Hybrid Nanoparticles with Ethylene Glycol for Car Radiator Application (RDU1403134)

UNIVERSITI MALAYSIA PAHANG

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ABSTRACT

This project is about Aluminium Oxide (Al_2O_3) nanoparticles with Ethylene Glycol for car radiator application. The research is conducted in order to prove that addition of Al_2O_3 nanoparticles with varying concentration provides a better heat transfer efficiency compared to usage of distilled water as radiator coolant. The objective of the research is to improve and create a new radiator coolant based on collaboration of Al_2O_3 nanoparticles with readily available coolants which is Ethylene Glycol and to investigate the erosion of Al_2O_3 nanoparticles coolant on automotive radiator. The scopes of the research are the nanoparticles used in the experiment is Al_2O_3 nanoparticles between ranges of size 40-80 nm. The tested concentration of Al_2O_3 nanofluids are as of 0.01%, 0.03%, 0.05%, 0.07% and 0.09%. The preparation of Al_2O_3 nanofluids are carried out Thermodynamics Laboratory of Universiti Malaysia Pahang. The experiment is carried out by running the radiator test rig with distilled water as radiator coolant. This is done so that the result obtained through experimental analysis of distilled water can be used as bench mark to for the comparison of heat transfer efficiency. The thermal coefficient test indicates that all the Aluminium Oxide (Al_2O_3) nanofluid with varying concentration possess better heat conducting properties compared to Ethylene Glycol. Furthermore, this proves that Aluminium Oxide (Al_2O_3) nanofluids can transfer the absorbed heat from the radiator to the surrounding air much faster compared to Ethylene Glycol. Experimental analysis shows that Al_2O_3 nanofluids have higher specific heat capacity compared to distilled water. Thus, Al_2O_3 nanofluids can absorb and store more heat compared to distilled water. Heat transfer coefficient result supports that application of Al_2O_3 nanofluids as car radiator coolant leads to increase in thermal absorption enhancement. However, as the concentration of Aluminium Oxide (Al_2O_3) nanofluid increase from 0.03% to 0.05% and so on, the heat transfer coefficient decreases rapidly. This is because formation of sediments of Aluminium Oxide (Al_2O_3) nanoparticles causes inactive involvement in heat transfer process but the sediments do no clogs in the flat tubes or trigger erosion on the internal wall of car radiator. It can be concluded that application of Aluminium Oxide (Al_2O_3) nanoparticles integrated with Ethylene Glycol as coolant in car radiator is acceptable and provides better heat transfer efficiency.

ABSTRAK

Tesis ini membentangkan mengenai Aluminium Oxide (Al_2O_3) nanopartikel dengan Ethylene Glycol untuk kegunaan sebagai cecair penyejuk radiator kereta. Objektif kajian adalah untuk menambahbaik dan menghasilkan cecair penyejuk radiator baru berdasarkan kerjasama Al_2O_3 nanopartikel dengan bahan penyejuk sedia ada iaitu Ethylene Glycol dan untuk menyiasat hakisan Al_2O_3 nanopartikel penyejuk pada radiator automotif. Skop kajian ini adalah nanopartikel yang digunakan dalam eksperimen ini adalah Al_2O_3 nanopartikel antara julat saiz 40-80 nm. Kepekatan cecair nano Aluminium Oksida (Al_2O_3) yang diuji adalah 0.01%, 0.03%, 0.05%, 0.07% dan 0.09%. Penyediaan cecair nano Aluminium Oksida (Al_2O_3) dijalankan Makmal Termodinamik Universiti Malaysia Pahang. Eksperimen ujian pelantar radiator dijalankan dengan menggunakan air suling sebagai cecair penyejuk radiator. Ini dilakukan supaya keputusan yang diperolehi melalui analisis eksperimen air suling boleh digunakan sebagai penanda aras untuk perbandingan kecekapan pemindahan haba. Ujian pekali haba menunjukkan bahawa semua cecair nano Aluminium Oksida (Al_2O_3) dengan variasi kepekatan mempunyai penyerapan haba yang lebih baik berbanding Ethylene Glycol. Tambahan pula, ini membuktikan bahawa cecair nano Aluminium Oksida (Al_2O_3) boleh memindahkan haba yang diserap daripada radiator ke udara sekitar lebih cepat berbanding Ethylene Glycol. Analisis eksperimen menunjukkan bahawa cecair nano Aluminium Oksida (Al_2O_3) mempunyai kapasiti penyimpanan haba yang lebih tinggi berbanding dengan air suling. Oleh itu, cecair nano Aluminium Oksida (Al_2O_3) boleh menyerap dan menyimpan lebih banyak haba berbanding dengan air suling. Namun, peningkatan dalam kepekatan cecair nano Aluminium Oksida (Al_2O_3) 0.03% kepada 0.05% dan sebagainya, pekali pemindahan haba berkurangan dengan cepat. Pembentukan sedimen Aluminium Oksida (Al_2O_3) nanopartikel menyebabkan proses pemindahan haba yang kurang efektif . Namun begitu, sedimen Aluminium Oksida (Al_2O_3) tidak menyebabkan sekatan dalam tiub atau mencetuskan proses hakisan di dinding dalaman radiator kereta. Konlusinya, penggunaan Aluminium Oksida (Al_2O_3) nanopartikel disepadukan dengan Ethylene Glycol sebagai cecair penyejuk radiator kereta boleh digunapakai dan sah menyebabkan haba kecekapan pemindahan yang lebih baik.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The purpose of this chapter is to explain about the project background, problem statement, project objectives, project scopes, and flow chart of the project to show the flow and overall process for this project.

1.2 PROJECT BACKGROUND

According to latest observation in the market, there are various types of radiator coolants which differ in heat absorption capacity, specification, function and thermal properties. Radiator coolant is defined as a heat transfer fluid which get rid of heat from automotive engine when coolant passed through it. The hot coolant will transmit the collected heat to air outside. Cooling system of an automotive engine handles the additional heat formed throughout the operation of the engine. It controls engine surface temperature for engine optimum efficiency (Leong, Saidur, Kazi, & Mamun, 2010)

Radiator is considered made up of three main portion which are inlet tank, core, and outlet tank. Two sets of channel which are tubes and fins are occupied in the core. The coolant will flow down the tubes while air drifts among fins to absorb the heat. The hot coolant which absorbed the heat will direct it from the tubes to fins. The air passing outside among fins pickups will carry the heat away (Amrutkar & Patil, 2013)

As mentioned above, there are various type of radiator coolants in the market but there are only few radiator coolants which actually provide efficient forced convection heat transfer between radiator and engine entirely.

The radiator coolants readily offered in the market for automotive engine lack in heat absorption properties. An automotive engine has to function efficiently through altitudes, weather and extreme road conditions. Therefore, an appropriate forced convection process between an automotive engine and radiator should be performed so that an automotive engine is not burdened by overheating.

The purpose of the project is to improve and create a new radiator coolant of combination of Ethylene Glycol and Aluminium Oxide (Al_2O_3) nanoparticles that would actually solve the problem of overheating which is faced by an automotive engine.

1.3 PROBLEM STATEMENT

Continuous improvement in automotive industries seeks for the demand of high competence engines. A high competence engine must have a better fuel economy which matches its high performance. The performance of a vehicle is optimized as the size and capacity of an engine is increased. However, the size of the radiator increases together with the capacity of the engine. Fin addition has been one of the approach to elevate the cooling speed of the radiator. This method result to better enhancement of air convective heat transfer as it offers larger heat transfer area.

Unfortunately, method of using micro channels and fins to extend the cooling rate of a radiator ended up being a traditional technology which already reached to its maximum limit. Moreover, Ethylene Glycol and water which referred as heat transfer fluids that currently used in car radiator exhibit very low thermal conductivity. This problem leads to research for latest and pioneering heat transfer fluids that will eventually improve the heat transfer rate in an automotive car radiator (Leong et all., 2010)

1.4 OBJECTIVE

a) To improve and create a new radiator coolant based on collaboration of Aluminium Oxide (Al_2O_3) nanoparticles with readily available coolants which is Ethylene Glycol.

b) To test for erosion of Aluminium Oxide (Al_2O_3) nanoparticles coolant on automotive radiator.

1.5 SCOPE

a) The nanoparticles used in the study are Aluminium Oxide (Al_2O_3) nanoparticles.

b) The concentration of the tested Aluminium Oxide (Al_2O_3) nanoparticles are as of 0.01vol%, 0.03vol%, 0.05vol% 0.07vol%. and 0.09%.

c) The size of the nanoparticles is between the ranges of 40-80 nm.

1.6 PROJECT PLANNING

The whole planning for the project is shown in both Gantt chart for Semester I and Semester II as attached in Appendix A1 and A2. (Refer to Appendix A1 and A2)

1.7 PROJECT HYPOPROJECT

It is expected that as the concentration of the Aluminium Oxide (Al_2O_3) nanofluid increases, the rate of heat transfer between radiator and cooling fluid to increase gradually. Besides that, Aluminium Oxide (Al_2O_3) nanofluid expected not to initiate the process of erosion on the wall of the radiator.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is responsible to a detailed description of literature review done on types of radiator coolant, types of radiator, nanoparticles, nanofluids innovation and thermo physical properties such as thermal conductivity, viscosity, concentration, particle size, friction and wear.

2.2 BACKGROUND OF PROJECT

Various studies on radiator coolant were done by many researchers in past studies. Chapter 2 provides the summarized reviews of previous published literatures which sets foundation and base for further research related to this project. This enables to deliver a clear view about the project and provides useful guidance for the whole report structure.

2.3 RADIATOR COOLANT

Coolant can be defined as a fluid that prevents overheating of a device by flowing through it to gather excessive unwanted heat produced by the device. The collected heat will be transferred to another device that will exploit or disperse it. A coolant with high thermal capacity, low-cost, low viscosity and is chemically inert whereby it does not cause or promotes corrosion of the cooling system is considered as an ideal coolant.

A coolant is normally chemically combined with a high boiling point liquid to form a compounded fluid. This compounded fluid function as an antifreeze agent against extremely cold conditions and as well as solves the problem of overheating during hot weather. A coolant with relatively high boiling temperature can cool faster as the engine gets hotter. During an operation of an internal combustion engine, about a third of heat energy produced are considered as unwanted heat that ends up in the cooling system. An engine is prevented from getting damaged when the radiator coolant elevates the boiling point of the water which permits it to transmit more heat away from the engine (Efeovbojhan, Enontiemonria, Ohiozua, & Nathaniel, 2013)

2.3.1 WATER

Water is a very functional fluid to be used as radiator coolant. It is cheap, possesses good heat-transferring qualities and readily available. It possess high specific heat capacity which enables it to be an effective thermal transitions medium between engine materials and radiators. This allows water to avoid any thermal overloads resulting from excessive component temperature. Water is categorized as an ideal coolant because of its ability to absorb and release heat efficiently. Apart from that, water is a liquid with low viscosity where it can flow easily. Thus, this characteristics permits water to be used commonly as radiator coolant.

However, water has a very low boiling point of 373 K. Since the temperature in a radiator can exceed 373K, this can cause water to vaporize. Loss of coolant can create gas pockets or voids in the water jackets that can cause localized hot spots and implosion. Since water freezes at 273K, this reduces its efficiency in circulating as a coolant in radiator (Jack & Ojapah, 2013). Thus, water cannot be used as radiator coolant in countries with winter season as it will eventually freeze up and lead to difficulty of starting up the car or causing serious engine damage.

2.3.2 ETHYLENE GLYCOL

An organic compound (IUPAC name: ethane-1, 2-diol), Ethylene Glycol is widely used as an automotive antifreeze. It is colourless and odourless in its pure form but Ethylene Glycol is extremely dangerous and any ingestion can result in death. This is mainly due to its high toxic properties. Ethylene Glycol marketed as antifreeze and it can be used during summertime as well as during cold weather because of its higher boiling points (Yadav & Singh, 2011). The main drawback of these coolants is that they are very toxic and can be dangerous to humans, animals and the environment.

Figure 2.1: Ethylene Glycol

Source: Yadav and Singh, (2011)

2.3.3 PROPYLENE GLYCOL

Propylene Glycol is considerably less toxic antifreeze compared to Ethylene Glycol. Propylene Glycol is utilized as antifreeze where the Ethylene Glycol usage would be inappropriate. Any exposure to heat and air causes Propylene Glycol to oxidize. This phenomenon leads to formation of lactic acid. Propylene Glycol is very corrosive, thus it need to be properly inhibited. In order, to prevent low pH attack on the system metals, Protodin is added to act as a buffer. Protodin helps to avert acid attack that causes corrosion by creating a protective skin inside the tank and pipelines.

Propylene Glycol supports the formation of biological fouling that leads to increment of corrosion rate in a radiator system. Corrosion of the radiator system starts after the formation of bacterial slime. Thus, radiator system which applies Propylene Glycol should be maintained on a continuous basis. Regular monitoring should be done on inhibitor level, pH and colour.

Nevertheless, routine checkup should be done on biological contamination. Colour changes of Propylene Glycol into red in colour can be used as an indication that it should be replaced (Yadav & Singh, 2011). Propylene Glycol are much safer to use around children and animals, and easier to dispose of than the more toxic ethylene products.

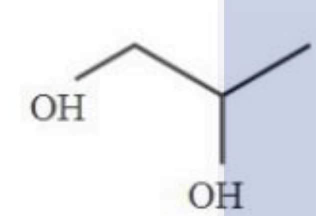

Figure 2.2: Propylene Glycol

Source: Yadav and Singh, (2011)

2.4 RADIATOR

A radiator is a heat exchanger which absorb heat from a hot coolant that passes through it and directs the collected heat to the air that blown in by the fan. It is made of many tubes which are mounted in parallel arrangement where the coolant will flow from the inlet to the outlet. Heat is extracted from the tubes by the fins on the radiator surface and transfer it to the air that flows in through the radiator. The amount of heat extraction depends highly on the difference between temperature of the fluid that runs through the radiator and tubes (Yadav & Singh, 2011)

Radiator is made up of three main portions such as inlet tank, core, and outlet tank. Core mainly consist of two sets of passage which are set of tubes and sets of fins. Tubes will be the flow passage for the coolant while air will flow between the fins.

Heat is transmitted to the fins by the tube that obtained it from the hot coolant. Air that flows between the fins will eventually pickup and carries the heat away. (Amrutkar & Patil, 2013)

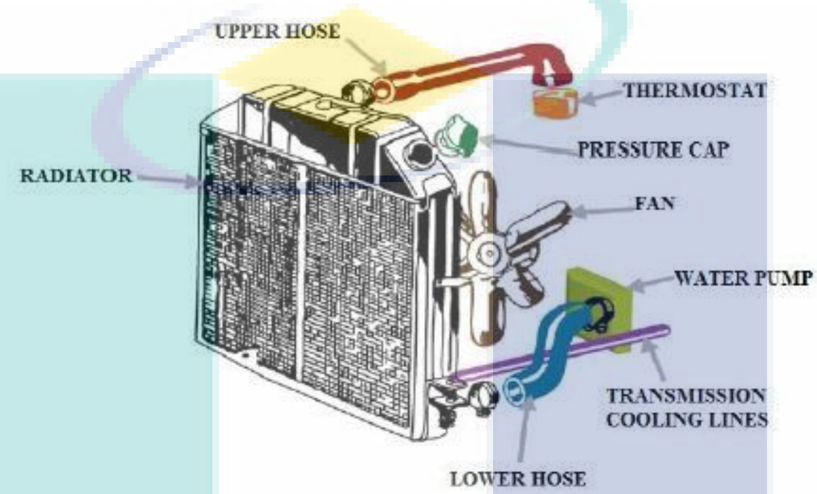

Figure 2.3: Parts of cooling system

Source: Yadav and Singh, (2011)

2.4.1 DOWN FLOW RADIATOR

A conventional vertical flow design which is still applicable in modern vehicles. Down flow radiator is well known among the heavy equipment manufacturers. The expansion inlet tank of a down flow radiator is situated at the top of the core. It is attached to the coolant outlet housing which secured on an engine with the aid of a flexible hose.

