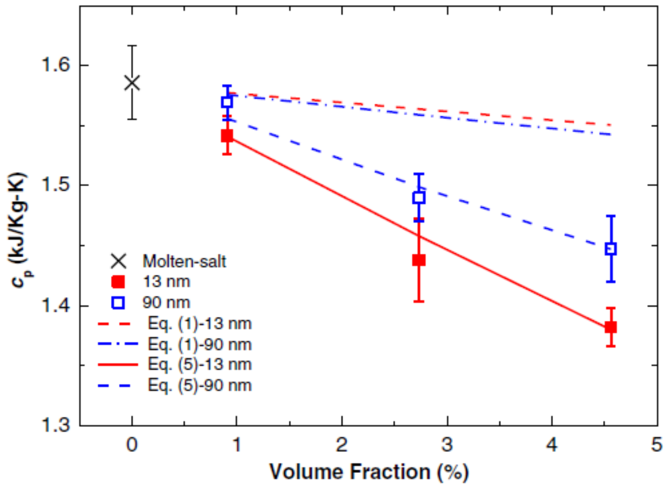

Figure 2.7: Effects of nanoparticle size and concentration of the specific heat capcity of nanofluid

(Source: Lu and Huang, (2013))

CHAPTER III

METHODOLOGY

3.1 INTRODUCTION

The concept of the experimental method is based on parameter used, techniques, apparatus and also way to conduct a research. As for this experiment, the preparation of stable nanofluid needs to be done by several steps with proper selection of parameter of carbon nanotube, dispersing agent and ethylene glycol. The Figure 3.1 will show the flow chart of the whole process formation of nanofluid. The flow chart includes all four chapter which are introduction, literature review, methodology and also result. Four experiments are considered in this study which are formulation of nanofluid samples, stability test, thermal conductivity test, heat capacity test and heat transfer analysis. The main idea for the experiment to be conducted is to find the percentage of enhancement of the nanofluid samples. All samples that being experimented must be in stable condition to avoid disturbance of the experimental results.

3.2 FLOW CHART

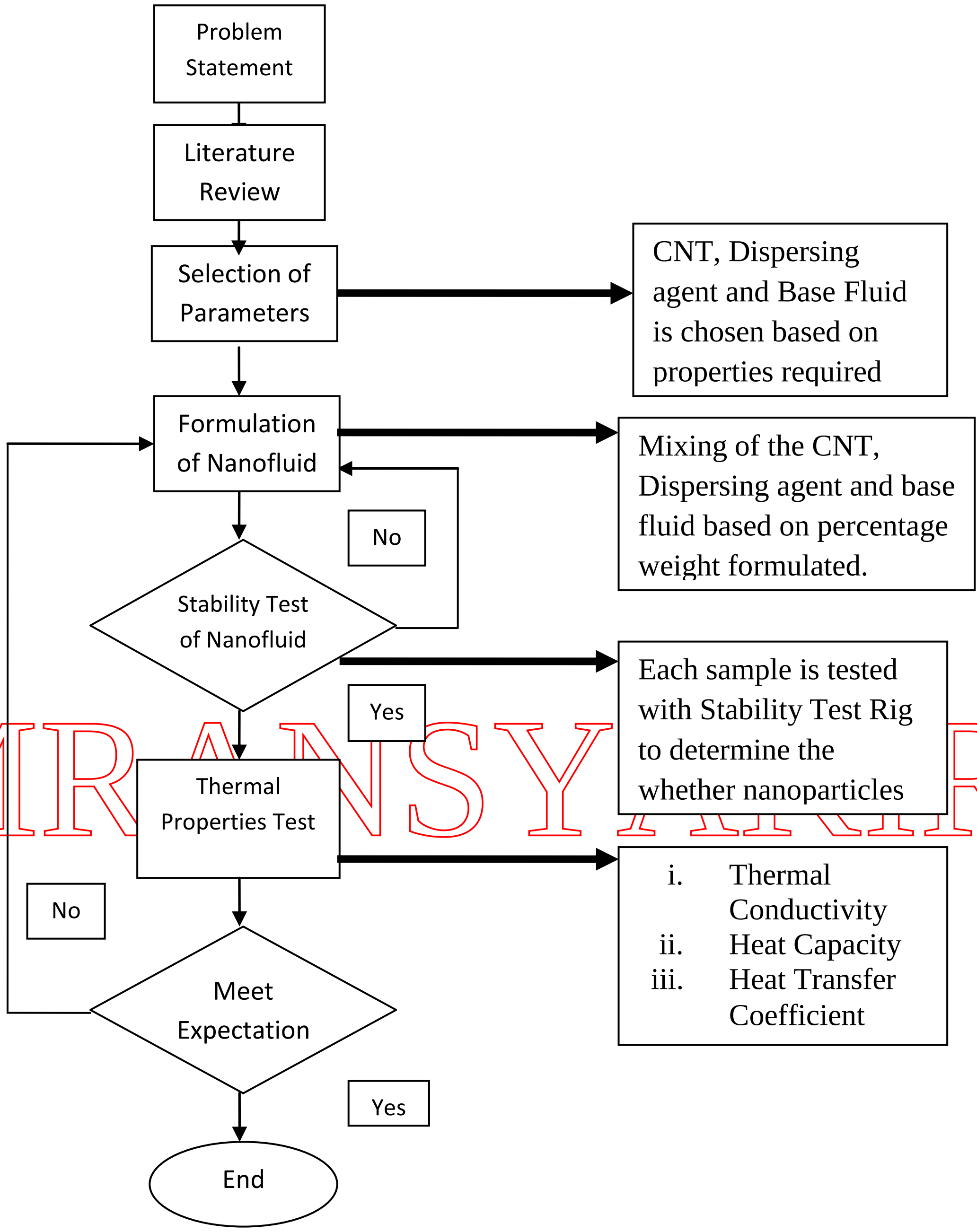

Figure 3.1: Flow chart of whole work flow

The flow chart in the Figure 3.1 shows the whole process of work starting from PSM 1 until PSM 2 which can be shown in Appendix B. The research begin with chapter 1 which to discover the problem statement of the research including the background, objective and scope. After that the literature review on various aspects like parameter concern regarding the stability of nanofluid need to be concern. For examples viscosity, thermal conductivity, basefluid, dispersing agent and so on. The selections of parameters have been determined in early stage. Further description on parameter used will be explained on parameter used section. After that formulate a stable ratio between CNT, dispersing agent and also ethylene glycol where the ratio obtained will be shown in chapter four. If there is sedimentation occurred, it is mean that the stability of the nanofluid did not achieved therefore need to reformulate new ratio of CNT, dispersing agent and also ethylene glycol. If the stability test rig shows a positive result, there were three experimental test that need to be conduct which are thermal conductivity test, heat capacity test and also heat transfer test. If the results meet all the expectation and make sense, proceed to further discussion and thesis completion.

3.3 PARAMETER USED

There are numerous sorts of parameter utilized within request to uncover the stability, thermal conductivity, heat capacity, and heat transfer efficiency of the nanofluids which are ethylene glycol as base liquids, carbon nanotubes as raw material, surfactant as the catalysts and likewise the sum proportion between carbon nanotube with the surfactant. Ethylene glycol is the major fluid base for convective heat transfer like car radiator engine and liquid cooled computers. Pure ethylene glycol has specific heat capacity for one half of water. That’s why ethylene glycol is the base fluid base. The CNT used for this project is Nanoamor carbon nanotube that manufactured by Materials and Electrochemical Corporation (MER) which is Multi-wall Carbon Nanotube (MWNT) as shown in Table 3.3. The catalysts used in this experiment are Polyvinylpyrrolidone (PVP). The experiment was carry out to determine the exact ratio of dispersing agent to achieve the best in stabilisation, thermal conductivity, heat capacity and also heat transfer coefficient by assisted with CNT in ethylene glycol.

3.3.1 Properties of Base Fluid

A current commercial coolant Toyota Long Life Coolant L215EU was chosen as the base fluid of the nanofluid because the coolant is almost pure (100%) of ethylene glycol as shown in Table 3.1 where Table 3.2 shows that the properties of the coolant with the standard properties of a radiator coolant.

Table 3.1: Base fluid properties

(Source: Toyota Long Life Coolant Material Safety and Data Sheet)

Parameter	Value
Boiling Point	>148.889 ºC
Melting Point	< -15 ºC
Density	1.13 g/cm^3
pH (50v/v%)	7.6
Solubility in Water	Infinite miscibility
Physical Appearance	Clear, marginally viscous, dark red dyed liquid

Table 3.2: List of Base Fluid Components

(Source: Toyota Long Life Coolant Material Safety and Data Sheet)

Components	Percentage
Ethylene Glycol	87-95
Diethylene Glycol	<5
Hydrated inorganic acid, organic acid salts	<5
Water	<5

3.3.2 Properties of CNT

In this experiment Nanoamor carbon nanotube which was founded in 2001 is used as the main CNT of the nanofluid. It was founded in Los Alamos, New Mexico, USA. Nanoamor CNT was chosen because it can improve thermal properties significantly. Xia Z. with the Eastman Chemical Company patented a composite polymer that uses MWNT with 95% of purity of Nanoamor titanium carbide nanoparticles (Xia Z. 2006).

