STUDY CHARACTERISTIC OF OIL-WATER EMULSION FUEL FOR DIESEL ENGINE

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ABSTRACT

This report deals with propose of new oil-water emulsion fuel mixtures which are to be improved by manipulating the percentage of oil and water added in the mixer. The objective of this project is to analysis the characteristic of the emulsion fuels produced by using laboratory analysis. The vertical mixer is used in this research. Emulsified fuels would be one of the best alternatives to replace the current fuel in the future. In order to produce the desired emulsion fuels, the mixer need to be designed and set up. After the emulsion fuels are produced, the mixture is later on be analysis using laboratory analysis such as ball-falling viscometer and oxygen bomb calorimeter. Data and results of the experiment are observed and recorded. The obtained data indicated that the emulsion fuel with 30% of water added shows the most stable physical characteristic. By the end of the report, the emulsion fuels where able to be produced by the mixer and the mixtures produced can be analysis.

ABSTRAK

Laporan ini berkaitan dengan campuran bahan bakar yang terbaru iaitu bahan bakar emulsi minyak-air yang harus dipertingkatkan dengan memanipulasikan peratusan minyak dan air yang dicampur di dalam pengadun. Tujuan projek ini dijalankan adalah untuk menganalisis ciri-ciri bahan bakar emulsi yang dihasilkan dengan menggunakan analisis makmal. Pengadun menegak digunakan dalam kajian ini. Bahan bakar emulsi merupakan salah satu alternatif terbaik untuk menggantikan bahan bakar yang diguna pakai pada saat ini di masa depan. Dalam rangka untuk menghasilkan bahan bakar emulsi yang dikehendaki, mesin pengadun perlu direka bentuk dan dibina. Setelah bahan bakar emulsi siap dihasilkan, kajian ke atas ia dilakukan menggunakan analisis makmal seperti bola-jatuh viskometer dan oksigen kalorimeter bom. Data dan keputusan dari kajian diamati dan direkodkan. Data yang diperolehi menunjukkan bahawa bahan bakar emulsi dengan 30% dari air yang ditambah menunjukkan ciri-ciri fizikal yang paling stabil. Pada akhir laporan, bahan bakar emulsi telah dapat dihasilkan oleh pengadun dan campuran yang dihasilkan boleh analisis.

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INTRODUCTION

1.1 Background

Water-in-oil emulsions/oil-water emulsion has existed since the turn of the century. However, only recently, the stability and quality of the emulsion are able to be controlled to make it advantageous and power-generating uses. The emulsions are engineered to provide reduced carbon particulate, lower opacity and lower nitrogen oxide levels.

Despite of only able to reduce the total particulate in combustion, there are others benefit of emulsion fuel that improve the combustion in the engine. Such as, atomize improvement, reduces unburned carbon and reduces SO_3 and NO_x emission. Each of these benefits has potential economic savings.

In this project, an oil-water emulsion fuel mixer is being design and built. The mixture produced by the mixer will be analysed whether it meets the right specification characteristic that can be used in engine or not. Oil-water emulsion fuel is one of the alternative fuels that may be used in the future.

1.2 Problem Statement

From the mid-1980s to September 2003, the inflation-adjusted price of a barrel of crude oil on New York Mercantile Exchange (NYMEX) was generally under US$25/barrel. After September 2003, the oil price rose and reach it peak price at US$147.40 in July 2008 following concern over Iranian missile test. But after the record peak, the oil price has decreased significantly. The oil recorded a trading between US$35 a barrel and US$82 a barrel in 2009 (Tim McMahon, 2010). The possible causes of the rising oil's price are world crude oil demand, the reduced or removed of state fuel subsidies and low supply growth of petroleum. Because of these problems, an alternative fuel is demanded. However, there are several doubts when doing this project. What is emulsion fuel? How can an emulsion fuel be produced? What are the materials needed to run this experiment? What are the characteristics of the emulsion fuel when the mixing ratio of oil and water is vary?

1.3 Objective

1. To analysis the characteristic of oil-water emulsions by laboratory analysis with variety percentage of water. Such as; 5%, 10%, 15%, 20%, 25% and 30% volume of the mixture.

1.4 Project Scopes

This project is focusing on producing the desired emulsion of oil-water with specific percent of oil, water and addictive. This focus area is done within the limits of analysing the viscosity, calorimetry and observations of emulsion fuel's characteristic after one week.

1.5 Organization of thesis

This thesis has been written with necessary details to the understanding of this project. Excluding the introduction, which is the first chapter of this thesis, the main point of this project is divided into four chapters. Chapter 2 consists of literature review of several previous studies on oil-water emulsion. Chapter 3 elaborates the setup of the apparatus rig and methodology used to achieve the objective of the study. The results of the analysis are recorded in Chapter 4. Finally in Chapter 5, it presents the conclusion of overall study and the future work recommendation.