The coolant drifts from the inlet tank, travelling down through the core to the bottom (outlet) tank which is also linked by a flexible hose to the water pump inlet port. This enables the coolant to circulate among the radiator when the thermostat is open.

Cooling process of an automatic-transmission- equipped car is done by circulating the automatic transmission fluid which is situated at the outlet tank that encompasses the transmission oil cooler unit or heat exchanger. All radiators use a pressure cap to prevent damage to the cooling system as the coolant heats up. The advantage of a down flow radiator is the tanks are positioned at the top and bottom of the core. The fluid flows from the top tank travelling downward through the tube due to gravity reduces the work load of the water pump. The disadvantage with down flow radiators, is the cap has to be placed on the top tank putting it on the high pressure side and causing the pressure cap to vent sooner.

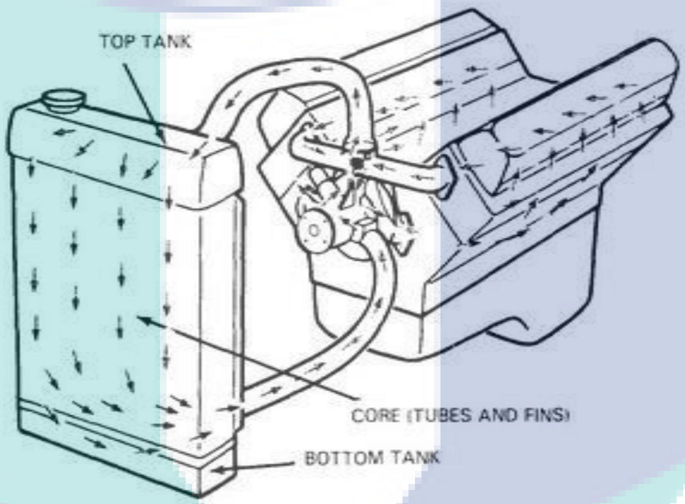

Figure 2.4: Down-flow Radiator

Source: autocorner.ca, (n.d.)

2.4.2 CROSS FLOW RADIATOR

The most abundant design among modern vehicles. It is an alteration of conventional down-flow radiator to sideways. Instead placing the header tanks at the top and bottom of a radiator, it is positioned on each side of a radiator instead. The coolant flows horizontally. The radiator cap is fixed together with header tank which is situated at the outlet tank. This is correspondent to the lower tank of the down flow design, and comprises transmission fluid oil cooler on automated-transmission- equipped models.

Advantage of a cross flow radiator is it aids in reducing pressure against the radiator cap. Cross flow radiator permit the radiator cap to be placed on the low-pressure suction side of the system. This avoids the coolant from forcing past the radiator cap at high rpm by the pressure formed from the high-flow water pump. This helps to prevent the radiator cap from exploding in case there is a blockage or the radiator overheats.

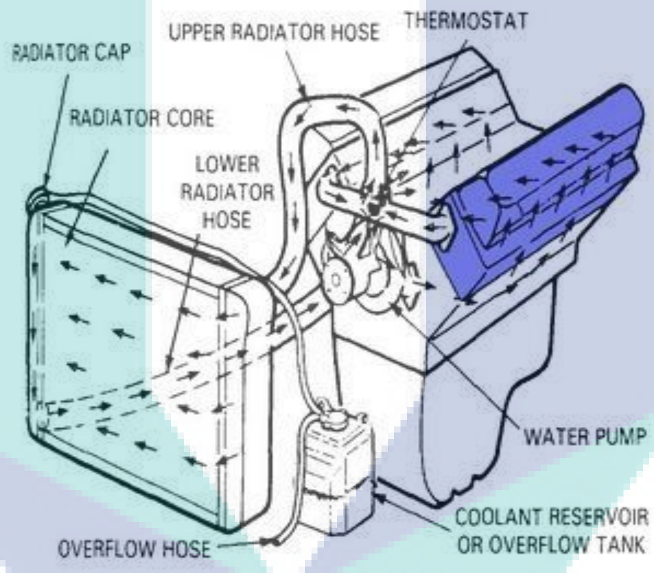

Figure 2.5: Cross Flow Radiator

Source: autocorner.ca, (n.d.)

2.4.3 MULTIPLE PASS RADIATOR

A design which is created for limited space in engine compartment or for additional cooling system. There are radiators that passes the coolant through the core twice or more time. The most common design is dual pass and triple pass radiators. Multiple pass radiator have an internally divided region where the coolant will enter and exit from another tank.

The coolant drifts along the inlet side of the primary tank as it flows to the end of the tank after flowing about half of the tubes. The coolant flows back to the outlet side of the primary tank via the other tank. U-flow type of design is achieved in the primary tank when the coolant passes through both inlet and outlet tank to the end tank.

The advantages of multiple flow radiators are it saves place in a limited engine compartment. Since the same amount of coolant travels multiple times over the surface area, these orientations give the coolants more time to cool. Another benefit is that it provides cooler temperature which ranges around 10 to 20 degrees compared to a single pass radiator would do through the similar core size.

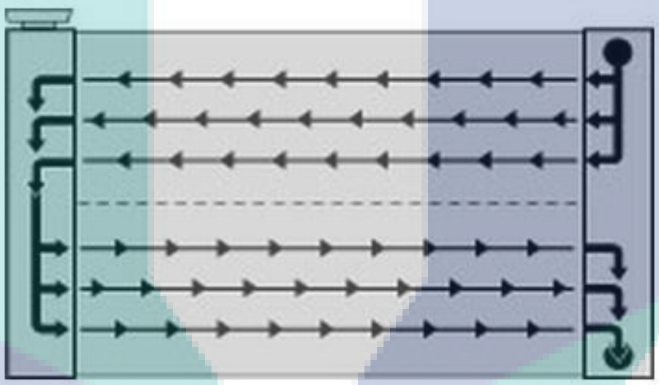

Figure 2.6: Multiple Pass Radiator

Source: static.speedwaymotors.com, (2004)

2.5 NANOPARTICLES

Nanoparticle research is presently a field of focused scientific research as it possess extensive potential application in biomechanics, sports optical, electronic, and automotive fields. Nanoparticles are great scientific innovation as it acts as a link between atomic or molecular structures and bulk materials. Nanoparticles classified as particles that have dimension between 1-100 nanometers.

The properties of variety of conventional materials are altered after fused together nanoparticles. This is mainly due to great surface area per weight which possess by nanoparticles compared to larger particles. This makes nanoparticles to be more reactive than certain molecules.

Paul Ehrlich was the first person to start up the historical development of nanoparticles. Later, several extensive research were done by groups under Professor Peter Speiser and Ursula Scheffel along with her colleagues during in the late 1960s and early 1970 at the ETH Zurich. Attention towards nanoparticles research grows larger to the years between 1970 and the early 1980s. Some of the innovation done with the application of nanoparticles are for the transfer of drugs along blood-brain barrier (BBB) and blood circulation is lengthened with the aid from PEGylated nanoparticles (Kreuter J. , 2007)

2.5.1 ALUMINA (Al_2O_3)

Aluminium Oxide or Alumina are ceramics which is used broadly compared to any other group of ceramics as it is most cost effective. Alumina are readily available and possess high grade of technical performance. Due to its excellent chemical and physical properties, Aluminium Oxide are used in variety of application.

Alumina nanoparticles are light, nontoxic and non-sparking. Alumina are selected in most of the machining or casting process because it be formed easily. The physical appearance of Alumina is in silvery manner and it is a better electricity conductor compared to Copper. Furthermore, Alumina is a brilliant corrosion resistance material that possesses high tensile strength and thermal conductivity.

Aluminium Oxide nanoparticles are widely used in aerospace, manufacture of automobiles chassis, electronics, marine, telecommunication cables, batteries, superconductors, containers and packaging, electrical transmission wire, paint pigment, metallurgy and construction

Table 2.1: Physical Properties of Alumina (Al_2O_3)

Environmental Properties	Resistance Factor 1= Poor, 5=Excellent
Wear	5
Oxidation at 500°C	5
UV	5
Sea Water	5
Organic Solvent	5

Source: azom.com, (2000)

Table 2.2: Chemical Properties of Alumina (Al_2O_3)

Properties	Minimum Value (S.I)	Maximum Value (S.I)	Units (S.I)
Specific Heat	451	955	J/Kg.K
Thermal Conductivity	12	38.5	W/m.K
Thermal Expansion	4.5	10.9	10^{-6} /K

Source: azom.com, (2000)

2.6 NANOFLUIDS INNOVATION

Automotive industries are competing strongly among each other to provide an automobile with the best design that have the highest safety and aesthetics value along with efficient performance and low fuel consumption. Cooling system of an automobile which consists of radiators, evaporators, AC condensers and charge air cooler contributes to the design of an automobile's front-end module along with the overall weight of the car. Frontal area and overall weight of an automobile are contributing factors that have impact on an automobile aerodynamic behaviour.

Thus, in order to increase the aerodynamics properties of an automobile, it is a necessary decision that more research and focus should be shifted towards attaining an automobile with the perfect design that compromises between weight, size, shape and performance. This is because improving the aerodynamic design of an automobile leads to better fuel economy as air resistance causes the acting of drag force on an automobile which result to additional energy is need to overcome it.

For an example, a truck have a large frontal area due to its extended size of radiator whereby the function of radiator is very important as it aid to regulate the engine temperature of the truck from overheating.. The radiator is fixed in front of the engine to maximize the cooling effect of oncoming air. However, due to the large frontal area of the truck, about 65% of energy produced through internal combustion were used to overcome aerodynamic drag (Bhatt, Patel, & Vashi, 2014)

Current cooling agents such as engine oil, Ethylene Glycol and water do not have high specific heat capacity and this result to poor heat transfer performance. Therefore, an ideal coolant with efficient heat transfer properties is necessary to promote effective heat transfer process. The most noticeable effort which have been made is the innovation adding additives to cooling liquids.

The latest advancement in nanotechnology lead to innovation of novel fluid which can be termed as nanofluids. Nanofluids are liquids which possess particles size that is significantly smaller than 100nm. This makes nanofluid to illustrate a higher thermal conductivity compared to the base liquid which are homogenously combined with them. Compared to orthodoxly used heat transfer fluids such as water and Ethylene Glycol, nanofluids have better thermal properties. Their thermal properties efficiency exceed heat transfer fluids enclosing particles on the micrometer scale (Peyghambarzadeh, Hashemabadi, Hoseini, & Jamnani, 2011)

Nanofluids are the new innovation which were established by several researchers that nanofluid can boost heat transfer performance.

Table 2.3: Summary of studies regarding nanofluid by various author

Nanoparticles	Base Fluid	Vol. Fraction of Particles	Thermal Conductivity Enhancement	Heat Transfer Enhancement
Al_2O_3	Water	1%	3%	45%
Al_2O_3	Water	-	15%	40%
Al_2O_3	Water	4.30%	30%	-
Al_2O_3	Engine Coolant	3.5%	10.41%	-
CuO Al_2O_3	Ethylene Glycol and Water	-	-	Improvement in convective heat transfer coefficient

Source: Bhatt, Patel, & Vashi, (2014)

2.7 PREVIOUS STUDIES ON RADIATOR COOLANT WITH NANOFLUIDS

Previous studies regarding application of nanofluids with radiator coolant which are water and Ethylene Glycol in radiator will be referred as benchmark in the research. This is to strengthen the obtained result during experiment.

The focused study will be fully about the manipulative variables in project such as thermal conductivity, nanoparticles volume concentration, nanoparticles size, viscosity and friction and wear caused by nanofluids in an automotive radiator.

With the development of nanostructured materials in the recent years, attempts were made to apply nanoparticles together with base fluids as radiator coolant to improve their cooling properties. When some nanoparticles were added into the radiator coolant, the coolant properties can be effectively improved. Many research studies have been conducted to test thermophysical characteristics of nanofluid and the findings were recorded with respect to the engine performance.

2.7.1 PREVIOUS STUDIES ON THERMAL CONDUCTIVITY

Thermal conductivity is defined as ability of a material to conduct heat. It is illustrated as the rate of heat transfer through a unit thickness of the material per unit area per unit temperature difference (Cengal et all., 2013).

Major improvement in cooling capabilities of conventional heat transfer fluids have come to halt although numbers of research and development effort were done to improve the heat transfer efficiency. This is mainly due to the low thermal conductivity properties of those fluids. It is a known fact that metal in solid state have larger thermal conductivities than fluids at room temperature.

The thermal conductivity of metals which are in liquid form is considerable better than that of nonmetallic liquids. Thus, thermal conductivities of fluids that comprise suspended solid metallic particles are expected to be considerably enhanced when compared with conventional heat transfer fluids (Choi & Eastman, 1995)

Table 2.4: Thermal Conductivity (W/m-K) of Various Material at 300k

Material	Thermal Conductivity
Metallic Solids Aluminium	237
Nonmetallic Liquids Water	0.613
Engine Oil	0.145

Source: Cengal et all., (2013)

Thermal conductivity of nanofluids differs with the particle size, shape of the particle, and type of nanoparticles. For an instance, non-metallic (oxide) nanoparticles were found out to have lower thermal conductivity compared to a nanofluid with metallic nanoparticles. Nanofluid with smaller particles size possess greater thermal conductivity and the thermal conductivity increases as the size of nanoparticle gets smaller. Furthermore, the shape of the particle also affects the thermal conductivity of the respective nanofluid. Nanofluid containing cylindrical shaped nanoparticles exhibit greater thermal conductivity compared to nanofluid having nanoparticles with spherical shape. (Murshed, Leong, & Yang, 2008).

2.7.2 INFLUENCE OF NANOPARTICLE VOLUME CONCENTRATION ON THERMAL CONDUCTIVITY

Volume concentration of a nanoparticle is set between the range of 0 to 1 vol.% and at variety of temperature starting from 10°C to 50°C in order to verify the influence of volume concentration on viscosity, specific heat, density and thermal conductivity of nanofluid. The result verified that viscosity, density and thermal conductivity of a nanofluid increases proportionally with the increment in volume concentrations (Elias, et al., 2014)

Particle volume fraction of basefluid and particles greatly influences the thermal conductivity of the nanofluid. Apart from that, thermal conductivity of particles and basefluid also plays an important role in determining the thermal conductivity of nanofluid (Yoo, Hong, Hong, Eastman, & Yang, 2007).

A studies was carried on Zinc Dioxide-Ethylene Glycol (ZnOeEG) based nanofluids to investigate its thermal properties .The result obtained shows approximately 26.5% improvement of thermal conductivity was made by addition of 5% volume fraction of Zinc Dioxide nanoparticles in ethylene glycol (Nguyen, Roy, Gauthier, & Galanis, 2007).

