MOHD AIDIL FIRDAUS BIN MUSTAFA KAMAL B. ENG. (HONS) MECHANICAL ENGINEERING JANUARY 2020

# STUDY OF STABILITY AND THERMAL CONDUCTIVITY OF MULTIWALL CARBON NANOTUBES AND COPPER OXIDE IN ETHYLENE GLYCOL AT MEDIUM TEMPERATURE

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by

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Dissertation submitted in partial fulfilment of
the requirements for the
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With Honours

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# CERTIFICATION OF APPROVAL

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BACHELOR OF ENGINEERING (Hons)

(Mechanical)

Approved by,

________________________

(AP. DR. SYED IHTSHAM UL HAQ GILANI)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2020

# CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Aidil Firdaus

MOHD AIDIL FIRDAUS BIN MUSTAFA KAMAL

## ABSTRACT

The main aim of this study is to prepare a stable MWCNTs / CuO in nanofluid hybrid Ethylene glycol. The experiment will be performed in different amounts and combinations of solid concentrations ranging from 0.01 to 1 per cent each. To prepare the hybrid-nanofluid, the most common method in the preparation of nanofluid which is a 2-step process will be used. Temperatures varying from 20$^{o}$C to 60$^{o}$C There will be a few characterization tests to verify the characteristics of the prepared nanofluid. The research that was performed for characterization was the study of particle distribution and thermal conductivity. Graphs shown were the findings at different temperatures of the stability and thermal conductivity of various concentrations of nanoparticles.

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# CHAPTER 1: INTRODUCTION

## 1.1 Background of study

When industrial science advances, energy of all sorts is commonly used to complement human use. Non-such as fossil oil, coal and natural gas are diminishing and depleting. Renewable source energy such as wind energy, hydropower, solar energy and geothermal energy are the alternatives source of energy which research and development are being done to replace the non-renewable source of energy such fossil fuels. Renewable energy sources are widespread around the world. Solar energy is an energy which has no limits. This is an asset that does not affect the environment, which adds to the greenhouse effect even less.

Solar power can be commonly used as thermal and electric power. Transforming solar energy into thermal energy requires efficient conductivity, convection, and intermediate radiation. Thermal conductivity properties are very significant in achieving a high thermal conductivity and high solar energy efficiency. Common fluids such as water, oil and ethylene glycol does not give a good efficiency because of their low thermal conductivity. Rather than common fluids, nanofluids are used to obtain high thermal conductivity. Scientists and engineers have made many attempts to improve the heat transfer efficiency of the modern fluids. Metal in solid form is well known to have higher conductivity compared to common fluids.

*TABLE 1.1: Thermal Conductivity of Various Materials [1]*

| | Material | Thermal Conductivity (W/m · K)[a] |
|---|---|---|
| Metallic solids | Silver | 429 |
| | Copper | 401 |
| | Aluminum | 237 |
| Nonmetallic solids | Diamond | 3300 |
| | Carbon nanotubes | 3000 |
| | Silicon | 148 |
| | Alumina ($Al_2O_3$) | 40 |
| Metallic liquids | Sodium at 644 K | 72.3 |
| Nonmetallic liquids | Water | 0.613 |
| | Ethylene glycol | 0.253 |
| | Engine oil | 0.145 |

[a] At 300 K unless otherwise noted.

Nanotechnology and nanoscience involve with the studies of particles and material at nanoscale level and modifying them for the advance of materials. Generally, nanoparticles with a size less than 100 nm are in the district of nanotechnology [2, 3]. Nanoparticles materials such as metal oxides ($Al_2O_3$, CuO), nitride ceramics (AlN, SiN), carbide ceramics (SiC, TiC), metals (Cu, Al, Au), semiconductors ($TiO_2$, SiC), single, double or multi walled carbon nanotubes (SWCNT, DWCNT, MWCNT), have been used for the nanofluid preparation. Particles, rods, tubes, sheets, and fibres are a few forms of nanomaterials that existing. [4]. The size of nanoparticles in the liquid mixture (usually less than 100 nm) gives the ability to interact at the molecular level with liquids and to conduct heat better depending on the type of nanoparticles.

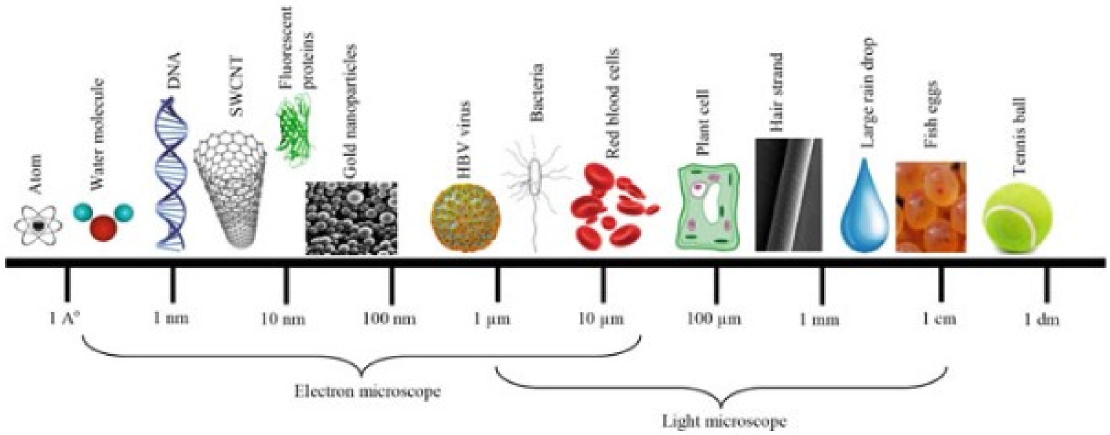


*FIGURE 1.1:Comparison of Size of Different Materials [4]*

The nanoparticles addition in liquids change the properties of the original liquids such as density, viscosity, thermal conductivity, and specific heat capacity. Currently, a lot of scientists have been focused on certain of hybrid nanofluids and carbon-based nanoparticles such as single-wall and multi wall carbon nanotubes [5], graphite [5], graphene [6] and graphene oxide to prepare nanofluids since they have properties which are have enhanced thermal, mechanical and chemical properties. Since carbon-based nanoparticles have higher thermal conductivity, their nanofluids represent extremely improved thermal performances such as thermal conductivity and heat transfer coefficient [7]. Hybrid mixture can utilize a broader wavelength spectrum of solar energy and absorb more heat compare to a single mixture of nanoparticle. [8].

## 1.2 Problem Statement

Energy conversion from solar to thermal energy requires effective heat transfer convection, conduction and radiation between the media. For thermal absorption application fluids such as water and oil are not suitable because of they have a low thermal conductivity. To obtain a high thermal conductivity property, nanofluids are used instead of common fluids. Nevertheless, there were a lot of interest to develop a new combination of nanofluid such hybrid nanofluid. Hybrid nanofluid form by suspending dissimilar nanoparticles either in mixture or composite form. Addition of two or more nanoparticles can alter or improve the thermal conductivity of nanofluid. Despite the thermal conductivity increase, the size of particles may increase due to the agglomeration between them and resulting an unstable nanofluid.

## 1.3 Objective

The objectives for this project are:

1. To prepare the hybrid nanofluids by using MWCNTs and CuO in Ethylene Glycol.
2. To test the hybrid nanofluid stability and thermal conductivity at different temperature ranges from 20°c-60°c.

### 1.4 Scope of Study

Four different concentrations of nanoparticles (MWCNT and CuO) are used for nanofluid preparation during the analysis. All the samples are left for a week to see some sort of sedimentation showing the nanofluid's stability. The nanofluid characterisation will be conducted at varying temperature scales from 60$^{o}$C-120$^{o}$C. Thermal conductivity and stability of the nanofluid will vary at various temperature scales.

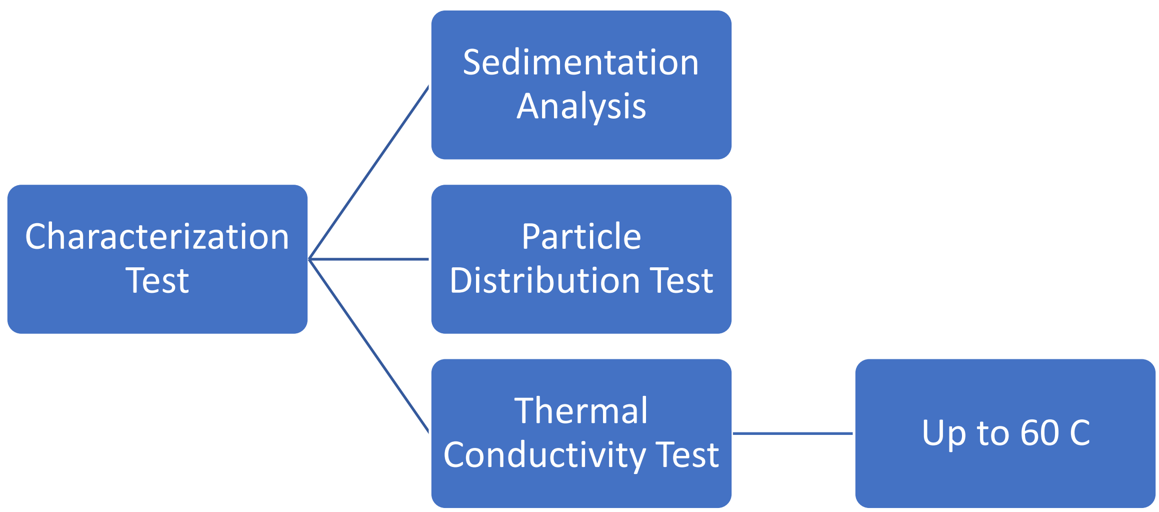


*FIGURE 1.2: Characterization Test*

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Nanoparticles and Base fluids

Nanofluids is consists of nanoparticles, base fluids and sometime surfactant was added to complete the preparations of the nanofluids. Example of nanoparticles are $Al_2O_3$ [9] , TiO2 [10], Cu [11], SiC, $Fe_2O_3$, $Fe_3O_4$, Ag, CuO, ZnO and $SiO_2$ [9]. Solid nanoparticles with high thermal conductivity can be used as nanoparticles to form nanofluid. Base fluids or conventional fluids such as water [5, 9, 10, 12], ethylene glycol [11], oil and glycerol have low thermal conductivity compare to solid.