CHAPTER 2

LITERATURE REVIEW

The aim of this chapter is to provide all the information of oil-water emulsion fuel. Why oil-water emulsion fuel is suits as an alternative fuel? How oil-water emulsion is being made? What are the characteristic of the mixture? Oil-water emulsion fuel will be discussed thoroughly in this chapter. Various sources including journal, thesis, reference books and literature reviews have been carried out and revised in writing this chapter.

2.1 Oil-water emulsion fuel

Why oil-water emulsion is suitable to become one of alternative fuel in the future? The use of water into diesel has a number of possible benefits. It has been found by many previous works that it has influence on reducing the peak flame temperature and hence reducing the nitrogen oxides, NO_x emissions (Psota et al., 1997). Besides that, adding water may help to improve atomization and mixing, which will lead to an attribution of micro explosion's' droplet (Dryer, 1976).

In the combustion process, the process of micro explosion took place. The micro explosion work as water droplets in an oil droplet explosively evaporate inside the combustion chamber which the temperature is very high, they break the oil droplet into the huge number of tiny droplet. The improved mixing is due to the increased vaporized fuel jet momentum, giving greater air entertainment into the fuel jet. When the mixing

of air and fuel are improved, the emissions from the diffusive burning portion of the combustion will be reduced as well as reducing the carbon formation.

This effect, together with the chemical effect of the water results in an increased ignition delay (Radwan and Salem, 1989). This promotes an increased in the premixed portion of the combustion process, which decreases the diffusive burning and hence also contributes to the reduction in the NO_x emissions and carbon formation (Greeves and Onion, 1976). In the journal by Andrews, Bartle, Pang and Nurein also stated that by adding water to diesel fuel can reduce the particulate matter PM or smoke emissions (Andrews et al., 1987).

According to Samec at al. (2000) in their journal, the water may be added to the fuel in several ways:

1. Continuously into the air stream via a single point system or periodically through intake valves via a multi-point system.
2. Water is injected directly into the cylinder through a separate nozzle, or is introduced to fuel within the injection nozzle when fuel injection does not take place.
3. By stratified fuel – water injection
4. Through the preparation of stabilized water/fuel emulsion.

Although all these methods produced a reduction in NO_x but the most effective technique for the reduction of diesel particulates or smoke is the use of water/diesel emulsion.

The focus in this project is “water in oil emulsion fuel/oil-water emulsion fuel” but what is oil-water emulsion?

Oil-water emulsion consists of base fuel and water is doped with a slight content of surfactant/additive. The emulsion is essentially a multi-component fuel that its base fuel and water are not miscible at the molecular level. Let say, the percentage of water in the emulsion is 20%, water fuel emulsions can be stated as a mix of about 80% diesel, 20% water and about 1% surfactant. The surfactant is included to maintain the

emulsion, enhance the lubricity, inhibit corrosion and protect against freezing. The presence of water in the emulsion reduces both PM and NO_x, by lowering the combustion temperature and altering the combustion pattern to more completely burn the carbon in the fuel.

2.2 Surfactant

The additive used in this project is inorganic emulsifier made of the mixture of sodium hydroxide, calcium hydroxide and chlorine. The molarity of the each chemicals property is 0.1M.

2.2.1 Sodium hydroxide

Sodium hydroxide (NaOH) is a caustic metallic base. At room temperature, sodium hydroxide is a white crystalline odourless solid that absorbs moisture from the air.

It is used in many industries, mostly as a strong chemical base in the manufacture of pulp and paper, textiles, drinking water, soaps and detergents (Cetin and Jurgen, 2005).

$$2\ Na^+ + 2\ H_2O + 2\ e^- \rightarrow H_2 + 2\ NaOH$$

For manufacture of biodiesel, sodium hydroxide is used as a catalyst for the transesterification of methanol and triglycerides. It is used more often than potassium hydroxide because it is cheaper and a smaller quantity is needed (Greenwood and Earnshaw, 1997).

2.2.2 Calcium hydroxide

Calcium hydroxide is an inorganic compound with the chemical formula $Ca(OH)_2$. It is colourless crystal or white powder. It is low of toxicity and traditionally called slaked lime.

$$CaO + H_2O \rightarrow Ca(OH)_2$$

As calcium hydroxide is easily handled and cheap, it is produced on a large scale. In the petroleum refining industry, calcium hydroxide is commonly used as additives to the oil (Greenwood and Earnshaw, 1997).