Investigated experiment on Alumina water (Al_2O_3/water) nanofluids regarding its convective heat transfer in laminar flow as it flows through a circular tube with stagnant wall temperature under dissimilar concentrations of nanoparticles shows attained augmentation of heat transfer coefficient of nanofluid as the concentration of nanoparticles rises (Zeinali et all., 2007).

Nanofluids of 3.7% volume concentration containing 170-nm Silicon Carbide particles is used as subject of study. Obtained outcome proves that conducted heat transfer experiments leads to conclusion that at stable Reynolds number, heat transfers coefficients of nanofluid are bigger by 50-60% when compared to basefluid. (Yu et al., 2009).

Copper Oxide/water based nanoparticles are experimentally tested under laminar flow regime in an automobile radiator. The overall heat transfer leads to finding that total heat transfer coefficient of basefluid were less than nanofluid at a concentration of 0 to 4 Vol% (Naraki, Peyhambarzadeh, Hashemabadi, & Vermahmoudi, 2013)

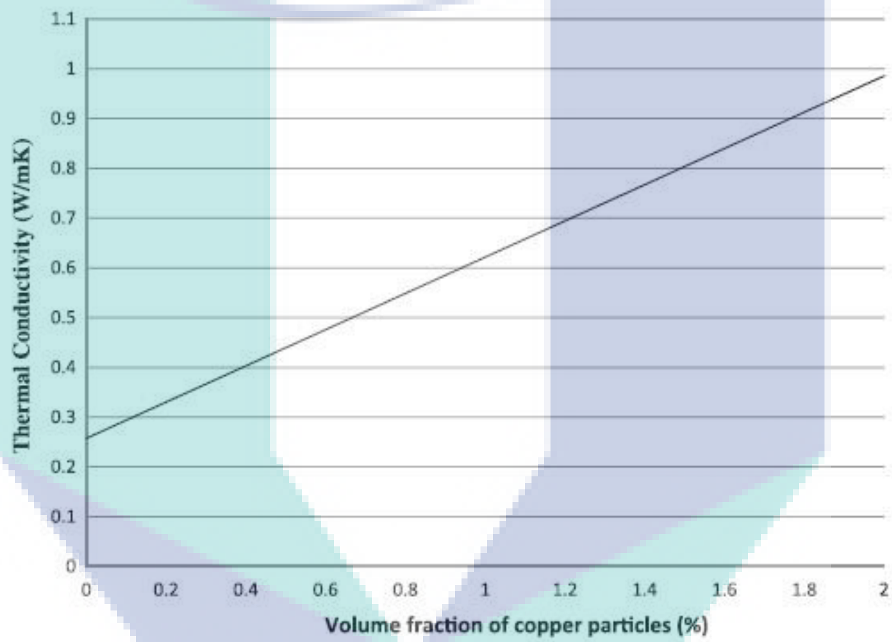

Figure 2.7: Thermal Conductivity of Ethylene Glycol based Copper Nanofluids

Source: K.Y. Leong, (2010)

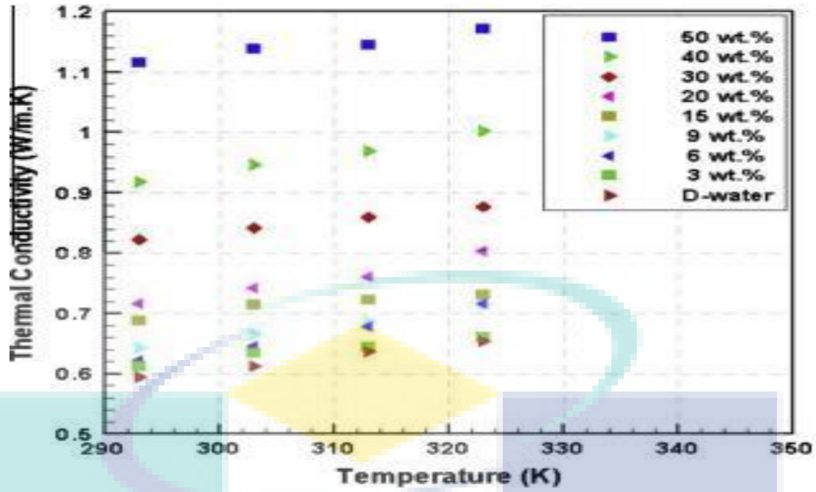

Figure 2.8: Thermal Conductivity of Al_2O_3-Water Nanofluids at Different Concentration

Source: M.Ghanbarpour, (2013)

2.7.3 INFLUENCE OF PARTICLE SIZE ON THERMAL CONDUCTIVITY

Several research were done to verify the influence of particles size in improving the thermal conductivity of nanofluid. Although previous studies provides proof that addition of small particles in fluid causes wearing of instruments and blockage but promising studies done by few researches provide ample result that combination of nanoparticles with a basefluid can increase the thermal conductivity of a fluid. It also able to reduce the problem arising from wearing and deposition of the heat exchangers. This is mainly due to the size of added nanoparticles are extremely small. Apart from that, the increment of thermal conductivity due to usage of nanoparticles of larger size that leads to reduction in volume fraction is much more higher compared to increment in thermal conductivity due to effect of temperature on nanofluids.

Brownian motion is a motion that occurs within a bulk liquid due to random motion of nanoparticles. As the particles and molecules collides endlessly within the bulk liquid, this result in thermal conductivity. The Brownian diffusion coefficient, D_B can be used to display the Brownian motion and can be illustrated using the Einstein-Stokes equation

$$D_B = K_B T/[3\pi(d_p/10^9)] \qquad (2.1)$$

Einstein- Strokes equation relates that Brownian diffusion coefficient is proportional to temperature however it is reciprocal to the particles diameter. This shows that addition of particles with small size of diameter at higher temperature can cause more vigorous collisions which yields better thermal conductivity. Thus, based on this obtained result, it can be concluded that increasing the temperature and by reducing the particles size can amplify the possibilities of vigorous collision among molecules within a bulk fluid. It can be verified that the thermal conductivity decreases under the condition of large sized particles and low temperature compared to thermal conductivity value under elevated temperature and small particle size.

(Minsta, Roy, Nguyen, & Doucet, 2009) investigated factors that affects the thermal conductivity of water based nanofluid of alumina and copper oxide. The variables factors are influence of temperature, volume of fraction and size of particles. It was found that thermal characteristics of the nanofluid can be boosted by increasing the temperature, size of particles and volume of fraction. Authors verified that larger size of particles leads to decrease in effectiveness of thermal conductivity of a nanofluid at the equal volume of fraction. Area of contact and vigorous collision during Brownian motion can be elevated by applying particles of smaller size under the equal volume of fraction which as a result leads to better thermal conductivity of nanofluids.

The thermal conductivity increases rapidly for particles less than 50nm approximately and decreases rather slowly thereafter. The viscosity increases with a decrease of particle size due to larger surface area. Observation illustrate that heat transfer coefficients to rise together with nanofluid concentration and influenced by particle size and operating temperatures.

Hence particle size influences the properties and hence heat transfer coefficients. (Sharma, Sarma, Azmi, & Mamat, 2012).

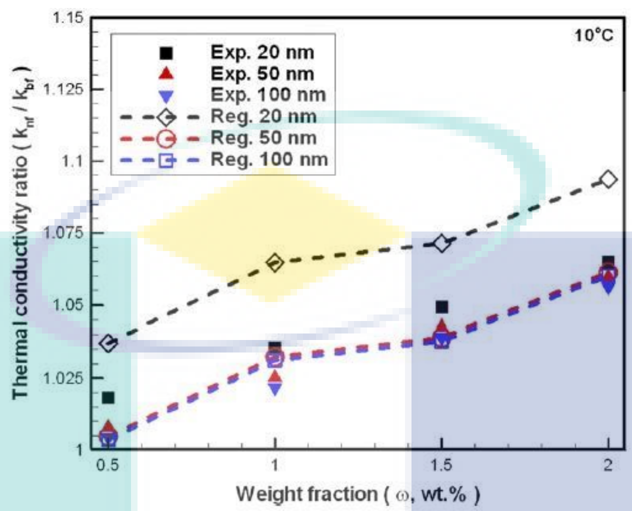

Figure 2.9: Dependence Relationship between Weight Fraction and Thermal Conductivity Ratio of Al_2O_3/Water Nanofluid with Different Particle Sizes at 10 °C.

Source: Tun-Ping Teng, (2010)

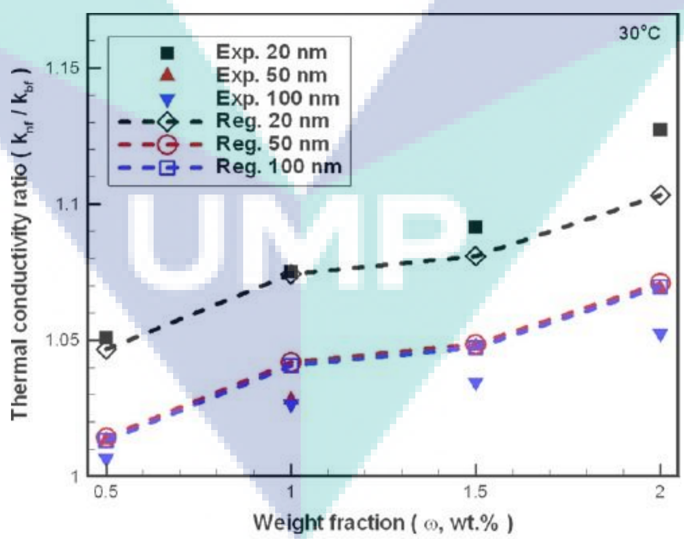

Figure 2.10: Dependence Relationship between Weight Fraction and Thermal Conductivity Ratio of Al_2O_3/Water Nanofluid with Different Particle Sizes at 30 °C.

Source: Tun-Ping Teng, (2010)

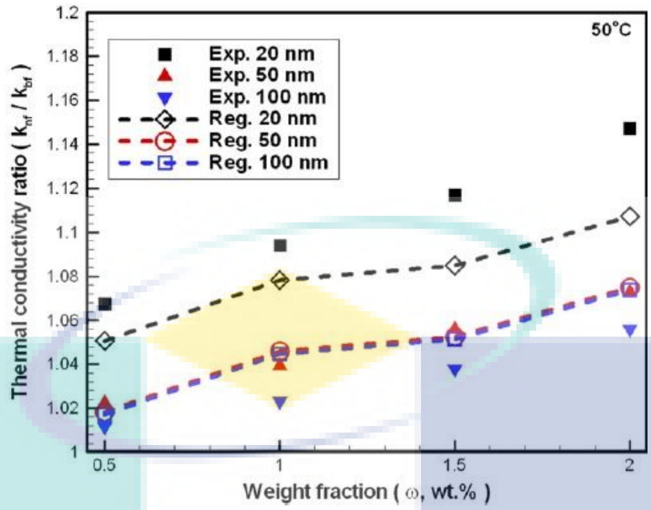

Figure 2.11: Dependence Relationship between Weight Fraction and Thermal Conductivity Ratio of Al_2O_3/Water Nanofluid with Different Particle Sizes at 50 °C.

Source: Tun-Ping Teng, (2010)

The results shown in Figure 2.9-2.11 reveal the relationship between the regression result and experimented data of thermal conductivity ratio of Aluminium Oxide/ water based nanofluid that varies according to different size of particles under different weight fraction and temperature. The temperature range is set at 10, 30 and 50 °C whereby the size of nanoparticles are varied among 20, 50, and 100 nm respectively

The result leads to understanding that decreasing the size of particles and elevating the temperature boost up the thermal conductivity of a nanofluid. As the temperature of the specimen was 10°C, the possibilities of increasing the thermal conductivity ratios were by 1.8-6.5%, 0.8-6.0% and 0.4-5.6%. Moreover, when the temperature of the three is elevated up to 30°C, enhancement in thermal conductivity ratios were by 5.1-12-8%, 1.4-6.9% and 0.7-5.3%.

When the temperature of the three samples were increased to 50°C, the enhancement in thermal conductivity ratios by 6.7-14.7%, 2.3-7.3% and 1.2-5.6% proves that size of nanoparticles indeed influence the increment in thermal conductivity ratio. As increasing the temperature leads to movement of particle to elevate rapidly resulting in high value of kinetic energy. Therefore, movement velocity of a particles of larger size can be slower compared to the movement of smaller particles. This incident may decrease the chance of collision among molecules.

Thus, it can be concluded that temperature plays a very minor role in increasing the fluid thermal conductivity when combined with particles of larger size. Furthermore, particles of smaller in size result to higher area of solid-liquid interface when it is exercised under equal conditions of concentration. Hence, size of particles plays an important role in thermal conductivity of a nanofluid.

2.7.4 EFFECT OF DENSITY ON THERMAL CONDUCTIVITY

Fluid density is another important thermophysical property. Like viscosity, fluid density has straight effect on the pumping power and drop of pressure. Density is strongly dependent on the nanoparticle material used, whereas other factors for instance nanoparticles size, shape, zeta potential and additives do not affect the density of nanofluids. Solids have a greater density compared to liquids. Therefore, the density of nanofluids is found to be amplified with the rise in concentration of nanoparticles in the fluid (Elias, et al., 2014).

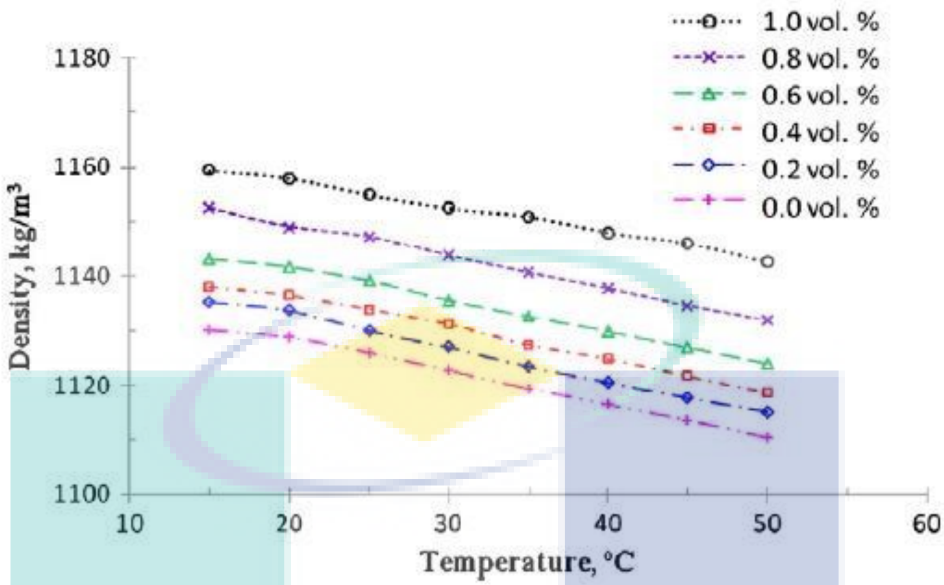

Figure 2.12: Density of Al_2O_3- Radiator Coolant Nanofluid as a Function of Temperature

Source: Elias, (2014)

The densities of Al_2O_3–Radiator Coolant nanofluid and pure radiator coolant with different temperatures for the concentrations of volume of 0 to 1.0 vol.% are portrayed in Fig. 2.12. The figure shows that the density of Al_2O_3–Radiator Coolant nanofluid and pure radiator coolant reduces with the rise of temperature, which is related to increase in the fluid volume by increasing the temperature.

