IMPROVING STABILITY OF WATER BASED NANOCARBON USING OH-CNT MODIFIED WITH POLYVINYL PYRROLIDONE AS DISPERSING AGENT

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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)"

Signature : ………………

Supervisor : ………………

Date : ………………

DECLARATION

"I hereby declare that the work in this report in my own except for summaries and quotations which have been duly acknowledge"

Signature : ....

Author : ....

Date : ....

This report was completed in dedication to both my beloved parents, Ruhaizi bin Abdul Rashid and Kalthum binti Hashim

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ABSTRACT

Nanotechnology is a new kind of field that mostly dealing with a nanosized materials, device or any other structure with dimensions ranging from 1 nm to 100 nm. With a variety of possible application, nanotechnology can be said as a key to the future technology. Many technological advance country like Japan, European country and United States had invest billions of dollar in nanotechnology research. Another branch of application of nanotechnology is nanofluids. Nanofluids is a suspensions that contains nanoparticle inside a based fluids. Nanofluids has become the need in industry or any thermal management application because of its potential and its wonder properties of high thermal conductivity and high heat transfer rate that cannot be obtain from other materials. For this particular project, the nanoparticle that being used is carbon nanotube (CNT). Because of its cylindrical shape, it will have the greatest surface area per volume compare to other. So with this geometry, it also help it to has the highest value for thermal conductivity and heat transfer capacity compare to other nanoparticle. For the based fluids, water has been chosen. The main intentions of this water based carbon nanotube is to be used for the application in automotive or in a central chilled air conditioning system. The real challenge in producing the water based carbon nanotube is to disperse the carbon nanotube in water because of the hydrophobic characteristic of the carbon nanotube itself. To overcome this problem, a dispersing agent is needed which is polyvinylpyrrolidone (PVP) to reduce the surface tension of the water to ensure that CNT can interact well with water molecules. A different weight percentage of CNT and PVP was used to find a suitable ratio between the two parameter. Final result shows some enhancement of thermal conductivity less than 10% compare to water.

ABSTRAK

Nanoteknologi merupakan bidang baru yang kebanyakannya berurusan dengan bahan berskala nano, peranti atau apa-apa struktur lain dengan dimensi yang terdiri daripada 1 nm hingga 100 nm. Nanoteknologi boleh dikatakan sebagai kunci kepada teknologi masa depan. Banyak Negara maju seperti Jepun, negara Eropah dan Amerika Syarikat telah melabur berbilion dolar dalam penyelidikan nanoteknologi. Satu lagi cabang aplikasi nanoteknologi adalah bendalir nano. Bendalir nano adalah larutan yang mengandungi nano partikel di dalam cecair asas. Bendalir nano telah menjadi keperluan dalam industri yang melibatkan pengurusan haba kerana potensinya yang mempunyai kekonduksian haba yang tinggi dan kadar pemindahan haba yang tinggi. Untuk projek ini, partikel nano yang digunakan adalah tiub nanokarbon. Kerana bentuk silindernya, ia mempunyai luas permukaan yang paling besar per isipadu berbanding dengan partikel nano lain. Dengan geometri ini, ia membantu agar tuib nano karbon mempunyai nilai tertinggi untuk kekonduksian haba dan muatan haba pemindahan berbanding nanopartikel lain. Tujuan utama menghasilkan tiub nano karbon berasaskan air adalah untuk digunakan bagi aplikasi di dalam industri automotif atau dalam sistem penyaman udara pusat. Cabaran sebenar dalam menghasilkan tiub nano karbon berasaskan air adalah untuk menguraikan tiub nano karbon dalam air kerana ciri hidrofobiknya yang tidak bertindakbalas dengan partikel air. Untuk mengatasi masalah ini, penggunaan agen penyerak yang dikenali sebagai polyvinylpyrrolidone (PVP) adalah perlu. Satu peratusan berat berbeza tiub nano karbon dan PVP telah digunakan untuk mencari nisbah yang sesuai antara kedua-dua parameter. Dalam kajian kekonduksian haba mendapati bendalir nano lebih baik daripada air dengan 10% peningkatan.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURE

LIST OF SYMBOL

α, Ψ, α Orientations of the water molecule in terms of angle 19

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Nowadays, nanotechnology has become a major topic for scientist and engineer to further their research. Nanotechnology is a field of science that dealing with a nano sized particle for example nano fluid. In general, Nano fluid is a fluid containing a nano size particle called nanoparticle. These nanofluids are engineered mostly to alter the properties of well-known traditional fluid based suspension for example water or oil that has some limitation that make it cannot be use or apply on certain application. So with the help of some alien particle like in this case is a carbon nanotube being mixed with these base fluid expecting it can change or eliminate the limitation of the base fluid. Nano fluids have been found to possess enhanced thermo physical properties such as thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients compared to those of base fluids like oil or water (Zhu *et al.* 2011).

Nanofluids have better properties that make them potentially very useful in many kind of modern application involving heat transfer including microelectronics, pharmaceutical processes, fuel cell technology, and a refrigerant technology that is more efficient that is can be potentially be used in high tech application like space technology, advance defense system, and nuclear reactor cooling system

1.2 OBJECTIVE

The objective of the study is:

- To produce a stable water based carbon nanotube using polyvinyl pyrrolidone as a dispersing agent.
- To investigate the relationship between the amount of carbon nanotube used and the value of thermal conductivity.

1.3 SCOPE

- To find the suitable ratio between the amount of carbon nanotube, amount of the dispersing agent and deionized water.
- To investigate the stability of the water based carbon nanotube using polyvinyl pyrrolidone as a dispersing agent.
- To determine the thermal conductivity value for each of the sample.

1.4 PROBLEM STATEMENT

Water are widely used as a coolant in automotive or in central air conditioning system because it is very cheap and the properties of high thermal conductivity and high heat transfer capacity make it very suitable substance to be used as a coolant. By using water based carbon nanotube, the properties of pure water can be alter to make it more efficient as a coolant compare to the standard tap water. Hence a further study about the water based carbon nanotube need to be done to observe whether it is better for coolant than tap water because in the theory, carbon nanotube has more surface area in a molecular level compare to the water molecule. Theoretically when the surface area are high so it maybe has a higher specific heat capacity compare to water.

1.5 EXPECTED RESULT

In this particular research, a stable nanofluid based nanocarbonwill be produced by using polyvinyl pyrrolidone as a dispersing agent. A comparison can be made between others type of dispersing agent in terms of stability.

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORY OF CARBON

Carbon is a building block or our life. All of the living things on earth made mainly from carbon even we are call a “carbon based living things”. Carbon has been used or exploit since ancient times in the form of soot, charcoal, graphite and diamonds. Ancient cultures did not acknowledge that all of the materials they used are made from a same materials but in a different form.

2.1.1 Early Experiments About Carbon

I. Early1772, a young French scientist name Antoine Lavoisier had done one simple experiment which he place a diamond in a closed glass jar. He focused the sun's rays on the diamond with a giant magnifying glass and let the diamond burn and disappear. Than Lavoisier noted that the overall weight of the jar was unchanged and he conclude that the diamond had combine with oxygen to form carbon dioxide. He noticed that the charcoal also made from the same element that make the diamond. (Krebs 2006)

II. In 1779, Swedish scientist Carl Scheele showed that graphiteburned to form carbon dioxide and so must be another form of carbon. (Mazaheri2011)

III. In 1796, English chemist name Smithson Tennant was established that diamond was pure carbon and not a compound of carbon; it burned to form only carbon dioxide. He proved that when exact equal weights of charcoal and diamonds were burned, they will produced exactly the same amount of carbon dioxide. (Mazaheri2011)

2.2 CARBON

Carbon material are the most promising adsorbents of traces gases or vapor (Liu, X, 2010). Recently, new carbon forms like for example carbon nanofibres (CNFs) or nanofilaments and carbon nanotubes (CNTs) have generated a growing interest in scientific community in these pass several years. the interaction of these structures with environment, an in particular with gases make a huge attractions due to the possibility of using this materials for an efficient gas storage that can maximized space in the same volume (Serp*et al.* 2003). This materials are attractive because of they can join relatively high specific surface and uniform mesoporous diameter is the reasons that make these materials being much more accessible to absorbs compare to the micropores found at common activated carbons (Hong 2005).

2.3 NANOCARBON

Nanomaterials are fairly new and interesting subject in physics nowadays. This new kind of field in physics had attracted many scientist around the world. The small dimensions, strength and their remarkable physical properties make them very unique materials with a whole range of promising applications like never before for example for the electronic and electromechanical applications of carbon nanotubes (Qiaohuan 2010). Nanomaterials also would be very useful for a mechanical reinforcement in high performance composites, nanotube based field emitters, and any possible new type of high performance materials. Carbon nanotube is one of the type of the nanocarbon family which have two main type that is single wall and multi wall carbon nanotube. Carbon nanotube also can be divided into three other sub family which is chiral type CNT, armchair type CNT and zigzag type CNT. From Figure 2.1 and Figure 2.2 shows how the carbon nanotube roll off geometry from a graphene sheets. This three type of CNT is only the geometry pattern of the carbon atom only.