2.2.3 Chlorine liquid

Chlorine is a halogen element. In its elemental form which is Cl_2 or dichloride under standard conditions, chlorine is a powerful oxidant. In chemical industry, chlorine is commonly used as an essential reagent.

At 10^oC and atmospheric pressure, one litter of water dissolves 3.10L of chlorine's gas. The solubility of chlorine in water will increased if the water added contains dissolved alkali hydroxide and chlorine liquid can be produced.

$$Cl_2 + 2\ OH^- \rightarrow ClO^- + Cl^- + H_2O$$

2.3 Viscosity

Viscosity is a measure of the resistance of fluid which is being deformed by either shear stress or tensile stress (Keith, 1971). Fluids for which the rate of deformation is proportional to the shear stress are called Newtonian fluids after Sir Isaac Newton, who expressed it first in 1687 (Cengel and Cimbala, 2006).

The principle of viscosity involve in this project is when a body moving in a fluid is acted on by a frictional force in the opposite direction to its direction of travel. The magnitude of this force depends on the geometry of the body, its velocity, and the internal friction of the fluid. A measure for the internal friction is given by the dynamic viscosity η.

For a sphere of radius r moving at velocity v in infinitely extended fluid of dynamic viscosity η, G.G. Stokes derived an expression for the frictional force:

$$F_1 = 6\pi\eta v r \tag{2.1}$$

If the sphere falls vertically in the fluid, after a time, it will move at a constant velocity v, and all the forces acting on the sphere will be in equilibrium: the frictional force F_1 which acts upwards, the buoyancy F_2 which also acts upwards and the downward acting gravitational force F_3. The latter two forces are given by:

$$F_2 = \frac{4\pi}{3} r^3 \rho_1 g \tag{2.2}$$

$$F_3 = \frac{4\pi}{3} r^3 \rho_2 g \tag{2.3}$$

And the equilibrium between these three forces can be described by:

$$F_1 + F_2 = F_3 \tag{2.4}$$

The viscosity can, therefore, be determined by measuring the rate of the fall v:

$$\eta = \frac{2}{9} r^2 \frac{(\rho_2 - \rho_1) g}{v} \tag{2.5}$$

Where v can be determined by measuring the fall time t over a given distance s. The viscosity then becomes:

$$\eta = \frac{2}{9} r^2 \frac{(\rho_2 - \rho_1) g t}{s} \tag{2.6}$$

In practice, equation (2.1) has to be corrected since the assumption that the fluid extends infinitely in all directions is unrealistic and the velocity distribution of the fluid particles relative to the surface of the sphere is affected by the finite dimensions of the fluid.

For a sphere moving along the axis of a cylinder of fluid of radius R, as in a falling-ball viscometer, the frictional force is:

$$F_1 = 6\pi\,\eta\,r\,\left(1 + 2.4\,\frac{r}{R}\right) \qquad (2.7)$$

And equation (2.6) becomes:

$$\eta = \frac{2}{9} r^2 \frac{(\rho_2 - \rho_1)\,g\,t}{s} \frac{1}{1+2.4\,(r/R)} \qquad (2.8)$$

Equation (2.8) can be used in a falling-ball viscometer to determines the viscosity if fluids.

2.4 Oxygen Bomb Calorimeter

Calorimeter is a device used for calorimetry, the science of measuring the heat of chemical reactions or physical changes as well as heat capacity. A bomb calorimeter is a type of constant-volume calorimeter used in measuring the heat of combustion of a particular reaction. Bomb calorimeters have to withstand the large pressure within the calorimeter as the reaction is being measured. The whole bomb, pressurized with excess pure oxygen at 30atm and containing a known mass of sample weighted less than 1.0g.

Later on, the oxygen combustion vessel is submerged under 2000 ml of water in oval bucket before the charge is ignited. The sample and oxygen in oxygen combustion vessel will form a closed system which means no air escapes during the reaction. The energy released by the combustion raises the temperature of the oxygen combustion vessel, its contents, and the surrounding water jacket. The temperature change in the water is then accurately measured. This temperature rise, along with a bomb factor which is dependent on the heat capacity of the metal bomb parts is used to calculate the energy given out by the sample burn. After the temperature rise has been measured, the excess pressure in the bomb is released.

Basically, a bomb calorimeter consists of a small cup to contain the sample, oxygen, a stainless steel bomb, water, a stirrer, a thermometer and ignition circuit connected to the bomb.