For example, the density of the base fluid decreases by 1.8%, when the temperature increases from 15 °C to 50 °C. However, density rises with the elevation of volume concentration and in all cases, nanofluid gave higher density than the base fluid. The higher density of the dispersed nanoparticles in the fluid evidently causes this.

2.8 CONVECTION

Convection is defined as transfer of energy that happens between an adjacent fluids such as gas or liquid which is in motion and a solid surface which comprise effects of fluid motion and conduction. Greater heat transfer through convection is achieved by fast motion of fluids.

Pure conduction of heat transfer between an adjacent fluid and a solid surface is accomplished during the absence of bulk fluid motion. Although the presence of bulk motion stimulates the elevation of heat transfer among fluids and a solid surface but the determination of the heat transfer rate becomes complicated.

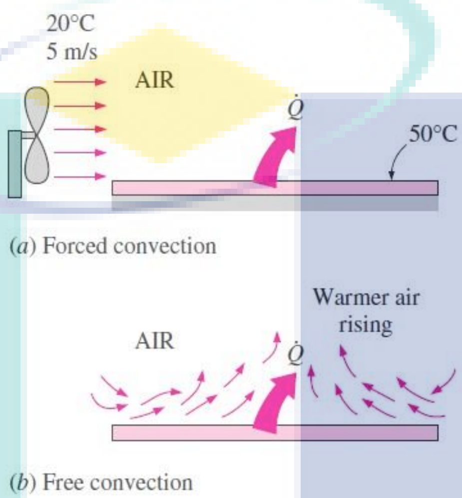

Figure 2.13: Heat transfer to the surrounding fluid by convection

Source**:** Cengal et all., (2013)

Rate of heat transfer through convection are conveniently expressed by Newton's law of cooling as in Equation 2.2

$$Q_{Convection} = hA_S(T_S - T_\infty) \qquad (2.2)$$

Where, *h* represent the convection heat transfer coefficient in $/m^2.K$, surface area is noted as A, surface temperature is represented using the symbol T_S whereas T_∞ is the ambient temperature. Heat transfer coefficient, *h* is a parameter which is experimentally determined and does not represent the property of the fluid. Its values varies based on conditions such as nature of fluid motion, surface geometry and bulk fluid velocity and properties of the fluid. Table 2.6 shows the values of *h* based on types of convection.

Table 2.5: Typical value of Convection Heat Transfer Coefficient

Type of Convection	h,W/m².°C
Free Convection of Liquids	10-1000
Forced Convection of Liquids	50-20000

Source: Cengal et all., (2013)

2.8.1 FORCED CONVECTION

Forced convection is a condition that occurs when flow of a fluid is forced over a surface by the application of external force such as fan, pump or blower. Forced convection can be divided into two main situations which are external force convection and internal force convection. External force convection happens in a situation where fluid flows over a surface such as wire, plate and pipe whereas in an internal forced convection, occurs in duct or pipe or can be described as fully confined place.

2.9 ADVANTAGES AND DISADVANTAGES OF NANOFLUIDS

Nanofluids possess a superior heat transfer characteristics which enables it to be merged together with readily available lubricants or cooling fluids to improve the heat absorption capacity. This application plays an important role in automotive field as current researchers are focusing on elevating the performance of an automobile engine that releases minimum heat from the engine. However, nanofluids does demonstrate some disadvantages that can question its application in automobile engines.

2.9.1 ADVANTAGES

Most experimented nanofluids have high thermal conductivity properties and enhanced heat transfer capacity. Nanofluids possess better qualities in replacing water and readily available coolants and lubricants as automobile coolant fluid. Application of nanofluids in cooling system leads to reduction of the size of the radiator, improves the ergonomics design and aerodynamics properties of an automobile. Furthermore, reducing the size of the radiator leads to decrease in total weight of an automobile and leads to lower cost of thermal apparatus.

Apart from that, nanofluids show promising result in removing the heat from the engine of an automobile more efficiently compared to readily available coolants. The benefits of enhanced cooling system leads to full utilization of engine capacity without overheating the engine that can cause the engine to be blown. This also helps in improving fuel economy as conversion of energy are fully optimized by the engine.

2.9.2 DISADVANTAGES

Improper choices of nanoparticles, inaccurate nanofluid preparation method and incompatible application of nanofluid in a system can lead agglomeration in the system. Agglomeration can cause erosion and clogging in the tank or pipe. The process of erosion and clogging can become more severe as the concentration of the nanofluid is increased. Failure to consider the erosion on the surface of the internal walls of radiator may result to short lifespan of the system which adopt the application of nanofluid.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will further clarify the systematic research development of Aluminium Oxide (Al_2O_3) nanoparticles with Ethylene Glycol for car radiator application. A theoretical analysis on the method of preparation of Al_2O_3 is enlighten thoroughly. Methodology encompasses the concept used to evaluate all the calculation concept and measurement. It will provide an appropriate standard operating procedures and description in conducting the research.

3.2 PROJECT FLOWCHART

Project flowchart will enlighten on the experiment setup and nanofluids thermophysical studies. This flowchart will be used as a guidance to run the radiator test rig research with Aluminium Oxide (Al_2O_3) nanofluid concentration of 0.01%, 0.03%, 0.05%, 0.07% and 0.09%.

The process starts with sample preparation of Aluminium Oxide (Al_2O_3) nanofluid. The preparation of Aluminium Oxide (Al_2O_3) nanofluid with different concentration are determined based on two step process of nanofluid preparation method. Next, the radiator test rig is set up for the collecting the data of the research.

The test rig is tested for any leakage and all the apparatus such the data logger and pump flow speed are calibrated in order to make sure that the retrieved data from the experiment are reliable and accurate.

In addition, the experiment is conducted with Aluminium Oxide (Al_2O_3) nanofluid of different concentration. USB 5203 temperature data logger is used to collect the data throughout the experiment. The retrieved data will be further analysed and discussed for further documentation and research presentation process.

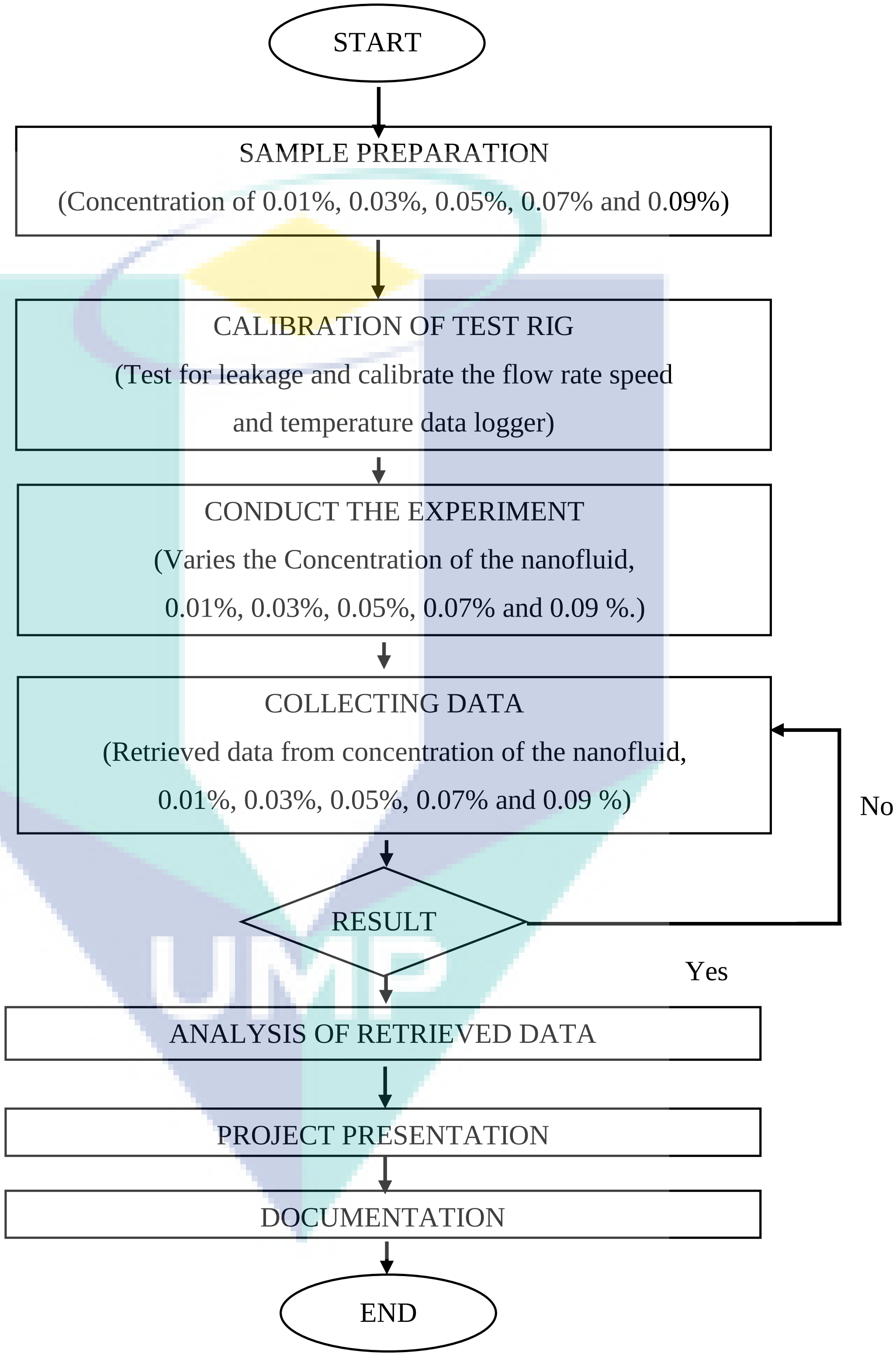

Figure 3.1: Project Flowchart

3.3 PREPARATION OF ALUMINIUM OXIDE (AL_2O_3) NANOFLUID

The preparation of Aluminium Oxide (Al_2O_3) nanofluid is carried out at nanoparticle laboratory of Faculty of Mechanical Engineering University Malaysia Pahang. There are few criteria that need to be finalized before the preparation of the nanofluid which are concentration volume, required volume of nanofluid and mass of Aluminium Oxide nanoparticles. The concentration volume is taken based on the objective of this research which are as of 0.01vol%, 0.03vol%, 0.05vol%, 0.07vol% and 0.09%.

During normal operation of a radiator in an automotive engine, the radiator cooling fluid is prepared with mixture of water and Ethylene Glycol with certain percentage which comprises the total volume of the radiator. For an instance, assuming the volume of the radiator is 1 litre, and the mixing ratio is set to be 50:50. Thus, the mixture of the cooling fluid in the radiator will be 500ml of water (50%) and 500ml of Ethylene Glycol (50%).

As proposed in this research, the volume of the radiator used is 2 litre and the agreed mixing ratio is 60:40 whereby 60% of total volume of radiator will be water while the rest will be Ethylene Glycol. Therefore, the required volume of nanofluid is 1.6L prepared for each volume concentration. The mass of nanoparticles is determined based on Equation 3.1 and 3.2 as shown below

$$\Phi = \frac{V_P}{V_P + V_{BF}} \tag{3.1}$$

$$\Phi = \frac{\frac{m_p}{\rho_P}}{\frac{m_P}{\rho_P} + \frac{m_f}{\rho_f}} \tag{3.2}$$

3.3.1 Mass Calculation of Aluminium Oxide Nanopowder

Based on NanoAmor- Europe.com;

Density = 3.5- 3.9 g/cm^3

Proposed density = 3.7 g/cm^3 or 3700 Kg/m^3

Propose volume for test rig = 800ml or 0.0008 m^3

Volume concentration = 0.01%

$$\frac{0.01}{100} = \frac{V_p}{V_{p+0.0008m^3}}$$

$$0.0001 = \frac{V_p}{V_{p+0.0008m^3}}$$

$$0.0001V_p + 8\times10^{-8} = V_p$$

$$V_P = 8\times10^{-8}\ m^3$$

Based on proposed density = 3700 Kg/m^3

$$\rho = \frac{m}{V}$$

$$3700 = \frac{m}{8\times10^{-8}\ m^3}$$

Mass of nanopowder = $2.960 \times 10^{-4} Kg$ or 0.296g

3.3.2 Procedure of making Aluminium Oxide Nanofluid

3.3.2.1 Weight the nanoparticles using weighing scale

1 Switch on the weighing scale.
2 Make sure the scale bubble which is situated at left side of the scale is inside the red circle. This is to ensure that the scale is level with the table flatness.
3 Set the scale to zero.
4 Put the beaker which where the nanoparticles will be placed into the scale. Reset the scale to zero to measure the nanoparticles weight only.
5 Close the lid after putting the calculated mass of nanopowder using a spatula into the beaker. This is to avoid error due to environment.
6 Wait until the reading becomes constant and record the value.
7 Always carry out the whole process by wearing the Personal Protective Equipment such as N95 mask and chemical resistant glove.

3.3.2.2 Dispersion of Aluminium Oxide (Al_2O_3) Nanofluid into base fluid

1 A one litre beaker is used to mix the Aluminium Oxide (Al_2O_3) nanopowder into base fluid which is distilled water and Ethylene Glycol.
2 Since the ratio of mixture of the distilled water and nanofluid is 60:40. Thus, the required volume of the distilled water is measured 60% of the total volume which is 2 Litre that adds up to 1.2 Litre. The correct volume of the distilled water is measured using a measuring cylinder.
3 The distilled water and Ethylene Glycol is poured into the finalized mass of nanopowder. A spatula is used to mix the nanopowder and distilled water.
4 Next, the beaker is placed on top of a magnetic stirrer. A magnet is dropped into the beaker which will play its role in mixing the mixture.
5 The speed of the magnetic stirrer is set at appropriate speed so that the nanofluid will not splash out of the beaker. The stirring process is carried out for 2 hours to ensure the nanopowder is fully diffused into the distilled water and Ethylene Glycol.