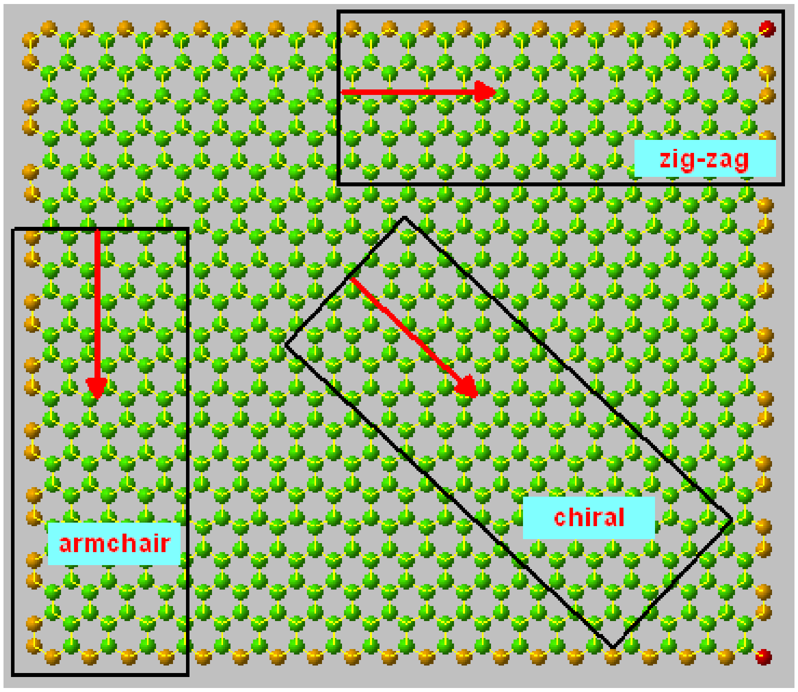


Figure 2.1 : A roll up vector of carbon nanotube from graphene sheet

(Source: Brian, 2002)

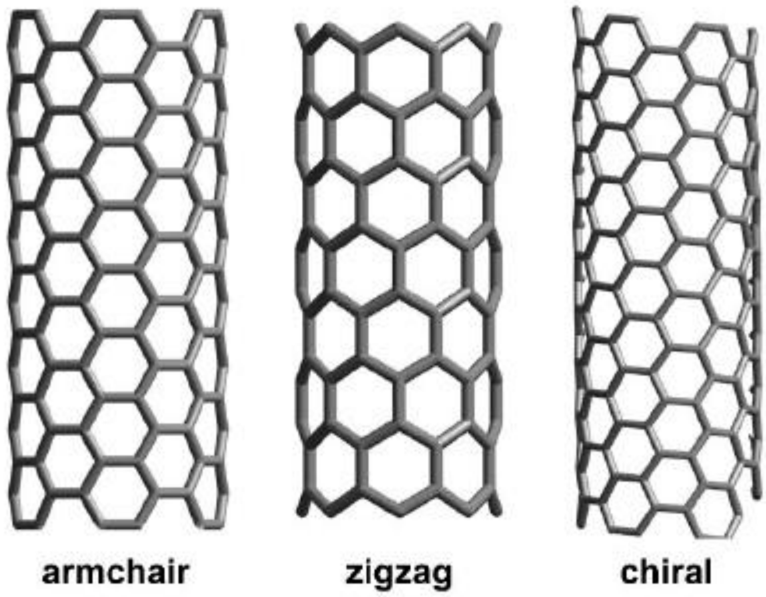


Figure 2.2: Type of carbon nanotube

(Source: Brian, 2002)

The name tube itself will describe the shape of the materials which is obviously tube shape. CNTs are predicted to have higher thermal conductivity than any known material including diamond (Beril*et al*. 2000), have high mechanical strength (Yu, M. 2000), are compliant, and can be grown as arrays of relatively high densities make it very unique and useful properties for any possible applications (Young*et al*. 2000).Carbon nanotube field effect transistors ~CNT-FETs have been shown to be very sensitive to ambient conditions (Xu2005). Carbon nanotubes are good in conductivity and can increase the performance of electrical appliances like sensor application.

2.3.1 Single Walled Carbon Nanotube

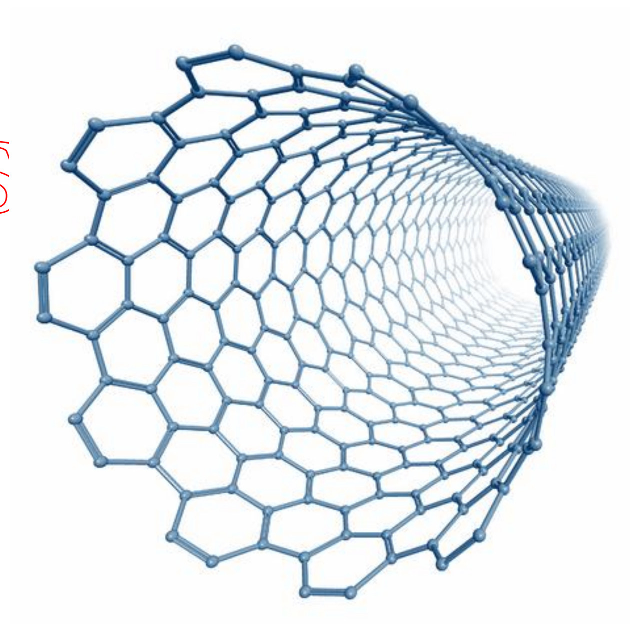


Figure 2.3 : a single wall carbon nanotube

(Source:Murshed, 2008)

A single walled carbon nanotube (SWNTs) are nanometer-diameter sized tube that consisting of a single grapheme sheets wrapped up to form a tube.Single-wall carbon nanotubes (SWNT) were independently discovered in early 1993 by researchers at IBM Almaden Research Center and at NEC in Japan. The IBM and NEC groups each found that transition metals co-vaporized with carbon catalyze the formation of SWNT with a narrow range of diameters around one nm (Almaden, IBM. 2011).Single walled carbon nanotube (SWNTs) has attracted many attention due to their unique structural, mechanical and electrical properties (Olga 2003). They are generally considered as a promising building blocks for a nanoscale for future nanoelectronic equipment (Ojha, U.*et al*. 2010). Single-walled carbon nanotubes (SWCNTs) have been considered as a promising nanostructured material for the realization of future nanoelectronic devices because of their very unique electrical properties such as the ballistic transportation of electrons or holes in SWCNTs.It is interesting to noted that the graphene can be characterized as either zero-gap semiconductor or a metal, since that the density of states (DOS) is zero at the Fermi energy (E_F), and apply those properties to a nanotube. It is also well known that the fundamental conducting properties of a graphene tubule will be depend on the nature of wrapping or chirality and the diameter which is typically single walled carbon nanotube have the diameter range of 0.4 nm to 2 nm(Olga 2003).

For semiconductor SWNTs, in the case of impurities or defects (doping), the Fermi energy is taken to be at references value of zero. However, for a realistic graphene based nanotube a finite doping or impurities can be said as inevitable due to the presence of adsorbents, from the ambient which would cause a charge transfer (Osmond *et al.*2007). The effect of temperature also need to be noted down because this is also one of the reasons for any impurities of the SWNTs.

2.3.2 Multi Walled Carbon Nanotube

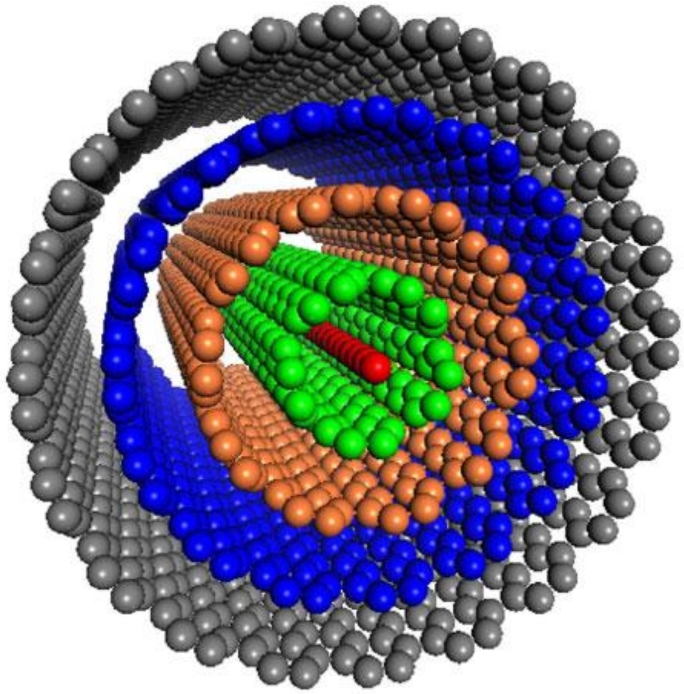


Figure 2.4: multi walled carbon nanotube

(Source: Donald,2002)

Multi-walled nanotubes (MWCNT) consist of multiple rolled layers (concentric tubes) of graphene. There are two models that can be used to describe the structures of multi-walled carbon nanotubes which is the Russian Doll model and the Parchment model. In the Russian Doll model, a carbon nanotube contains another nanotube inside it (the inner nanotube has a smaller diameter than the outer nanotube) (Ho 2008). In the Parchment model, a single graphene sheet is rolled around itself multiple times, resembling a rolled up scroll of paper (Ho 2008). The interlayer distance in multi-walled nanotubes is close to the distance between graphene layers in graphite, approximately (330 pm). Multi-walled carbon nanotubes have similar properties to single-walled nanotubes, yet the outer walls on multi-walled nanotubes can protect the inner carbon nanotubes from chemical interactions with outside materials. Multi-walled nanotubes also have a higher tensile strength than single-walled nanotubes. Multi walled nanotubes can come in an even more complex array of forms, because each concentric single-walled nanotube can have different structures, and hence there are a variety of sequential arrangements. The simplest sequence is when concentric layers are identical but different in diameter. However, mixed variants are possible, consisting of two or more types of concentric CNTs arranged in different orders. These can have either regular layering or random layering (Azonano, 2011).

2.4 PROPERTIES OF CARBON NANOTUBE

2.4.1 Tensile Strength

In the experiment performed by (Hong 2005)Ph.D, associate professor of physics in Arts & Sciences and his research group, individual multiwalled carbon nanotubes were being selected and positioned on a nanometer length scale, firmly attached by a novel method, and tensile loaded (stretched by applying a force) until broken. A result showedthat the applied force to the individual carbon nanotube. In some cases, the micro-Newtons of force were needed to break individual nanotubes, an average force of many times higher than the force that would be needed to break a similar sized nanotube made of high-grade steel (Rodney2005).

Carbon nanotubes have a higher tensile strength compare to steel and even Kevlar. Their strength comes from the bonds between the individual carbon atoms itself.Carbon nanotubes are not only strong but they are also elastic. You can press on the tip of a nanotube and cause it to bend without damaging to the nanotube, and the nanotube will return to its original position when the force is removed(Tang 2003).