*TABLE 2.1: Materials Thermal Conductivity [13]*

| Material | | Thermal conductivity (W/Mk) |
|---|---|---|
| Metallic solids | Cu | 401 |
| | Al | 237 |
| | Ag | 428 |
| | Au | 318 |
| | Fe | 83.5 |
| Nonmetallic solids | $Al_2O_3$ | 40 |
| | CuO | 76.5 |
| | Si | 148 |
| | SiC | 270 |
| | CNTs | ~3000(MWCNTs)~6000(SWCNTs) |
| | BNNTs | 260~600 |
| Base fluids | $H_2O$ | 0.613 |
| | Ethylene glycol (EG) | 0.253 |
| | Engine oil (EO) | 0.145 |

## 2.2 Nanoparticles Volume Fraction

The volume concentration percentage of nanoparticles to prepare the nanofluid is very important. Too many amounts of nanoparticles will result in an unstable nanofluid and in a short period cause sedimentation. A small amount of nanoparticles will increase the thermal conductivity of nanofluids. Therefore the following equation can be used to determine the volume fraction of nanoparticles to be used in the preparation of nanofluid [14],

$$\phi = \left[ \frac{(\frac{w}{\rho})_{nanoparticle}}{(\frac{w}{\rho})_{nanoparticle} + (\frac{w}{\rho})_{basefluid}} \right] \times 100 \quad .......... 2.1[14]$$

$\phi$ = Percentage of solid volume fraction

W = Mass (kg)

$\rho$ = Density (kg/m$^3$)

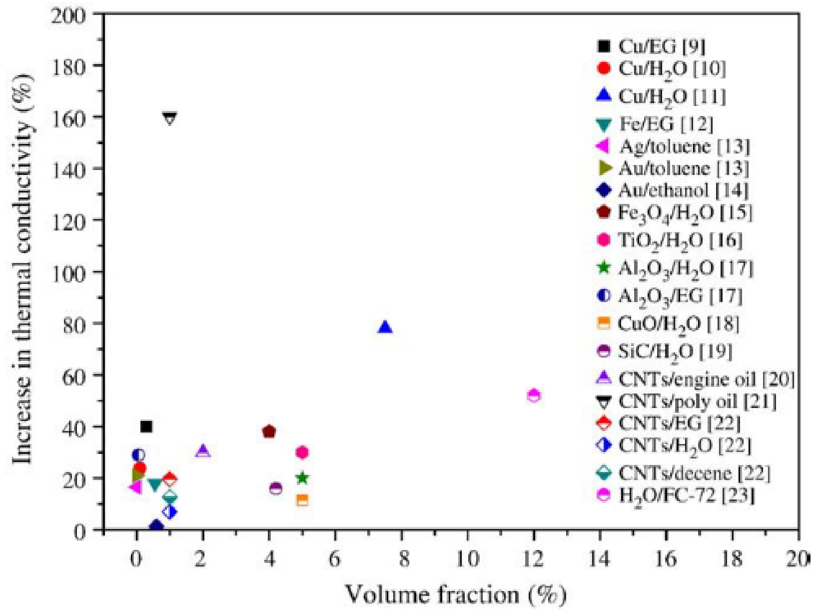


*FIGURE 2.1: Comparison Of Experimental Data On Thermal Conductivity Of Nanofluids [13].*

## 2.3 Nanofluids Preparations

There are 2 methods in preparations of nanofluid which are one-step method and two-step method [13, 15]. One-step method is not a common step to prepare nanofluids compare to two-step method [11]. A study to prepare nanofluid with the mixture of ethylene glycol solution (0.1 M) of copper sulfate pentahydrate ($CuSO4 \cdot 5H2O$) was added together with of ethylene glycol solution (0.01 M) of polyvinylpyrrolidone (PVP-K30) in a beaker and stirred for 30 minutes. Then ethylene glycol solution (0.25 M) of sodium hypophosphite ($NaH2PO2 \cdot H2O$) was added and stirred for an extra 15 minutes. The nanofluid and base fluid mixture was then placed into a microwave oven to allow it to react under medium power for 5 minutes. The mixture was then cooled to room temperature and Cu nanofluid was obtained [11].

The most common method to prepare nanofluid is two step method [7, 10, 16, 17]. Nanoparticles that been used in this method are produced as a powder and the nanosized powder is then spreaded into a base fluid in the second processing step [13]. The two-step process may result in nanoparticles being agglomerated, and the settlement may decrease the thermal conductivity Thereby, ultrasonic agitation or the application of surfactant to the fluids widely used to minimize aggregation and improve the nanoparticles 'dispersion activity in the solution. Nanoparticles of alumina powder ($Al_2O_3$) was used as to prepare a nanofluid [9, 16-18]. The nanoparticles are dissolved in the base fluid which is water. Alumina nanoparticles, distilled water and 0.0001 M HCl as an electrolyte were used to prepare nanofluids using a two-step method. 1 hour of sonication time for dispersing nanoparticles using an ultrasound sonicator [16]. In order to prepare CuO-engine oil based nanofluids with different CuO nanostructures, the two-step method was used. This was observed that a strong dispersion of nanoparticles into the oil was achieved by using planetary ball milling because of the high viscosity of the engine oil. The nanofluids which were prepared, were stable and after 30 days no sedimentation was observed [19].

*TABLE 2.2: Literature Review on Different Preparation Method*

| Reference | Nano Particles | Base Fluid | Preparation Method |
|---|---|---|---|
| Ghadimi & Metselaar (2013) [10] | TiO2 | Distilled water | Two-Step |
| Farbod et al. (2015) [19] | CuO | Engine Oil | Two-Step |
| Asadi & et al (2016) [20] | MWCNT-ZnO | Engine Oil | Two-Step |
| Zhu et al. (2004) [11] | Cu | Water | One-Step |

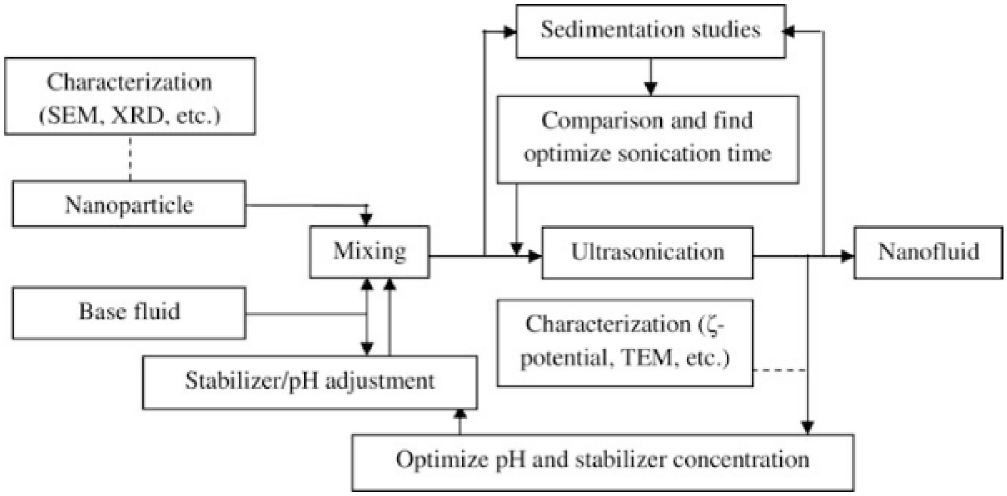


*FIGURE 2.2: Two-Step Method To Prepare Stable Nanofluids [4]*

## 2.3 Stability Evaluation

There are methods that can test the stability of nanofluid. The tests are sediment photograph capturing, zeta potential analysis, transmission electron microscopy (TEM) particles size distribution, scanning electron microscopy (SEM) and sedimentation balance method.

Capturing sediment photography is a easy tool for checking stabilization of the nanofluid. After full nanofluid preparation, some sample of increasing concentration was set aside for photo capture after a certain period. Through comparing the images of each sample, nanoparticles can become evident in sedimentation. Octahedral-Cu2O nanofluid which have been left for 24 hours shows the different results [15].

*FIGURE 2.3: Octahedral-Cu2O Nanofluids 24 Hours After Their Preparation [15].*

TEM and SEM test is a technique to prove particle dimensions and the accumulation of nanoparticles. It also distinguishes the shape and distribution of nanoparticles. Both uses electron beam to see features at nanoscale level. TEM have a major drawback which the sample use must be dry to attach on the carbon matrix. The particles are not entirely in liquid state and agglomeration between the particles will occur during drying [2] [15].