Table 3.3: Properties of Nanoamor CNT

(Source: Nanostructured and Amorphous Materials Inc.)

CNT Types	MWNT Carbon Nanotube
Purity	95%
Core Diameter	0.0070 µm
Length	5-15 um
Specific Surface Area	40 - 300 cm3/g
Density	2.1 g/cm3
Colour	Black

3.3.3 Dispersing Agent

Surface tension of the nanofluid which is hydrophobic in characteristic need to be lowered in order to fully dispersed. Thus Polyninylpyrrolidone (PVP) has been choosed to lower the surface tension of the basefluid because it induces less foam. The density of the PVP is 1.6 g/cm3, J & K Scientific Ltd. (2008).

3.3.4 Percentage Weight of CNT, PVP and Base Fluid

As the size of the container, the total volume of the mixture of base fluid, dispersing agent and distilled water can only be 100 ml. Trial and error is the only way to find the perfect ratio between the dispersing agent and CNT to achieved stability with low percentage of CNT. The volume of 100 ml of the percentage weight formula is used to find the volume of CNT and PVP. Due to only 40 ml specimen will be used which equivalent to 40% of total percentage, the volume of the base fluid can be determine by obtained the remaining volume left from total of CNT and PVP. There is only 40 ml volume of solution used because the sample will be transferred to 40 ml specimen container. The example of weight percentage and volume of CNT, PVP and base fluid shown in Table 3.4 with 40% percentage of PVP. Therefore further detail calculation on weight percentage of CNT and PVP are shown in Appendix A. The volume of solution is shown in Equation 3.1.

$$\text{Volume} = \frac{\text{Weight percentage}}{\text{Density}} \quad (3.1)$$

Table 3.4: Example of weight percentage and volume of CNT, PVP and Base Fluid

CNT (%)	CNT Volume (ml)	PVP (%)	PVP Volume (ml)	Base Fluid (ml)
0.1	0.0476	0.04	0.025	99.9274

3.4 APPARATUS

3.4.1 Mechanical Homogenizer

Figure 3.2 shows the homogenizer that was manufactured a large known company Lab Genius which applying rotational shear force to homogenized the surfactant, CNT into the distilled water. The rotational spped can be up to 27000 rpm. For the best result, set the speed 10000 rpm in five minute to stir the solution.

Figure 3.2: Mechanical Homogenizer

3.4.2 Ultrasonication

In our laboratory, the ultrasonic as in Figure 3.3 was manufactured by Elma Hans Schmidbauer GmbH & Co. KG, German. Due to strong bonding forces between the CNT particles, with the perfect setting of temperature and frequency ultrasonic may overcome the problem. This is because of the ultrasonication generate shear forces and micro turbulences ultrasound which can assist in the surface coating and chemical reaction of nanotubes with other materials. The maximum capacity of the container that can be put into the ultrasonic apparatus is eight at one time.

Figure 3.3: Ultrasonic Cleaning Unit

3.4.3 pH meter

In order to check the stability of the nanofluid solution after the dispersion in ultrasonic, the pH value is indeed needed to be checked by pH meter as in Figure 3.4. The reading of pH meter and suitable ratio must be accurate between the dispersing agents and the carbon nanotube.

Figure 3.4: pH meter

3.4.4 Stability Test Rig

Stability test rig identify the stability of nanofluid by using the combination of laser and test rig as shown in Figure 3.5. It is used to check the stability of nanofluids based nanocarbon. It operates with both Light Emitting Diode (LED) and Light Dependant Resistor (LDR). If the nanofluid in unstable condition, LDR will received light that emitted by the LED because the light can penetrate through the solution. The increasing of light intesity will cause decreasing of the ability of resistency of the LDR. The right LED shows the stable nanofluid where the leftside of the LED shows the unstable nanofluid condition as shown in Figure 3.5.

Figure 3.5: Stability Testing Rig

3.4.5 KD2-Pro Thermal Properties Analyzer

KD2- Pro is a handheld device manufactured by Decagon Devices Inc. used to measure thermal properties which is shown in Figure 3.6. It consists of several controllers and sensors that can be inserted to any materials. Single needle sensors measure thermal conductivity and resistivity suitable in fluids while the dual-needle sensor measures thermal conductivity, resistivity, volumetric specific heat capacity and diffusivity.

Figure 3.6: KD2-Pro Thermal Properties Analyzer

3.4.6 DIGITAL ANALYTICAL BALANCE

All the parameter will be weight by the digital analytical balance as shown in Figure 3.7. The analytical balance was manufactured by Mettler Toledo Inc. Due to the state condition of the CNT and PVP which are in powder form, the precision measuring for both powder must be accurate and required 0.1 milligram to 10 microgram readability. That is why digital analytical balance is used during the weighing of the weight percentage of CNT and PVP as well as ethylene glycol.

FIGURE 3.7: Digital Analytical Balance Dragon 204

3.5 EXPERIMENTAL PROCEDURE

3.5.1 Synthesis of Nanofluid

The preparation and synthesizing of the nanofluid as well as the testing of the thermal conductivity, heat capacity and heat transfer efficiency will be shown by following procedure:

i. The amounts of all parameters were weighed by using analytical balance by the weight percentage of CNT, PVP and base fluid.

ii. CNT, PVP and base fluid were mixed together with the correct ratio that been formulated earlier in glass container. The container must be shaken well to increase the possibility of the nanofluid dispersion.

iii. The solution sample then been homogenized by mechanical homogenizer under speed of 10000 rpm for 60 seconds. The propeller was placed about one centimetre from the bottom of the container. The container was covered by a plastic wrap as the precaution step to avoid samples from splashing out.

iv. After homogenization process, the samples undergo ultrasonication inside the ultrasonic cleaner. The temperature was set up to 25 °C at the highest frequency to ensure CNT and PVP dispersed completely inside the deionized water for 60 minutes.

v. The pH value for the samples was identified by pH meter after ultrasonication process.

vi. Then the samples been homogenized again for three minutes at 1000 rpm. Placed the propeller just like step number three.

vii. The result of the stability of the samples will be tested by stability test rig after 100 hours.

viii. The samples that pass the stability test undergo thermal conductivity test by using KD2-Pro Thermal Properties Analyzer.

ix. Heat capacity and heat transfer efficiency test was conducted after selection of the best enhancement of samples in terms of thermal conductivity.

3.5.2 Thermal Conductivity Test

The sensor of the KD2-Pro with single needle or known as KS-1 sensor is specifically designed to test the liquid sample which provides a very small heat pulse. The KS-1 sensor will attached to the sensor slot at KD2-Pro. Before run the test, the samples must be transferred to the specimen container with the attachment of silicon cap so that the needle of KS-1 sensor will remain static during the testing process. Then turn the KD2-Pro in automatic mode and take the measurement in one minute as shown in Figure 3.8. The thermal conductivity test of the nanofluid will be taken at 3 °C, 25 °C and 60 °C. To obtain such temperature of the nanofluid, those samples will be immersed in the water bath so that the temperature of the samples will maintain at desired temperature.

Figure 3.8: Thermal conductivity test of ethylene glycol at room temperature

3.5.3 Heat Capacity Test

Calorimeter bomb as shown in Figure 3.9(a) will be used for measuring the heat capacity test. The sample will be put into the crucible for 0.5 gram of the nanofluid and then place the crucible at the crucible holder. A cotton thread was tied up to the crucible holder and dipped the end of the thread into the sample of nanofluid. Placed the cover along with the sample inside the decomposition vessel and closed firmly with union nut. Oxygen is filled by the oxygen gas station for 30 seconds right after the pressure gauge reached 30 kPa. The composition vessel will be placed at the centre between the three locating bolts inside the calorimeter vessel as shown in Figure 3.9(b). Then the ignition adaptor was slidely closed onto the decomposition vessel. Pour two litres of water into the storage tank. Then the data of the sample like weight and errors were administered to start the testing of heat capacity. The testing will take about 20 minutes to complete.

Figure 3.9: (a) Complete set of Calorimeter Bomb,
(b) Position of decomposition vessel inside the vessel of calorimeter.

3.5.4 Heat Transfer Coefficient

The apparatues was set up as shown in Figure 3.10. The copper coil was soaked inside the water bath where the inlet was attached to water pump and the outlet will be flow out back into the 400 ml beaker. The thermocouple wire will be placed at the inlet and outlet of the copper coil to take the temperature differences of the nanofluid. The beaker will be filled by 400 ml of nanofluid with the ratio of 400% of samples. The water pump was placed inside the sample which will pump up the nanofluid to the copper coil. The nanofluid undergoes heat transfer process and flow to the outlet of copper coil, thus flow back into the beaker. The pump will ensure the constant flow of the nanofluid through the passage ways. The reading will be taken at 6 °C, 25 °C and 45 °C of the temperature of water bath in each five minutes after the flow of the nanofluid constantly flow. The detail setup experiment of heat transfer coefficient can be observed in Appendix C.