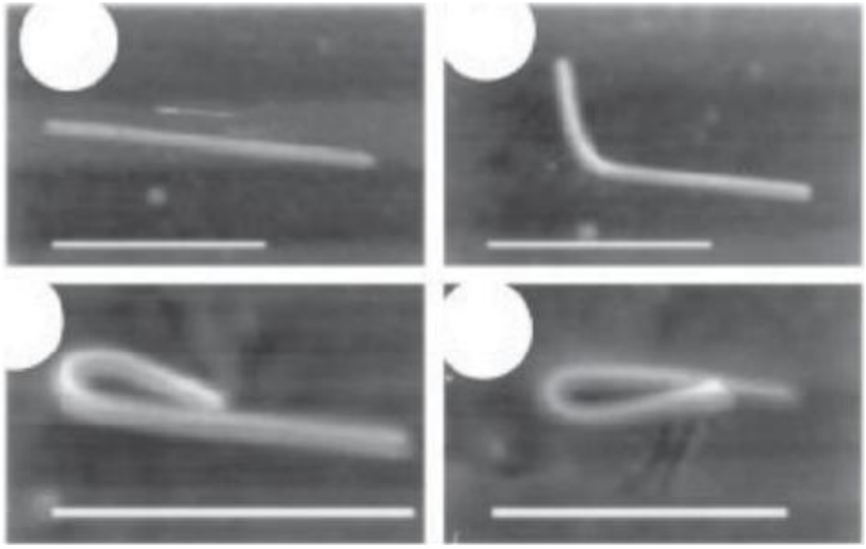


Figure 2.5 : a series of deformation of MWCNT

(Source: Endo,2004)

A nanotube's elasticity does have a limit, and under very strong forces, it is possible to permanently deform to shape of a nanotube. A nanotube's strength can be weakened by defects in the structure of the nanotube itself that can be a breaking point of a carbon nanotube. Defects occur from atomic vacancies or a rearrangement of the carbon bonds. Defects in the structure can cause a small segment of the nanotube to become weaker, which in turn causes the tensile strength of the entire nanotube to weaken. The tensile strength of a nanotube depends on the strength of the weakest segment in the tube removed (Howard *et al.*2004).

2.4.2 Thermal Conductivity

The thermal conductivity of nanotubes has been examined both in theoretically and experimentally. The theoretical work predict at a room temperature, the thermal conductivity will be larger than graphite or even diamond. Measurement shows a room temperature thermal conductivity is over 200W/m K for bulk samples of a single walled carbon nanotube (SWCNTs), and over 3000W/m K for an individual multi walled carbon nanotube (MWCNTs). An addiction of nanotubes to epoxy resin can double the thermal conductivity for a loading of only 1%. All this data shows that the carbon nanotube both for single walled and multi walled carbon nanotube would be very useful for any thermal management applications (Hui*et al.*2006).

Table 2.1: List of thermal conductivity

Materials	**Form**	**Thermal conductivity(W/m K)**
Carbon	Nanotubes	1800-6600
	Diamond	2300
	Graphite	110-190
	Fullerenes	0.4
Metallic solids (pure)	Silver	429
	Copper	401
	Nickel	237
Non-metallic solids	Silicon	148
Metallic liquid	Aluminum	40
	Sodium at 644 K	72.3
Others	Water	0.631
	Ethylene glycol	0.253
	Engine oil	0.145
	R-134a-tetrafluoroethane	0.0811

(Source:Farhan, 2011)

2.5 FLUID

In physics, a fluid is a substance that can be said as continuously deform of flows under an applied force. Fluids are one of the phase in matter which is also include liquids, gas and plasma. Although the term “fluids” itself which is include both liquid and gas phase, in common usage “fluids” is often uses as a synonym for “liquid” (Vaisman2006).

Fluid viscosity is a very important characteristic for fluid dispensing, and it has a very significant effect on the volume and velocity of the fluid in the terms of flow pattern (Venerus2009).

2.5.1 Nanofluids

Nanofluids are dilute liquid suspensions of nanoparticles with at least one critical dimension smaller than ~100nm. In the past decade, this new material that some would say future materials of composite material because of its enhance properties and behaviors associated with heat transfer has gained many attention to scientists and researchers worldwide(Yulong2012). Common base fluids include water or any organic liquids. Nanoparticles are typically made of chemically stable metals, metal oxides or carbon in various forms or any other possible materials. The size of the nanoparticles imparts some unique characteristics to these fluids, including greatly enhanced energy, momentum and mass transfer, as well as reduced tendency for sedimentation and erosion of the containing surfacesbecause of the sized of the particle itself that make the nanofluids is stable compare to microfluids. Nanofluids are being investigated for numerous applications, including thermal management, manufacturing, chemical and pharmaceutical processes, medical treatments, cosmetics and others possible field (Nanotech 2011).

2.5.2 Stability of Nanofluids

Nanofluid is a kind of new engineering material consisting of nanometer-sized particles dispersed in base fluid. In this study, various nanoparticles, such as multi-walled and single walled carbon nanotube (MWCNT), fullerene, copper oxide, and silicon dioxide have been used to produce nanofluids for enhancing or improving thermal conductivity, lubricity or any other desired possible property to be alter.As base fluids normally water, ethylene glycol, and oil have been used. The stability of nanofluidcan be estimate or measurewith UV spectrophotometer. Thermal conductivity of nanofluid has been increased with increasing volume fraction of nanoparticle except for water-based fullerene nanofluid which has lower thermal conductivity than that of base fluid due to its lower thermal conductivity, 0.4 W/mK (Ludovic2009). Stability of nanofluid has been influenced by the characteristics between base fluid and suspended nanoparticles used (Yujin2006).

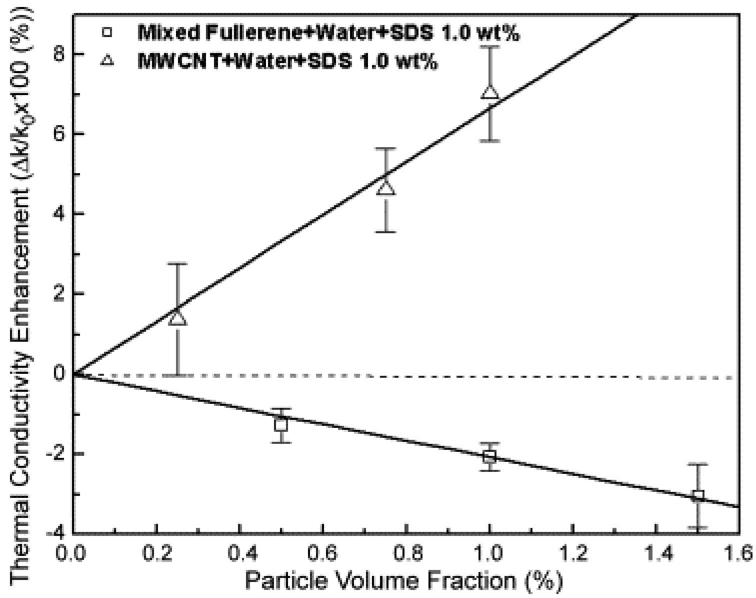
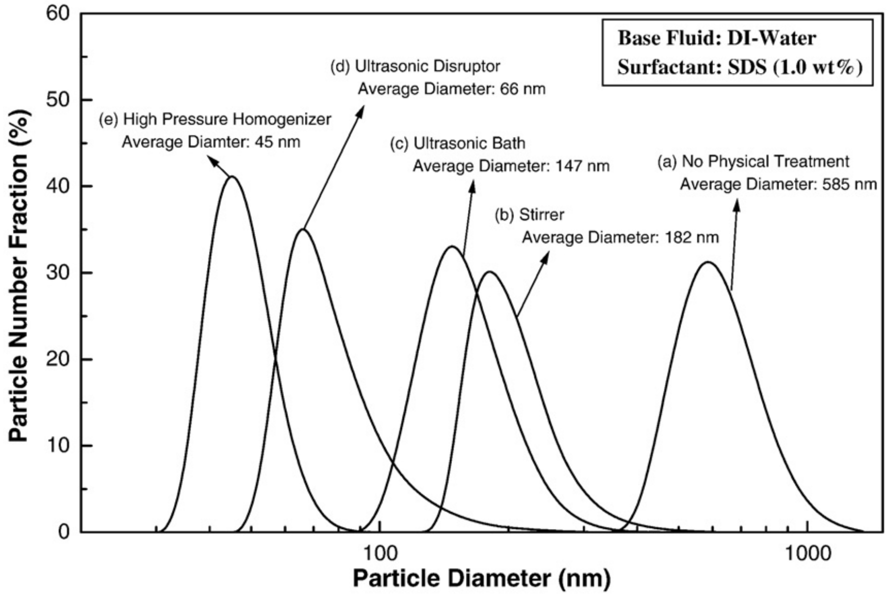


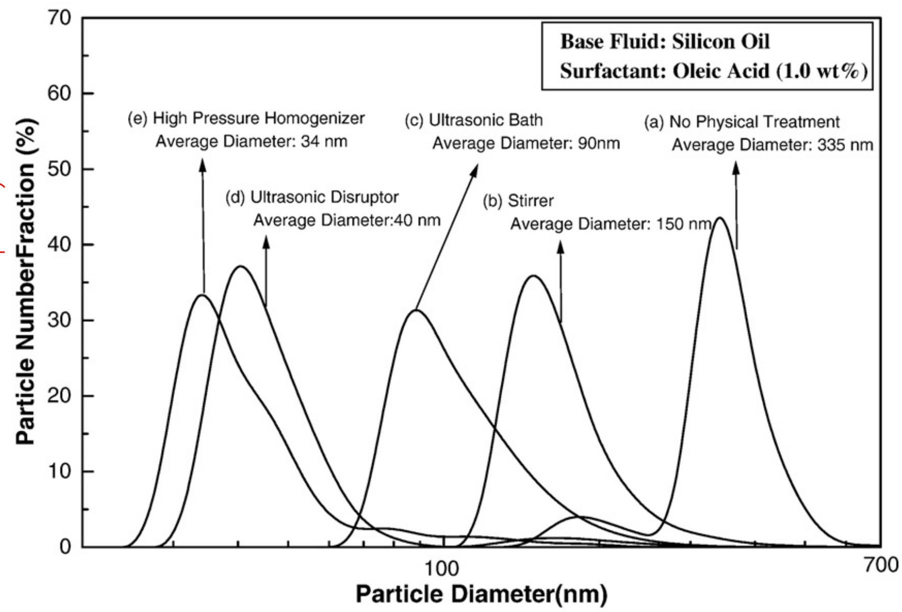
Figure 2.6 : Thermal conductivity enhancement of water based WCNTs and fullerene nanofluids

(source :Yujin, 2006)

The stability of nanofluid based nanocarbon are very vital because thermal conductivity enhancement will depends on the volume fraction of the suspended particles, thermal conductivities of the particles and basefluids as shown in Figure 2.6. Stability of nanofluid is strongly affected by the characteristics of the suspended particle and basefluids such as the particle morphology, the chemical structure of the particles and basefluid (Hui,*et al*. 2006).