2.5 Previous studies

Many researches and experiments on oil-water emulsion fuel had been carried out. In the journal entitled “an experimental study of stability of oil-water emulsion” states that, an emulsion can be defined as two immiscible liquids wherein droplets of one phase (the dispersed or internal phase) are encapsulated within sheets of another phase (the continuous or external phase). According to journal by Chen and Tao (2005), it summarized that; to form a stable emulsion, three basic conditions must be met:

1. the two liquids must be immiscible or mutually insoluble in each other;
2. sufficient agitation must be applied to disperse one liquid into the other;
3. an emulsifying agent or a combination of emulsifiers must be present.

There were many researches and experiments have been carried out for years. Different researcher used different method and application in producing emulsion fuels. For instance, Nohara (2001) stated in his research that he made emulsion fuels by adding warm water to heated heavy oil. The heavy oil is heated to lower the viscosity of the heavy oil so that, in mixing process, the cohesion happens among water particles and the oil.

Besides that, many method and research have been made by Kandori (1991). In Kandori’s journal, he stated that he was able to prepare an emulsion fuel by SPG filter emulsion method and by Shirasu-porous-glass filter emulsification technique.

In Vladisavljevic’s journals (2002), stated that he prepares the emulsion fuels using microporous polypropylene hollow fifers. Further research was later on made by Reyes and Charcosset (2010) using membrane emulsification method. From previous researches also, it is noted that, even different method were carried out to produce emulsion fuels, the existence of surfactant is essential.

The surfactant can be either organic based or inorganic based. The surfactant is essential as it will form a thin interfacial film between the two liquids and maintain emulsion

In “Formation of water-in-oil emulsions and application to oil spill modelling” by Fingas and Fieldhouse, they stated that, a stable water-in-oil emulsion are brown or reddish. A stable emulsion remains stable for at least four weeks under laboratory and test tank conditions.

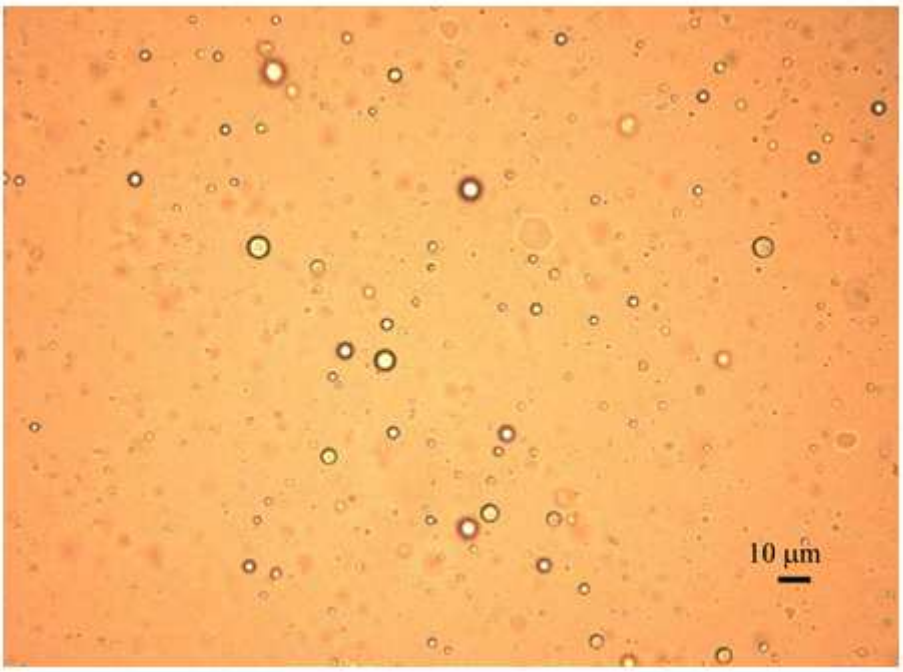

Figure 2.1: Image of W/O emulsion

Source: Reyes and Charcosset 2010

Figure 2.1 shows the typical optical microscopy image of W/O emulsion obtained by membrane emulsification. The emulsion fuels prepared by Reyes and Charcosset meet the claim made by Fingas and Fieldhouse even method of producing is differ.

Another research done by Dukhin and Goetz (2005) gives different image of emulsion fuel when emulsion is prepared by adding similar volume of water to the kerosene with different ratio of 0.01M KCI, potassium chloride relative to kerosene. Figure 2.2 shows the image of emulsion fuels prepared after 40minutes the stirrer is turned off.

