EXPERIMENTAL STUDY OF AN INLET GUIDE VANE DESIGN (IGVD) FOR EMULSIFIED BIOFUEL APPLICATION IN DIESEL ENGINE

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references.

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ABSTRAK

Enjin diesel adalah salah satu keperluan dalam pelbagai industri termasuk automotif, marin dan lain-lain. Dalam projek ini, tumpuan utama adalah untuk mereka dan menghasilkan bilah pandu bagi meningkatkan prestasi diesel enjin. Skop untuk kajian ini ialah mengkaji kesan bilangan bilah pandu yang berbeza, dan kesan sudut bilah pandu yang berbeza terhadap prestasi enjin diesel Yanmar L70AE. Dalam kajian ini, sembilan sampel bilah pandu telah di reka bentuk dan dihasilkan. Antara bilah pandu sudut berbeza yang dihasilkan ialah 20˚, 25˚, 30˚, 35˚ dan 40˚, manakala bilah pandu yang berbeza bilangan bilah juga direka bentuk dan dihasilkan ialah 3, 4, 5 dan 6 bilah. Bahan api alternatif juga telah digunakan secara meluas dalam pelbagai industri untuk berbagai tujuan kerana sumber bahan api fosil yang semakin berkurangan. Oleh itu, bahan api seperti bahan api bio beremulsi telah digunakan untuk menggantikan bahan api diesel. Dalam kajian ini, bahan api bio beremulsi dihasilkan menggunakan minyak sawit yang telah dicampurkan dengan air. Bahan api bio beremulsi ini telah diadun menggunakan mesin penghomogen ultrasonik. Emulsi antara minyak sawit dan air dikatakan mampu menghasilkan fenomena letupan mikro. Peratusan air yang berbeza di dalam larutan minyak sawit akan memberikan kesan yang berbeza. Oleh itu peratusan sampel 1-5% kandungan air telah dikaji sifatnya termasuk saiz struktur mikro, nilai kalorifik dan ketumpatan. Bahan api bio beremulsi dengan kandungan 5% air mempunyai saiz kira-kira 4 µm (dalam julat untuk menghasilkan fenomena letupan mikro). Sampel reka bentuk bilah pandu telah diuji untuk mendapatkan kadar aliran jisim bahan api, tork enjin, kuasa brek, penggunaan bahan api tentu brek, kecekapan haba brek dan tekanan berkesan min brek dengan menggunakan bahan api bio beremulsi yang mengandungi 5% kandungan air. Prestasi enjin yang terbaik dilihat pada bilangan 3 bilah pandu dan sudut bilah pandu 40˚. Anggaran tork mampu dihasilkan ialah 14Nm, kuasa brek 5kW, penggunaa bahan api tentu brek ialah 0.4kg/kwh, kecekapan haba brek ialah 24% dan tekanan berkesan min brek ialah 280kPa.

ABSTRACT

The diesel engine is one of the need in many industries including automotive, marine and others. In this project, the main focus was to design and produce the guide vanes to improve the performance of diesel engines. The scope of this study was to investigate the effect of different number of vanes and angle of guide vanes towards performance of L70AE Yanmar diesel engine. In this study, nine samples of guide vanes have been designed and produced. The different angles of the guide vanes that have been produced were 20˚, 25˚, 30˚, 35˚ and 40˚, while different number of guide vanes also designed and produced were 3, 4, 5 and 6 vanes. Alternative fuels also has been widely used in various industries for various purposes because fossil fuel resources are dwindling. Thus, fuels such as bio-oil emulsion, has been used to replace diesel fuel. In this study, emulsified biofuel was produced by using palm oil that has been mixed with water. The mixture was blended using an ultrasonic homogenizer. Emulsion between oil and water able to produce the phenomenon of micro explosions. The different percentage of water in oil solution would give a different effect. Thus the properties each percentage of 1-5% water content samples were studied, including the size of microstructure, density and calorific value. Emulsified biofuel with 5% of water content has a size about 4μm, (in the range to produce the phenomenon of micro explosions). The sample of design guide vanes were tested to obtain the mass flow rate of fuel, engine torque, brake power, brake specific fuel consumption, brake thermal efficiency and brake mean effective pressure by using emulsified biofuel with 5% water content. The best diesel engine performance was observed at the optimum conditions of 3 number of vane and 40 degree angle of vane using the emulsified biofuel at 5% water composition. Approximately torque produced is about 14Nm, brake power is 5kW, brake specific fuel consumption is 0.4kg / kwh, brake thermal efficiency is 24% and brake mean effective pressure is 280kPa.