(a) CB-water nanofluids



(b) Ag-silicon nanofluids

Figure 2.7: (a)The particle size distributions in water based nanofluids as a function of the dispersion method, (b) The particle size distributions in Ag-siliconnanofluids as a function of the dispersion method

(Source: Yujin, 2006)

According to J.H Walter, in his journal Carbon Nanotubes in Water: Structural Characteristics and Energetics, since the discovery of a single walled carbon nanotube which is made from a graphene sheets rolled up to form a tube, the scientist expect that the CNT will has the same properties same as the graphene which is hydrophilic or able to interact with water molecule without any help from any other materials. After a study was being made, the scientist found that the CNT is highly hydrophobic, and to exhibit a preferred orientation of the water dipole moment tangential to the interface. However, many studies that has being made to idealized the geometry and interaction potentials and for planar interfaces but not for graphite and water interfaces with convex geometries such as found on those carbon nanotube itself. The wetting properties of carbon nanotube were found that it will depend of the surface tension of the of the fluid, which threshold value between 100 to 200 mN/m indicating that the water that has a surface tension of 72 mN/m should be able to wet the carbon nanotube. The idea of adding the hydrophilic group to the solution to open ends of the tubes or by fluoridating their side wall.

In the latest studies that has being made, the scientist has examine thestructural properties of water surrounding of a carbon nanotube by performing a detailed fully atomistic molecular dynamics simulation of a 12 nm diameter zigzag type carbon nanotube in water. The carbon-water interaction is described by a carbon-oxygen Van Der Walls force relation adding with carbon quadropole moment water partial charge interaction(Werder 2002).

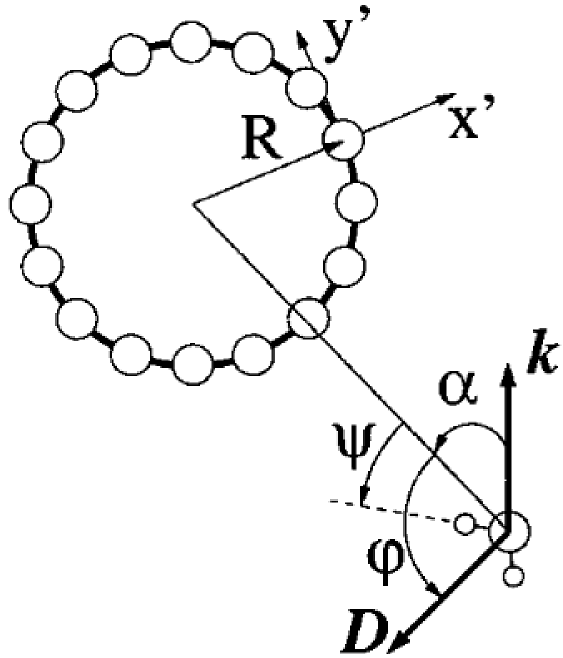


Figure 2.8: schematic of CNT-water interaction. R=radius of CNT, D=water dipole moment, *k*=plane of water molecule, *(x',y')*=local coordinates system, *æ,Ψ,α* = orientations of the water molecule in terms of angle.

(Source: Walther, 2001)

The properties of water and carbon nanotube interface will be discuss by the structural properties of the water-carbon nanotube interface are studied by examination of the water radial density profile, water orientation, and hydrogen bond profiles. The water molecules distance from the carbon nanotube molecules is approximately 3.2nm in distance.

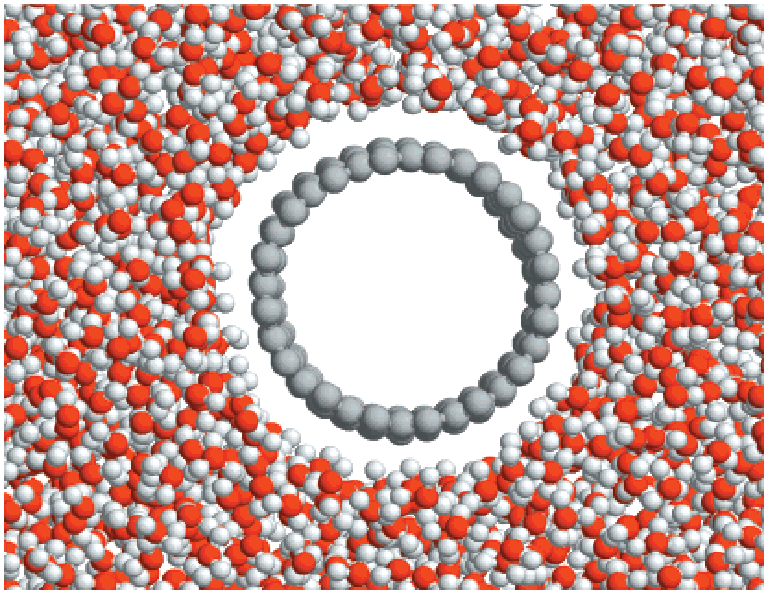


Figure 2.9: Simulation of carbon nanotube in water

(Source: Walther, 2001)

2.5.3 Dispersing Agent

Dispersing agent is a material used to help the hydrophobic carbon nanotube to be disperse well in water. Dispersing agent also help the nanofluid keep stable at a certain amount of time. The type of dispersing agent that being used for water based carbon nanotube application is called polyvinylpyrrolidone (PVP).

CHAPTER 3

METHODOLOGY

3.1 EXPERIMENTAL PROCEDURE

The main part of this experiment is firstly get the weight each ingredients which consists of CNT, dispersing agent and based water. The CNT, dispersing agent and based water need to be weight according to the formulation that being made earlier using a more accurate analytical balance that can measure up to four decimal places of number. Then the CNT and dispersing agent being mixed with based water in a special container. Then the suspensions need to be homogenized using the homogenizer at a speed of 10000rpm for one minute. After finish homogenized the suspension, put the container in an ultrasonic cleaning machine to further disperse the suspension for about one hour. After finish all that procedure, the suspension need to be left for about 100 hour or about four days after the suspensions can be decided whether it is stable or not by using the stability test rig that is specially design for this purpose.

3.2 FLOW CHART

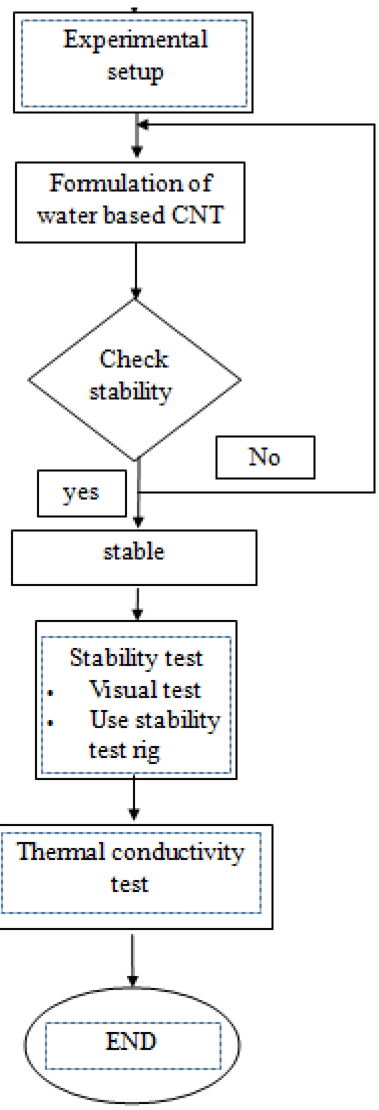


Figure 3.1 : flow chart

3.3 PARAMETER USED IN EXPERIMENT

3.3.1 Deionized Water

Deionized water is a water that has had its mineral ions removed, for example cations like sodium, calcium, iron, and copper, and anions such as chloride and sulfate. The reasons of using the deionized water instead of normal tap water or distilled water is deionized water is more pure and any possible contaminant can be eliminate. The contaminant found in normal tap water or distilled water may distort or alter the properties of pure water that had being so suitable as a based fluid for any thermal management application because of its thermal conductivity and heat transfer capacity. In table 3.1 show some important properties of deionized water.

Table 3.1 : Properties of deionized water

Parameter	**Value**
Density	Liquid : 1000 kg/m^3 Solid : 917 kg/m^3
Melting point	0^0C
Boiling point	100^0C
Specific heat	4180 J/kg ^{0}C
Latent heat	333.55 kJ/kg
Viscosity	893 × 10^{-6}kgs/m
pH	Approximately 7.0

(Source: Safiuddin, 2011)

3.3.2 Type of CNT used

The type of CNT used in this experiment is Nanoamor type which is a multi-walled type carbon nanotube. The main reasons of using this type of CNT is because of to make a comparisons between the previous experiment that are using also the multi walled type carbon nanotube from a different brand. The density of this particular type of carbon nanotube is $1.7g/cm^3 – 1.9g/cm^3$ at 20°C.

3.3.3 Dispersing Agent Description

According to journal produced by (Senak, *et al*. 1987), polyvinylpyrrolidone (PVP) polymers will come in several grade difference in the term of viscosity and ranging from low to high molecular weight. This different range with coupled with solubility in aqueous and organic solvent system combined with its nontoxic character will gives PVP a great flexibility. PVP solution viscosity does not change appreciably over a wide pH range, but it will increases in concentrated hydrochloric acid (HCL).The densities of PVP water solutions are only slightly change despite a significant increase in the concentration of PVP K-30.

Table 3.2: Effect of pH on viscosity of 5% aqueous PVP K-30 ta 25°C

pH	10	9	7	4	2	1	0.1	Conc, HCl
Viscosity (cp)	2.4	2.4	2.4	2.4	2.3	2.3	2.4	4.96

(Source: Senak, 1987)

Table 3.3 : Effect of PVP K-30 concentration on density in water

Density at 25^{0}C (g/ml)	1.02	1.04	1.07	1.09	1.12
PVP concentration (%)	10	20	30	40	50

(Source: Senak, 1987)

PVP is readily very soluble in even cold water and other possible concentration and the only limited is by viscosity. PVP also soluble in many other organic solvents like water, alcohol, some chlorinated compound and many more. It is not soluble in hydrocarbon, ethers, ketones and esters (Mazaheri, 2011).