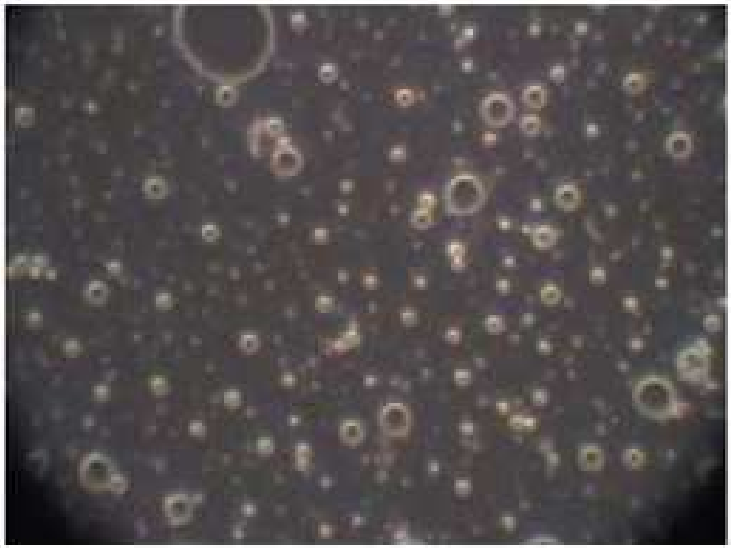

Figure 2.2: Emulsion fuel image captured by microscope

Source: Dukhin and Goetz 2005

In addition, there was an experimental study had been done by Chen and Tao in effect of surfactant dosage used, effect of oil/water ratio, effect of stirring intensity and temperature to the emulsion fuels produced. The surfactant used was sorbitan monooleate (SM) and the emulsion fuels produced using NMR self-diffusion method.

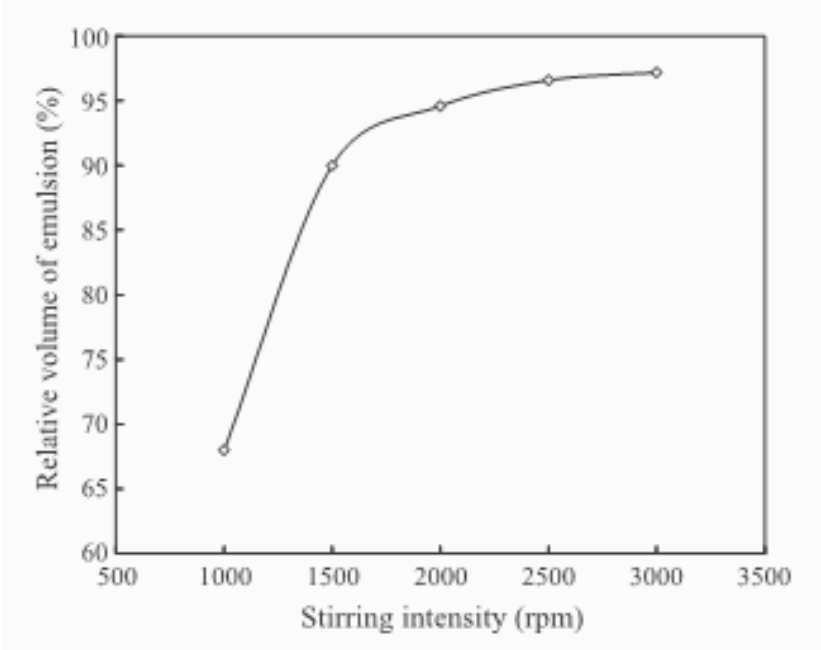

Figure 2.3: Relationship between stirring intensity and relative emulsion

Source: Chen and Tao 2005

The purpose of stirring is to form a stable and homogeneous emulsion by breaking large liquid drops into smaller drops. Figure 2.3 clearly indicates that a more stable emulsion was achieved with higher stirring speed. From their studies also, the mixing time also is another factor for emulsification. Figure 2.4 clearly shows that, the emulsifier becomes more effective with increased mixing time. However, if the mixing time is too long, the effectiveness of emulsifier will be decreased because the intense stirring will cause the emulsifier to drop out from the oil-water interface.