Figure 3.2: N95 Mask

Figure 3.3: Chemical Resistance Glove

Figure 3.4: Example of reading recorded using a weighing scale

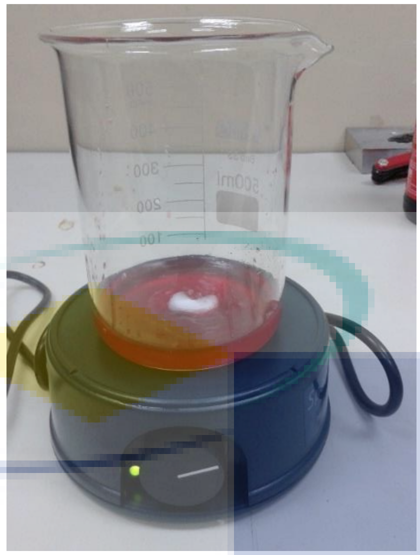

Figure 3.5: Mixing Process of Nanopowder with Ethylene Glycol and Distilled Water Using a Magnetic Stirrer

3.4 EXPERIMENT SETUP

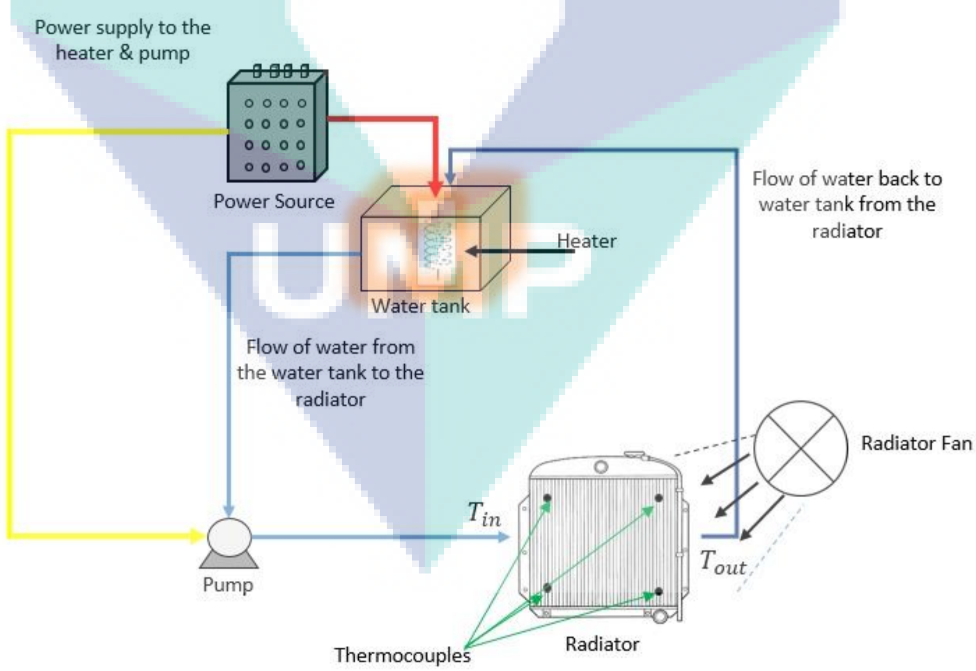

Figure 3.6: Schematic Drawing of the Radiator Test Rig

Figure 3.6 shows the schematic diagram of the radiator test rig design. The 24V DC power supply is the main source of power for the pump and heater. The radiator test rig is a closed loop system whereby the water from the tank is redirected back to the tank to complete the cycle by using a 24V DC water pump.

K- Type thermocouples are fixed at four points on the radiator wall to obtain the surface temperature of the radiator. A 12V powered laptop cooling fan is used as radiator fan. The cooling fan functions as normal radiator fan which are attached together onto the radiator. The design resembles as readily available automobile radiator. A 500W heater is used to imitate the heat produced in an automobile engine system during its routine application. A 5 litre metal tank is used as water tank to store the 2 litre of fluids which are essential coolant fluids made up of nanofluid and distilled water.

3.5 RADIATOR TEST RIG

The radiator test rig is one of the important fabrication of the research. The radiator test rig is the final system where the prepared nanofluid will be tested to record reliable temperature difference reading using six K-type thermocouples. Thus, the design of the radiator test rig plays a vital role in the succession of the research.

The preliminary design of the radiator test rig have few problems when tested using water. The pipes connections were not sealed properly as there were a lot of leakage of water when the experiment was conducted. The pipes connection corrodes due to exposed to air that causes the change in water colour and contaminate it. The pumps unable to pump the water from the radiator back to the tank as the leakage causes loss of water pressure. This leads to incomplete of the closed loop cycle. The placement of the power source at the front of the foundation board caused short circuit due to water spills on it during the experiment was conducted.

The radiator test rig foundation which is a 1cm thick PVC board where all the experiment apparatus attached are overweight causing the test rig to lose its stability. The usage of plastic tank turn out to be inappropriate as the usage of 500W heater might melt the plastic tank. Hence, a total improvement was made on the design so that the test rig can function properly.

Figure 3.7: Preliminary design of the radiator test rig

Improvement were made in the design of the pipes to reduce leakage and contamination of water. 15mm PVC pipes and PVC pipe connectors were used to replace steel pipe connector to discard the corrosion. The pump was able to function properly as there were no loss in water pressure. The stability was increase by using wooden foundation with better design to sustain the whole weight of the experiment apparatus.

The plastic tank was replaced with metal tank to eliminate the chances of tank melt down due to heat produced by the 500W heater. The wiring of the power source for the pump and heater were shifted to the back portion of the test rig wooden foundation. This is to ensure that no short circuit occurs if there is any water splash during the test rig was tested.

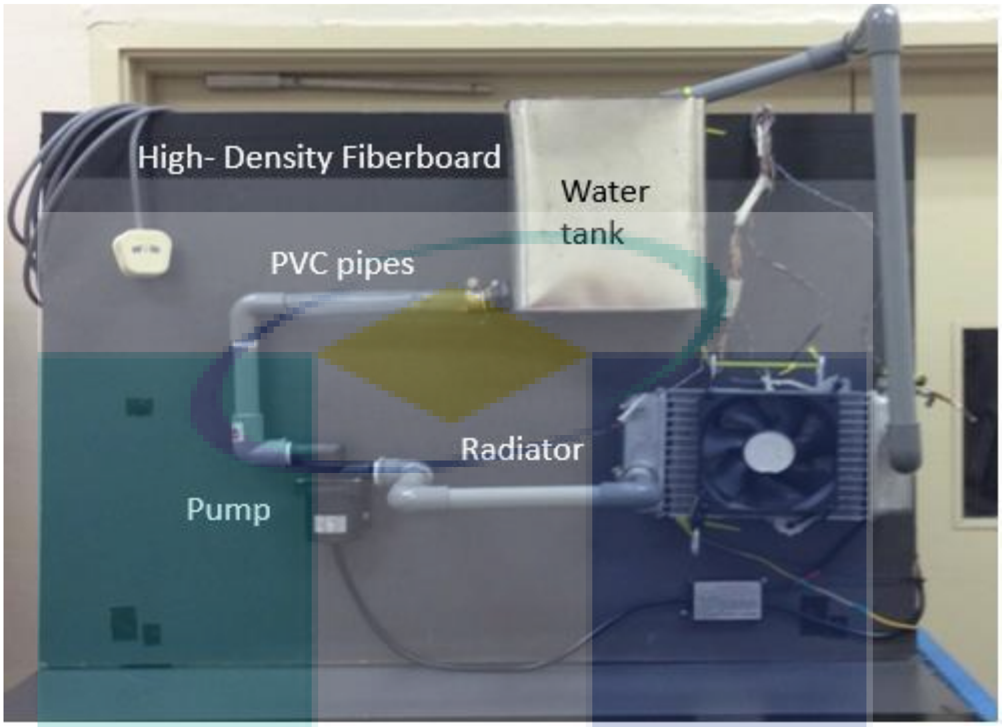

Figure 3.8: Finalized design of the radiator test rig

3.6 EXPERIMENT APPARATUS

The following list of apparatus are crucial components which plays a major role in the radiator test rig.

3.6.1 24V PUMP

The model of the pump is DC 50C-2465A. It functions as 24 Volt DC Pump which can provide maximum head of 6.5 M and maximum flow of 2450L/H. The power required by the pump is 86.9W. The brown wire indicates the positive joint whereas blue wire indicated the negative joint.

Figure 3.9: DC Pump

3.6.2 500W HEATER

The water heater is used to imitate the temperature produced in the engine by heating up the coolant fluids which enters the radiator in a close loop system. It functions normally around 220-240V which produces a maximum power of 500W. The length of the heating tube is 29 cm. It does not have a vessel to detect water boiled temperature. Thus, the water heater need to be fully immersed in the liquid in order to prevent overheating which can cause the plastic cover to melt.

Figure 3.10: 500W Heater

3.6.3 USB 5203 TEMPERATURE LOGGER

Temperature measuring device which is compatible with K-type thermocouples. Temperature Logger aids in converting analogue input into digital data. It requires a standalone power source of 2.5W USB as power supply adapter. Temperature Logger able to integrate with DAQ softwares to process the binary analogue data into signal graph

Figure 3.11: USB 5203 Temperature Logger

3.6.4 24V POWER SUPPLY

Used to supply power to 24V DC water pump and 12V cooling fan. The power supply best fixed at back portion of the test rig in order to prevent short circuit in case there is water spills during conducting the experiment. Wire colours are based on standard international codes, (Red= Life, Black= Neutral, Green= Ground)

Figure 3.12: 24V Power Supply

3.6.5 THERMOCOUPLES

K-Type thermocouples are used in the research to collect the data during the close loop system is complete and radiator test rig is functioning. K-Type thermocouples has temperature range of -200°C to 1250 °C. It is environmentally inert and provide better resistance to oxidation. However, K-Type thermocouples a vulnerable to sulphur attack. The positive point is Chrome which is in red colour while negative point is Aluminium which will be in black colour

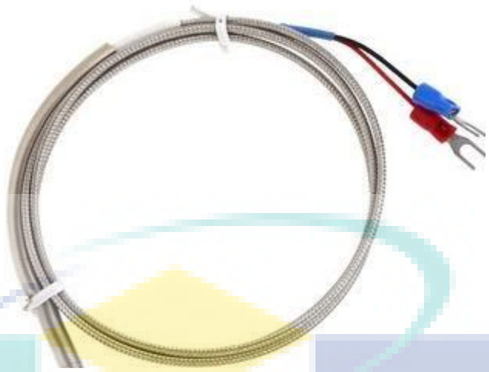

Figure 3.13: K-Type Thermocouple

3.6.6 RADIATOR

Radiator is fixed with the laptop cooling fan which acts as radiator fan. The total volume capacity of the radiator is one Litre. It is a Yamaha 135 LC motorbike radiator. The cooling fan is a 12V laptop fan.

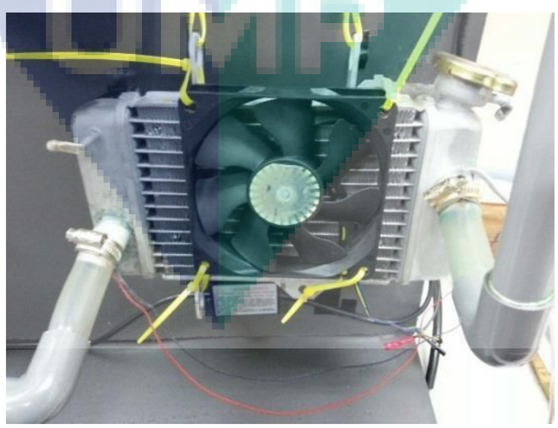

Figure 3.14: Radiator

3.6.7 INSTACAL

Software which is used for installing, calibrating, testing and configuring the USB 5203 Temperature Logger. K-Type thermocouple can be used to conduct analogue and digital test in order to determine analogue inputs and digital bits function properly

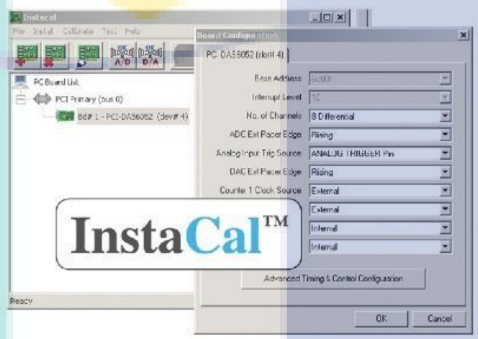

Figure 3.15: InstaCal

3.6.8 TRACERDAQ

Virtual instrument software with strip chart, oscilloscope and rate generator. Convert the binary analogue data into signal graph. Detect any open- circuit or short-circuit at the thermocouple sensor.

Figure 3.16: TracerDAQ

3.7 EXPERIMENT CONDUCTING PROCEDURE

The radiator test rig is set up and all the pipe lines are checked for any leakage so that there would not be any water pressure lost that can affect the close loop system. Next, six KType thermocouples are fixed at the radiator. 2 K-Type thermocouples each are fixed at inlet and outlet point at the radiator.

These thermocouples will record the inlet and outlet temperature at the radiator when the test rig experiment is conducted. Moreover, four K-Type thermocouples are fixed onto the wall of the radiator to obtain the wall temperature. During analysing the data in the next chapter, average of these four wall temperatures are used for calculation purpose. The radiator schematic diagrams can be used as guidance for the fixture of the thermocouples to the radiator.

In addition, all the six thermocouples are fixed to the USB 5203 Temperature Logger to calibrate and test the accuracy of the six thermocouples reading at room temperature in order to prevent any distortion of temperature reading. InstaCal software is used calibrate and configure the type of thermocouples used for the experiment in the USB 5203 Temperature Logger. Figure 3.17 shows the calibration and testing process of the USB 5203 Temperature Logger and the result obtained during the testing of the six K-Type thermocouples points.

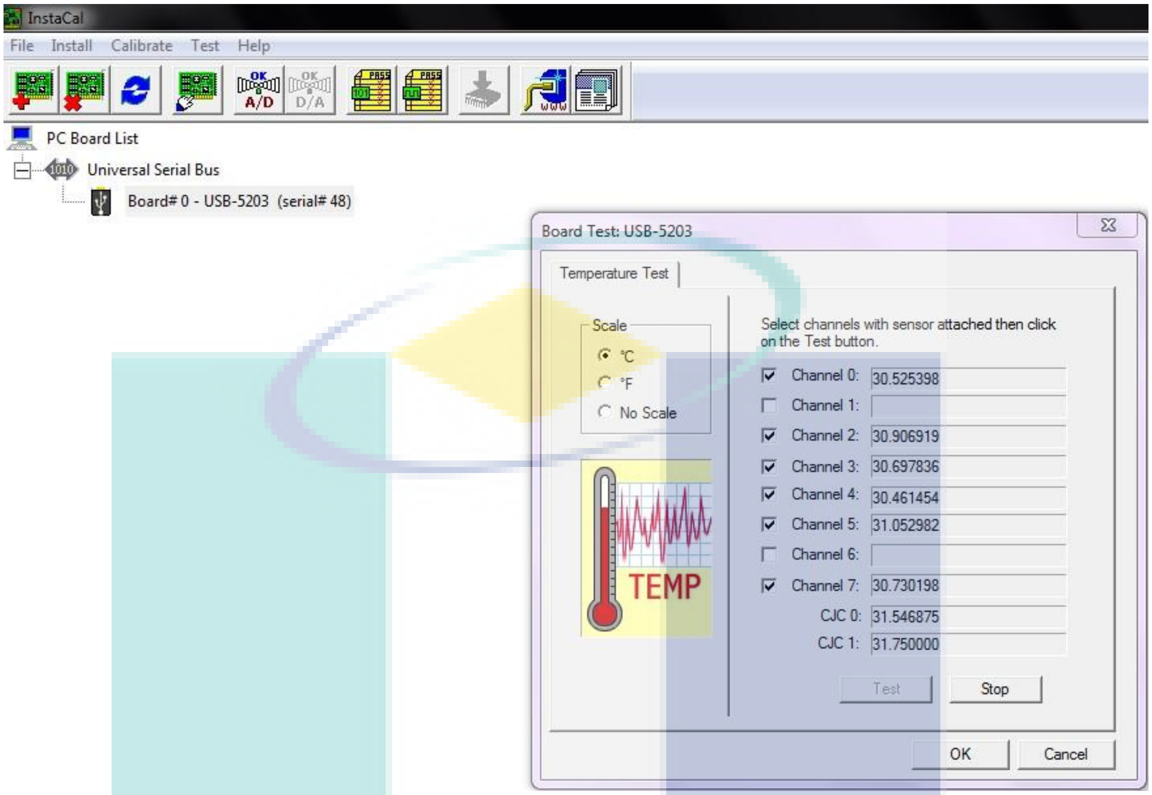

Figure 3.17: Calibration and testing of K-Type Thermocouples

Firstly, the InstaCal is synchronize with the USB 5203 Temperature Logger by choosing the Board #0 – USB-5203 (series #48) as shown in Figure 3.9. Later, the connection channels are selected based on the connection of thermocouple to the USB 5203 Temperature Logger. The connection of six K-Type thermocouples are shown in Table 3.1 below.