CHAPTER 1
INTRODUCTION

1.1 Overview

Nowadays, engineer or manufacturer of internal combustion engine face a two-fold challenge to provide the green engine. First, they must reduce the emission, or in another word, produce the engine towards zero emission. On the other side, they also have to increase the power of engine with higher efficiency. The diesel engine is very promising solution for the both issues. This is due to its superior fuel efficiency, compared to its gasoline counterpart, as well as its reliability and high torque. However, diesel engine also has few limitations and one of the main issues of diesel engine is the difficulty of performing cold starting [1]. Its difficulties situation to starting the diesel engine. Fuels is most important part to increasing the temperature and generated self-ignition.

Diesel engine usually uses diesel as a fuel. The diesel can be considered an environmentally friendly engine mainly due to its reduced. However, these fuels will not last long in the future as human will keep use it as source of fuels in their daily applications. Lately, there are many alternative fuels produced by human such as biofuel. Biofuel is production from vegetables, sunflower oil and palm oil. It considered one of most sustainable alternative to diesel fuel because vegetables, sunflower and palm can grow it ourselves. Emulsified palm oil is a one instance of the biofuel. Emulsified biofuel is a mixture of palm oil, surfactant, and water. Generally, people know that the two types of liquids, oil and water cannot be mix together because have differently density and surface tension. Main function of surfactant is tend to reduce the surface tension between oil and water and then makes them mix together. Next, different ratio water content in emulsified biofuel can be effect of atomization and micro-explosion.

Performance of engine depend on many factors. Many techniques have been implemented to improve the engine performance, such as adding additives, preheating the fuel before injection into the cylinder, adjusting the injection timing, increasing injection pressure or even modifying the combustion chamber geometry [2]. Emulsified biofuel is alternative fuel which has higher viscosity, boiling points and density compared to the diesel. From theory of internal combustion engines, it is known that the molecular chain of fuel inside the combustion chamber is disintegrated by swirl of air. Air swirl would assist the combustion inside the combustion chamber and mix the fuel with air better [3]. This concept is come out from the previous idea, which is generating a swirl of air flow before enters the combustion chamber by using guide vanes.

1.2 Problem Statement

Nowadays, the world is confronted with two issues, which crises on yield reduction of fossil fuel and environmental problem. Biofuel are used as new alternative for fossil fuel. Biodiesel is a one of biofuel where, many research about biodiesel state that it produce low regulated and unregulated emission [4]. Generally, biodiesel has lower brake thermal efficiency and higher brake specific fuel consumption compare to the diesel fuel. After that, biofuel from another sources are provided such as palm oil. However, a CI engine operating on palm oil fuel experiences a reduction in engine power, torque and an increase in specific fuel consumption compared to conventional diesel fuel. It is because to higher viscosity and density of palm oil as compared to the conventional diesel. Furthermore, emulsification of fuel is a one new technique to improve the fuel performance [5]. Emulsification of fuel is most suitable for diesel engines applications. Water-in-oil emulsion is means, water enclosed by oil droplet provide micro-explosion diesel surrounded water particle. Micro-explosion would occur when low boiling point produce by water surrounded by a high boiling point of diesel.