Figure 3.10: Set up of heat transfer coefficeint test

3.6 Safety Precaution

All experiments have their safety and precautions. It is based on what kind of material and experiment that they are handling. In our case, we are handling Nanoamor carbon nanotube powder. As the size of the powder is in less than milimeters it can easily get into your lung during inhalation. As we know carbon can damage our organ and cause cancer. It can flow through your vein and become poison that attack our heart. That is why we need to handle the experiment with extra careful and precise. During the experiment, we need to wear an apron, mask and a pair of glove. If the carbon powder spilled or drop on the table or floor, clean them with sweeper or vacuum cleaner. Spray with water after that at the entire area. Do not to forget wash your hands after you are done the experiment with soap or any detergents as long as it able to kill bacteria and keep our hand clean.

CHAPTER IV

RESULT AND DISCUSSION

4.1 INTRODUCTION

The experimental results that obtained from stability test, thermal conductivity test, heat capacity test and also heat transfer coefficient test were gathered and shown in graphical charts and tabulation of data. All the data obtained will be discussed in further explanation to make a good decision to show the results meet an expectation. The data from the experiment show a tally results with the previous studies that contain in literature review. This shows that the results obtained meet all the expectation. Most of the samples experienced an enhancement but there is also meet a decrement in terms of thermal conductivity, heat transfer efficiency and also heat capacity. The best sample obtained is the NF17 with 0.3 wt% of CNT. Further explanations and details will be shown in this chapter. All the comparison of the best enhancement and most reduction of the samples will be explained in graphical method to ensure better understandings.

4.2 RESULT

4.2.1 Stability Test

The stability test was conducted after the samples were left for 100 hours of observation. Besides using the stability testing rig where the whole process of the experiment is shown in Appendix B, all samples can be observed if there are any failures in term of stability where the sedimentation can be seen at the bottom of the nanofluid samples. The unstable samples were not being tested by KD2-Pro to perform thermal conductivity test because the sediment will affect the result. Table 4.1 show the result of the stability of the samples. In order to obtained the value of the precise formulation of the samples, try an error approach was used by referring the previous studies as a guide. The red font as in Table 4.1 show the primary stable sample that used to perform the conductivity test, heat transfer coefficient test and also heat capacity test. All samples of the Nanoamor CNT were dispersed in commercial coolant by helps of PVP as surfactant during the formulation. Several parameters that been used here are the density of the CNT which is 2.1 g/cm^3, density of PVP which is 1.6 g/cm^3 and also volume of the ethylene glycol which at 40 ml.

Table 4.1: Stability of nanofluid sample

Sample	CNT (%)	PVP (%)	Base Fluid (ml)	Stability		
				24hr	72hr	>100hr
NF01	0.4	0.16	99.71000	Stable	Unstable	Unstable
NF02	0.6	0.24	99.56000	Stable	Unstable	Unstable
NF03	0.8	0.32	99.42000	Stable	Unstable	Unstable
NF04	1.0	0.40	99.28000	Stable	Unstable	Unstable
NF05	0.1	0.01	99.94575	Stable	Unstable	Unstable
NF06	0.1	0.02	99.93950	Stable	Unstable	Unstable
NF07	0.1	0.03	99.93325	Stable	Unstable	Unstable
NF08	0.1	0.04	99.92740	Stable	Unstable	Unstable
NF09	0.1	0.05	99.92075	Stable	Unstable	Unstable
NF10	0.1	0.2	99.82740	Stable	Stable	Stable
NF11	0.1	0.22	99.81490	Stable	Stable	Stable
NF12	0.1	0.24	99.80240	Stable	Stable	Stable
NF13	0.1	0.26	99.78990	Stable	Stable	Stable
NF14	0.1	0.28	99.78990	Stable	Stable	Stable
NF15	0.1	0.30	99.76490	Stable	Stable	Stable
NF16	0.2	0.4	99.65480	Stable	Stable	Stable
NF17	0.3	0.6	99.48210	Stable	Stable	Stable
NF18	0.4	0.8	99.30950	Stable	Stable	Stable
NF19	0.5	1.0	99.13690	Stable	Stable	Stable
NF20	0.6	1.2	98.96430	Stable	Stable	Stable
NF21	0.7	1.4	98.79170	Stable	Stable	Stable
NF22	0.8	1.6	98.61900	Stable	Stable	Stable
NF23	0.9	1.8	98.44640	Stable	Stable	Stable
NF24	1.0	2.0	98.28800	Stable	Stable	Stable

Table 4.1 show that the first four samples which are NF01, NF02, NF03 and NF04 were formulated by 40% percentage weight (wt%) of PVP based on the previous studies. The result shows a failure in next 72 hours later. The next five samples which are NF05, NF06, NF07, NF08 and NF09 had been formulated with ratio of 10%, 20%, 30%, 40% and 50% of PVP respectively. Those samples also show unstable condition where the sedimentation occurred in next 72 hours. Samples with 200% to 300% of PVP which are NF10, NF11, NF12, NF13, NF14 and NF16 show positive result when tested by stability test rig for the next 100 hours. So the

selected samples with red font shown in Table 4.1 will undergo thermal conductivity test are the samples that have 200% ratio of PVP and the range of CNT started from 0.1 wt% to 1.0 wt%.

4.2.2 Thermal Conductivity Test

After stable sample was obtained, thermal conductivity test was performed. The experiment tested at five different temperatures which are 3 °C, 6 °C, 25 °C, 45 °C and 60 °C because need to obtain the enhancement or thermal conductivity change due to the temperature difference. Table 4.2 show the result of the samples of thermal conductivity and Figure 4.1 show the graph of the thermal conductivity results. The sample will be placed in the water bath to ensure the temperature needed for the nanofluid is achieved. This is because the temperature of the water bath can be control, so by immersing the sample into the water bath can control the temperature of the nanofluid.

Table 4.2: Thermal Conductivity of samples at temperatures 3 °C, 6 °C, 25°C, 45 °C and 60 °C

Code	CNT (%)	Thermal Conductivity (W/m.K) at temperature (°C)				
		3°C	6°C	25°C	45°C	60°C
Standard	-	0.255	0.259	0.243	0.231	0.200
NF10	0.1	0.262	0.271	0.242	0.267	0.233
NF16	0.2	0.299	0.260	0.248	0.317	0.255
NF17	0.3	0.273	0.289	0.243	0.349	0.329
NF18	0.4	0.281	0.256	0.210	0.237	0.267
NF19	0.5	0.282	0.277	0.288	0.322	0.260
NF20	0.6	0.290	0.273	0.129	0.312	0.280
NF21	0.7	0.293	0.311	0.127	0.331	0.297
NF22	0.8	0.258	0.227	0.044	0.333	0.292
NF23	0.9	0.324	0.314	0.351	0.271	0.219
NF24	1.0	0.318	0.266	0.277	0.309	0.239

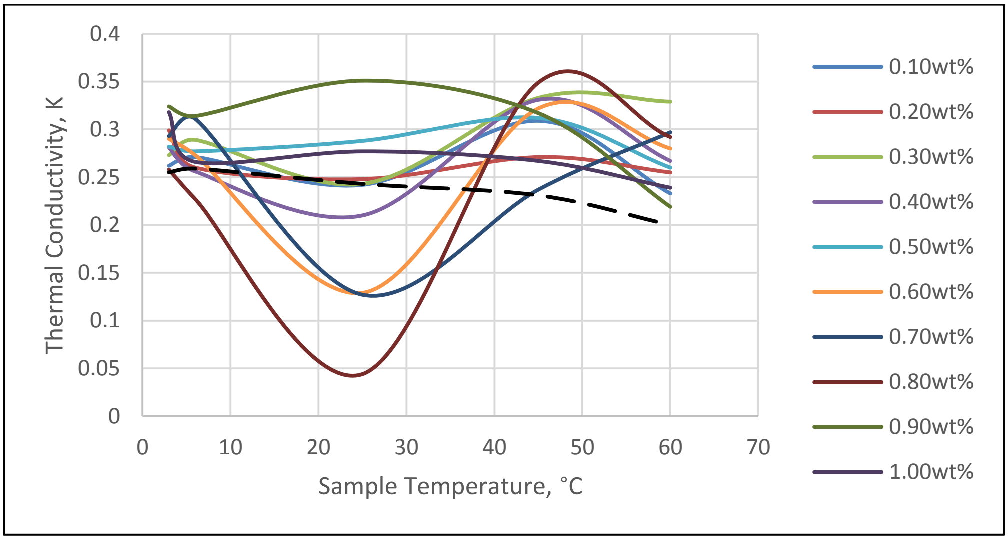

Figure 4.1: Graph of thermal conductivity of samples at 3 °C, 6 °C, 25 °C, 45 °C and 60 °C

Thermal conductivity of coolant in Table 4.2 is inversely proportional to the increasing temperature which will be set as datum to compare the thermal conductivity of the samples. The result can be seen clearly at Figure 4.1 where it shows the graph of the thermal conductivity of the samples. It shows that all samples have higher thermal conductivity than the standard coolant at both 3 °C and 60 °C. However at temperature of 25 °C, five samples experienced reductions which are 0.1 wt%, 0.4 wt%, 0.6 wt%, 0.7 wt% and 0.8 wt%. It seems that thermal conductivity at higher temperature has greater than the lower temperature. The highest thermal conductivity at 3 °C is NF23 with 0.9 wt% which is 0.324 W/m.K. The highest thermal conductivity at 25 °C is NF19 with 0.5 wt% which is 0.288 W/m.K and the highest thermal conductivity at 60˚C is NF17 with 0.3 wt% which is 0.329 W/m.K. The enhancement of the thermal conductivity of the samples can be seen clearly in Figure 4.2, Figure 4.3, Figure 4.4, Figure 4.5 and Figure 4.6.