Following is the standard procedure for standard SEM/TEM micrographs [15]:

1) A stable nanofluid is prepared in solution form or collected.
2) A drop of nanofluid is deposited on the adhesive side of the SEM specimen holder film.
3) The vacuum oven was heated with a drop of liquid to allow it to dry or dry naturally.
4) The solid particles were obtained.
5) Put in the vacuum chamber of SEM/ TEM after it coated with gold (Au) or palladium (Pd) for pictures.

Dynamic light scattering (DLS) technique is used in nanosuspensions to measure the particle size [4]. This study determines the mean value of the liquid agglomerate. The average particle size is measured as a laser beam illuminates the experiment, and then the photon detector measures the variations of the reflected light. Curves of distribution of the particle size are obtained by frequency or volume. This approach will achieve distribution curves of particle size for particles of a dimension as small as one nm.

Zeta potential analysis is one of the most important tests to validate nanofluids stability through a study of its electrophoretic behaviour. Its measure interfacial potential between attached thin layer on the surface of the particles and dispersion medium [4]. In other words, the repulsive interaction between the particle and the dispersant was determined. Nanosuspensions with zeta potential values more than ±30 mV is considered stable for a longer time. Zeta potential value between 0 and 5 mV will give a poor stability and the rate of agglomeration will be high. The zeta potential values can be altered by altering the pH content of the suspension, surface nanomaterial coatings or by applying surfactants [4]. The zeta potential of SDS-CNT nanofluid gives higher value compare to only CNT nanofluid [10]. It is due to the repulsion of negative charged cluster surface which played an important role to stabilize the CNT. When particles have a high surface charged it tend to not accumulate with another particle.

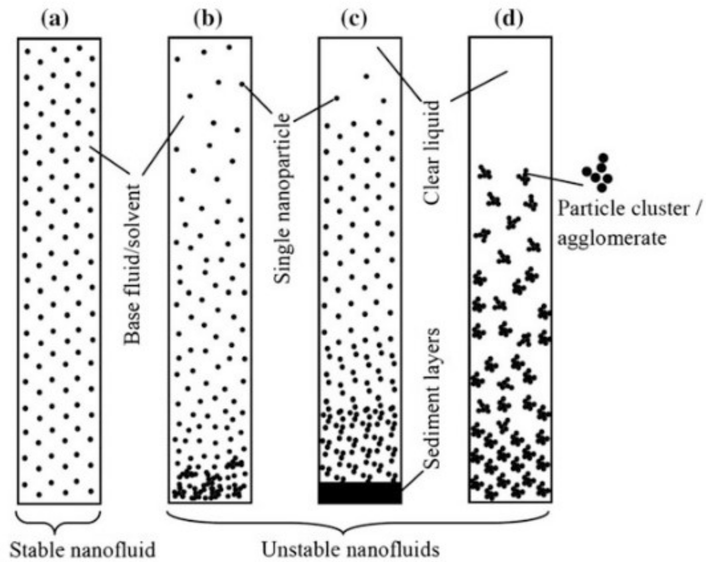


*FIGURE 2.4: Different Scenarios Of Stable And Unstable Nanofluids [4]*

## 2.4 Stability Improvement

A highly stable, uniform nanofluid can be obtained by using a tool or by applying a solvent. Ultrasonication is a process where the technique of mixing with the sound waves used creates interference between various sediment layers. The distortion splits these massive agglomerates into smaller agglomerates. The stability of nanofluids is determined by sonic frequency and sonication time [4]. It is found that the time of the higher solid concentrations to calm down over an ultrasonic duration of up to 10 hours is greater than that of the lower ones. Nevertheless, the pattern is entirely different for 10 hours or more of ultrasonic times; the high solid concentrations took longer settling time as the time for ultrasonic increased [21]. Increasing the horn ultrasonic time will shift the particle size distribution and dismantle the agglomeration into smaller particle size. In addition, it will increase the absorbance of low concentration nanofluid by increasing the duration of ultrasonic. It reveals from the samples that 15 minutes of the ultrasonic procedure will decrease the sedimentation rate and particle accumulation, particularly if it is accompanied by surfactant additions [10]. The MWCNT and ZnO particles were mixed in the base fluid and stirred for 2 hours. The mixture was exposed to ultrasonic processor with 20 kHz for an hour to achieve an uniform dispersion and breakdown the agglomeration of nanoparticles [20].

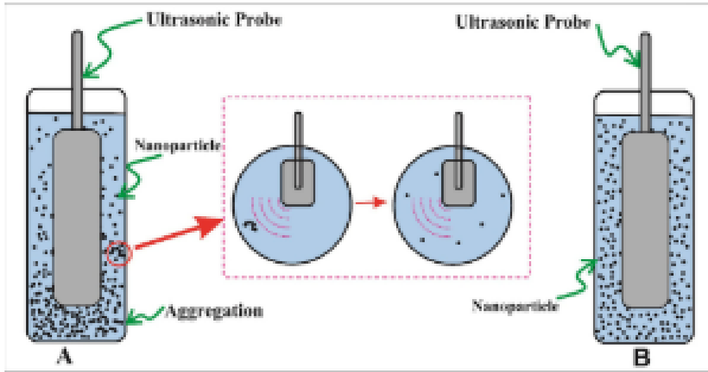


*FIGURE 2.5: The Process Of Ultrasonication On How It Breaks Down The Agglomerations Of Nanoparticles [21].*

Addition of surfactant modify the surface properties of nanoparticles in nanofluids. The hydrophobic surfaces of the nanomaterials in aqueous-based nanosuspensions are modified into hydrophilic surface and vice versa [4]. Cetrimonium bromide (CTAB), sodium dodecyl benzene sulfonate (SDBS), sodium dodecyl sulfate (SDS) and gum Arabic are commonly used as surfactants. Ultrasonification was applied to help the homogeneity and Sodium Dodecyl Sulfate (SDS) as anionic surfactant was added to observes the stability of the samples. Sodium dodecyl sulfate (SDS) remarkably influences the zeta potential value in titania (0.01%) and alumina (0.05%) nanofluids [10]. In other study, the fluids were prepared with sodium dodecyl-sulfate surfactant of equal mass to help minimize the effects of aggregation of nanoparticles. [5].

## 2.5 Characterization Test

Measurement of thermal conductivity is for calculating the ability of the nanofluid to absorb and transfer heat. There was a lot of ways to calculate a nanofluid's thermal conductivity. Transient hot wire method (THW) is a technique that is well established, accurate and used by many researchers. This technique removed the effects of natural convection which is unwanted heat transfer. KD2 Pro is a device that use THW method to measure the thermal conductivity. The device has a 5% accuracy over 5-60 C temperature range [10].

The measurement of Al2O3 and CuO were made at room temperature and there is no attempt to maintain the surrounding temperature. A small amount of nanoparticles will increase the thermal conductivity compared to the same base fluid which has no nanoparticles adding [22]. The test shows that the nanofluid's thermal conductivity relies upon the thermal conductivity of base fluid and nanoparticles. Whatever type of base fluid used in the preparation of nanofluids, with the same volume fraction of nanoparticles, the thermal conductivity of the CNT suspensions was much greater.

For some situations, the nanofluid's thermal conductivity with high nanoparticles thermal conductivity was less compared to the mixture of nanoparticles with low thermal conductivity that generates high nanofluid thermal conductivity. The example is bulk Fe3O4 crystal has a lower thermal conductivity than Al2O3, CuO, and TiO2 bulk crystals. Based on the study Fe3O4/aqueous nanofluids have higher thermal conductivity property compare to the other oxide aqueous nanofluids at the same volume fraction of nanoparticles[13].

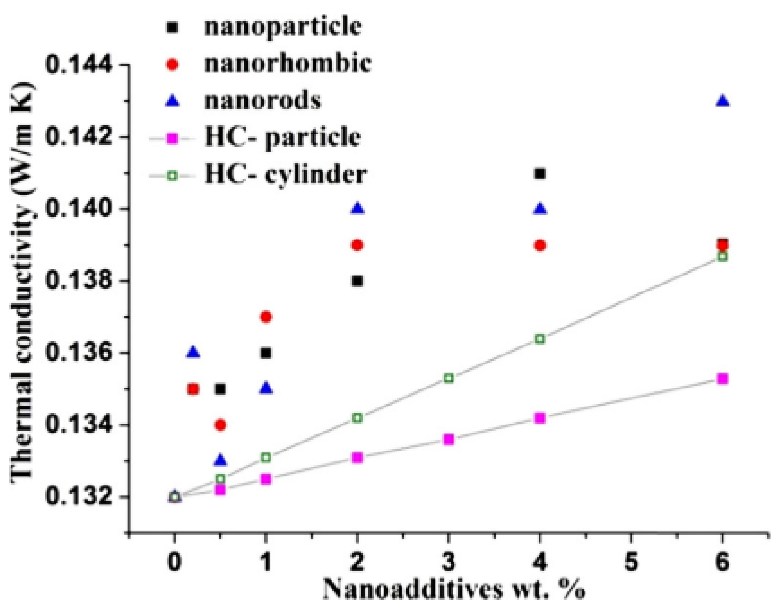


*FIGURE 2.6: Percentage of Nano additives VS Thermal Conductivity*

The viscosity measurement is as important as thermal conductivity. Most study used Brookfield cone and plate viscometer (CAP2000) to measure the nanofluid viscosity. The device allow user to set temperature of the nanofluid and keep it stable over the experiment period. The device working temperature is between 5 C to 75 C temperature range. It also has an accuracy of ± 2 %.