Percentage of water-in-oil emulsion that can effect atomization and micro-explosion of biofuel. This research, different percentage of water are tested on the Yanmar L70AE diesel engine. Surfactant is used in the solution of water and palm oil. Surfactant is used in order to reduce surface tension between water and oil. When both surface tension are release, it makes both liquid easy to blend together. In preparing process of emulsified biofuel, one important factor is time of blend. Time of blend the emulsified biofuel must be consistent. Ultrasonic Homogenizer is use to mixing two of different liquid (palm oil and water).

However, a CI engine operating with using biofuel has experiences like reduction in engine power, torque and an increase in specific fuel consumption compared to conventional diesel fuel. These problems arise from the physical and chemical properties of biofuel compared to conventional diesel fuel such as higher viscosity and boiling points. Thus, biofuel operated engines provide lower combustion efficiency and this can lowers the engine performance because the fuel molecules are heavier and this reduces the ability of the fuel to move and mix with the air. New research must been implemented to solve these problems. The main issue for this problem is higher viscosity of biofuel. It makes fuel molecules are heavier and reduces the ability of the biofuel to move and mix with air.

By referring previous research by Carrareto et al. the properties of biodiesel compared to diesel fuel. The research state that the viscosity of biodiesel is higher than diesel fuel. In study of internal combustion engine, the molecules of biodiesel can evaporate more and move as fast mixing process with air. The result show that by using biodiesel will similar or better performance compared to diesel fuel. In order to improve the fast mixing between air and biofuel, swirl of air must be increased. The swirl of air can guide by vane. The concept is generated swirl in the air flow before it enters the combustion chamber. This concept expected can improve the mixing between air and biofuel. Then, the biofuel with higher viscosity can combust smoothly and improve the overall performance of diesel engine.

1.3 **Objective**

The objectives of this project are as follow:

1. To study the effect of emulsified biofuel by different water composition as the source of fuel to the overall performance of diesel engine.
2. To design and fabricate the inlet guide vane design (GVD) at different number and different angle of vane for biofuel application in diesel engine.
3. To study the effects of inlet guide vane design (GVD) to the performance of diesel engine using biofuel as source of fuel.
4. To determine the best performance of diesel engine at the optimum conditions of biofuel emulsion (water composition), number of vane and angle of vane.

1.4 **Scope**

This project is to characterize different water composition as the source of fuel and different characteristic of guide vane design to use on the diesel engine. Therefore, this project will cover the scopes as follow:

1. Providing procedures of emulsification process for emulsified biofuel by using Ultrasonic Homogenizer (UH).
2. Prepare various samples of emulsified biofuel with different percentages of water content (1-5%) in the emulsion between palm oil and water.
3. Design the inlet guide vane in term of different number of guide vane and different angle of guide vane by using software SolidWorks2014.
4. Print the design of inlet guide vanes by using the machine 3D Printing Rapid Prototyping.
5. Do test run on Yanmar L70AE diesel engine by using different samples of emulsified biofuel to each inlet guide vanes design
6. Study the engine performance.
7. Determine the best design and the optimum percentage of water content (%) based on the best engine performance.

1.5 **Outline of report**

This thesis is divided into five main chapters. The first chapter discusses on overview of emulsified biofuel and guide vanes. Problem statement regarding the development of emulsified biofuel and guide vane are also reviewed in this chapter. This chapter also contains the project scopes, project objectives and outline of the report.

In Chapter 2, the literature review based on the Principle of water-in-diesel emulsion, microstructure of emulsified biofuel, engine performance using emulsified diesel fuel, significance of various properties of biodiesel and introduction to the guide vanes design will be presented.

In Chapter 3, the methodologies in term of experimenting the emulsified biofuel will be presented. This chapter also include the fabrication of guide vane.

In Chapter 4, results obtained from the experiments will be discussed and verified here. Then, optimization will be discussed to ensure that the results from the experiment are acceptable.