Table 3.1: Connection channel to USB 5203 Temperature Logger

Channel	Description
Channel 0	Inlet point temperature
Channel 2	First point temperature
Channel 3	Second point temperature
Channel 4	Outlet point temperature
Channel 5	Fourth point temperature
Channel 7	Third point temperature

As all the thermocouple reading are room temperature reading, therefore the reading obtained by the thermocouples are precise and accurate. Next, required concentration of nanofluid and distilled water is poured into the water tank to conduct the experiment. 500W heater is placed into the water tank and switched on to heat the nanofluid and distilled water solution for eight minutes. During this heating process, flow rate of the fluids are kept constant by maintaining the water pump speed at 6×10^{-6} $m^3.s$

After heating for eight minutes, heater is switched off and USB 5203 Temperature Logger is pressed once to start the retrieving the analogue inputs of temperature from the six K-Type thermocouples. The USB 5203 Temperature Logger is pressed again after recording the analogue data for 20 minutes. This process is repeated for three times for one type of concentration in order to obtain the analogue temperature reading with precise and accurate result. The retrieved analogue temperature data are converted into digital temperature signal using the Tracer DAQ software.

The analogue temperature files are imported from the USB 5203 Temperature Logger to convert the data into digital form. Strip Chart application are selected to tabulate the analogue input in graph format. Figure 3.18 and 3.19 shows the configuration and overview of the Tracer DAQ software.

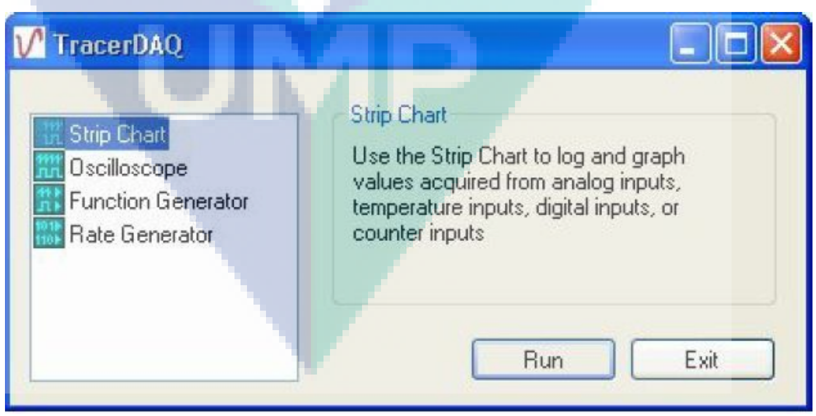

Figure 3.18: Tracer DAQ Configuration

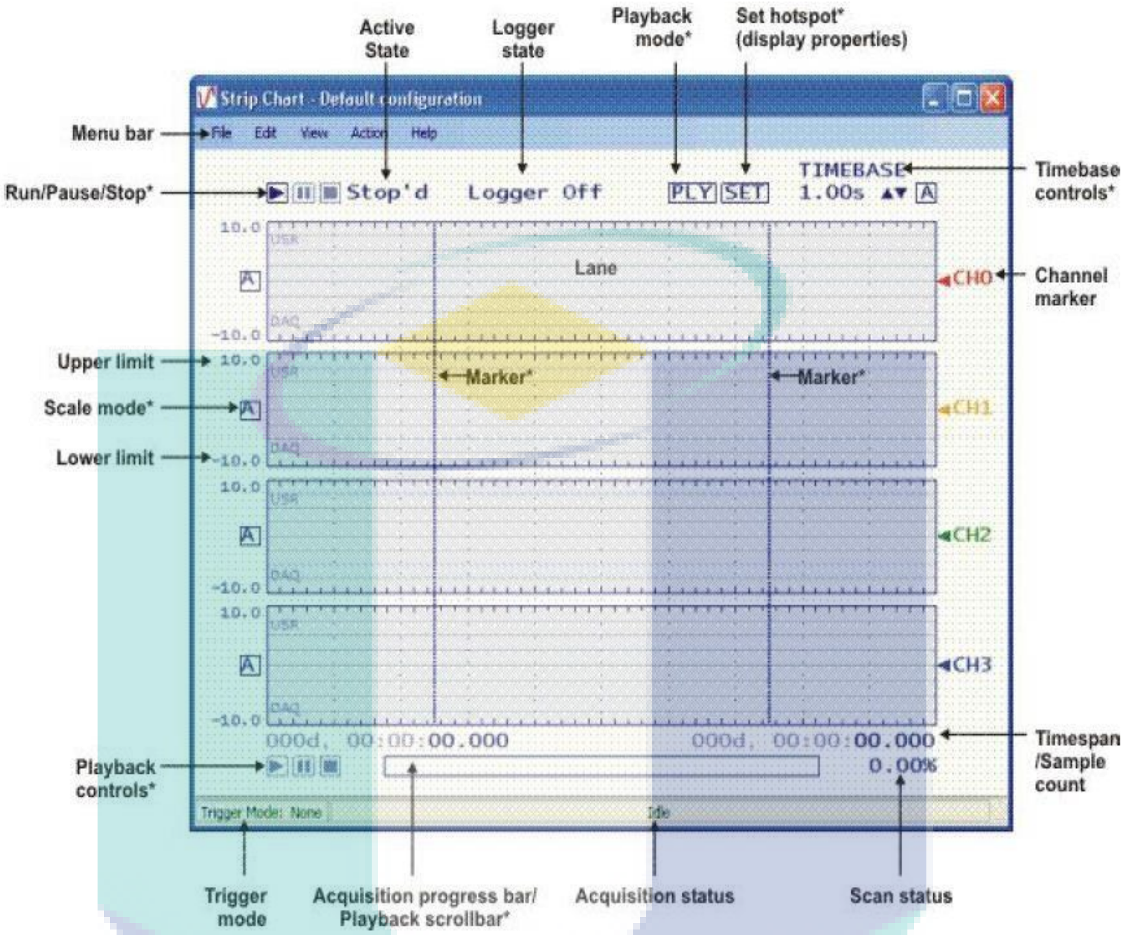

Figure 3.19: TracerDAQ Overview

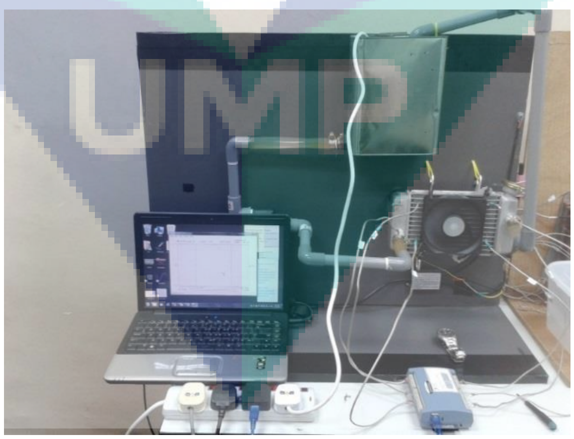

Figure 3.20: Radiator Test Rig with complete experiment apparatus overview

3.8 EXPERIMENT PARAMETERS

These are parameters which kept constant and manipulated during running the radiator test rig experiment. Table 3.2 enlighten the variables that plays an important role in determining the result obtained during the radiator test rig experiment.

Table 3.2: Parameters and description of variables of the experiment

Parameters	Description
Constant	Flow rate of fluids Thermocouples points Heating and data retrieving time period Radiator fan speed Position of 500W heater Total volume of the experimented fluids (800ml nanofluids & 1200ml of distilled water)
Manipulated	Concentration of the nanofluids (0.01%, 0.03%, 0.05%, 0.07% and 0.09 %)

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter will elaborate on the result gathered during experiment of Aluminium Oxide (Al_2O_3) nanoparticles with Ethylene Glycol for car radiator application. The data will be tabulated and discussed in order to verify the outcome of the experiment. Tracer DAQ and Excel sheets are used to visualize the final result of the research.

4.2 THERMAL CONDUCTIVITY TEST

Thermal conductivity is an important criteria which determines the heat conductivity rate of a fluid. Metal have higher thermal conductivity compared to liquids. The main reason of adding Aluminium Oxide (Al_2O_3) nanoparticles into Ethylene Glycol is to evaluate its thermal conductivity and heat diffusivity ability and its differences through variable concentration. Table 4.1 shows the tabulated thermal conductivity of Aluminium Oxide (Al_2O_3) nanofluid at different concentration level.

Table 4.1: Thermal Conductivity test for Aluminium Oxide (Al_2O_3) nanofluid

Concentration (%)	Thermal Conductivity (W/(m. K)
0.01	0.415
0.03	0.447
0.05	0.462
0.07	0.465
0.09	0.477

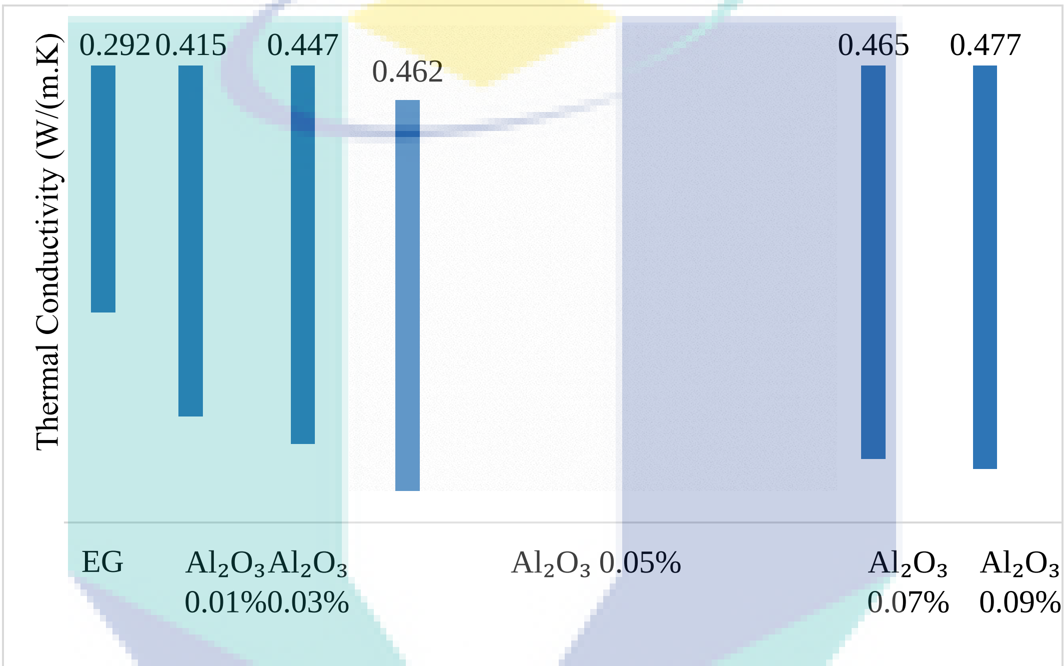

Figure 4.1: Relationship between thermal conductivity and Volume Concentration

Based on figure 4.1, thermal conductivity test proves that as the volume concentration increases, the efficiency of Aluminium Oxide (Al_2O_3) nanofluid to store and conduct heat also rises. The thermal conductivity value of Ethylene Glycol as base fluid is 0.292 W/(m. K) which is lesser than lowest 0.01% volume concentration thermal conductivity result at 0.415 W/(m. K). The movement of Aluminium Oxide (Al_2O_3) nanoparticles becomes vigorous as the temperature increases and this promotes raise in thermal conductivity of the nanofluid.

Although it is a fact that at room temperature, the thermal conductivity of water is 0.605 W/(m. K) but greater value of thermal conductivity of a liquid such as water leads to longer duration of time that it takes to release the heat which is absorbed from a system to the surrounding environment. This because there are no metallic particles which triggers increase in particles movement to release the heat. This is referred as thermal diffusivity capacity of a fluid.

Thermal diffusivity represent how fast a fluid to diffuse heat through it. The larger the thermal diffusivity, the faster the propagation of heat through a fluid. Although water which is readily available coolant might be relevant to be used as radiator coolant but water takes longer period of time to release the heat which is absorbed from the radiator to the surrounding. This is the factor which makes water to be a poor radiator coolant compared to Aluminium Oxide (Al_2O_3) nanofluid.

4.3 EXPERIMENTAL RESULT OF ALUMINIUM OXIDE

The following data are retrieved when conducting the experiment of Aluminium Oxide (Al_2O_3) nanoparticles with Ethylene Glycol for car radiator application. There are few assumption which were made when conducting the experiment in order to ease the tabulation of the result such as the whole experiment is conducted in controlled environment. Radiation heat transfer is negligible and steady operating conditions exist when the temperature reading were taken. The flow of the fluid is steady and incompressible.

There were no changes made in the speed of the pump, position of the heater placed in the tank and position of thermocouple fixed onto the radiator. The only variables in the experiment are types of fluid and concentration of Aluminium Oxide (Al_2O_3) nanofluid with Ethylene Glycol.

Figure 4.2 shows the result of running the radiator test rig with distilled water. The highest temperature recorded was 46°C at the inlet and lowest temperature around 34°C. The difference in the inlet and outlet temperature is 12°C.

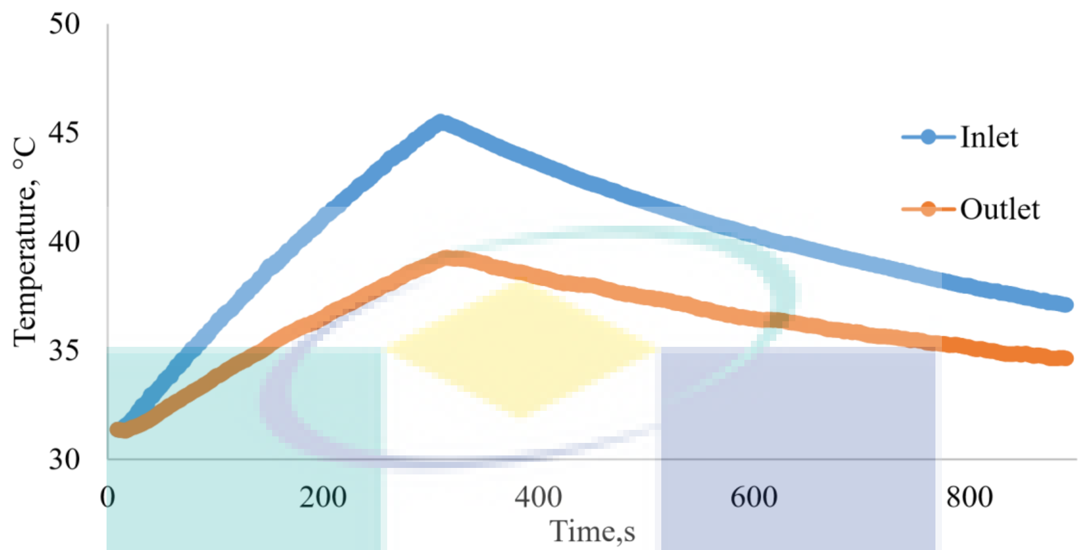

Figure 4.2: Experiment Result Running with distilled water.