FIGURE 2.7: Brookfield Cone And Plate Viscometer (CAP2000) [20].

Both samples have the same nanoparticles concentration in the analysis, which is 0.1wt % each. Both samples show differing levels viscosity values. T2 and T6 give a high viscosity value which is not ideal for nanofluid use. The difference is due to surfactant use and ultrasonic time.

TABLE 2.3: Different Homogenization Method For Nanofluid Preparation [10].

| Sample | Homogenization technique |
|---|---|
| T1 | 0.1 wt.% $TiO_2$, a simple mixture |
| T2 | 0.1 wt.% SDS and $TiO_2$, a simple mixture |
| T3 | 0.1 wt.% $TiO_2$ prepared by 15 min ultrasonic horn |
| T4 | 0.1 wt.% $TiO_2$ and SDS prepared by 15 min ultrasonic horn |
| T5 | 0.1 wt.% $TiO_2$ prepared by 3 h ultrasonic bath |
| T6 | 0.1 wt.% $TiO_2$ and SDS prepared by 3 h ultrasonic bath |

TABLE 2.4: Zeta Potential, Particle Size, Thermal Conductivity and Viscosity Results of Titania Nanofluid [10].

| No. | Zeta potential (mv) | Particle size (nm) | Relative thermal conductivity $K_{nf}/K_{bf}$ | Viscosity $\mu_{nf}/\mu_{bf}$ |
|---|---|---|---|---|
| T1 | −33.1 | 250.4 | 1 | 1.001 |
| T2 | −44 | 276.75 | 1.008 | 1.05 |
| T3 | −31.1 | 188.2 | 1.009 | 1.04 |
| T4 | −47.9 | 176.9 | 1.01 | 1.045 |
| T5 | −33.3 | 212 | 1.008 | 0.989 |
| T6 | −55 | 237.65 | 1.01 | 1.05 |

Experiment reveals that the viscosity is improved by reducing the temperature of the nanofluid MgO-therminol. As the concentration of MgO decreases the viscosity will increase. The calculated viscosity is higher relative to the theoretical value by contrasting the experimental value with the theoretical value [23].

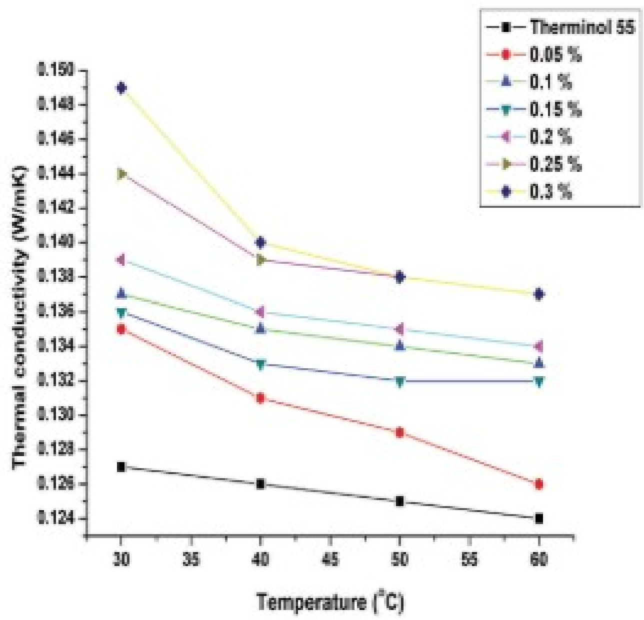


*FIGURE 2.8: Graph of Temperature VS Concentration [23].*

| No. | Author | Nanoparticle | Base fluid | Surfactant | Concentration | Result | Remark |
|---|---|---|---|---|---|---|---|
| 1. | Ghadimi & Metselaar (2013) [10] | $TiO_2$ | Distilled water | (SDS) | 0.007–0.012 wt.% | Addition of surfactant increase the thermal conductivity of the nanofluid and the stability for a month. | Surfactant helps to stable the nanofluid. |
| 2. | Zhu & et al (2004) [11] | Cu | Water | SDBS | 0.1 to 0.2 wt% | Nanofluid was stable for more than 3 weeks. | There is no any result on the thermal conductivity and viscosity. |
| 3. | Karim & et al (2019) [24] | Sodium Nitrate | Salt base fluids (potassium nitrate salts) | - | 60:40 | Receiver efficiency increases with increasing solar concentration, decreasing nanoparticle volume fraction and, extension, increasing receiver height. | No data on the thermal conductivity. |
| 4. | Mondragón & et al (2012) [9] | $SiO_2$ and $Al_2O_3$ | Water | HCl or NaOH (change pH value) | 0.5% v., 1% v., 5% v; | Thermal conductivity increases until 80 C. after 80 C thermal conductivity starts to decrease. Viscosity increase with the particles and decrease with temperature. | A good test that show the effect of temperature. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5. | Otanicar & et al (2010) [5] | Carbon Nanotubes, Graphite, and Silver | Water | sodium dodecyl-sulfate (SDS) | 0.5% | High efficiency level achieved with the 20 nm silver nanoparticles. | None. |
| 6. | Sajid & et al (2014) [16] | Alumina (Al2O3) | Water | 0.0001 M HCl | 0.05% v/v | Water-based alumina nanofluid with a high extinction coefficient in the UV region is only capable of enhancing the absorption capacity of water. Alumina nanofluids are not suitable for absorption of solar energy but could be used for reflective solar energy applications due to its high dispersion coefficient. | None. |
| 7. | Tyagi & et al (2009) [12] | Aluminum | Water | - | 0.1% - 5% | As the particle size increase the collector efficiency increased slightly. | None. |
| 8. | Farbod et al. (2015) [19] | CuO | Engine oil (SAE20W50) | - | 0.2–6wt.% | The thermal conductivity increases as the volume fraction of nanoparticles increase. Viscosity of nanofluids with 0.2 wt.% of nanoparticles decreases | Increasing the nanoparticles, increase the viscosity. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | and increases as the volume of nanoparticle increasing. | |
| 9. | Asadi & et al (2016) [20] | MWCNT/ZnO | Engine Oil (10W40) | - | 0.125%, 0.25%, 0.5%, 0.75%, and 1%. | The viscosity of the nanofluid decrease when temperature increased. 5 hours of sonication time gives the nanofluid highest value of thermal conductivity. The thermal conductivity increases as the temperature increase. | Temperature effect the thermal conductivity and viscosity of nanofluid. |
| 10. | Anish & et al (2018) [23] | MgO | Therminol 55 | - | 0.05%–0.3% | Thermal conductivity increase, Viscosity decrease as the volume fraction increase. | Volume fraction of nanoparticles varies the thermal conductivity and viscosity. |

# CHAPTER 3: METHODOLOGY

This section describes the chemicals used, the preparation of the samples and the equipment used to prepare and analyze nanofluid stability.

## 3.1 Calculation of Chemical Volume Fraction

The nanoparticles which will be used are copper oxide (CuO) and multi-surface carbon nanotube (MWCNT). Ethylene glycol is the main fluid which will be used in this analysis. The surfactant chemical should not be used to stabilize the nanofluid, because it will change the conductivity of the liquid.

*TABLE 3.1: Properties of Copper Oxide[14] [25]*

| Properties | CuO | MWCNT | Ethylene Glycol |
|---|---|---|---|
| Density (kg/m3) | 6500 | 2100 | 1113.2 |
| Thermal Conductivity (W/m K) | 17.65 | 1500 | 0.258 |
| Specific Heat (J/kg K) | 533 | - | - |
| Viscosity (N/m2 s) | - | - | 29.6 |

$$\phi = \left[\frac{(\frac{w}{\rho})_{nanoparticle}}{(\frac{w}{\rho})_{nanoparticle} + (\frac{w}{\rho})_{basefluid}}\right] \times 100 \quad ........ 2.1[14]$$

$\phi$ = Percentage of solid volume fraction

W = mass (kg)

$\rho$ = Density (kg/m$^3$)

*TABLE 3.2: Mass of Different Concentration of Nanofluid*

| Concentration (%) | Total Mass | Total Nano Particle Conc. | 20 % MWCNTs (m. grams) | 80 % CuO (m. grams) |
|---|---|---|---|---|
| 0.25 | 61.2624 | 153.156 | 30.6312 | 122.5248 |
| 0.5 | 61.2624 | 306.312 | 61.2624 | 245.0496 |
| 0.75 | 61.2624 | 459.468 | 91.8936 | 367.5744 |
| 1 | 61.2624 | 612.624 | 122.5248 | 490.0992 |

### 3.2 Nanofluid Preparation

The experiments will be used 4 different volume fractions of nanoparticles which are 0.25%, 0.5%, 0.75% and 1% wt. In Ethylene Glycol each of the volume fractions will be distributed later. The most popular approach or methodology used is a two-step, literature-based survey approach. A sonification process is performed to balance the nanoparticles evenly in the base fluids. Magnetic stirrer blends the nanoparticles into the basefluids for one hour. Ultrasonic equipment (ultrasonic bath / ultrasonic probe) will be used to sonicated the nanofluid for one to two hours. The method of ultrasonisation will decrease and break down the concentration of particles. It also makes the nanofluid stable with even particle distribution for a long time.