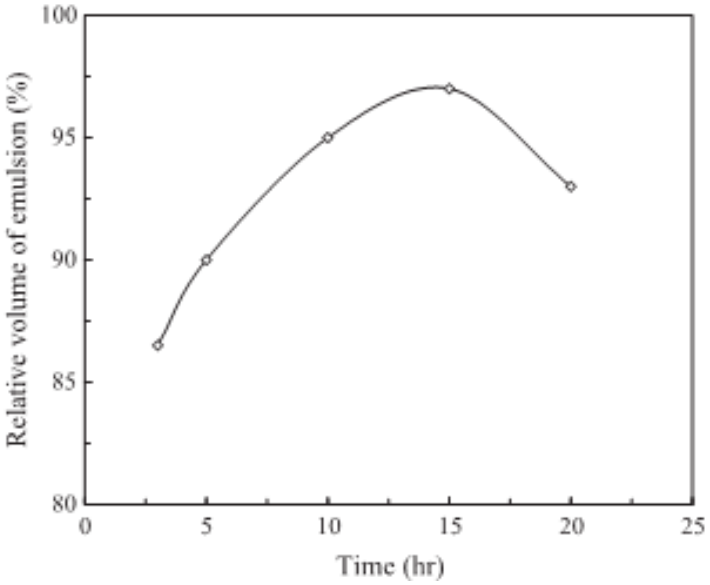

Figure 2.4: Relationship between mixing time and relative volume of emulsion

Source: Chen and Tao 2005

CHAPTER 3

METHODOLOGY

This chapter will describe further on the experiment which is setting up the rig, producing the oil-water emulsion fuel and analysis the emulsions. In order to complete the experiment, methodology is one of the most important things that need to be considered. The objective of the methodology is to make sure that the project is running on schedule and the data obtained from the experiment can later be analysed.

In this chapter, all the details and related discussion on the process and methods involved in the project are described. The process flow and timeline of the project is illustrated using flow chart and Gantt chart. Both charts are fundamental for this project as both charts explained every step to achieve the objective of the project. The project starts with working on literature review and end by submitting the complete report to the faculty.