3.3.4 Ratio Between All Parameter (CNT, dispersing agent, water)

Table 3.4 shows the ratio of all parameter used in the formulation of nanofluids using Nanoamor type of carbon nanotube with PVP as a dispersing agent

Table 3.4: Ratio of Nanoamor and PVP

CNT (weight%)	Volume CNT (cm^3)	PVP (weight%)	Volume PVP (cm^3)	water (ml)
0.04	0.0235	0.0000	0.00000	39.9765
0.04	0.0235	0.0080	0.00667	39.9698
0.04	0.0235	0.0160	0.01333	39.9631
0.04	0.0235	0.0240	0.02000	39.9565
0.04	0.0235	0.0320	0.02667	39.9498
0.04	0.0235	0.0400	0.03333	39.9431
0.08	0.0471	0.0320	0.02667	39.9263
0.16	0.0941	0.0640	0.05333	39.8525
0.20	0.1176	0.0800	0.06667	39.8157
0.24	0.1412	0.0960	0.08000	39.7788
0.32	0.1882	0.1280	0.10667	39.7051
0.40	0.2353	0.1600	0.13333	39.6314
0.48	0.2824	0.1920	0.16000	39.5576
0.56	0.3294	0.2240	0.18667	39.4839
0.60	0.3529	0.2400	0.20000	39.4471
0.64	0.3765	0.2560	0.21333	39.4102
0.72	0.4235	0.2880	0.24000	39.3365
0.80	0.4706	0.3200	0.26667	39.2627

Table 3.5 shows the ratio of all parameter used in the formulation of nanofluids using Nanoamortype of carbon nanotube with SDS as a dispersing agent

Table 3.5: Ratio of Nanoamor and SDS

CNT (weight%)	**Volume CNT (cm^3)**	**SDS (weight%)**	**Volume SDS (cm^3)**	**water (ml)**
0.04	0.0235	0.0000	0.00000	39.9765
0.04	0.0235	0.0080	0.00792	39.9685
0.04	0.0235	0.0160	0.01584	39.9606
0.04	0.0235	0.0240	0.02376	39.9527
0.04	0.0235	0.0320	0.03168	39.9448
0.04	0.0235	0.0400	0.03960	39.9369
0.08	0.0471	0.0320	0.03168	39.9213
0.16	0.0941	0.0640	0.06337	39.8425
0.20	0.1176	0.0800	0.07921	39.8031
0.24	0.1412	0.0960	0.09505	39.7638
0.32	0.1882	0.1280	0.12673	39.6850
0.40	0.2353	0.1600	0.15842	39.6063
0.48	0.2824	0.1920	0.19010	39.5275
0.56	0.3294	0.2240	0.22178	39.4488
0.60	0.3529	0.2400	0.23762	39.4094
0.64	0.3765	0.2560	0.25347	39.3701
0.72	0.4235	0.2880	0.28515	39.2913
0.80	0.4706	0.3200	0.31683	39.2126

3.4 APPARATUS

A mechanical homogenizer and ultrasonic cleaning machine used to further disperse the suspension produced. A pH meter used to monitor the pH value of the suspensions and stability test rig is an apparatus used to measure the stability of the suspensions produced.

3.4.1 Homogenizer

A mechanical homogenizer manufactured by LabGeniuswas use to homogenized the dispersing agent, CNT, and deionized water. A single propeller attachment was used during the homogenization process. The homogenizer model that being used did not has any isolation assembly to prevent the environment contaminant from dissolving into the nanofluids during the homogenization process. In figure 3.2 show that how the apparatus was being set up before start homogenizing the nanofluids.

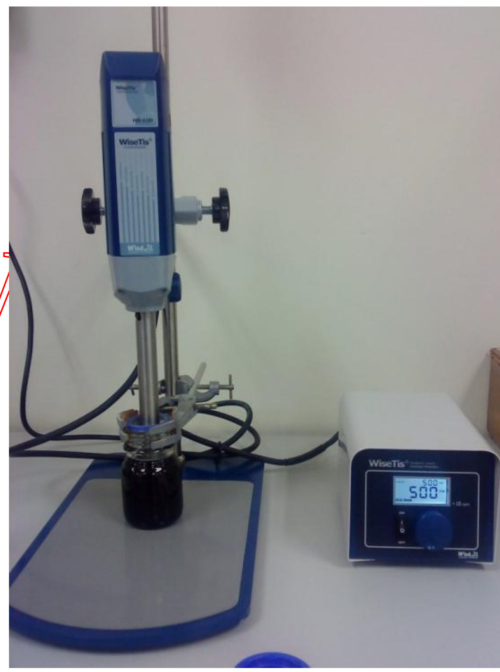


Figure 3.2 : Mechanical Homogenizer

3.4.2 Ultrasonicator

AElmasonic S ultrasonic manufactured by Elma Hans Schmidbauer GmbH & Co. KG, A German company was used for the CNT dispersion process. The ultrasonicator consist of a vibrated tub that need to be filled with water. The tub will vibrate at the frequency of ultrasonic wave to further disperse the CNT and dispersing agent. In figure 3.3 show how actually the apparatus setup for the ultarsonicator.

Figure 3.3 :Ultrasonicator

3.4.3 pH meter

A pH meter is an electronic device that used for measuring the pHvalue of the solution produced by showing a number ranging from 0 to 14. The value ranging of 7>pH is consider as acidic, the value ranging of 7<pH is consider as alkaline whereas

the value of exact 7 is neutral.A typical pH meter consist of a special measuring probe normally a glass electrode connected to an electronic meter that measure and display the reading. In figure 3.4 show that the actual model of the pH meter that being used in UTeM chemistry lab.

Figure 3.4 : pH meter

3.4.4 Stability Test Rig

A stability test rig is a simple device that being used to measure the stability of a nanofluid produced. The device consist of a horizontal and vertical hole. The bigger vertical hole is used to place the nanofluid with its container and the horizontal hole is used to channel the laser light through the hole then the light will hit the nanofluids and a receiver at the other end of the hole. If the laser light can travel through the nanofluid and hit a receiver at the other ends of the hole, the solution is considered as not stable. Then the laser light are not visible at the other ends of the hole, the solution can be consider as a stable nanofluids. In figure 3.5 shows that the experimental setup for the stability verification method using stability test rig in laboratories.

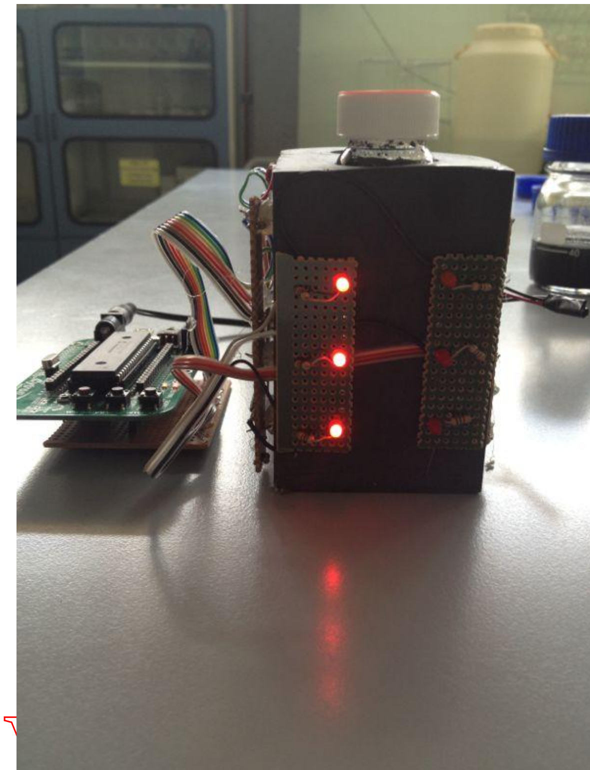


Figure 3.5: Stability test rig

3.4.5 KD2 PRO

KD2-Pro is a device used in this experiment on determining the thermal conductivity of nanofluidsmanufactured by Decagon Services. It can be used fully portable field and lab thermal properties analyzer. This device are using line heat source method to measure all thermal properties including thermal diffusivity, specific heat, thermal conductivity and thermal resistivity.

Figure 3.6 : KD2 PRO device

3.5 EXPERIMENTAL PROCEDURE

3.5.1 Nanofluids Formulation

The following procedure will discuss about the preparation of nanofluid including the thermal conductivity test.

1. All the parameter for nanofluid preparation was weighed up which is CNT, PVP, and water
2. CNT and PVP was being mixed together in the deionized water by following the ratio given in a glass container. The bottle was shook in order to make the solution well-mixed

3. The homogenizer was setup with the mixture of nanofluid. The propeller of the homogenizer is placed a few centimetres from the bottom of glass container. The speed of the homogenizer is set to 10000 rpm and this process took 60 second to complete.
4. After the mixture of nanofluid is well homogenized, the ultrasonic cleaner was set up. The mixture of nanofluid is placed inside the ultrasonic cleaner. The temperature was set to 25°C at the highest frequency in order ensure the CNT and dispersing agent disperse evenly inside the deionized water. This process took 60 minutes to complete
5. The pH of the nanofluid was measured by using the pH metre before carry out the stability test.
6. The mixture of nanofluid once again being homogenized by mechanical homogenizer by set the 1000 rpm of propeller speed in a few minutes like stated in procedure number 3.
7. For the stability test to determine whether the actual CNT had been totally dispersed within the deionized water, it will begin right following the mixture had been produce and it might take a week to check on if any kind of agglomerate occurs in the beaker. These types of stability assessments were examined periodically inside 1 in order to 100 several hours.
8. After the nanofluid passes the stability test, the mixture of nanofluid can be tested with thermal conductivity test by using the KD2-Pro and viscometer respectively.

3.5.2 Thermal Conductivity Measurement

The following procedure will discuss on how the thermal conductivity measurement is being done.

1. Put all thenanofluids sample in the water bath.
2. Set the desired temperature of the water bath.
3. Set all the setting on the KD2-PRO device to match the type of fluids used.
4. Dip the sensor of KD2-PRO device in the nanofluids, then after a few minutes, the result will appear on the display of the device.

3.6 SAFETY PRECAUTION

Polyvinyl pyrrolidone (PVP) and CNT are in powder form. For CNT, skin and eye contact may cause irritation. If CNT made contact with eye, washing with distilled water by soaking it directly to the eye is amust. Inhalation of CNT may cause damage to the lung or will eventually cause some disease. Hence, usage of dust respirator is of a face mask is a must and in case the CNT powder is spilled or flew away from the sweeper. If there is any spill of CNT or PVP, remove it by using sweeper or vacuum cleaner or spray with water. When altering the pH value for nanofluids it will require to use HCL and nitric acid. This acid is highly hazardous because of its very high in concentration, it need to be handle with care for example always wear safety goggles for eye protection in case of its splash and always wear a rubber gloves to protect skin.