Last but not least, the conclusion of the project will be made in chapter five. Some suggestions and recommendations are given for improvement in future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Engine performance using emulsified diesel fuel

Previous research were conduct the experiment to compare engine performance together with their impact on the environment has been tested when the machine was powered by both diesel fuel pure and provided with various quantities of water content in diesel fuel [6]. The total quantity of water added is between 5% and 30% by volume. The engine speed during experimental work is in the range of 1000-3000 rpm.

A four-stroke, four-cylinder, water-cooled and direct injection engine used in this work. A type 4-cycle diesel engine is 30 automotive test bed with 4 cylinders, cylinder diameter is 72.25 mm, 88.18 mm stroke length, and has a compression ratio of 21.5 was used in this study. Additional amenities include a dynamometer to measure the force acting on the shaft, then the tachometer to measure the revolution of the output shaft, and a stopwatch to measure the time required for the fuel consumption.

To stabilize the emulsion, 2% by volume of Tween 20 surfactant was used. Six diesel mixed liquid provided, namely; 5%, 10%, 15%, 20%, 25% and 30% water by volume. The density, viscosity and caloric value has been determined for the fuel emulsion is provided. Pure diesel was first used to set a baseline for comparison. Thermodynamic DIESEL-RK software has been used widely and performance optimization for compression ignition engines. The main reason for using the software is to make a comparison between experimental and theoretical studies using the software DIESEL-RK.

2.1.1 Engine Torque

Values obtained experimentally engine torque compared with the theoretical value in Figure 2.1 and Figure 2.2 As shown in these figures, the torque increases with engine speed to the maximum and then begins to decrease due to friction losses (negative torque), which increases the engine speed and also due to the fact that the engine is not able to swallow a full charge with water at high speed.

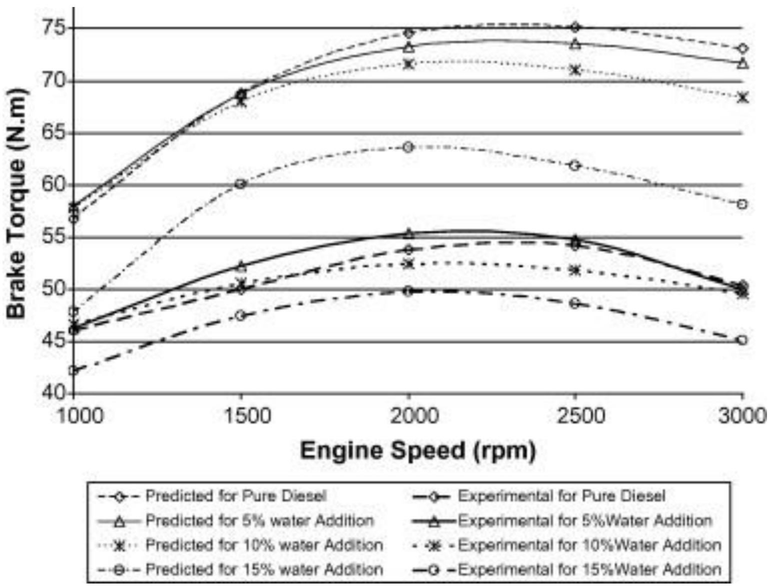

Figure 2.1 Comparison between experimental and theoretical values (DIESEL-RK software) of brake torque for pure diesel, 5%, 10% and 15% water addition