4.2.2.1 Percentage of Enhancement of Thermal Conductivity

To calculate the percentage of enhancement of the thermal conductivity, the result of thermal conductivity of the sample that obtain will be compared to the thermal conductivity of the standard coolant in desired temperature which shown in

Appendix A. The thermal conductivity of the standard coolant is differ by each temperature which are 0.255 W/m.K, 0.243 W/m.K and 0.200 W/m.K at 3 °C, 25 °C and 60 °C temperature respectively.

$$Percentage\ of\ enhancement = \frac{T.C\ of\ NF17 - T.C\ \ of\ standard}{T.C\ of\ standard} \times 100 \qquad (4.1)$$

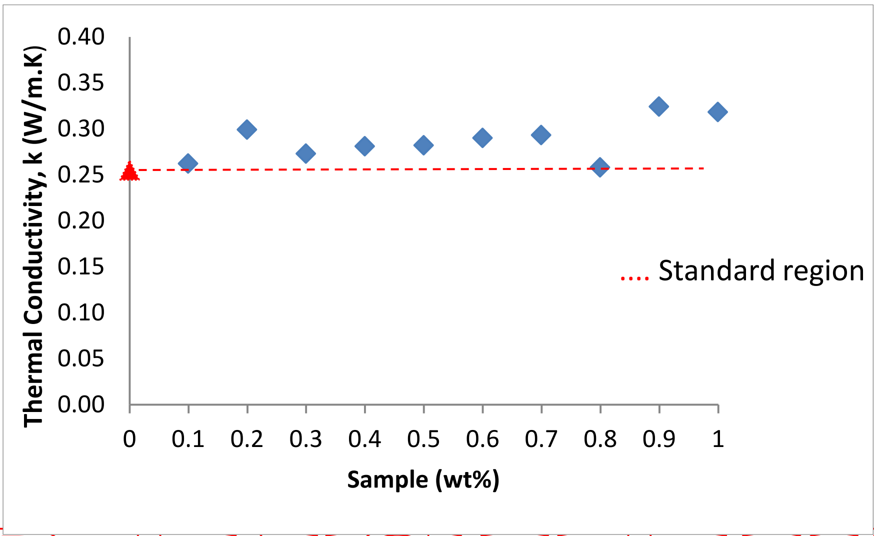

Figure 4.2: Thermal Conductivity of sample at 3 °C with enhancement

Based on Figure 4.2, all samples experienced an enhancement in terms of thermal conductivity. The increasing of wt% of CNT shows increment of thermal conductivity. Sample with 0.2 wt% shows good enhancement with 17.25% unlike sample NF22 with 0.8 wt% shows only a little enhancement which is 1.18%. The highest thermal conductivity enhancement is at sample NF23 with 0.9 wt% which is 27.06% higher than sample NF24 with 1.0 wt% which at 24.71%. The result of the thermal conductivity for 3 °C shows a linear increment basically. Only 0.2 wt% and 0.8 wt% of CNT shows an anomalous result. This phenomenon was explained in subtopic 2.7 where the nanofluid shows an irregular result in term of thermal conductivity. The only way to estimate their thermal conductivity is by testing it by experiment. In this study, KD2-Pro thermal properties analyzer was used to define thermal conductivity of the samples.

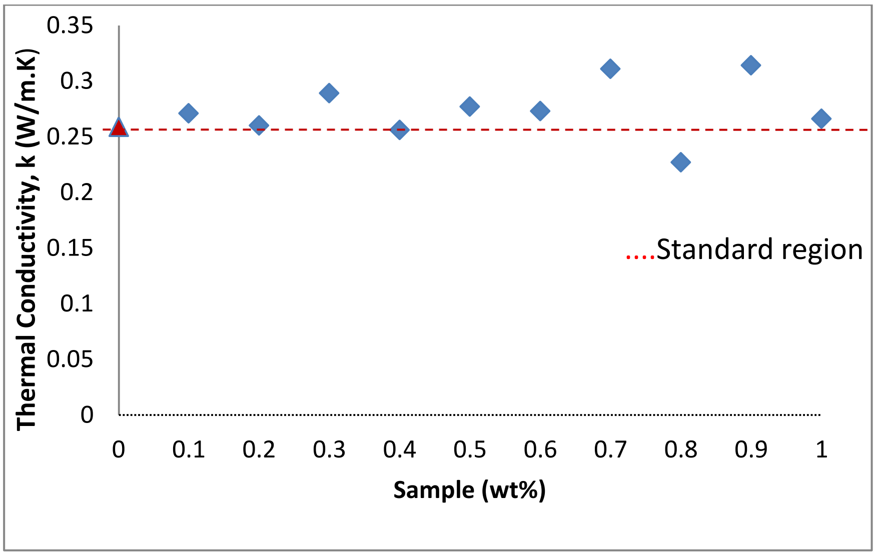

Figure 4.3: Thermal Conductivity of sample at 6 °C with enhancement

Based on the result in Figure 4.3 the highest enhancement experienced by sample NF23 with 0.9 wt% of CNT which is 21.26% of enhancement in term of thermal conductivity. Second highest is belongs to sample NF21 with 0.7 wt% of CNT by slight difference compare to sample NF 23 which is 20.1% of enhancement. The highest reduction clearly seen in sample NF22 with 0.8 wt% of CNT which is -12.36% of reduction. The other reduction experienced by sample NF18 with 0.4 wt% of CNT which is only -1.16%. The other sample exhibit an enhancement compare to the standard sample as the commercial coolant. The standard thermal conductivity as referred in Table 4.2 is 0.259 W/m.K.

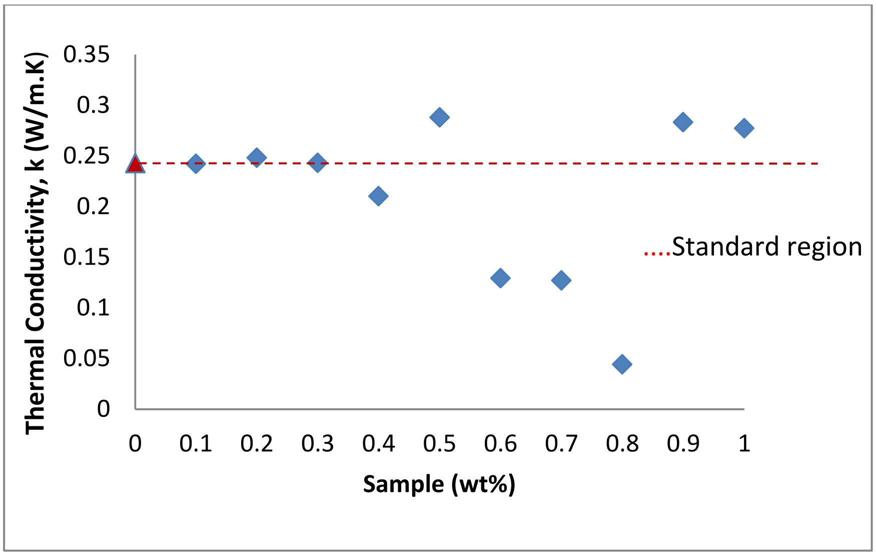

Figure 4.4: Thermal Conductivity of sample at 25 °C with enhancement

The results of the samples in terms of thermal conductivity in Figure 4.4 shows that only four samples undergoes enhancement which are NF16, NF19, NF23 and NF24 with 0.2 wt%, 0.5 wt%, 0.9 wt% and 1.0 wt% of CNT respectively. where as the other experienced reduction. 0.3 wt% has the same thermal conductivity as the standard coolant which is 0.243 W/m.K. The highest enhancement at 25 °C is sample NF19 with 0.5 wt% of CNT which is 18.52%. It seems that the thermal conductivity of the sample decreases with the wt% of CNT increases. Up until sample NF22 with 0.8 wt% has the lowest reduction of thermal conductivity with -81.9% and then sample NF23 with 0.9 wt% shows the increment with 16.46% followed by sample NF24 with 1.0 wt% which is 14% enhancement. Among the other temperature being tested in thermal conductivity, the lowest reduction exhibit by the sample is the room temperature which is 25 °C at sample NF22 as shown in Figure 4.4. Therefore most of the samples did not perform an enhancement in terms of thermal conductivity in this temperature.