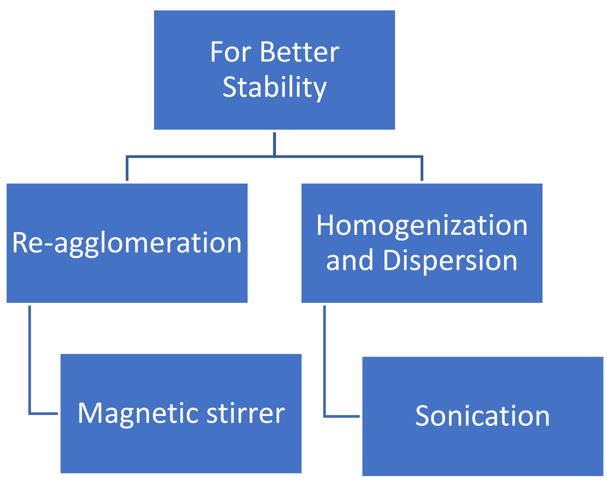

FIGURE 3.1: Magnetic Stirrer

FIGURE 3.2: Sonicator

**3.3 Characterization of Nanofluid**

Each of the sample will be tested at different temperature between 20°C-60°C. At different temperature, thermal conductivity of the nanofluids will be varied. Too many concentration of nanoparticles may result a high thermal conductivity.

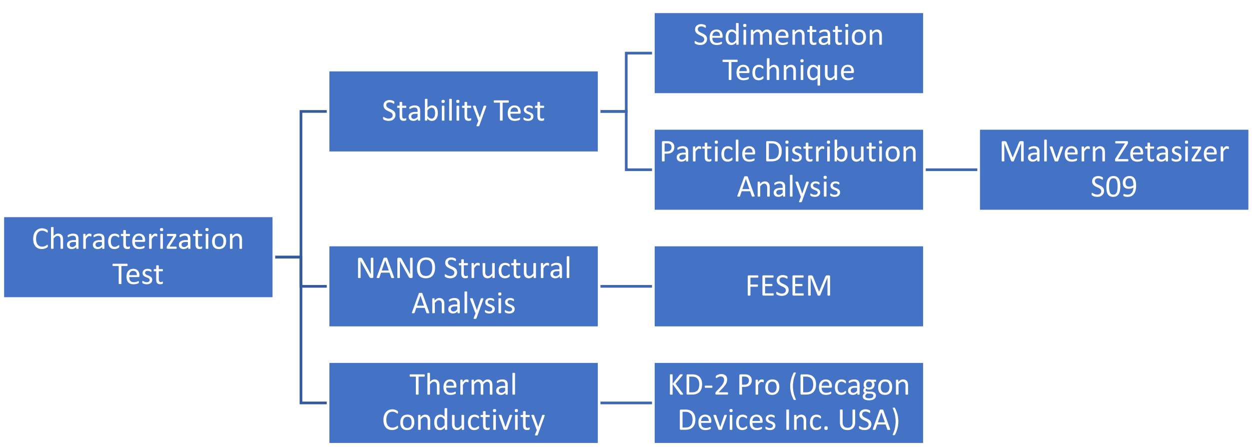


FIGURE 3.3:Characterizatin Test

Sedimentation technique is a study in which a natural phenomenon happens due to gravity and is often affected by particle aggregation. Analyzing the stability of nanofluid is a basic technique. Theoretically particles that is less than 1 micron are not affected by gravity forces [4]. By the force of gravity, as the material starts to aggregate and bind together, the particles appear to calm down more quickly.

NANO structural evaluation is an estimation of the distribution and stabilization of nanoparticles with the application of electron microscopy. With this study, because of its high magnification it shows the nanoscale materials with high clarity. The downside to electron microscopy, however, is that it cannot show particle size that is less than 0.5 micron [4]. This research is very useful for collecting the sample properties such as structure, morphology of the crystalline structure and specimen topography.

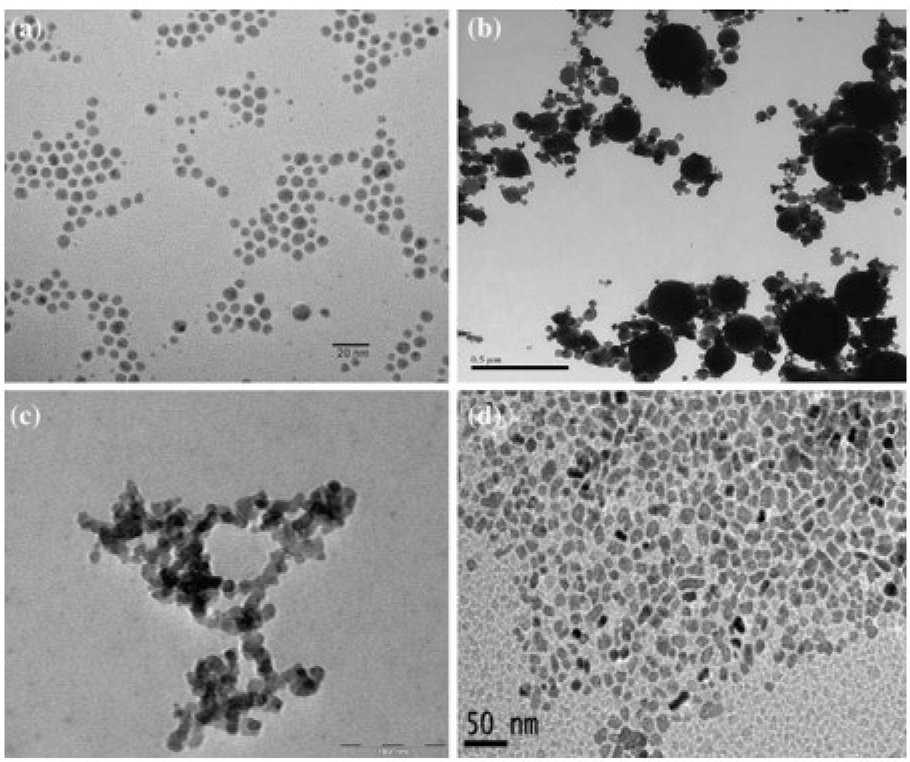


*FIGURE 3.4:Example Of Particles Under Electron Microscope [1].*

After stabilization of the nanofluid, the thermal conductivity value will be tested using KD-2 Pro which is available in the laboratory. In this study, nanofluids with various nanoparticles concentrations range from 0.1 per cent-1 per cent are studied at varying temperatures up to 60 per cent at an interval of 10 C the temperature will rise.