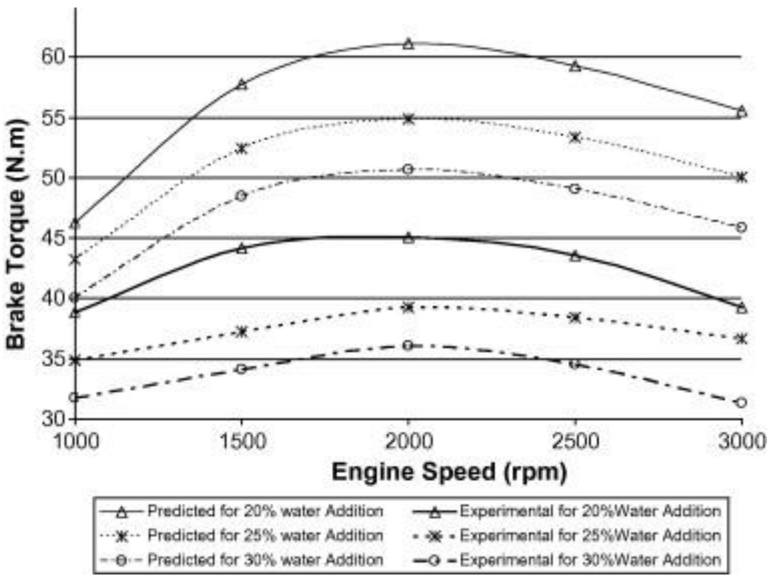

Figure 2.2 Comparison between experimental and theoretical values (DIESEL-RK software) of brake torque for 20%, 25% and 30% water addition.

The effect of the addition of water in the form of emulsions in engine torque in a state of flux for a variety of speeds shown above. As indicated in this figure is the maximum torque is generated when the engine power of a fuel water emulsion 5% and operating at a practical speed. Increasing the percentage of water in the emulsion generated torque decreases. This is due to the extra power above the piston is provided by the pressure exerted by steam. When the charge was dismissed in the cylinder, the water will turn to high pressure.

2.1.2 Engine Power

Values obtained from experimental engine braking power as compared with theoretical values in Figure 2.3 and Figure 2.4. As indicated in this figure is the maximum power generated when the engine is powered by a fuel-water emulsion 5% and operating at a practical speed. And as increasing the percentage of water in the emulsion resulting reduction in power. Fuel emulsion requires less compression work (negative) of diesel fuel for any further delay in the compression stroke. This helps to achieve higher peak pressure after TDC to generate more power output during the expansion stroke. In addition, when the rise in diesel ignition delay will be ready for more physical (evaporation, mixing) to a chemical reaction, which increases the fraction of diesel combusted and the heat release rate in the premixed combustion. This causes an increase in combustion and improved combustion efficiency.

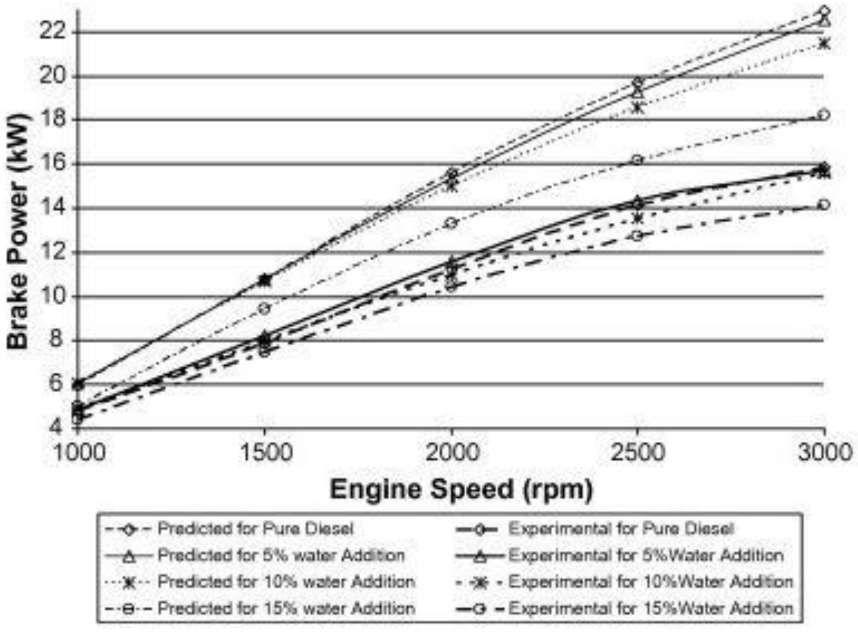

Figure 2.3 Comparison between experimental and theoretical values (DIESEL-RK software) of brake power for pure diesel, 5%, 10% and 15% water addition.