For the apparatus safety precaution, begin with the homogenizer, before actually using this device, reading the provided manual provided by the company brand is recommended to avoid the possible accident because this kind of device it dealing with a very high rotating speed of its spindle.

CHAPTER 4

RESULT AND DISCUSSION

4.1 STABILITY OF NANOFLUIDS

A stable nanofluidshas become one of the most concern because is tremendously important if it going to be applied for heat management system in any kind of industry or machine.

4.1.1 Stability Evaluation Methods

Nowadays there are many procedure and instrument to determine the stability of a suspension. There some methods that are introduced to evaluate stability of nanofluids. Sedimentation balance methods and sedimentation photograph are two methods that are commonly used in determining the stability of nanofluids.

For this particular experiment, the test that are going to use on determining the stability of nanofluids is by using the stability test rig and a simple visual test. This two stability test method are being chosen is because it is can be consider as the most simple methods to determine the stability of nanofluids.

4.1.2 Experimental Result on Stability (Nanoamor)

Table 4.1 shows the stability condition of Nanoamor with PVPafter 100 hours.

Table 4.1 : Stability of nanoamor type CNT using PVP as dispersing agent

Samples	CNT (weight%)	PVP (weight%)	Water (ml)	Observation
NP001	0.04	0.0000	39.9765	stable
NP002	0.04	0.0080	39.9698	stable
NP003	0.04	0.0160	39.9631	stable
NP004	0.04	0.0240	39.9565	stable
NP005	0.04	0.0320	39.9498	stable
NP006	0.04	0.0400	39.9431	stable
NP007	0.08	0.0320	39.9263	stable
NP008	0.16	0.0640	39.8525	stable
NP009	0.20	0.0800	39.8157	stable
NP010	0.24	0.0960	39.7788	stable
NP011	0.32	0.1280	39.7051	stable
NP012	0.40	0.1600	39.6314	stable
NP013	0.48	0.1920	39.5576	stable
NP014	0.56	0.2240	39.4839	stable
NP015	0.60	0.2400	39.4471	stable
NP016	0.64	0.2560	39.4102	stable
NP017	0.72	0.2880	39.3365	stable
NP018	0.80	0.3200	39.2627	stable

Table 4.2 shows the stability conditions of Nanoamor with SDS after 100 hours.

Table 4.2: Stability of nanoamor type CNT using SDS as dispersing agent

Samples	**CNT (weight%)**	**PVP (weight%)**	**Water (ml)**	**Observation**
NS001	0.04	0.0000	39.9765	stable
NS002	0.04	0.0080	39.9685	stable
NS003	0.04	0.0160	39.9606	stable
NS004	0.04	0.0240	39.9527	stable
NS005	0.04	0.0320	39.9448	stable
NS006	0.04	0.0400	39.9369	stable
NS007	0.08	0.0320	39.9213	stable
NS008	0.16	0.0640	39.8425	stable
NS009	0.20	0.0800	39.8031	stable
NS010	0.24	0.0960	39.7638	stable
NS011	0.32	0.1280	39.6850	stable
NS012	0.40	0.1600	39.6063	stable
NS013	0.48	0.1920	39.5275	stable
NS014	0.56	0.2240	39.4488	stable
NS015	0.60	0.2400	39.4094	stable
NS016	0.64	0.2560	39.3701	stable
NS017	0.72	0.2880	39.2913	stable
NS018	0.80	0.3200	39.2126	stable

4.1.2.1 Stability of Nanoamor

From Table 4.1 and Table 4.2, it can be seen that all of the suspension is in stable condition after 100 hours. The observation method on determining the stability of all these nanofluids is by using the stability test rig and the visual test. From observation that was being made see that in the first hour there is no sedimentation at all for almost all sample, but after 100 hours there is a sedimentation at the bottom of the container but when test in the stability test rig it is still show the stable result, so it can be conclude that the nanofluids is stable.

Table 4.2 that show that the result of condition of the nanofluids after 100 hours with SDS used as dispersing agent. As stated on the table, the condition afnanofluids is all stable just like nanofluids samples with PVP as dispersing agent.

4.1.3 Experimental Result on Stability (MER)

Table 4.3 shows the stability conditions of MER with PVP after 100 hours.

Table 4.3 : stability of MER type CNT using PVP as dispersing agent

Samples	CNT (weight%)	PVP (weight%)	Water (ml)	Observation
MP001	0.04	0.0000	39.9765	unstable
MP002	0.04	0.0080	39.9698	unstable
MP003	0.04	0.0160	39.9632	unstable
MP004	0.04	0.0240	39.9560	unstable
MP005	0.04	0.0320	39.9491	stable
MP006	0.04	0.0400	39.9432	stable
MP007	0.08	0.0320	39.9263	stable
MP008	0.16	0.0640	39.8526	stable
MP009	0.20	0.0800	39.8157	stable
MP010	0.24	0.0960	39.7788	stable
MP011	0.32	0.1280	39.7051	stable
MP012	0.40	0.1600	39.6314	stable
MP013	0.48	0.1920	39.5576	stable

Table 4.4 shows the stability condition of MER with SDS after 100 hours.

Table 4.4: Stability of MER type CNT using PVP as dispersing agent

Samples	CNT (weight%)	SDS (weight%)	Water (ml)	Observation
MS001	0.04	0.0000	39.97647	unstable
MS002	0.04	0.0080	39.96855	unstable
MS003	0.04	0.0160	39.96063	unstable
MS004	0.04	0.0240	39.95271	unstable
MS005	0.04	0.0320	39.94479	unstable
MS006	0.04	0.0400	39.93687	unstable
MS007	0.08	0.0320	39.92126	stable
MS008	0.16	0.0640	39.84252	stable
MS009	0.20	0.0800	39.80315	stable
MS010	0.24	0.0960	39.76377	stable
MS011	0.32	0.1280	39.68503	stable
MS012	0.40	0.1600	39.60629	stable
MS013	0.48	0.1920	39.52755	stable
MS014	0.56	0.2240	39.44881	stable
MS015	0.60	0.2400	39.40944	stable
MS016	0.64	0.2560	39.37006	stable
MS017	0.72	0.2880	39.29132	stable
MS018	0.80	0.3200	39.21258	stable

4.1.3.1 Stability of MER

From Table 4.4 which is uses MER type of CNT with PVP as a dispersing agent, the condition of the first foursample is in unstable condition after 100 hours. As shown in Figure 4.5 which is uses MER type of CNT also but with SDS as a dispersing agent and the result showed that the first sixsample is in unstable state after 100 hours.

4.1.4 Experimental Result on Stability (Pyrograph HHT)

Table 4.5 shows the stability condition of MER with SDS after 100 hours.

Table 4.5 : Stability of Pyrograph HHT type CNT using SDS

Samples	CNT (weight%)	SDS (weight%)	Water (ml)	Observation
PS001	0.04	0.0000	39.98000	unstable
PS002	0.04	0.0080	39.97208	unstable
PS003	0.04	0.0160	39.96416	unstable
PS004	0.04	0.0240	39.95624	stable
PS005	0.04	0.0320	39.94832	stable
PS006	0.04	0.0400	39.94040	stable
PS007	0.08	0.0320	39.92832	stable
PS008	0.16	0.0640	39.85663	stable
PS009	0.20	0.0800	39.82079	stable
PS010	0.24	0.0960	39.78495	stable
PS011	0.32	0.1280	39.71327	stable
PS012	0.40	0.1600	39.64158	stable
PS013	0.48	0.1920	39.56990	stable
PS014	0.56	0.2240	39.49822	stable
PS015	0.60	0.2400	39.46238	stable
PS016	0.64	0.2560	39.42653	stable
PS017	0.72	0.2880	39.35485	stable
PS018	0.80	0.3200	39.28317	stable

4.1.4.1 Stability of Pyrograph HHT

Table 4.6 shows the stability condition of pyrograph type of CNT using SDS as dispersing agent after 100 hours. The stability evaluation methods is the same where using the visual test and using the stability test rig. The condition of nanofluids of the first threesample is in unstable condition.

4.2 THERMAL CONDUCTIVITY OF NANOFLUIDS

Thermal conductivity is a measurement of certain material on how easy they conduct heat. It is evaluated primarily in the terms of Fourier Law for heat conduction (Young, 2000). Heat will be transfer across material faster if the particular material has higher value of thermal conductivity compare to material that has low value of thermal conductivity. Usually, the material of high thermal conductivity is more desirable for heat management application because of the heat will be transfer faster compare to low thermal conductivity material. The application of low thermal conductivity is more desirable for the thermal insulation application.

For this particular cases, this nanofluids is intended to replace water as a coolant in central chill air conditioning system, so the thermal conductivity need to be more that water so that the heat transfer process is more faster and the air conditioning system will require less energy. For this particular task, the device used to find the value of thermal conductivity is y using KD2 PRO device. Thermal conductivity value will be taken at three different temperatures which is 6°C, 25°C, and 40°C.

4.2.1 Thermal Conductivity Test Result

After testing the nanofluids with KD2 PRO device, following result was obtain. The testing will be made three times for each one of nanofluids sample in three different temperatures to obtain an average reading to ensure its accuracy. During the test, there are temperature fluctuation due to the surrounding heat transfer. The device are able to record the temperature at the very moment of the device taking its thermal conductivity. The acceptable range of actual temperature is ±0.5°C. In Table 4.6 and Table 4.7 shows the thermal conductivity value for temperature 6°C, 25°C and 40°C.