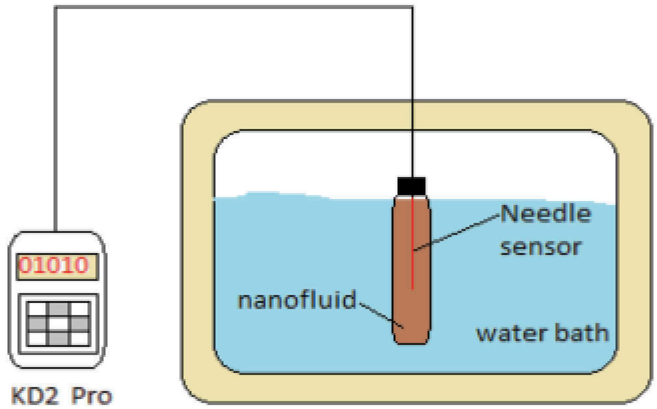


*FIGURE 3.5: KD2 Pro Thermal Analyser [23].*

Flow Chart

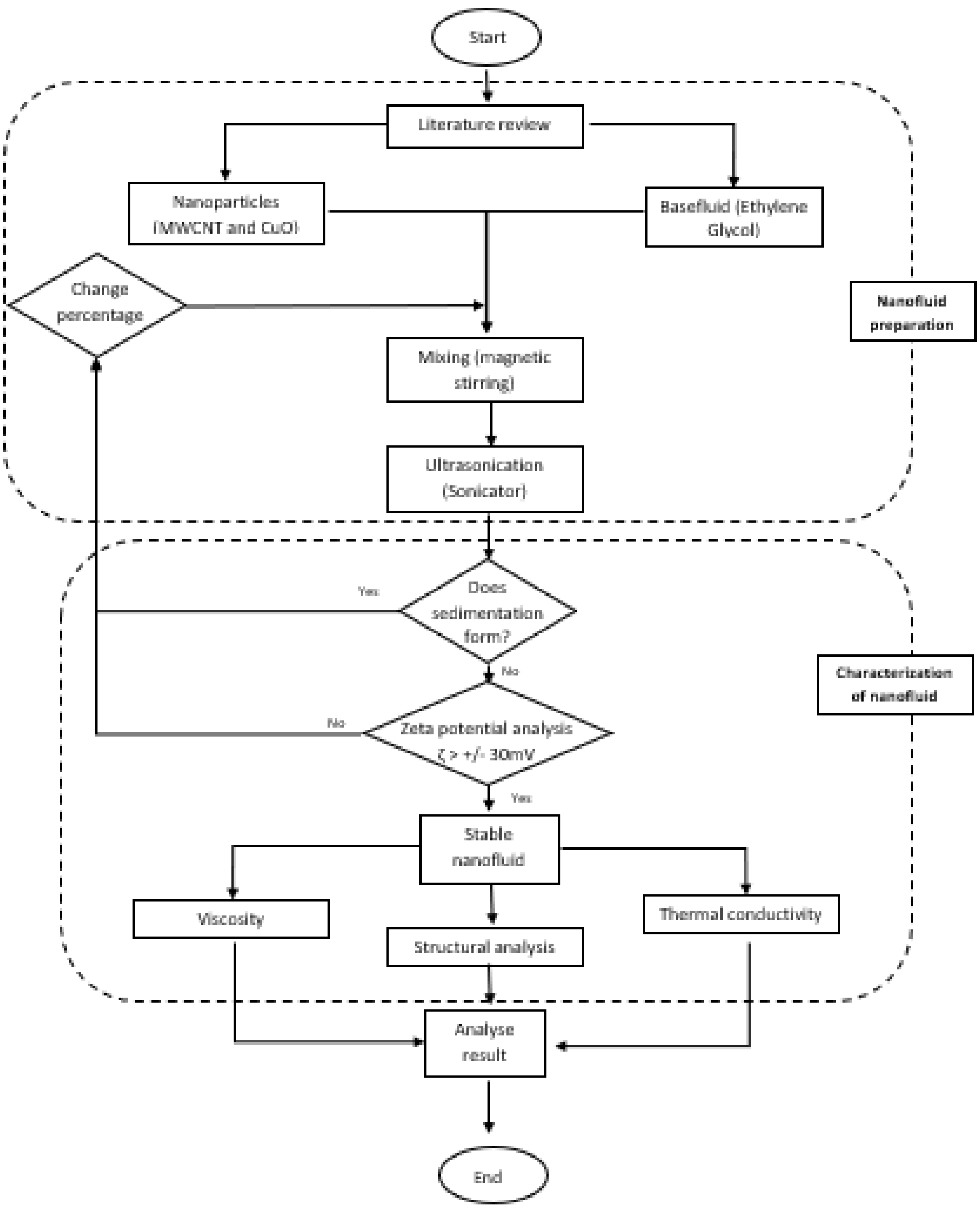


*FIGURE 3.6: Flow Chart of Nanofluid Preparation and Tests.*

Gantt Chart

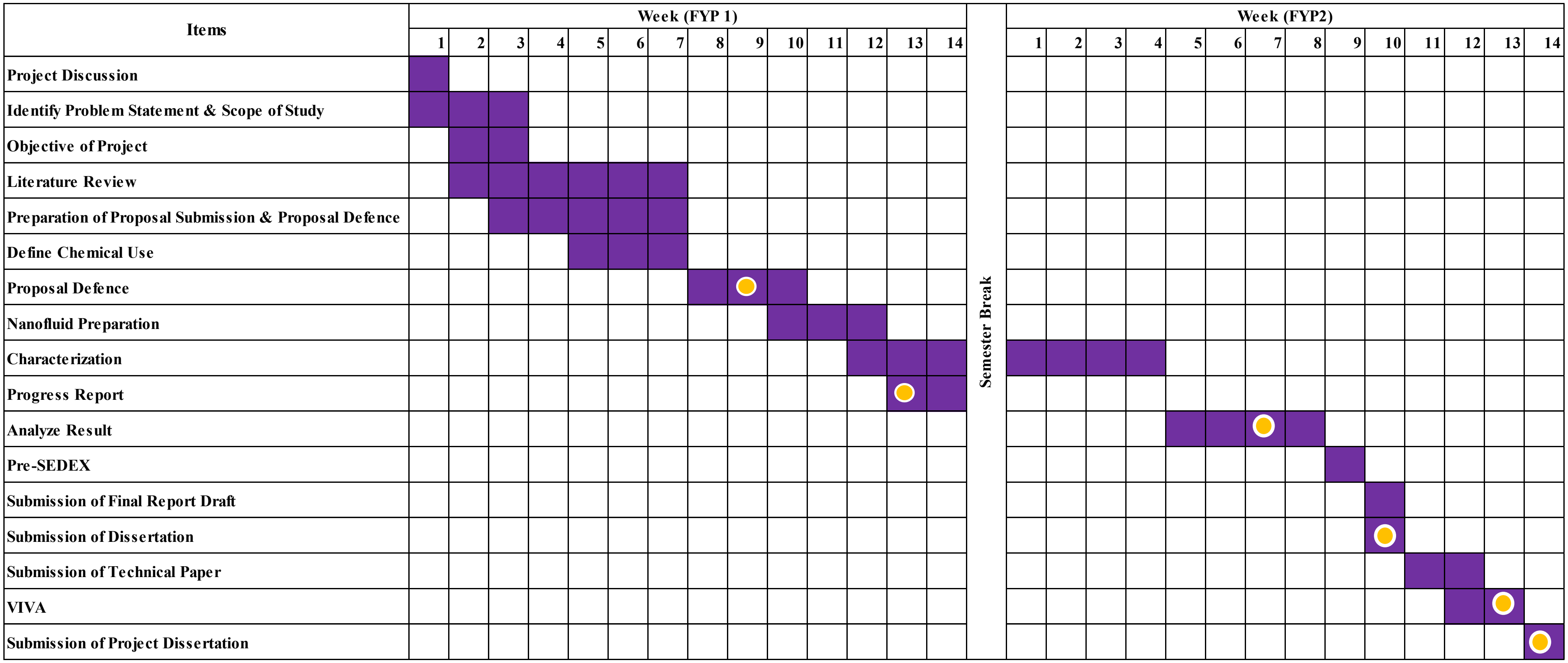


*FIGURE 3.7: Gantt Chart and Key Milestone*

Key Milestone =

# CHAPTER 4: RESULT AND DISCUSSION

## 4.1 Result and Discussion

### 4.1.1 Stability (Particles Size Distribution)

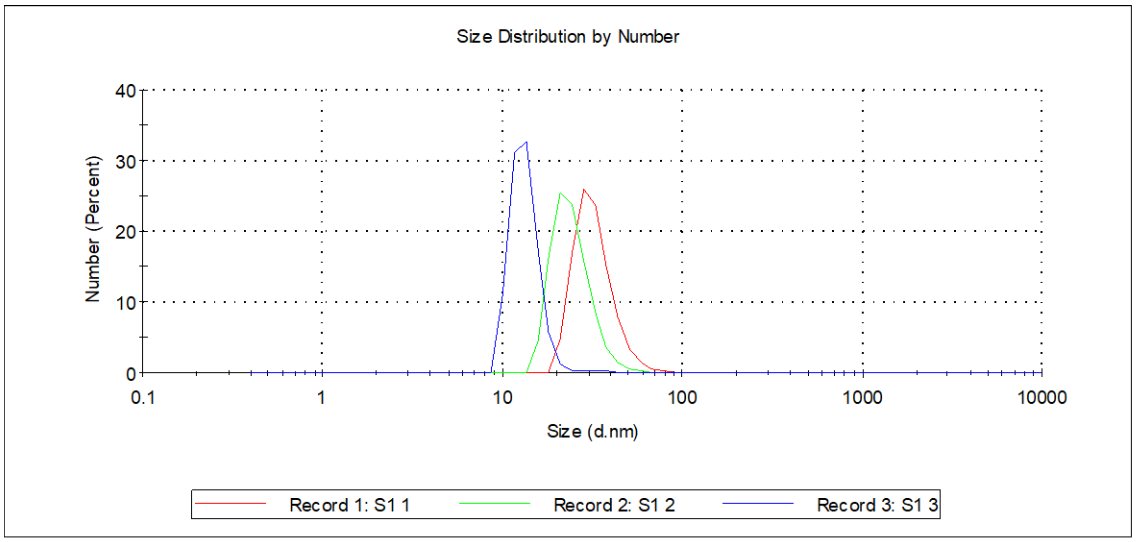


*FIGURE 4.1: Particle Size Distribution of 0.25% Nanoparticles Concentration*

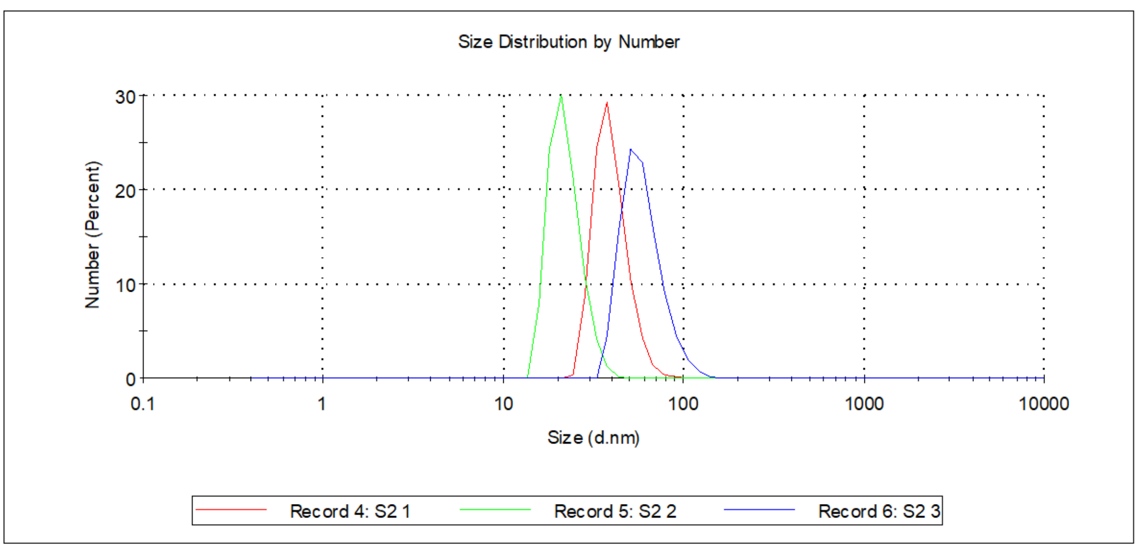


*FIGURE 4.2: Particle Size Distribution of 1.0% Nanoparticles Concentration*

MWCNT and CuO nanoparticles are used in the experiment and dispersed in ethylene glycol. The particle size distribution obtained is shown in Figure 4.1 and figure 4.2. Figure 4.1 shows the size of 0.25% of nanoparticles concentration which is between 8 nm-90 nm. While Figure 4.2 shows the size of 1.0% of nanoparticles concentration between 10 nm-200nm. The size of particles in term of diameter for 0.25% concentration are smaller compare to 1.0% concentration.