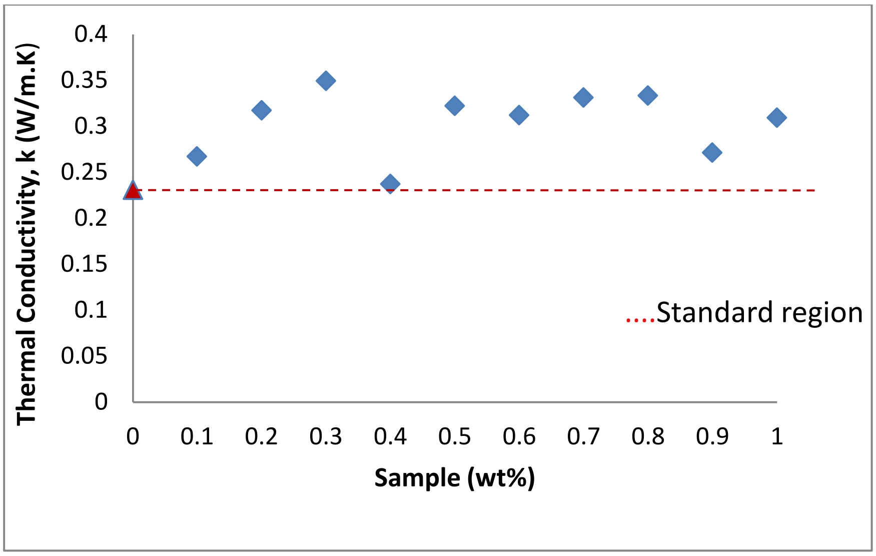

Figure 4.5: Thermal Conductivity of sample at 45 °C with enhancement

Figure 4.5 show that all samples have positive enhancement in terms of thermal conductivity. A linear increment can be seen between samples NF10 with 0.1 wt% of CNT until NF17 with 0.3 wt% which is the highest enhancement in term of thermal conductivity at 45 °C with 51.08%. Sample NF18 with 0.4 wt% of CNT show the lowest enhancement in this temperature which is only 3%. After that sample NF19 increase with 39.39% of enhancement. A minor reduction occurred at sample NF20 with 0.6 wt% of CNT which is 35.06%. Sample NF24 with 1.0 wt% of CNT seems to be higher enhancement than NF23 with 17.32% enhancement. The standard thermal conductivity at temperature 45 °C is 0.231 W/m.K. as shown in Table 4.2.

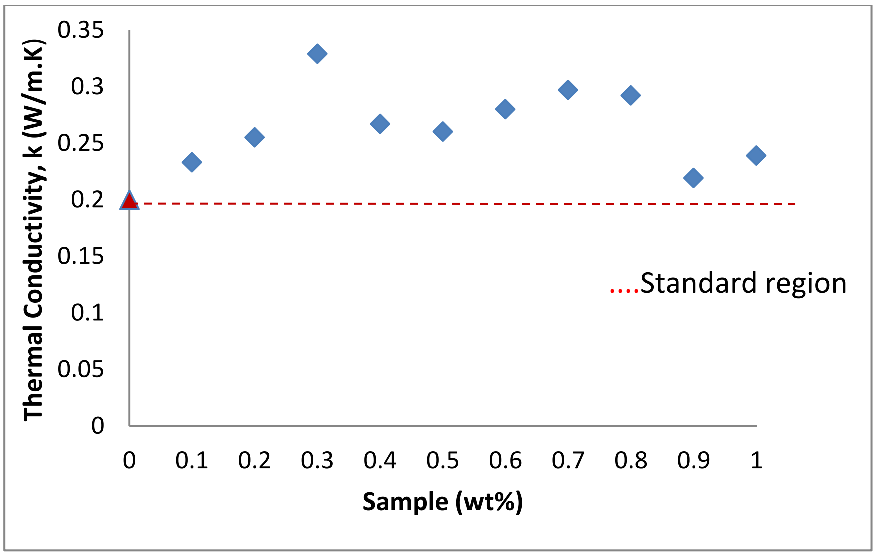

Figure 4.6: Thermal Conductivity of sample at 60 °C with enhancement

The result shows that all samples also experienced enhancement as shown in Figure 4.6. The graph shows that the medium wt% has better enhancement compared to the higher wt%. The enhancement is increasing from 0.1 wt% to 0.2 wt% which are 16.5% and 27.5% respectively. Then followed by 0.3 wt% which got the highest enhancement that is 64.5%. The lowest enhancement can be seen at 0.9 wt% which only 9.5% of enhancement. The thermal conductivity of samples at 60 °C has higher enhancement compared to thermal conductivity at temperature 3 °C and 25 °C where mostly have higher than 30% of enhancement. The lowest enhancement of thermal conductivity at 60 °C is sample NF23 with 0.9 wt% of CNT which is 9.5% of enhancement.

4.2.3 Heat Transfer Test

The heat transfer test will be conducted at 6 °C, 25 °C and 45 °C. The top three samples with highest enhancement in thermal conductivity will be selected to perform the heat transfer test. This is because higher enhancement of thermal conductivity has higher rate of heat transfer. To find the best enhancement the thermal conductivity at all temperature will be total up and the highest enhancement will be selected. According to Table 4.3 NF17, NF19 and NF23 have the highest total enhancements which are 134.22%, 105.45% and 94.67% respectively. So these three samples will be conducted by heat transfer test. Heat transfer test results will be shown in Table 4.4, Table 4.5 and Table 4.6.

Table 4.3: Percentage of enhancement of thermal conductivity

Code	CNT	Percentage of Enhancement (%) at temperature (°c)					
	(%)	3°C	6 °C	25°C	45 °C	60°C	Total
NF10	0.1	2.75	4.63	- 0.41	15.58	16.50	39.05
NF16	0.2	17.25	0.39	2.06	37.23	27.50	84.43
NF17	0.3	7.06	11.58	0	51.08	64.50	134.22
NF18	0.4	10.20	-1.16	- 13.58	3	33.50	31.96
NF19	0.5	10.59	6.95	18.52	39.39	30.00	105.45
NF20	0.6	13.73	5.41	- 46.91	35.06	40.00	41.88
NF21	0.7	14.90	20.10	- 47.74	43.3	48.50	79.06
NF22	0.8	1.18	12.36	- 81.9	41.16	46.00	- 5.92
NF23	0.9	27.06	21.26	4.44	17.32	9.50	91.54
NF24	1.0	24.71	2.70	14.00	33.77	19.50	94.67

Table 4.4: Temperature of inlet and outlet for heat transfer analysis at 6 °C

Time (minute)	Sample							
	Standard		0.3 wt%		0.5 wt%		1.0 wt%	
	T_{in}	T_{out}	T_{in}	T_{out}	T_{in}	T_{out}	T_{in}	T_{out}
0	27.3	7.9	28.4	8.4	27.8	8.1	27.1	7.9
1	27.3	7.8	28.5	8.3	27.8	8.2	27.3	7.8
2	27.3	7.8	28.3	8.2	27.8	8.0	26.9	7.8
3	26.6	7.8	28.3	8.2	27.9	7.9	26.4	7.8
4	27	7.8	27.9	8.2	27.8	8.0	27.4	7.8
5	26.9	7.8	28.3	8.2	27.8	8.0	27.3	7.8

Table 4.5: Temperature of inlet and outlet for heat transfer analysis at 25 °C

Time (minute)	Sample							
	Standard		0.3 wt%		0.5 wt%		1.0 wt%	
	T_{in}	T_{out}	T_{in}	T_{out}	T_{in}	T_{out}	T_{in}	T_{out}
0	24.1	25.0	27.5	25.0	26.6	25.0	26.7	25.0
1	24.0	25.0	27.5	25.0	26.8	25.0	26.7	25.1
2	24.0	25.0	27.5	25.3	27.3	25.0	26.8	25.3
3	24.1	25.0	28.1	25.1	27.5	25.1	27.1	25.0
4	24.0	25.0	27.6	25.0	27.1	25.0	26.9	25.0
5	24.1	25.0	27.3	25.3	27.3	25.0	27.2	25.0

Table 4.6: Temperature of inlet and outlet for heat transfer analysis at 45 °C

Time (minute)	Sample							
	Standard		0.3 wt%		0.5 wt%		1.0 wt%	
	T_{in}	T_{out}	T_{in}	T_{out}	T_{in}	T_{out}	T_{in}	T_{out}
0	27.0	44.1	27.7	43.2	27.3	44.5	27.7	44.0
1	27.1	44.0	27.7	43.1	27.2	44.6	27.7	44.0
2	27.2	44.3	27.7	42.8	27.2	44.6	27.8	44.1
3	27.2	44.3	27.8	43.2	27.9	44.4	27.6	44.4
4	27.0	44.3	27.7	43.1	27.5	44.5	27.9	44.2
5	27.2	44.1	27.6	42.9	27.3	44.5	27.8	44.0

Based on the Table 4.4, Table 4.5 and Table 4.6, the average of the temperature inlet and outlet will be taken into account to determine performance of the heat transfer by comparing with the average of the standard coolant as shown in Table 4.7.

Table 4.7: Average temperature of samples at 6 °C, 25 °C and 45 °C

Sample	CNT (%)	Average Temperature (°C) 6°C	25°C	45°C
Standard	-	19.25	0.95	17.10
NF17	0.3	20.02	2.46	15.35
NF19	0.5	19.8	2.08	18.35
NF24	1.0	20.29	1.80	16.37

Table 4.7 shows the average temperature of NF17, NF19 and NF24 of inlet and outlet of the copper coil at 6 °C, 25 °C and 45 °C. It shows how much the heat that been transferred inside the copper coil. The heat transferred at room temperature is so small which is only 0.95 °C not even achieved 1 °C compared to other temperature. The enhancement of heat transfer will be shown in Figure 4.7, Figure 4.8 and Figure 4.9 where Table 4.8 shows the percentage of enhancement of the samples. The percentage of enhancement of the temperature difference can be obtained in Appendix A.