Table 4.6: Thermal conductivity of Nanoamor carbon nanotube with PVP

Sample no	**Thermal conductivity at 6^{0}C (W/m.K)**	**Thermal conductivity at 25^{0}C (W/m.K)**	**Thermal conductivity at 40^{0}C (W/m.K)**
NP002	0.562	0.62	0.658
NP007	0.574	0.632	0.672
NP008	0.576	0.644	0.678
NP009	0.563	0.647	0.682
NP010	0.586	0.657	0.696
NP011	0.622	0.663	0.701
NP012	0.625	0.678	0.723

Table 4.7: Thermal conductivity of Nanoamor carbon nanotube with SDS

Sample no	**Thermal conductivity at 6^{0}C (W/m.K)**	**Thermal conductivity at 25^{0}C (W/m.K)**	**Thermal conductivity at 40^{0}C (W/m.K)**
NS002	0.584	0.624	0.656
NS007	0.598	0.628	0.662
NS008	0.622	0.627	0.67
NS009	0.618	0.632	0.672
NS010	0.630	0.637	0.686
NS011	0.626	0.641	0.674
NS012	0.634	0.652	0.692

4.3 DISCUSSION OF STABILITY AND THERMAL CONDUCTIVITY

In this part will discuss about which better CNT and dispersing agent in the terms of stability and in thermal conductivity terms.

4.3.1 Type of CNT

The reasons that Nanoamor type of carbon nanotube is so capable of producing a very impressive result of stability is because it has an OH functional group which made it easier to be interact with the water molecule around. This particular kind of carbon nanotube also need less adhesion force from the dispersing agent to create bond with water, so in the other word it will require less dispersing agent to produce a stable nanofluids compare to the other type of carbon nanotube that does not has OH functional group.

From this pattern, it can be concluded that the stability of this particular nanofluids is not because of the effect of dispersing agent but it is definitely because of the type of CNT used that has an OH functional group that make it more easier to bond with water molecules.

4.3.2 Thermal conductivity enhancement

The reasons of choosing carbon nanotube for thermal management application is because in theory it can improve the thermal conductivity and heat transfer because of it has a larger surface area over other kind of material due to its tube shape that has inner and outer surface. So from the experiment that has being conducted, it can be seen that there is little enhancement in thermal conductivity value compare to water. From Figure 4.1, the yellow, green and red line indicates that the thermal conductivity value of water at that particular temperature and can be seen also on the graph that the thermal conductivity of nanofluids exceed that line by some margin, this indicates that there is an enhancement of thermal conductivity of nanofluids compare to water.

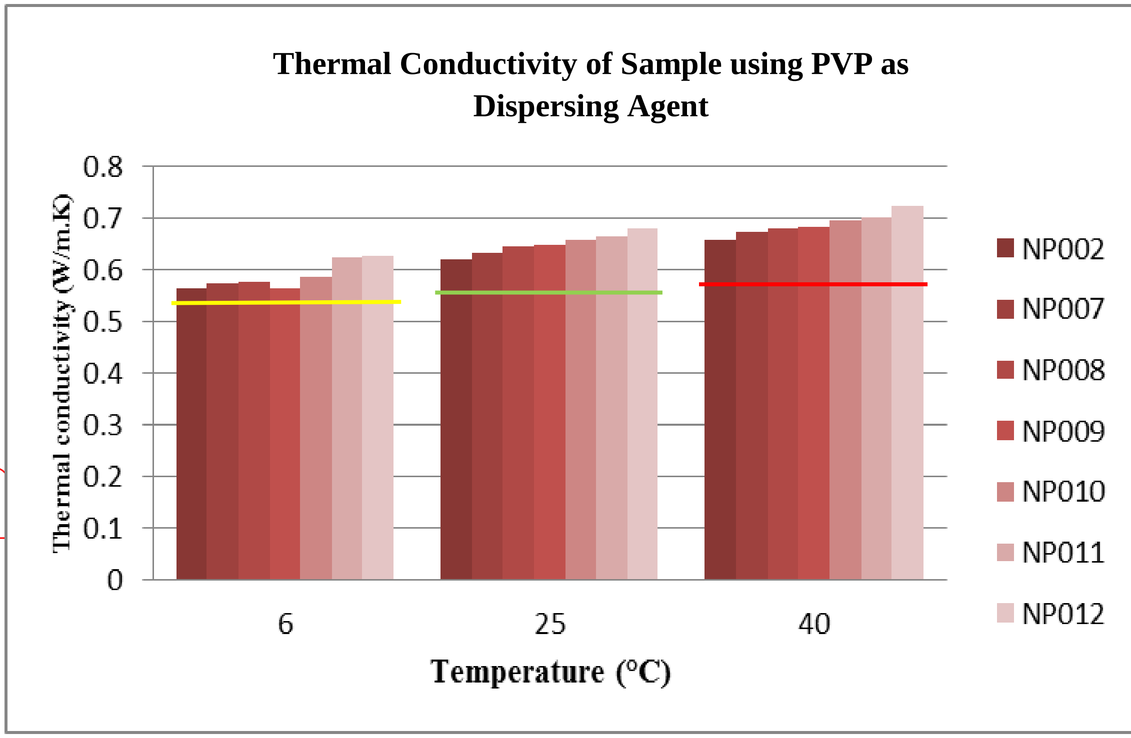


Figure 4.1: Thermal conductivity enhancement of Nanoamor and PVP

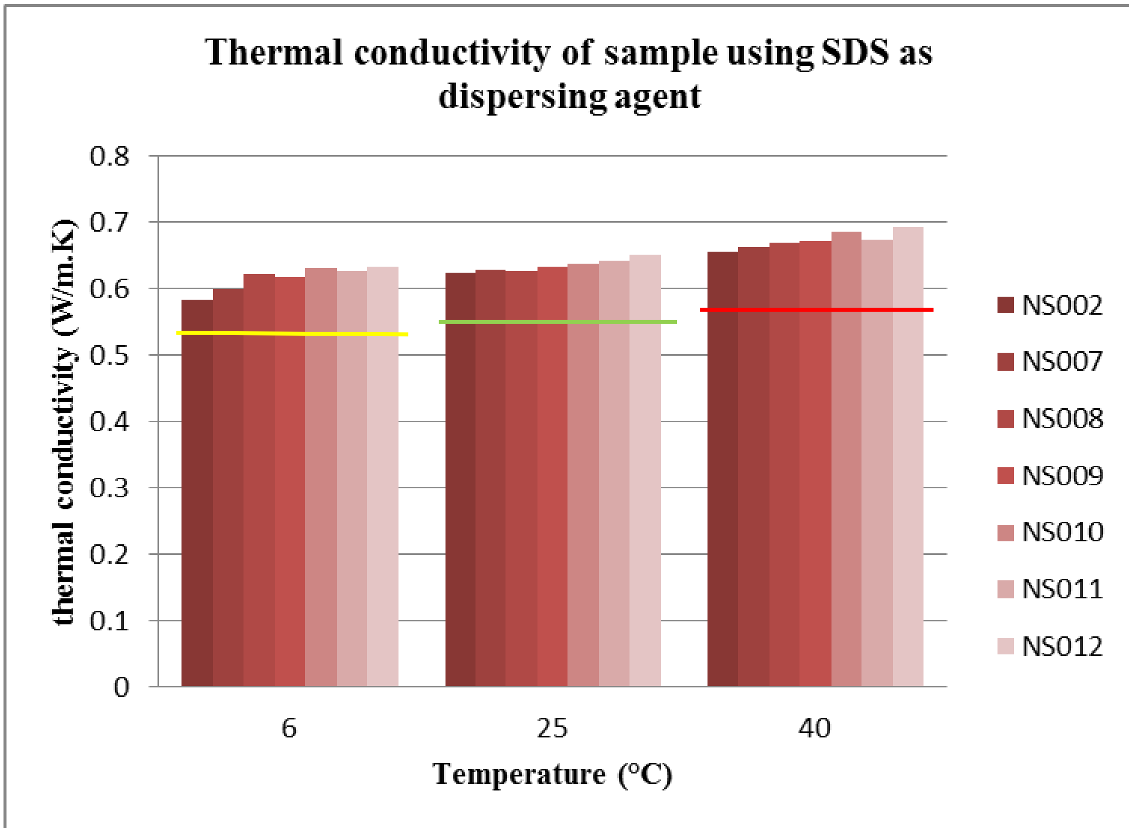


Figure 4.2: Thermal conductivity enhancement of Nanoamor and SDS

From Figure 4.1 and Figure 4.2 can be seen that value of thermal conductivity will be proportional to the temperature, this is due to the energy of particle in higher is proportional to the temperature, so at molecular level the molecule will move faster and more carbon nanotube particle can actually participate in the heat transfer process and causes the thermal conductivity value to rise.

4.3.3 Comparison Between PVP and SDS

In the terms of stability, it is obviously PVP is better than SDS because in. This claim was being made because from table 4.4 that shows MER with PVP has only 4 unstable sample compare to MER with SDS where there is 6 unstable sample as in show in Table 4.5. Observation from experiment shows that SDS will produce a very thick foam after homogenizing process and this problem don't occur on sample with PVP.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

The stability of nanofluids using Nanoamor with PVP and SDS as dispersing agent has been investigated. Nanofluids stability with different weight percent of CNT and dispersing agent has being determine by using a visual test and the stability test rig. Basically, for the sample of using Nanoamor that has an OH functional group is more stable than other type of carbon nanotube that doesn't has an OH functional group such as Pyrograph HHT and MER.The OH functional group on Nanoamor make it more suitable for the nanofluids application. From thermal conductivity test, it can be conclude that there no significant difference with other type of CNT seen from previous experimental result. A conclusion that can be made for this particular chapter is, when seeing from the result clearly it shows that Nanoamor type CNT is better in the terms of stability. For dispersing agent, it can be concluded that PVP is better that SDS in the term of stability because it is capable of producing more stable nanofluids. In the term of future application for coolant in central chilled air conditioning system, PVP is consider better than SDS since it not produce any foam. This foam can form cavitation on the turbine blade of the pump.

For thermal conductivity test, several sample had being chosen form various weight percent of CNT from both sample using PVP and SDS. All samples had being test and analyzed using KD2 Pro device with three different temperatures that is 6°C, 25°C and 40°C. From the result, all samples had shown some enhancement compare to water. From the analysis also, can be seen that the value for thermal conductivity is proportional to the temperature. Another importance finding on thermal conductivity test is the amount of CNT use is proportional to thermal conductivity value.

5.2 RECOMMENDATION

Besides investigating all possible thermal properties, actually test this nanofluids for actual thermal management application for example test it on car radiator to see how it will perform and behave on the real world. In house development of CNT also is possible where lectures and student can actually research on the process and how to manipulate the process to produce a different kind and quality of carbon nanotube. In future, research about the mechanical and electrical properties alsowill be worth trying because this kind of properties also is important in various fields like electronic, super conductor and micro structures.

For the thermal conductivity test, nanofluids need to be tested on higher temperature near its limits so that it can shows us how far it can actually go and what are the limitation.