The smaller the size of particles, it will stay dispersed within the fluid for a much longer period of time compare to a bigger particles size. In addition, the bigger the size of particles agglomeration, it will take less time for the particles to settle and not stay within the fluid.

### 4.1.2 Thermal Conductivity

*TABLE 4.1: Thermal Conductivity of Different Concentration of Nanoparticles at Different Temperature*

| Temperature (°C) | Basefluid | Nanoparticles Concentration (%) | | | |
|---|---|---|---|---|---|
| | | 0.25 | 0.5 | 0.75 | 1 |
| | Thermal Conductivity (W/m K) | | | | |
| 25 | 0.55 | 0.59 | 0.635 | 0.68 | 0.73 |
| 35 | 0.58 | 0.6175 | 0.65 | 0.705 | 0.745 |
| 45 | 0.6 | 0.635 | 0.675 | 0.725 | 0.765 |
| 55 | 0.62 | 0.65 | 0.695 | 0.745 | 0.78 |

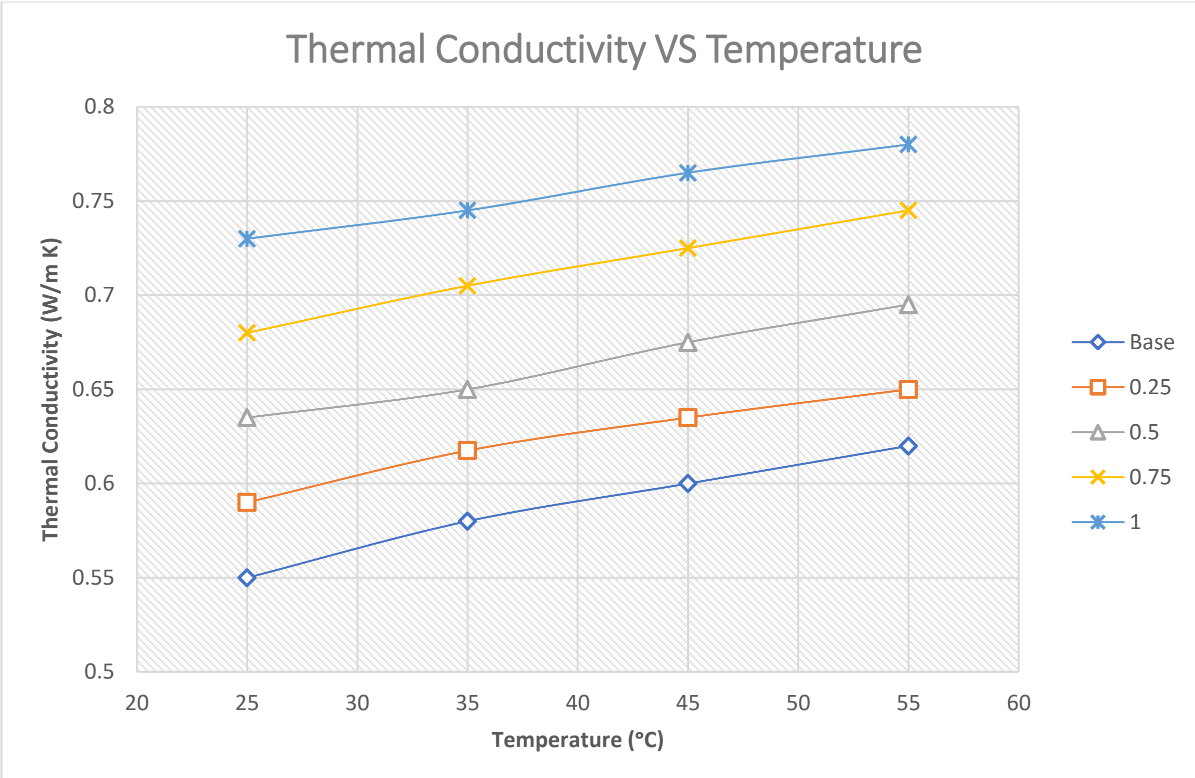


*FIGURE 4.3: Thermal Conductivity VS Temperature of Each Nanoparticles Concentration*

Figure 4.3 shown above are the comparison of thermal conductivity of base fluid and 0.25%, 0.5%, 0.75% and 1.0% of nanoparticles at different temperature. From the figure, the value of thermal conductivity of the base fluid at 25 °C is 0.55 W/m K. As the temperature of the base fluid increase, the value of the thermal conductivity also increases gradually by 5.4% for each 10 °C rise.

Base fluid with 0.25% of nanoparticles gives out 0.59 W/m K of thermal conductivity at 25 °C. At 25 °C, thermal conductivity value is increases by 7.2% compared to base fluid with the addition of 0.25% of nanoparticles. Thermal conductivity of 0.25% concentration nanofluid increases as the temperature increases.

The thermal conductivity of 0.5% of nanoparticles concentration at 25 °C is 0.635 W/m K. The property's value of thermal conductivity is increases by 15.5% compare to base fluid only at 25 °C. It also shows a trend where the value of thermal conductivity increases with the temperature.

By adding 0.75% of nanoparticles concentration the value of thermal conductivity is 0.68 W/m K at 25 °C. The graph of 0.75% of nanoparticles concentration keep on rising as the temperature increase. With the addition of 1.0% of nanoparticles concentration, the value of thermal conductivity is 0.73 W/m K at 25 $^{o}$C. The trend of the graph gradually increases as the temperature of nanofluid increase.

The base fluid is the control experiment. For each concentration of nanoparticles into the base fluid gives a value of thermal conductivity higher than the base fluid. Moreover, the value of thermal conductivity of base fluid and different concentration of nanoparticles will increase when the temperature increase. To conclude the figure 4.3, the value of thermal conductivity will increase when the concentration of nanoparticles in the base fluid and temperature of nanofluid increase.

The thermal conductivity is one of the most important properties in what concerns the use of hybrid nanofluids in heat exchange. In this study a few samples have been prepared MWCNT/ CUO/ ethylene glycol hybrid nanofluids and measured the thermal conductivity in the particle concentrations of 0.25%, 0.5%, 0.75% and 1.0% wt in the temperatures range from 20 °C to 60 °C. Based on the results, each of the different concentrations, have different thermal conductivity value at different temperatures. It is observed that, the thermal conductivity value improved by 7.2% at 0.25% concentration of nanofluid compared to base fluid only. Since MWCNT and Cu originally have high thermal conductivity compare to base fluid which is ethylene glycol. At the same time by increasing the nanoparticles concentration, the thermal conductivity also improved. Thus, it is expected that by mixing the nanoparticles into nanofluid will improved the thermal conductivity of the fluid and even more at higher nanoparticles concentration. This hypothesis is confirmed to be a fact which is shown in the result. This also approved by many researchers such as Mondragon [9], water based nanofluids of $SiO^2$ and $Al^2O^3$ are tested that the thermal conductivity is increases with the solid content due to the higher number of particles present in the suspension and the higher number of contacts between them. The Brownian motion can be noted to be responsible for the change. Raising the temperature triggers collisions in nanofluids between suspended particles and higher base fluid molecules, thereby increasing the thermal conductivity.

# CHAPTER 5: CONCLUSION

## 5.1 Conclusion and Recommendation

In this study, a hybrid multi-walled carbon nanotubes (MWCNT) and copper oxide (CuO) were mixed together with ethylene glycol and prepared using two step method. The samples were stirred and undergoes ultrasonication to evenly spread out the particles. The stability of the nanofluid were tested with particles size distribution analysis which shows at lower concentration the size were smaller and vice versa. The thermal conductivity of the nanofluid were depend on the concentration of nanoparticles and the temperature of nanofluid. When the concentration of nanofluid and temperature increase, the thermal conductivity also increases.

During this study, the actual stability of nanofluid was unable to obtain due current crisis. When the stability is known, other properties such as viscosity can be study deeper. Plus, based on other research, there is a limit where the thermal conductivity properties do not increase anymore when the concentration of the nanoparticles increase. The limit should be study, so the nanofluid can be used at full potential in terms of thermal conductivity.