Table 4.8: Percentage of enhancement of heat transfer at 6 °C, 25 °C and 45 °C

Code	CNT (%)	Percentage of Enhancement (%) at temperature (°C) 6°C	25°C	45°C
NF17	0.3	12.03	158.95	- 10.41
NF19	0.5	2.86	129.47	0.12
NF24	1.0	5.14	93.84	- 4.15

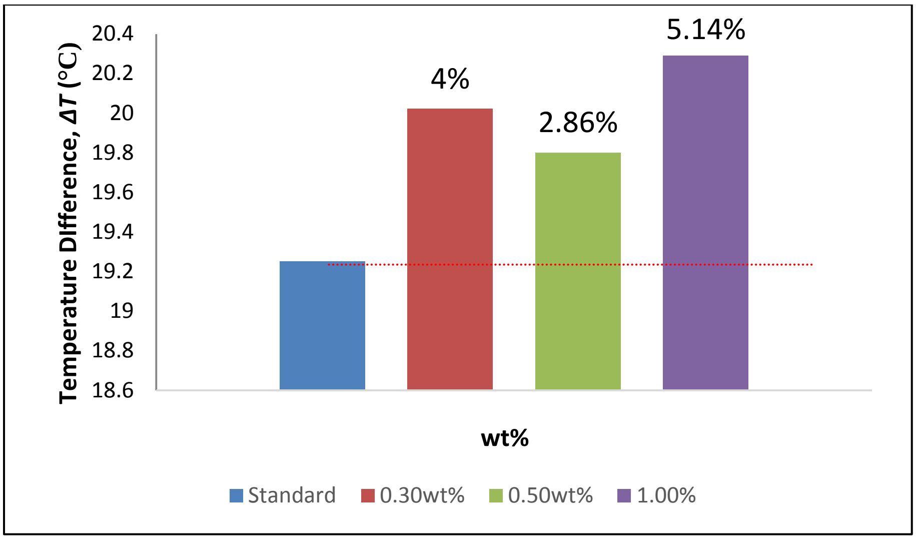

Figure 4.7: Temperature difference of samples at 6 °C

The Figure 4.5 shows that all three samples had better enhancement. 1.0 wt% had highest enhancement which is 5.14% where the lowest is at 0.5 wt% with 2.86% of enhancement. Then the second highest belongs to 0.3 wt% with 4% enhancement.

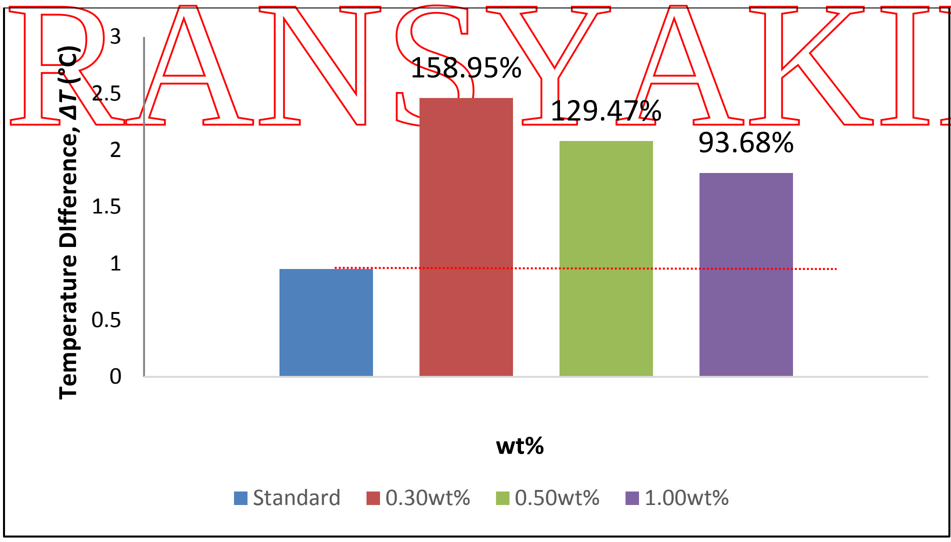

Figure 4.8: Temperature difference of samples at 25 °C

Figure 4.6 show the samples have greater enhancement compare to the other temperature. The 0.3 wt% has highest enhancement with 158.95% followed by 0.5 wt% and 1.0 wt% which are 129.47% and 93.68% enhancement respectively. The pattern shows that the temperature difference is inversely proportional to the wt% unlike the results in Figure 4.4 and Figure 4.5.

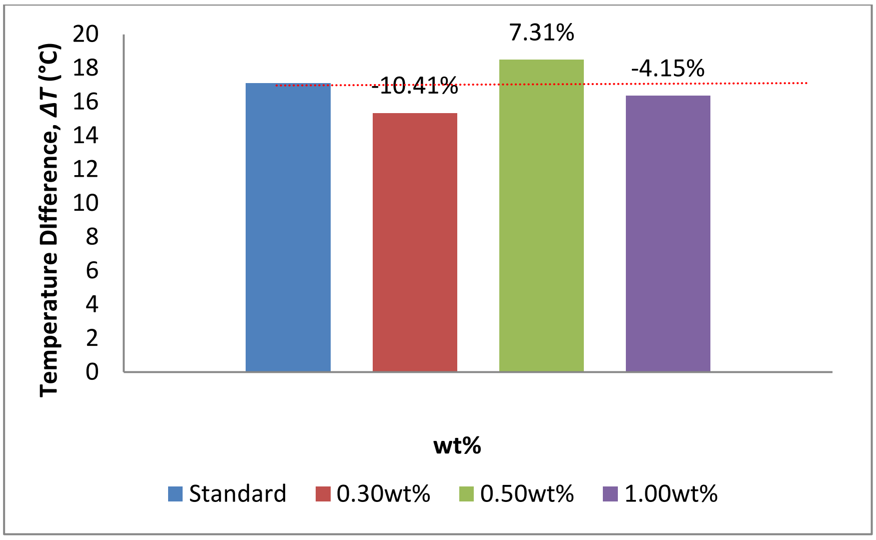

Figure 4.9: Temperature difference of samples at 45 °C

Figure 4.7 show that two samples undergo reduction in temperature difference. Only 0.5 wt% had 7.31% of improvement where 0.3 wt% and 1.0 wt% decreases to -10.41% and - 4.15% of temperature difference. The decrement is due to the properties of the commercial CNT that produced without heat treatment causing the heat transfer performance not so effective in high temperature.

4.2.4 Heat Capacity Test

The three selected samples which are NF17, NF19 and NF24 with best thermal conductivity enhancement will be experimented on heat capacity test by using calorimeter bomb. Only using 0.5 ml of the sample to perform the test and the result is shown in Table 4.9. The calculation of enhancement will be shown in Appendix A.

Table 4.9: Specific heat capacity of sample

Code	CNT (wt%)	Specific Heat Capacity (Cal/g)
Standard	-	4063
NC017	0.3	3969
NC019	0.5	3872
NC024	1.0	3846

4.2.4.1 Enhancement of Heat Capacity

Figure 4.8 show that all sample exhibit reduction in enhancement. Standard coolant has 4063 Cal/g of specific heat capacity. The highest reduction is 1.0 wt% of CNT with -5.34% followed by 0.5 wt% with -4.7% and lastly the lowest reduction of heat capacity is 0.3 wt% with -2.31%.

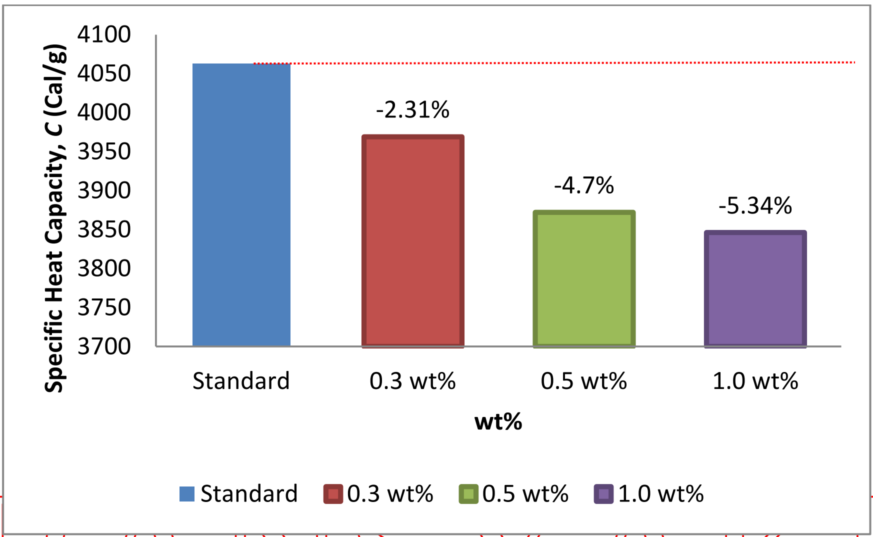

Figure 4.10: Percentage of enhancement of sample in specific heat capacity

4.3 DISCUSSION

4.3.1 Stability Test Analysis

During formulation of the ratio of nanofluid, several parameters reviewed from the previous studies to make sure the stability of the nanofluid can be obtained. There are two parameters that need to be concerned about which are PVP as the dispersing agent and also ultrasonication process. According to (Fendler 2001) the using of PVP during the formulation will enhanced the stability of the nanofluid due to the properties of PVP which significantly reduces the particle agglomeration due to van der Waals forces of attraction by the electrostatic repulsion between surfactant-coated nanoparticles. The validity of the nanofluid is only long as it is stable. An agglomerated nanofluid is different in properties which may cause operational problems such as sedimentation and clogging of the systems. Therefore nanofluid will be implemented in heat transfer devices or installation involves working at high temperature conditions. Therefore (Prasher et al. 2006) suggest that the stability of the nanofluid need to be in constant stable condition even in high temperature due to high probability of aggregation of nanoparticles. Thus surfactants or dispersing agent will help to reduce the agglomeration of nanoparticles. The ultrasonication process is also important for stability of nanofluid. Based from (Hays et al. 2006) the longer duration of ultrasonication process have better thermal conductivity enhancement of nanofluid.