Figure 4.3 shows the result of running the radiator test rig with Aluminium Oxide (Al_2O_3) nanofluid with a concentration of 0.01Vol%. The highest inlet temperature recorded was 53°C and the lowest outlet temperature is 20°C. The difference in temperature is 20°C.

Based on the previous result of running the radiator test rig with distilled water, the application of Aluminium Oxide (Al_2O_3) nanofluid with a concentration of 0.01Vol% shows a big changes in temperature difference compared to when applying distilled water as radiator coolant. This result proves that usage of Aluminium Oxide (Al_2O_3) nanofluid as radiator coolant does provide a better heat absorption efficiency compared to distilled water.

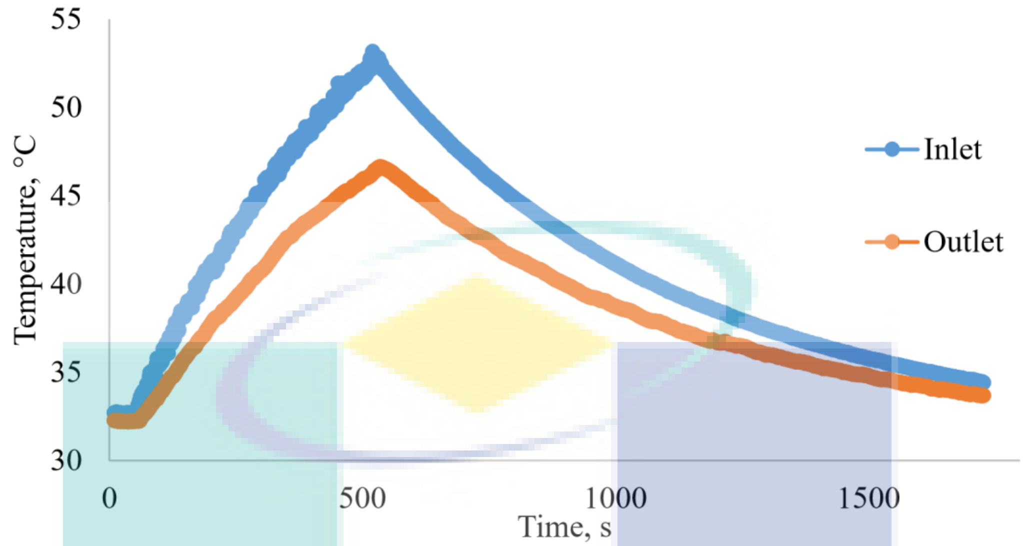

Figure 4.3: Experiment Result Running with Al_2O_3, 0.01%

Figure 4.4 shows the result of running the radiator test rig with Aluminium Oxide (Al_2O_3) nanofluid with a concentration of 0.03Vol%. The inlet temperature is recorded around 53°C and outlet temperature shows around 22°C. The changes in temperature between inlet and outlet is 22°C. There is a slight increment of 2°C of compared to Aluminium Oxide (Al_2O_3) nanofluid with a concentration of 0.01Vol% and 0.03Vol%. As the concentration of the Aluminium Oxide (Al_2O_3) nanofluid increases, the heat absorption efficiency also increases gradually.

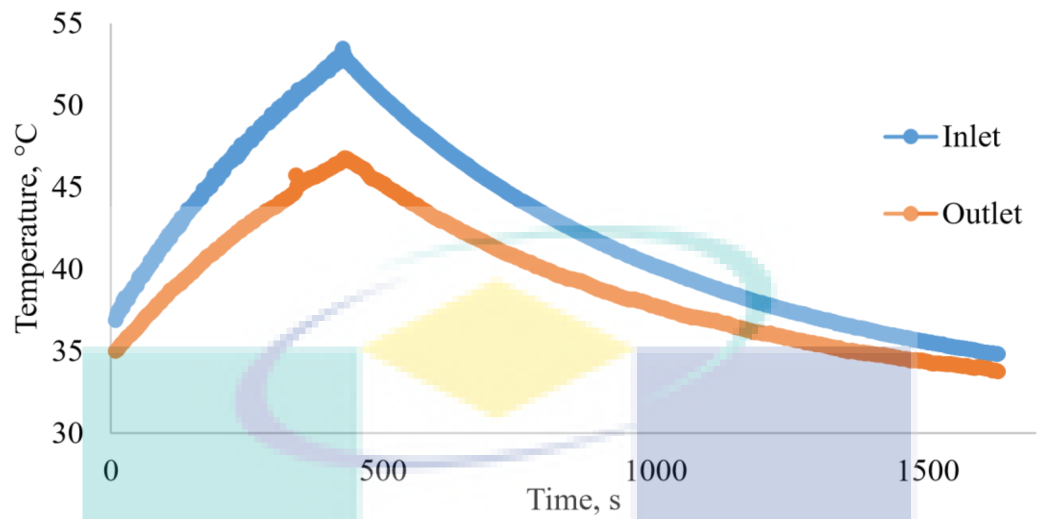

Figure 4.4: Experiment Result Running with Al_2O_3, 0.03%

Figure 4.5 shows the result of running the radiator test rig with Aluminium Oxide (Al_2O_3) nanofluid with a concentration of 0.05Vol%. The highest inlet temperature is 54°C and lowest outlet temperature is 31°C. The difference is temperature is 23°C.

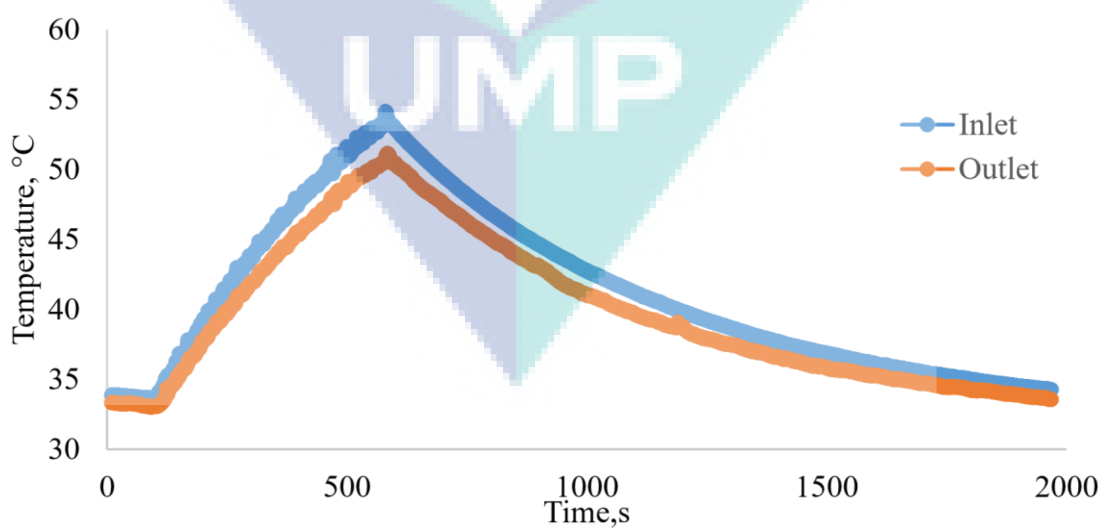

Figure 4.5: Experiment Result Running with Al_2O_3, 0.05%

Figure 4.6 shows the result of running the radiator test rig with Aluminium Oxide (Al_2O_3) nanofluid with a concentration of 0.07Vol%.The highest inlet temperature is 54°C and lowest outlet temperature is 31°C. The difference is temperature is 23°C.

Both the concentration of 0.05Vol% and 0.07Vol% exhibit same value of temperature difference and indicate both concentration have same heat absorption efficiency. However, figure 4.6 shows that formation of sediments start to visualize its effect at the outlet as the outlet temperature keep falling and rising. This can be clearly seen through the instable pattern of the graph line which represent the outlet temperature.

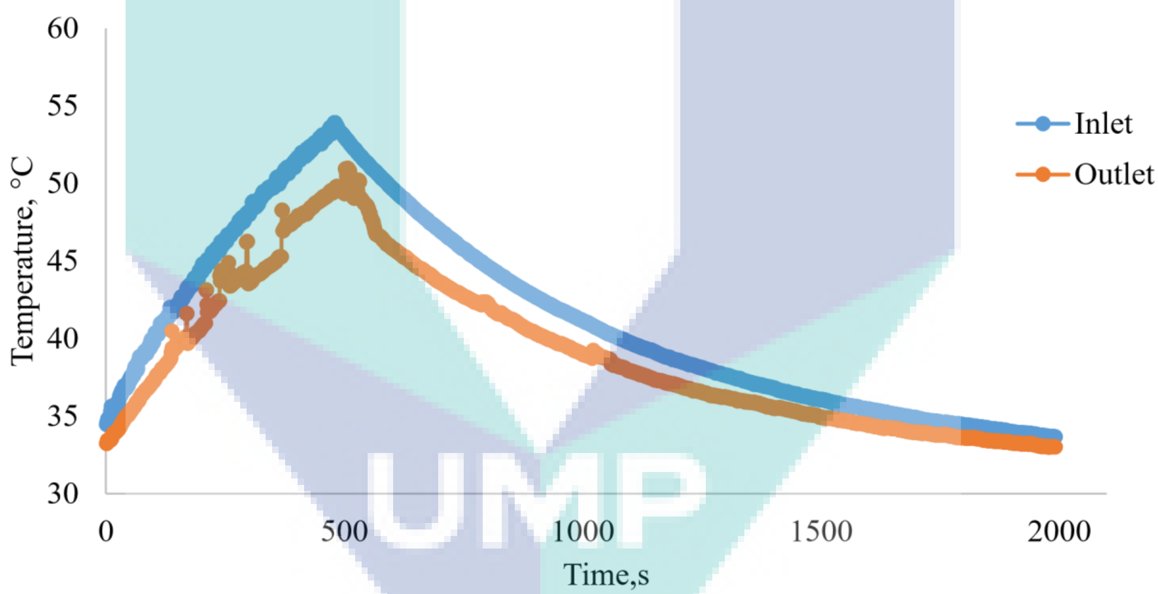

Figure 4.6: Experiment Result Running with Al_2O_3, 0.07%

Figure 4.7 shows the result of running the radiator test rig with Aluminium Oxide (Al_2O_3) nanofluid with a concentration of 0.09Vol%.The highest inlet temperature is 52°C and lowest outlet temperature is 32°C. The difference is temperature is 20°C.

The heat absorption efficiency for Aluminium Oxide (Al_2O_3) nanofluid with a concentration of 0.09Vol% shows a decrement compared to previous Aluminium Oxide (Al_2O_3) nanofluid with a concentration of 0.07Vol%.

The temperature difference between Aluminium Oxide (Al_2O_3), 0.07Vol % and Aluminium Oxide (Al_2O_3), 0.09Vol % displays decrease of 3°C. The formation of sedimentation in Aluminium Oxide (Al_2O_3), 0.09Vol % is higher compared with Aluminium Oxide (Al_2O_3), 0.07Vol %. This causes the Aluminium Oxide (Al_2O_3), 0.09Vol % to lose its ability as better radiator coolant compared to Aluminium Oxide (Al_2O_3), 0.07Vol %.

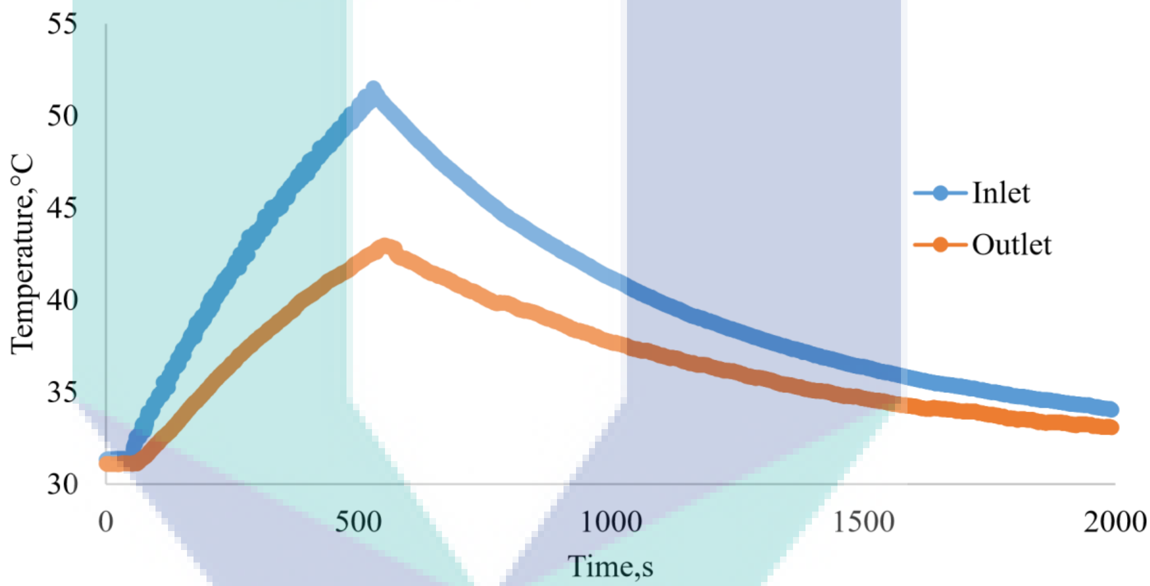

Figure 4.7: Experiment Result Running with Al_2O_3, 0.09%

The result of changes in temperature differences between inlet temperature and outlet temperature are tabulates in Table 4.2 below

Table 4.2: Difference between inlet and outlet temperature of respective fluids

Types of fluid in the radiator test rig test	Difference in temperature (°C)

Distilled Water	12
Aluminium Oxide (Al_2O_3), 0.01Vol%	20
Aluminium Oxide (Al_2O_3), 0.03Vol%	22
Aluminium Oxide (Al_2O_3), 0.05Vol%	23
Aluminium Oxide (Al_2O_3), 0.07Vol%	23
Aluminium Oxide (Al_2O_3), 0.09Vol%	20

4.4 EXPERIMENTAL DATA ANALYSIS

The following calculation are carried out based on referring to Newton's Cooling Law as in Equation 4.1.

$$Q_{CONV} = \dot{m}\, C_P(T_{IN} - T_{OUT}) \qquad (4.1)$$

In order to ease the calculation process, assumption is made that only power which is supplied to the radiator test rig system is from the 500W heater and power supplied to the close loop radiator system is equal to output of the system which means no energy is lost to the surrounding. The power supplied to the radiator fan and water pump is considered negligible in the calculation.

The example of the calculation to find the required specific heat capacity of water are illustrated as Equation 4.2 below

$$\dot{m} = \rho V \qquad (4.2)$$

Where V can be find by using Equation 4.3

$$\frac{Volume}{Time} \qquad (4.3)$$

A 300ml beaker and stopwatch were used in order to determine the volume flow rate. The stopwatch was pressed to determine the time taken by the radiator test rig system to fill up a 300ml beaker. The reading were taken five time and the average value of the volume flow rate is calculated by using Equation 4.3 and the result is shown as in Equation 5 below

$$V = 6 \times 10^{-5} m^3/\text{s} \qquad (4.4)$$

The density of the fluids which were used in the radiator test rig experiment are distilled water, Ethylene Glycol and Aluminium Oxide nanoparticles. For the ease of calculation, the density of the Ethylene Glycol and pure water are taken at 20°C. The density of the respective fluids are tabulated as in Table 4.3.