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# APPENDIX

| Concentration (%) | Base Fluid | Base Fluid Mass | Base Fluid | Base Fluid Mass |
|---|---|---|---|---|
| 0.25 | Water | 47.904 | Ethylene Glycol | 13.3584 |
| 0.5 | Water | 47.904 | Ethylene Glycol | 13.3584 |
| 0.75 | Water | 47.904 | Ethylene Glycol | 13.3584 |
| 1 | Water | 47.904 | Ethylene Glycol | 13.3584 |

| Total Mass | Total Nano Particle Conc. | 20 % MWCNTs (m. grams) | 80 % CuO (m. grams) |
|---|---|---|---|
| 61.2624 | 153.156 | 30.6312 | 122.5248 |
| 61.2624 | 306.312 | 61.2624 | 245.0496 |
| 61.2624 | 459.468 | 91.8936 | 367.5744 |
| 61.2624 | 612.624 | 122.5248 | 490.0992 |

**Particles size**

| X Number | Record 1: S1 1 | Record 2: S1 2 | Record 3: S1 3 |
|---|---|---|---|
| 0.4 | 0 | 0 | 0 |
| 0.463 | 0 | 0 | 0 |
| 0.536 | 0 | 0 | 0 |
| 0.621 | 0 | 0 | 0 |
| 0.719 | 0 | 0 | 0 |
| 0.833 | 0 | 0 | 0 |
| 0.965 | 0 | 0 | 0 |
| 1.12 | 0 | 0 | 0 |
| 1.29 | 0 | 0 | 0 |
| 1.5 | 0 | 0 | 0 |
| 1.74 | 0 | 0 | 0 |
| 2.01 | 0 | 0 | 0 |
| 2.33 | 0 | 0 | 0 |
| 2.7 | 0 | 0 | 0 |
| 3.12 | 0 | 0 | 0 |
| 3.62 | 0 | 0 | 0 |
| 4.19 | 0 | 0 | 0 |
| 4.85 | 0 | 0 | 0 |
| 5.61 | 0 | 0 | 0 |
| 6.5 | 0 | 0 | 0 |
| 7.53 | 0 | 0 | 0 |
| 8.72 | 0 | 0 | 0 |
| 10.1 | 0 | 0 | 11.2 |
| 11.7 | 0 | 0 | 31.3 |
| 13.5 | 0 | 0 | 32.7 |
| 15.7 | 0 | 4.41 | 17.2 |
| 18.2 | 0 | 16.2 | 5.63 |
| 21 | 4.73 | 25.6 | 1.09 |
| 24.4 | 17 | 23.9 | 0.143 |
| 28.2 | 26 | 15.8 | 0.16 |
| 32.7 | 23.6 | 8.31 | 0.212 |
| 37.8 | 15.2 | 3.65 | 0.175 |
| 43.8 | 7.87 | 1.39 | 0.109 |
| 50.7 | 3.44 | 0.462 | 0.0566 |
| 58.8 | 1.33 | 0.14 | 0.0255 |
| 68.1 | 0.469 | 0.0419 | 0.0104 |

| | | | |
|---|---|---|---|
| 78.8 | 0.16 | 0.015 | 0.00392 |
| 91.3 | 0.0571 | 0.0072 | 0.00143 |
| 106 | 0.0235 | 0.00415 | 0.000525 |
| 122 | 0.0114 | 0.00249 | 0.000208 |
| 142 | 0.00644 | 0.00152 | 9.59E-05 |
| 164 | 0.00415 | 0.000987 | 5.42E-05 |
| 190 | 0.00306 | 0.000711 | 3.83E-05 |
| 220 | 0.00249 | 0.00056 | 3.17E-05 |
| 255 | 0.00209 | 0.000455 | 2.82E-05 |
| 295 | 0.00171 | 0.000361 | 2.52E-05 |
| 342 | 0.00133 | 0.000271 | 2.18E-05 |
| 396 | 0.000958 | 0.00019 | 1.80E-05 |
| 459 | 0.000633 | 0.000121 | 1.41E-05 |
| 531 | 0.000376 | 6.95E-05 | 1.05E-05 |
| 615 | 0.000196 | 3.45E-05 | 7.30E-06 |
| 712 | 8.57E-05 | 1.40E-05 | 4.78E-06 |
| 825 | 2.82E-05 | 4.09E-06 | 2.83E-06 |
| 955 | 5.56E-06 | 6.28E-07 | 1.36E-06 |
| 1.11E+03 | 3.12E-07 | 0 | 5.06E-07 |
| 1.28E+03 | 0 | 0 | 1.59E-07 |
| 1.48E+03 | 0 | 0 | 4.08E-08 |
| 1.72E+03 | 0 | 0 | 7.18E-09 |
| 1.99E+03 | 0 | 0 | 4.89E-10 |
| 2.30E+03 | 0 | 9.91E-09 | 5.60E-10 |
| 2.67E+03 | 0 | 5.08E-08 | 2.62E-09 |
| 3.09E+03 | 0 | 1.27E-07 | 6.06E-09 |
| 3.58E+03 | 0 | 2.17E-07 | 9.72E-09 |
| 4.15E+03 | 0 | 2.92E-07 | 1.25E-08 |
| 4.80E+03 | 0 | 3.31E-07 | 1.38E-08 |
| 5.56E+03 | 0 | 2.54E-07 | 1.04E-08 |
| 6.44E+03 | 0 | 8.40E-08 | 3.43E-09 |
| 7.46E+03 | 0 | 0 | 0 |
| 8.63E+03 | 0 | 0 | 0 |

| X Number | Record 4: S2 1 | Record 5: S2 2 | Record 6: S2 3 |
|---|---|---|---|
| 0.4 | 0 | 0 | 0 |
| 0.463 | 0 | 0 | 0 |
| 0.536 | 0 | 0 | 0 |
| 0.621 | 0 | 0 | 0 |

| | | | |
|---|---|---|---|
| 0.719 | 0 | 0 | 0 |
| 0.833 | 0 | 0 | 0 |
| 0.965 | 0 | 0 | 0 |
| 1.12 | 0 | 0 | 0 |
| 1.29 | 0 | 0 | 0 |
| 1.5 | 0 | 0 | 0 |
| 1.74 | 0 | 0 | 0 |
| 2.01 | 0 | 0 | 0 |
| 2.33 | 0 | 0 | 0 |
| 2.7 | 0 | 0 | 0 |
| 3.12 | 0 | 0 | 0 |
| 3.62 | 0 | 0 | 0 |
| 4.19 | 0 | 0 | 0 |
| 4.85 | 0 | 0 | 0 |
| 5.61 | 0 | 0 | 0 |
| 6.5 | 0 | 0 | 0 |
| 7.53 | 0 | 0 | 0 |
| 8.72 | 0 | 0 | 0 |
| 10.1 | 0 | 0 | 0 |
| 11.7 | 0 | 0 | 0 |
| 13.5 | 0 | 0.0811 | 0 |
| 15.7 | 0 | 8.03 | 0 |
| 18.2 | 0 | 24.2 | 0 |
| 21 | 0 | 29.9 | 0 |
| 24.4 | 0.405 | 21.2 | 0 |
| 28.2 | 8.73 | 10.8 | 0 |
| 32.7 | 24.4 | 4.17 | 0 |
| 37.8 | 29.2 | 1.23 | 4.4 |
| 43.8 | 20.5 | 0.254 | 15.7 |
| 50.7 | 10.4 | 0.0297 | 24.2 |
| 58.8 | 4.25 | 0.00889 | 22.9 |
| 68.1 | 1.44 | 0.0162 | 16 |
| 78.8 | 0.423 | 0.0169 | 9.1 |
| 91.3 | 0.117 | 0.0123 | 4.42 |
| 106 | 0.0388 | 0.00725 | 1.89 |
| 122 | 0.0192 | 0.00378 | 0.732 |
| 142 | 0.0126 | 0.00186 | 0.261 |
| 164 | 0.00927 | 0.00093 | 0.0867 |
| 190 | 0.00731 | 0.000495 | 0.0259 |
| 220 | 0.006 | 0.000279 | 0.00649 |
| 255 | 0.00483 | 0.000159 | 0.00406 |

| | | | |
|---|---|---|---|
| 295 | 0.00363 | 9.16E-05 | 0.00967 |
| 342 | 0.00245 | 5.99E-05 | 0.0182 |
| 396 | 0.00143 | 5.25E-05 | 0.0258 |
| 459 | 0.000687 | 5.78E-05 | 0.0299 |
| 531 | 0.000248 | 6.57E-05 | 0.0297 |
| 615 | 5.58E-05 | 6.99E-05 | 0.0261 |
| 712 | 5.04E-06 | 6.79E-05 | 0.0204 |
| 825 | 1.05E-05 | 5.70E-05 | 0.0137 |
| 955 | 4.11E-05 | 3.82E-05 | 0.00716 |
| 1.11E+03 | 7.53E-05 | 2.07E-05 | 0.00279 |
| 1.28E+03 | 9.63E-05 | 1.02E-05 | 0.000858 |
| 1.48E+03 | 0.000105 | 4.67E-06 | 0.000194 |
| 1.72E+03 | 0.000104 | 1.92E-06 | 2.39E-05 |
| 1.99E+03 | 9.58E-05 | 6.06E-07 | 0 |
| 2.30E+03 | 8.22E-05 | 1.04E-07 | 6.41E-06 |
| 2.67E+03 | 6.58E-05 | 5.45E-08 | 3.79E-05 |
| 3.09E+03 | 4.91E-05 | 2.36E-07 | 0.000106 |
| 3.58E+03 | 3.38E-05 | 4.99E-07 | 0.000197 |
| 4.15E+03 | 2.11E-05 | 7.34E-07 | 0.000279 |
| 4.80E+03 | 1.16E-05 | 8.74E-07 | 0.00033 |
| 5.56E+03 | 5.02E-06 | 6.87E-07 | 0.000259 |
| 6.44E+03 | 1.16E-06 | 2.30E-07 | 8.68E-05 |
| 7.46E+03 | 0 | 0 | 0 |
| 8.63E+03 | 0 | 0 | 0 |