4.3.2 Thermal Conductivity Analysis

There are several factors affecting the thermal conductivity of the nanofluid. Based on the results of thermal conductivity of the samples it was discussed that the temperature, ratio percentage weight of CNT and the base fluid are the factor that affect the thermal conductivity of nanofluid.

4.3.2.1 Effect of temperature

The temperature of two different component mixture like nanofluid depends on temperature of solid component. The increasing temperature enhance the collision between nanoparticles (Brownian motion) and induce aggregation between nanoparticles (Li et al. 2008). The aggregation will result in changes in thermal conductivity. Based on Table 4.2 it show that higher enhancement of thermal conductivity at 60 °C. Mohamad et al. (2013) stated that the possible reason is because of higher mobility and activity of particle. Mobility of suspended particles will increase with temperature through convection of heat transfer and conduction (Lee et al. 2010) Researchers have explained the enhancement in thermal conductivity with temperature in aspect of Brownian motion of particles since it increases the micro convection in nanoparticle suspension.

4.3.2.2 Effect of Percentage Weight

From result and analysis obtained in 4.2.2.1 the percentage weight of CNT give irregular or known as anomalous enhancement in term of thermal conductivity. (Choi S. 1995; Choi S. et al. 1999; Eastman et al. 1995) give the strong support on the study of anomalous behaviour of the nanofluid. To explain the reasons for the anomalous behaviour of thermal conductivity in nanofluids, Keblinski et al. (2002) and Eastman et al. (2004) suggest four possible mechanisms which are Brownian motion of the nanoparticles, molecular level layering of the liquid at liquid/particle interface, nature of heat transport in naoparticles and the effects of nanoparticles clustering.

4.3.2.3 Effect of Base Fluid

Based on conventional effective medium theory (Maxwell 1873), as the base fluid thermal conductivity decreases, the effective thermal conductivity of a nanofluid increases. Most of the experimental studies agree with theoretical values by the conventional mean field model. Wang et al (1999) found that ethylene gycol has highest thermal conductivity ratio as the base fluid compared to water, engine oil and vacuum pump oil.

4.4.3 Heat Transfer Coefficient Analysis

The result of heat transfer coefficient enhancement based on Table 4.3 also suggest the anomalous characteristic yet still show improvement by comparing with the heat transfer coefficient of standard coolant. The enhancement of the heat transfer coefficient is related to the factors affecting the thermal conductivity as in subtopic 4.3.2 which are temperature, weight percentage and also base fluid. As the increasing of weight percentage of CNT, the effective thermal conductivity of nanofluid tend to increase with Brownian motion of nanoparticles since it depends on weight percentage and temperature. The heat convection by the Brownian motion of nanoparticles resulting in increase of thermal conductivity. Therefore, the characteristic of the CNT which is multi-walled induced the increment of heat transferred due to the large surface area compared to single-walled CNT (Mohamad I. S. et al. 2013).

4.4.4 Heat Capacity Analysis

From the previous studies and researchers, aqueous experienced reduction in the specific heat capacity. The result from Figure 4.10 shows that the increment of weight percentage of CNT result in reduction of specific heat capacity which is support the result of the previous researcher in subtopic 2.9. It stated that Lu and Huang (2013) found the same results where Das et al (2009) also showed that the addition of nanoparticles in mixture of water and ethylene glycol causing reduction of specific heat capacity compared to the ethylene glycol itself. Sample NF17 with lowest wt% of CNT which is 0.3 wt% is capable to release lowest amount of energy in the form of heat compare to sample NF19 and NF24 with 0.5 wt% and 1.0 wt% respectively. Due to the result, these three samples were unable to store thermal energy since obtained lower specific heat capacity than standard sample but NF17 show the lowest thermal emission to be comparing with NF19 and NF24, so NF17 is more capable to store more energy. NF24 show the highest thermal emission which means it has lowest capability of storing the energy in form of heat. As mention in subtopic 2.9, this phenomenon can be explained by Debye model of heat capacity of solids where the heat capacity decreases as the Debye temperature increases. The increment of Debye temperature will increase particle size resulting in reducing specific heat capacity.

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The highly efficient carbon based nano-coolant using Nanoamor carbon nanotube is sample NF17 with 0.3 wt% of CNT by using PVP as the dispersing agent with 0.6% of PVP and Toyota coolant (ethylene glycol) as the base fluid. The enhancement in term of thermal conductivity of NF17 shown in Table 4.3 show that it has the highest enhancement in five temperatures which at 3 °C, 6 °C, 25 °C, 45 °C and 60 °C with enhancement 7.06%, 11.58%, 0%, 51.08% and 64.5% respectively as shown in Table 4.3. Even there is no enhancement or reduction at 25 °C, yet NF17 still has the highest total enhancement with 26.84% from five reading of temperature compared to the other samples. The detail about the total enhancement can be seen in Appendix A. It support that three factors consequently affects the enhancements of the nanofluid, which is when the heat applied, the percentage weight of the CNF and also base fluid used in the nanofluid sample which was discussed in subtopic 4.2.2. In term of heat transfer coefficient, NF17 exhibit reduction at 45 °C with -10.41%. Its shows that the nanofluid give anomalous behaviour which support the literature review in subtopic 2.7 .However at room temperature, NF17 has the highest enhancement with 158.95% and 4% at 6 °C which is higher than NF19 that is 2.86% enhancement only. As for the specific heat capacity, NF17 undergoes decrement from the standard coolant sample yet has the lowest reduction compared to NF19 and NF24 with -2.31% only compared with NF19 and NF24 with -4.7% and -5.34%

reduction respectively. Therefore it is tally with the result by the previous researchers in subtopic 2.9.

5.2 Recommendation

The heat transfer analyzer which was to perform the heat transfer capacity of the samples used a low power of pump which is designed specifically for small aquarium. So ethylene glycol exhibit lower flow rate compared to water to flow through the tube to reach the beaker. This is due to the higher viscosity compared to water which has lower viscosity. Plus the small diameter size of copper coil induces lower fluid flow to reach to the beaker. This probably gives an error which might affect the result of the heat transfer coefficient. So as for recommendation, higher power of pump and bigger size of copper coil is suggested in order to reduce the error of the result obtained.

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APPENDIX A

Sample Calculation

i. Percentage Weight

Determination of volume of base fluid for 40 ml specimen container:-

Density of Base Fluid (g/cm^3): 1.13

Density of CNT (g/cm^3) : 2.1

Density of PVP (g/cm^3) : 1.6

wt% CNT : 0.1

wt% PVP : 0.2

$$\text{Volume} = \frac{\text{Weight percentage}}{\text{Density}} \quad (3.1)$$

Volume of CNT = $\frac{\text{wt\% CNT}}{\text{density CNT}} = \frac{0.1}{2.1}$ = 0.0476 ml

Volume of PVP = $\frac{\text{wt\% PVP}}{\text{density PVP}} = \frac{0.2}{1.6}$ = 0.125 ml

Volume of Base Fluid = 40 ml – (Volume of CNT + Volume PVP)

= 40 ml – (0.0476 ml + 0.125ml) = 39.8274 ml

ii. Percentage of enhancement for thermal conductivity

Thermal conductivity of coolant at 3°C = 0.255 W/m.K

Thermal conductivity of NF17 at 3 °C = 0.273 W/m.K

$$Percentage\ of\ enhancement = \frac{T.C\ of\ NF17 - T.C\ of\ standard}{T.C\ of\ standard} \times 100 \qquad (4.1)$$

$$= \frac{0.273 - 0.255}{0.255} \text{ x } 100 = 7.05\%$$

iii. Percentage of enhancement for specific heat capacity (SHC)

SHC of coolant = 4063 Cal/gram

SHC of NF17 at 0.3 wt% = 3969 Cal/gram

$$Percentage\ of\ enhancement = \frac{SHC\ of\ NF17 - SHC\ of\ standard}{SHC\ of\ standard} \times 100$$

$$= \frac{3969 - 4063}{4063} \text{ x } 100 = -2.31\%$$

iv. Total enhancement of five reading temperature of thermal conductivity

Total percentage of enhancement for NF17 = 7.06% + 11.58% + 0% + 51.8% + 64.50% + 71.56%