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APPENDIX

APPENDIX A

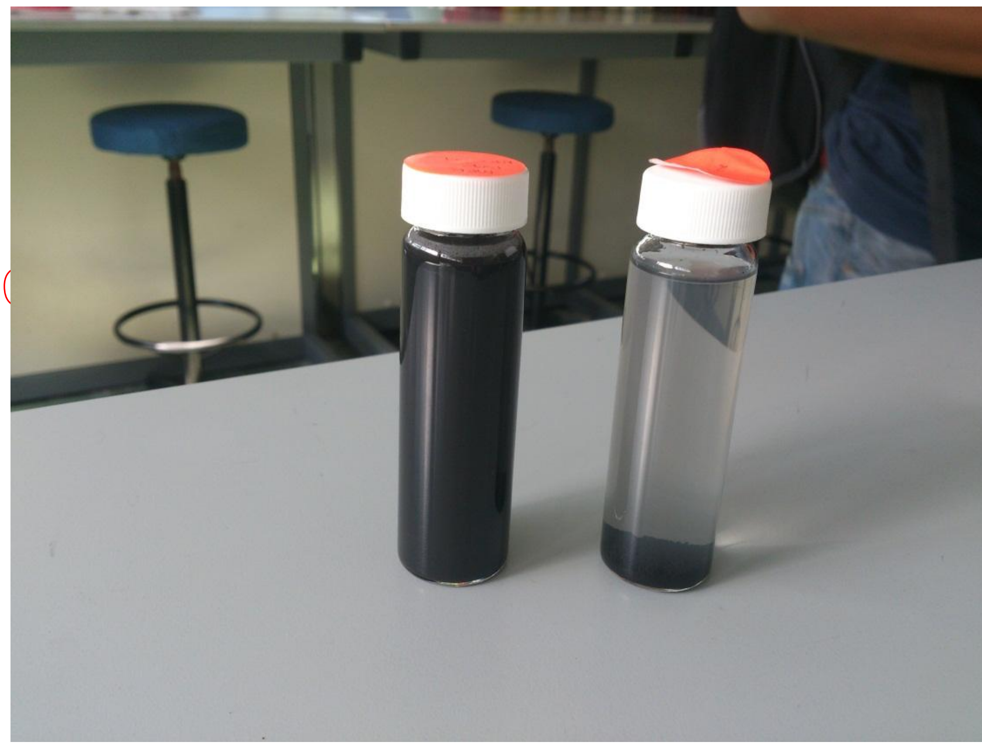

Figure A 1: A comparison of a stable nanofluids on the left side of the picture and unstable nanofluids on the right side.

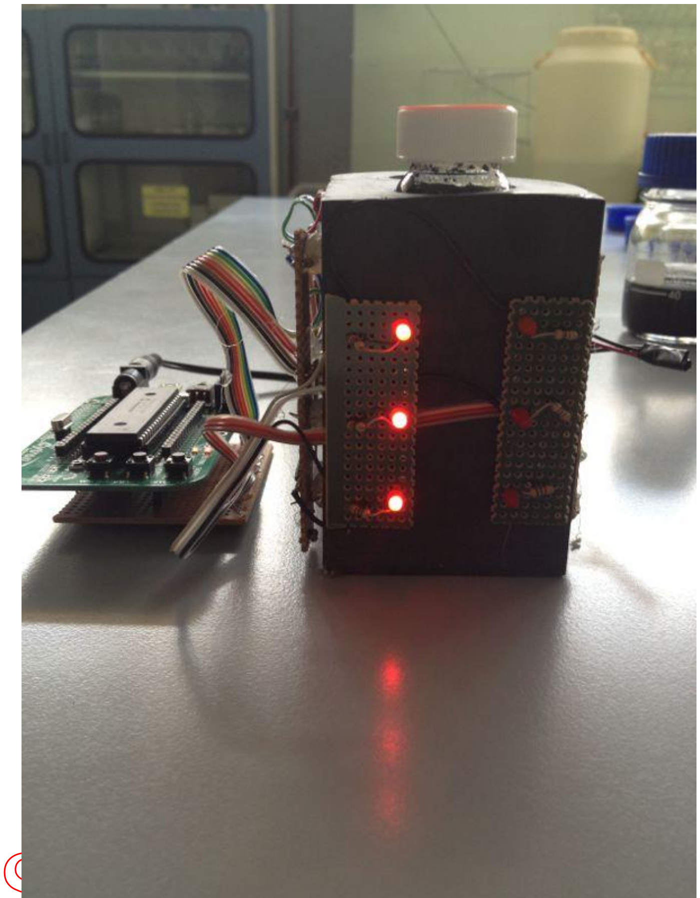

Figure A 2: Stability test rig show that all 3 LED lighted indicate that nanofluids is stable

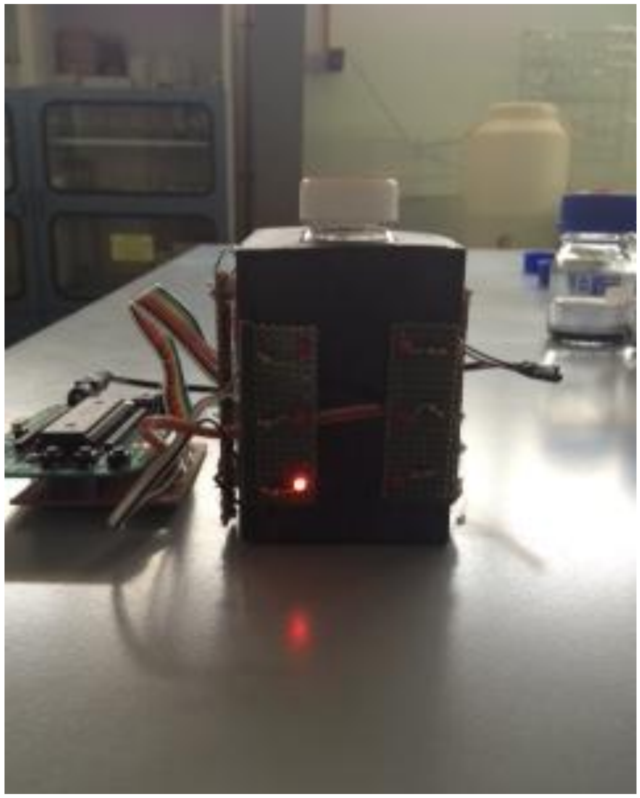

Figure A 3: Stability test rig shows that only one LED lighted indicate that the nanofluids is not stable.

APPENDIX B

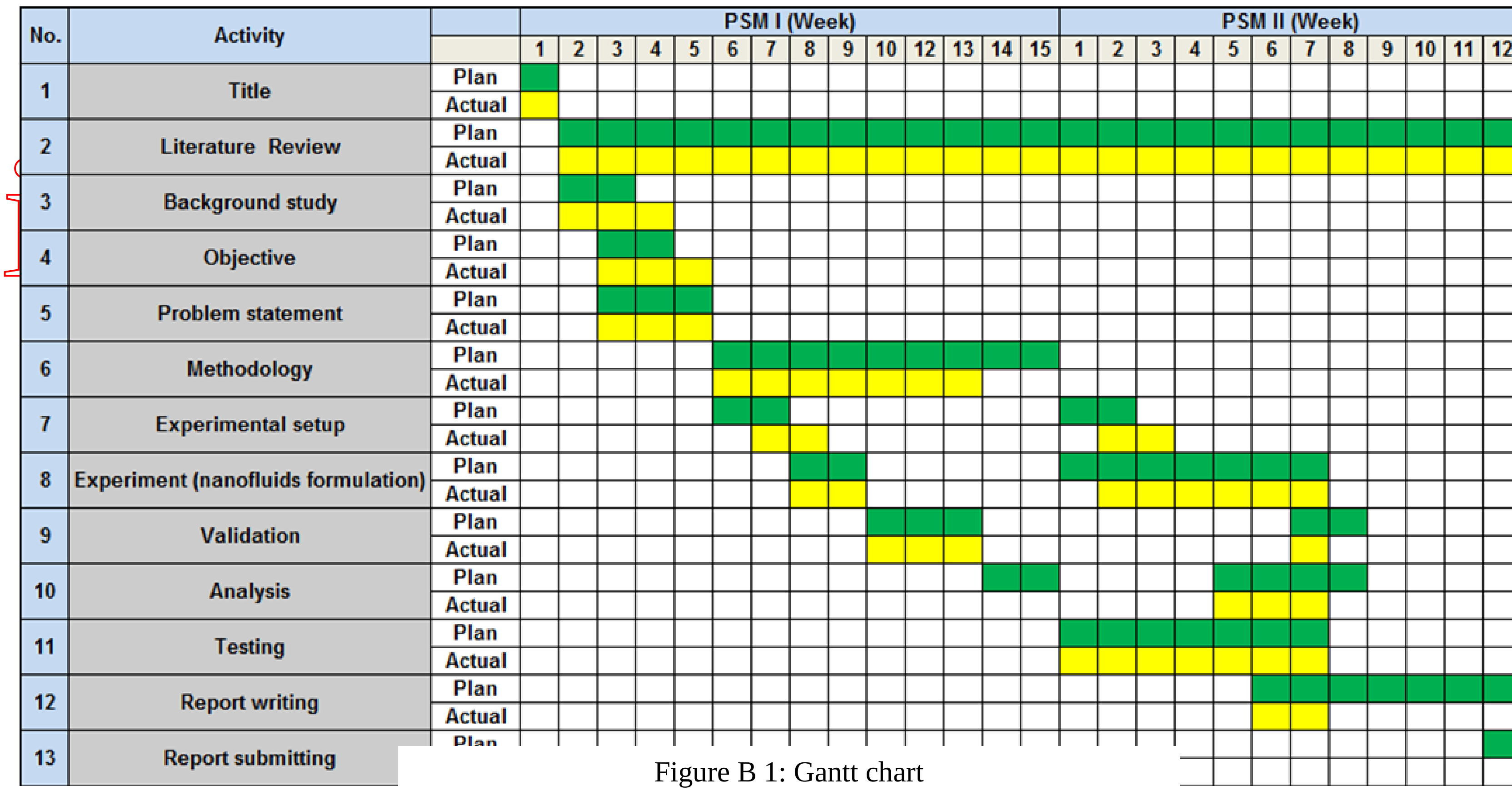

Figure B 1: Gantt chart