Table 4.3: Density of respective fluids involved in the radiator test rig experiment

Fluids	**Density (Kg/m^3)**
Al_2O_3	3700
Ethylene Glycol	1109
Distilled Water	998

Source**:** Cengal et all., (2013)

Thus, the mass flow rate of distilled water is calculated only by including density of distilled water as the volume flow rate of the system is constant. The calculation of mass flow rate of distilled water using Equation 4.2 are as follows

$$\dot{m} = \rho V$$

$$= (998\ \text{Kg/m}^3)\ (6 \times 10^{-5} m^3/s)$$

$$= 0.0599\ \text{Kg/s}$$

The calculated mass flow rate value for fluids involved in the radiator test rig are tabulated in Table 4.4 below

Table 4.4: Mass flow rate of fluids involved in the radiator test rig

Material	Mass flow rate (Kg/s)
Al_2O_3 + EG+ Distilled Water	0.3484
Distilled Water	0.0599

The example of calculation in order to determine the specific heat capacity of distilled Water are done by using Equation 4.1

$$Q_{Conv} = 500\ \text{W}$$

$$T_{in} - T_{out} = 12℃$$

$$\dot{m} = 0.0599\ Kg/s$$

$$c_P = \frac{Q}{(T_{IN} - T_{OUT})(\dot{m})}$$

$$= 0.6956\ \text{KJ/Kg. °C}$$

The following specific heat capacity values of fluids involved in the radiator test rig are presented as in Table 4.5.

Table 4.5: Specific heat capacity of respective fluids involved in radiator test rig

Fluids	Specific Heat Capacity (KJ/Kg. °C)

Distilled Water	0.6956
Aluminium Oxide (Al_2O_3), 0.01Vol% +EG	2.9118
Aluminium Oxide (Al_2O_3), 0.03Vol%+ EG	2.9052
Aluminium Oxide (Al_2O_3), 0.05Vol%+ EG	2.9024
Aluminium Oxide (Al_2O_3), 0.07Vol%+ EG	2.9024
Aluminium Oxide (Al_2O_3), 0.09Vol%+EG	2.9118

Heat transfer coefficient can be evaluated by applying the Equation 4.4 which is as below

$$h_{EXP} = \frac{\dot{m}C_p(T_{IN} - T_{OUT})}{A_s\ (T_B - T_S)} \qquad (4.4)$$

The calculated value of bulk temperature and average surface value of all the fluids involved in the radiator test rig are shown in Table 4.6

Table 4.6: Bulk temperature and Average surface temperature of fluids

Fluid	Bulk Temperature (°C)	Average Surface Temperature (°C)
Distilled Water	40	38.6226
Al_2O_3, 0.01Vol%	43	40.2664
Al_2O_3, 0.03Vol%	42	41.0052
Al_2O_3, 0.05Vol%	42.5	39.7641
Al_2O_3, 0.07Vol%	42.5 42	39.1323 38.7507
Al_2O_3, 0.09Vol%		

Example of calculating heat transfer coefficient of distilled water by applying Equation 4.4 are as below

$\dot{m}_{\ water}$ = 0.0599 Kg/s

$C_{p,water}$= 0.6956 KJ/Kg. °C

$$T_{IN} - T_{OUT} = 12\ °C$$

$$T_B - T_S = 1.3774\ °C$$

$$A_s = 2 \text{ surface} \times 0.18\text{m} \times 0.025\text{m} \times 12 \text{ tubes}$$
$$= 0.108\ \text{m}^2$$

$$h_{EXP} = \frac{\dot{m} C_p (T_{IN} - T_{OUT})}{A_s\ (T_B - T_S)}$$

$$= 3.36\ \text{W/m}^2.\ °C$$

The calculated value of heat transfer coefficient of all the fluids involved in the radiator test rig are shown in Table 4.7

Table 4.7: Heat transfer coefficient of respective fluids involved in radiator test rig

Fluids	Heat Transfer Coefficient (W/m². °C)	Thermal Enhancement
Distilled Water	3.36	-
Al_2O_3, 0.01Vol%	68.7244	19.45%
Al_2O_3, 0.03Vol%	207.3442	60.71%
Al_2O_3, 0.05Vol%	78.7117	22.43%
Al_2O_3, 0.07Vol%	63.9449	18.03%
Al_2O_3, 0.09Vol%	57.8172	16.21%

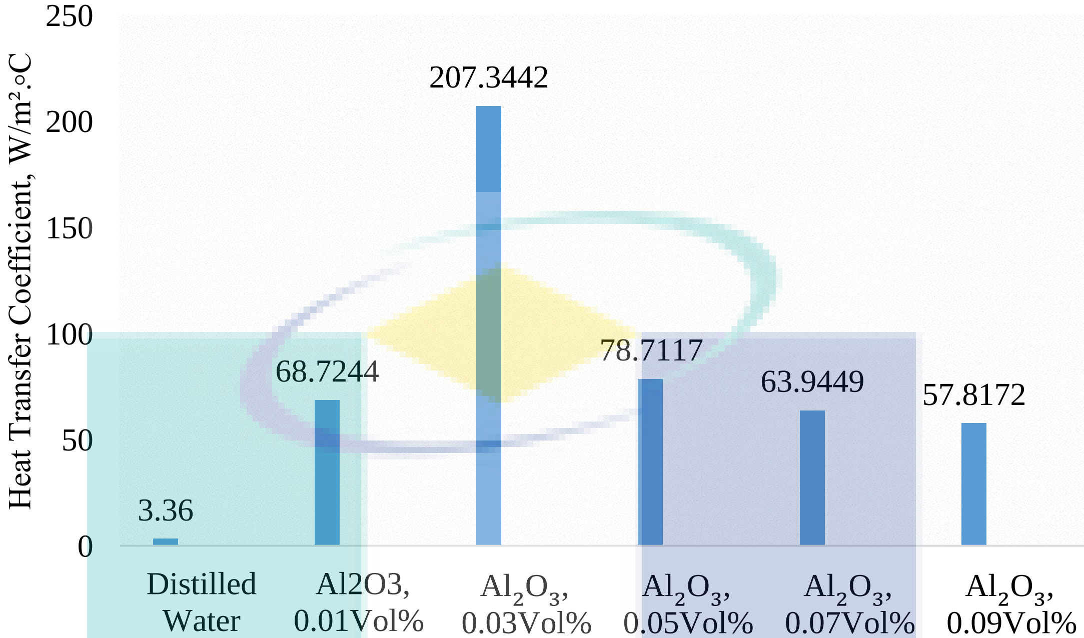

Figure 4.8: Heat Transfer Coefficient of respective fluids used in the radiator test rig

Based on Figure above, it is known that addition of Aluminium Oxide (Al_2O_3) nanoparticles in Ethylene Glycol shows a significant increase in thermal enhancement compared with distilled water. All the fluid added with Aluminium Oxide (Al_2O_3) nanoparticles shows a better heat transfer enhancement compared with distilled water. This proves that nanofluid are indeed better radiator coolant than distilled water.

The thermal enhancement of the nanofluid increase as the concentration of the Aluminium Oxide (Al_2O_3) nanoparticles increases. The highest heat transfer coefficient is reached when Aluminium Oxide (Al_2O_3) nanoparticles with a concentration of 0.03% is used and the lowest is recorded for Aluminium Oxide (Al_2O_3) nanoparticles with 0.09%. The heat transfer coefficient drops from 207.3442 W/m². °C to 57.8172 W/m². °C.

This result shows that the sedimentations process starts during the preparation of Aluminium Oxide (Al_2O_3) with 0.05% itself. The heat transfer coefficient drops gradually as the formation of sediments of Aluminium Oxide (Al_2O_3) powders rise. Thus, sedimentations of Aluminium Oxide (Al_2O_3) nanoparticles reduces the heat transfer coefficient of the nanofluids.

4.5 EROSION TEST OF RADIATOR TEST RIG

Erosion test is carried out in order to determine the effect of application of Aluminium Oxide (Al_2O_3) nanoparticles in Ethylene Glycol as car radiator coolant. The test is carried out by draining out the all the used Aluminium Oxide (Al_2O_3) nanofluids of different concentration from the radiator after every experiment process.

The fluids which have been drained out are filled in a clear beaker to spot any foreign materials such as metal strips or metal sediments. Based on observation using naked eyes, there were no proof of Aluminium Oxide (Al_2O_3) nanofluids causes erosion on the internal walls of the radiator.

Therefore, it can be concluded that application of Aluminium Oxide (Al_2O_3) nanoparticles in Ethylene Glycol do not initiate process of erosion on the internal walls of the radiator and can be used widely as a radiator coolant.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter will summarize all the result and outcome of the research of Aluminium Oxide (Al_2O_3) nanoparticles with Ethylene Glycol for car radiator application. The experimental results will be used to validate the objective and hypoproject of the research. Further improvement which can be done in order to advance the usage of Aluminium Oxide (Al_2O_3) nanoparticles in Ethylene Glycol will be discussed in this chapter.

5.2 CONCLUSION

Based on the experimental data obtained through calculation and research, it is proven facts that the application of Aluminium Oxide (Al_2O_3) nanoparticles with Ethylene Glycol for car radiator application shows a better thermal absorbing efficiency compared to distilled water. All the Aluminium Oxide (Al_2O_3) nanofluids of variable concentrations displays a better rate of heat transfer compared to distilled water. Thermal conductivity test shows that compared to Ethylene Glycol, Aluminium Oxide (Al_2O_3) nanofluids have better thermal conductivity. The highest thermal conductivity is possessed by Aluminium Oxide (Al_2O_3) nanofluids with a concentration of 0.09% at 0.477W/m.K while the lowest thermal conductivity at 0.415 is owned by Aluminium Oxide (Al_2O_3) nanofluids of 0.01% concentration.

Aluminium Oxide (Al_2O_3) nanofluids enables the heat absorbed by the fluid to be dissipated to the surrounding air more faster than distilled water or Ethylene Glycol as Aluminium

Oxide (Al_2O_3) nanoparticles are better heat conductor compared to Ethylene Glycol or distilled water.

Furthermore, tabulation of result after running the radiator test rig with distilled water and variable concentration of Aluminium Oxide (Al_2O_3) nanofluid. The outcome shows there is a significant changes in the difference between inlet and outlet temperature of the fluid flowing through radiator test rig. Although the sedimentation of Aluminium Oxide (Al_2O_3) nanoparticles start to form at the concentration of 0.05% which causes the highest heat transfer coefficient of 207.3442 W/m². °C obtained through Aluminium Oxide (Al_2O_3) nanofluids with a concentration of 0.03% to decrease rapidly to 57.8172 W/m². °C by Aluminium Oxide (Al_2O_3) nanofluids with a concentration of 0.09% but the sediments of Aluminium Oxide (Al_2O_3) nanoparticles do not clog the flat tubes in the radiator test rig. In addition, the sediments of Aluminium Oxide (Al_2O_3) nanoparticles also do not contribute to erosions of internal walls of the radiator test rig.

In conclusion, the objectives of the research which is to determine thermal influences of Aluminium Oxide (Al_2O_3) nanoparticles with readily available Ethylene Glycol in radiator is achieved by conducting radiator test rig experiment with distilled water and variable concentration of Aluminium Oxide (Al_2O_3) nanofluids. Moreover, investigation on effect of erosion of Aluminium Oxide (Al_2O_3) nanoparticles coolant on automotive radiator were also carried out to justify and support the credibility of Aluminium Oxide (Al_2O_3) nanofluids as an efficient radiator coolant.

5.3 RECOMMENDATION

Heat transfer coefficient of Aluminium Oxide (Al_2O_3) nanofluids can be increased by preventing the formation of sediments. Sediments of Aluminium Oxide (Al_2O_3) nanoparticles lead to inactive involvement of Aluminium Oxide (Al_2O_3) nanoparticles in heat transfer process.

Therefore, improvement can be done by introducing ultrasonic water bath in the preparation process of Aluminium Oxide (Al_2O_3) nanofluid to further break down the particles into simpler form which can prevent from formation of sediments.

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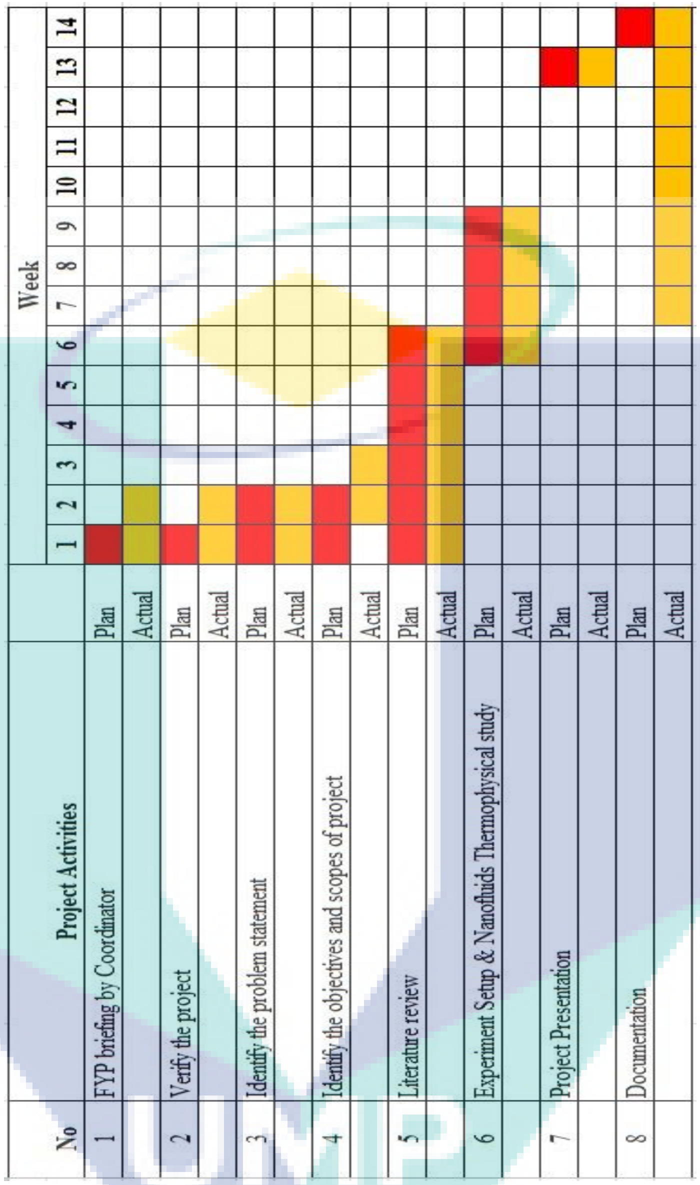
APPENDIX A1

GANTT CHART FOR SEMESTER I



APPENDIX A2

GANTT CHART FOR SEMESTER 2

1	Running experiment & Collecting data	Plan														
		Actual														
2	Conclusion & Result	Plan														
		Actual														
3	Project Presentation	Plan														
		Actual														
4	Documentation	Plan														
		Actual														