= 134.22%

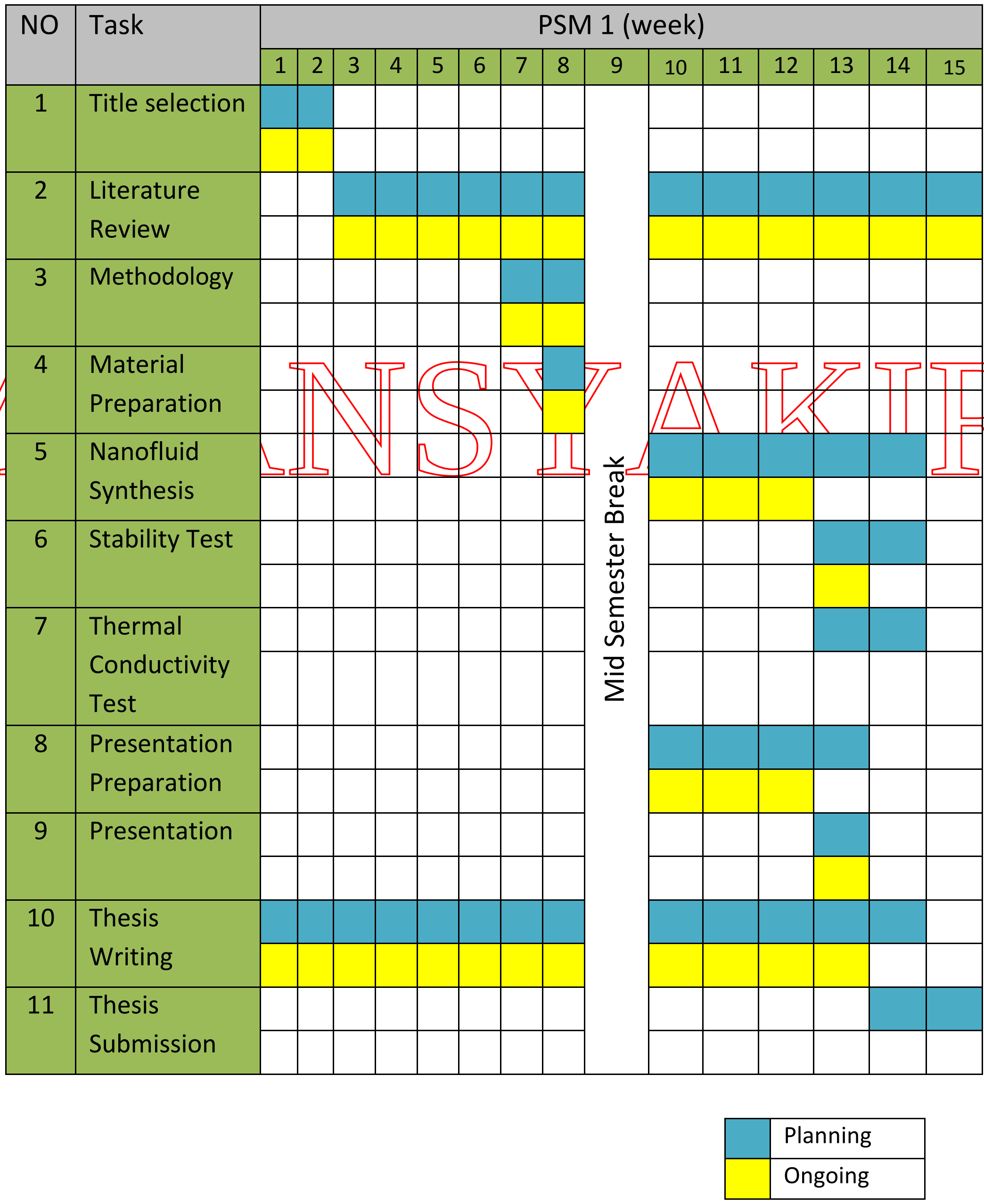
Actual total percentage of enhancement = 500%

$$Percentage\ of\ enhancement = \frac{Total\ percentage\ of\ enhancement}{Actual\ total\ percentage\ of\ enhancement} \times 100$$

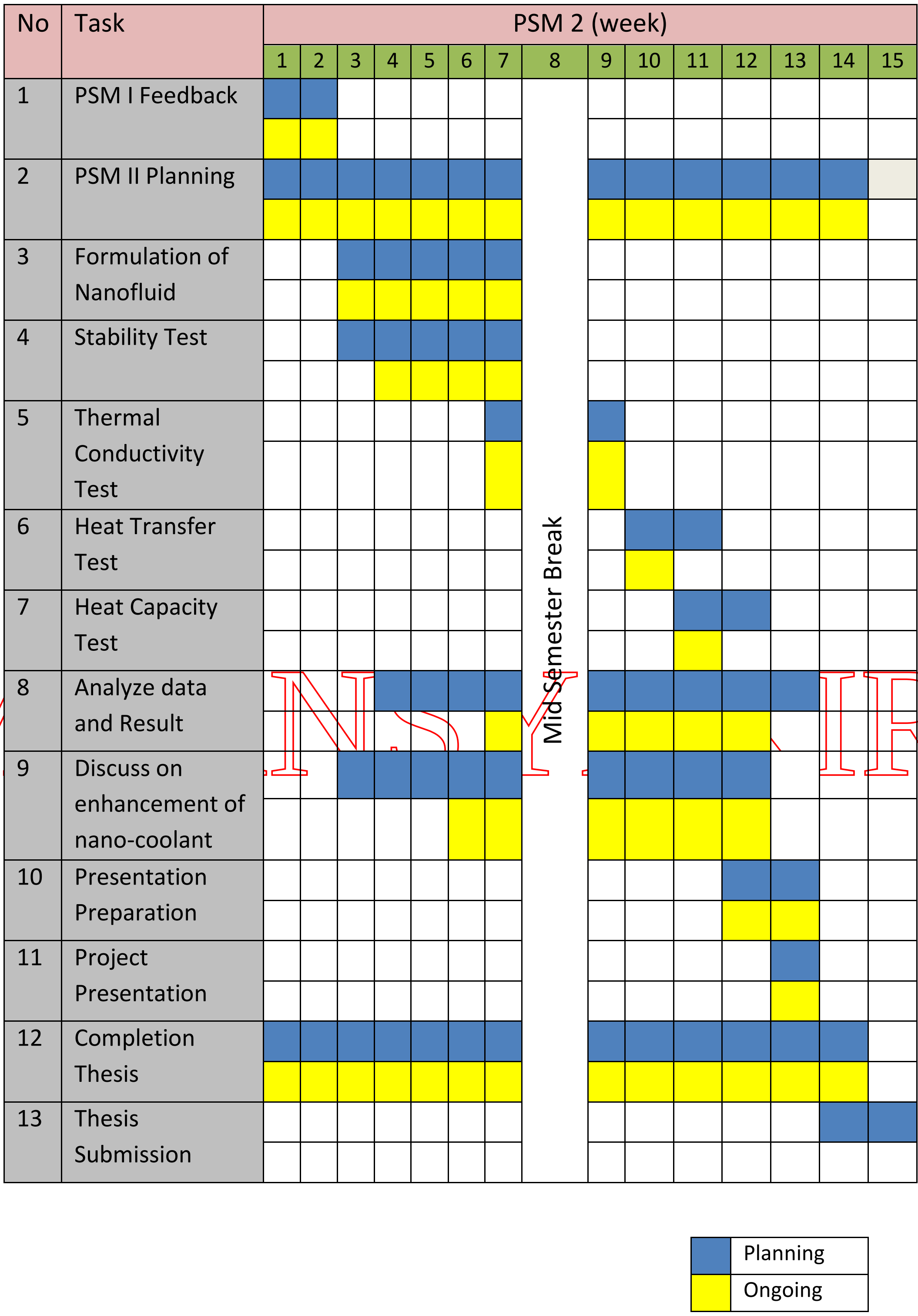
$$= \frac{134.22}{500} \text{ x } 100 = 26.84\%$$

APPENDIX B

(i) Gantt chart for PSM 1

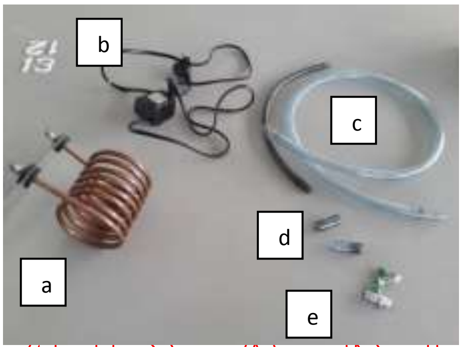


(ii) Gantt chart for PSM 2



APPENDIX C

Heat transfer coefficient experiment setup is as shown below:



a) Copper coil
b) Small pump
c) Tube
d) Tube joint
e) Tee joint

- Setup apparatus a, b, c and d as shown in left figure.

- Place pump into a 400ml beaker that will be filled with sample.
- Place the copper coil inside water bath so that needed temperature can acquired.