3.1 Project flowchart

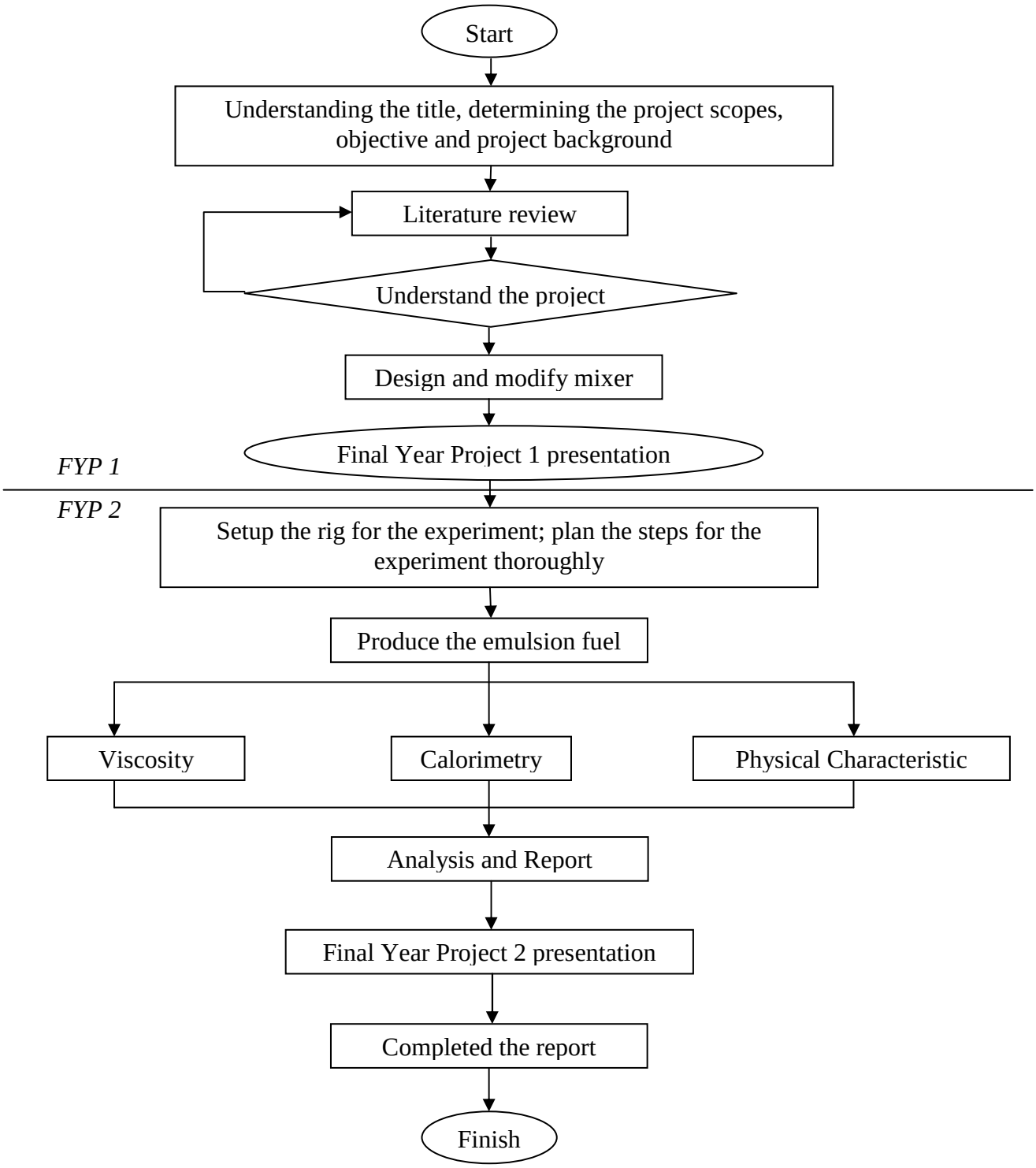

Figure 3.1: Framework of methodology

3.2 Flow Chart Description

Figure 3.1 shows the flow chart of every process that needed to complete the project. In the beginning, the project starts with understanding the title, determining the project scope and general background of the project.

After that, literature review of the project is being made. The sources for the information of the literature review came from the books, journal and research from the internet. The information for the project is understood better after literature review is done. The data and information from previous research can be used to gain new idea and concept to be used in the project.

The project starts with designing the rig of the experiment. The rig of the experiment is designed using application of Solidworks. The next procedure of the project is doing a research on previous studies that relate with oil-water emulsion fuel. After all information on oil-water emulsion fuel is understood, the presentation slide for Final Year Project 1 presentation is prepared.

For Final Year Project 2, methodology continued with setting up the rig and determining the procedure for the experiment. The rig is setup based on the designed made on Final Year Project 1.After the setup process is finished, the oil-water emulsion fuel is produced with variety percentages of water that are 5%, 10%, 15%, 20%, 25% and 30% of emulsion’s volume fuels.

The experiments were carried out to analyse the viscosity, calorimetric and observation of physical characteristic of the emulsion fuels produced. The data from the experiments were next discussed. If the data from experiment did not satisfy the objective and scope of the project, the experiment is repeated to get the desired results. After the objective and scope of the project were fulfilled, the next step of the project is to present the Final Year Project 2 to the panels. Final step of the project is to compile and submit the completed report of the project to faculty.

3.3 Literature Analysis

Literature analysis is a combination and elaboration of the literature review that are made from the information of journals and analysis of previous researches. Before starting the project, it is very fundamental to understand the objective of the project that is to analysis the characteristic of oil-water emulsions by laboratory analysis with variety percentage of water. In order to understand that, the best and precise information must be gathered from the right and trusted sources. The sources of the information that required for the project are internet, books and Project Supervisor.

3.3.1 Internet

Internet is the simplest and easiest way to get any information that related to the project. There are many journals and technical papers written by previous researchers can be easily found from the internet. The information from the internet cannot be trusted blindly. It is better to compare the information from internet with other sources such as books to get accurate and relevant information for the project.

3.3.2 Books

Well published books are one of good example sources to get precise information for the project. The books published were written by professional and qualified people. Most of the books can be found in the library. Information that relates to the project such as analysis, concept and mathematical calculation information can be found in the book.

3.3.3 Project Supervisor

After going through the internet and books, there is some information that is hard to understand. So, project supervisor advices and guidance are very crucial in this project as the project supervisor is an expert in the field that relate to the project. Besides that, by discussing with the project supervisor can generate new idea or concept that can be used in the project.

3.4 Framework Rig Design

Before producing oil-water emulsion fuel, the framework rig of the mixer is needed to support the motor of the mixer. The design of the framework rig is carried out with Solidworks. The framework rig designed should be able to fit and support the motor while mixing the mixture in the experiment.

Figure 3.2: Framework Rig Design

3.5 Tools

There are many tools that have been used in order to complete the project especially to fabricate the framework rig design. The tools used are disk cutter, MIG welding, vertical driller and lath machine.

Figure 3.3: Lath Machine

Figure 3.4: Disk Cutter

Figure 3.5: Vertical Driller

Figure 3.6: MIG Welding

3.6 Apparatus

3.6.1 Mixer

In this project, the mixer selected is vertical mixer. When vertical mixer is operating in normal working position, only a part of shaft and propeller is submersed in the substance to be mixed. Driving unit, consisting of electric motor is located above liquid's level. In this way, mixer's life span can be lengthened significantly. Vertical mixer is usually fixed to a fabricated framework.

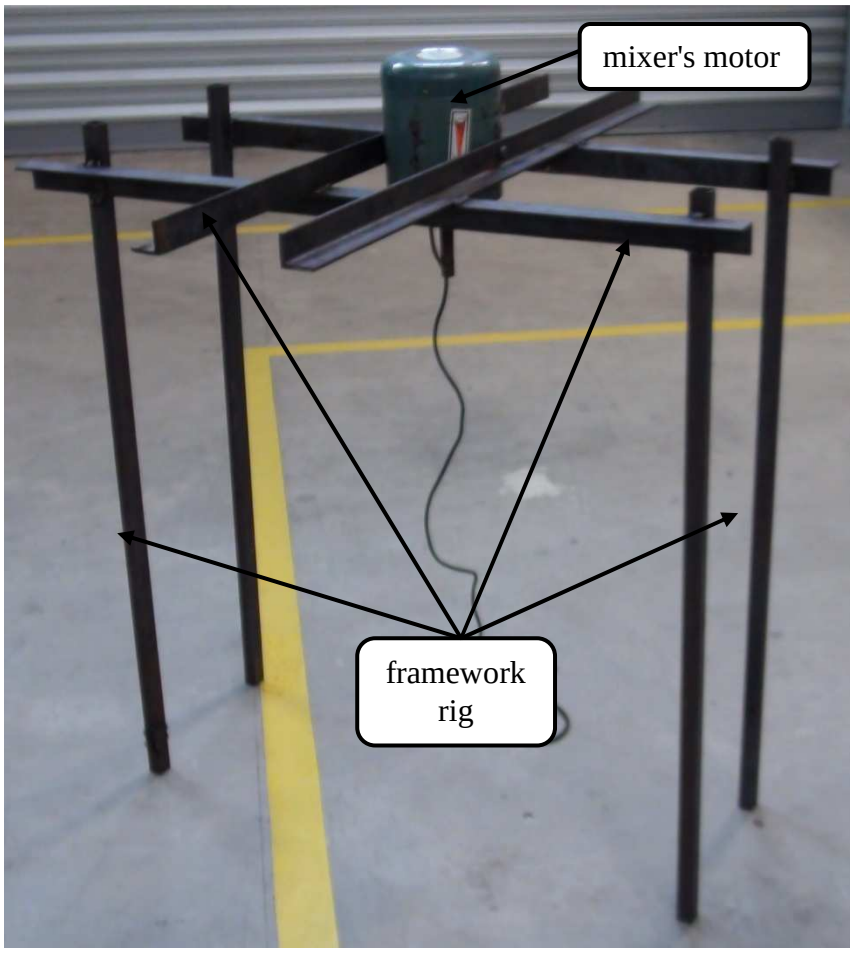

Figure 3.7: Framework Rig and Mixer's Motor

The driving unit of the mixer used is the motor of industrial heavy duty exhaust fan, model: IHEF – 2400. It is operate on AC single phase. It requires 220V to 240V to operate.

Propeller of the mixer is made of aluminium. It is a 2 blade propeller and has a buffed mirror finish that minimizes speed loss from drag and reduces corrosion. Its rotation is clockwise when viewed from the motor end. This creates a downward flow to produce optimal tank turnover or mixing.

Figure 3.8: Bottom view of the propeller

Figure: 3.9: Side view of the propeller

Figure 3.10: Mixer

3.6.2 Laboratory Viscometer

The laboratory viscometer used in this project is falling sphere viscometers. It consists of measurement tape, 1000mL cylinder tube and steel sphere.

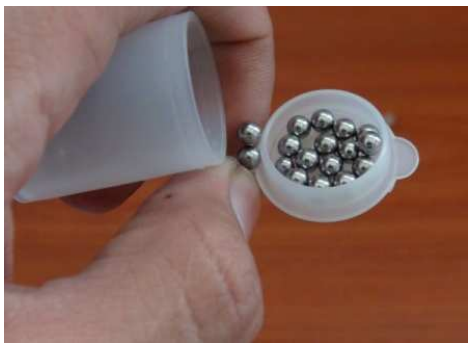

Figure 3.11: Steel sphere ball

Figure 3.12: Measurement tape

3.6.3 Oxygen Bomb Calorimeter

The amount of calorie of each emulsion fuel can be analyzed using oxygen bomb calorimeter. The model used in this project is Parr 1341 Plain Oxygen Bomb Calorimeter. To improve the precision and simplify the procedure for measuring and recording the temperature rise in the 1341 Oxygen Bomb Calorimeter, Parr 6772 Calorimetric Thermometer is used also.

Figure 3.13: Parr 1341 Plain Oxygen Bomb Calorimeter

Figure 3.14: Parr 6772 Calorimetric Thermometer

3.6.4 Digital Laser Tachometer

The digital laser tachometer is used to measure the RPM of the rotating shaft of the vertical mixer. The model of the tachometer used in this project is TM-5010 (Line Seiki).

Figure 3.15: Digital Laser Tachometer

3.6.5 Tank

The tank used for the mixer is made from aluminium. The diameter of the tank is 0.3m and height of 0.35m.

Figure 3.16: Mixer's Tank