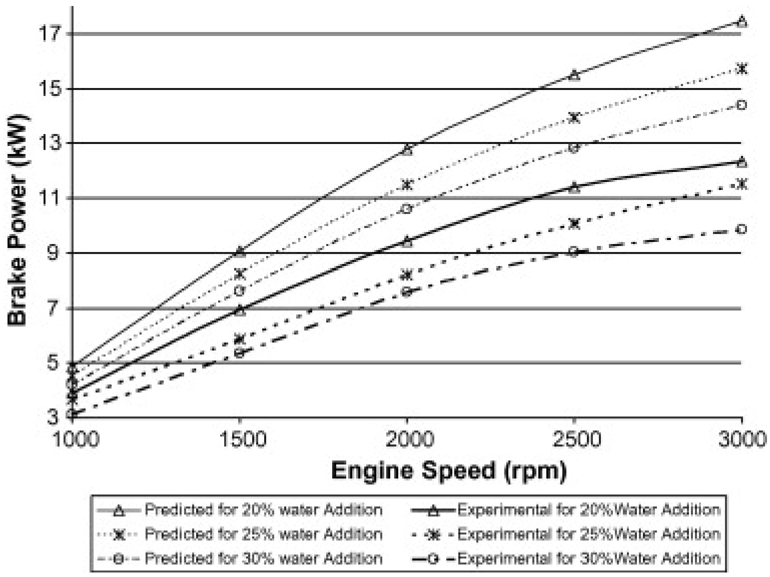

Figure 2.4 Comparison between experimental and theoretical values (DIESEL-RK software) of brake power for 20%, 25% and 30% water addition.

2.1.3 Engine Brake Specific Fuel Consumption (BSFC)

Value experimentally derived from the specific fuel consumption engine braking compared with the theoretical value in Figure 2.5 and Figure 2.6. As shown in these figures, the BSFC decreases engine speed until it reaches a minimum value, beyond which it increases the speed of the engine; because at low speeds, the heat loss to the walls of the combustion chamber and the combustion efficiency is proportionately larger poorer, resulting in fuel consumption higher for the power generated. At high speed, the friction force increased at a rapid pace, resulting in a slower increase in power versus fuel consumption with a consequent increase in BSFC.

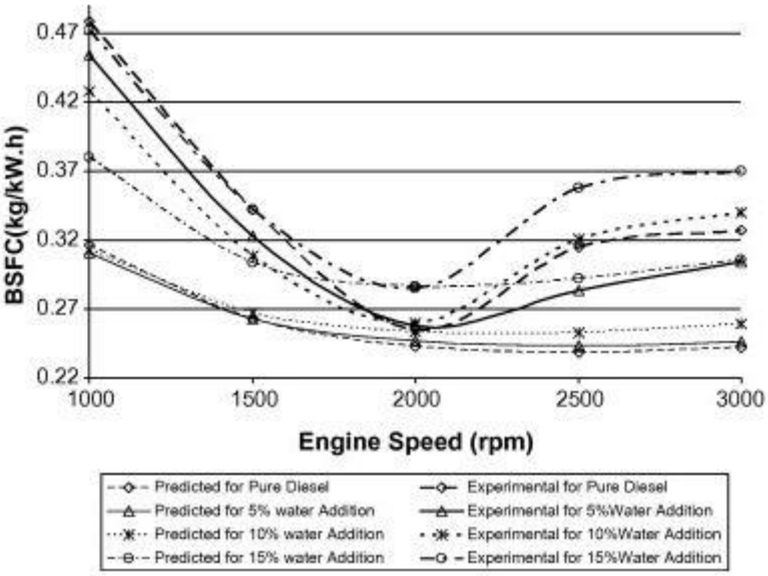

Figure 2.5 Comparison between experimental and theoretical values (DIESEL-RK software) of brake specific fuel consumption for pure diesel, 5%, 10% and 15% water addition.

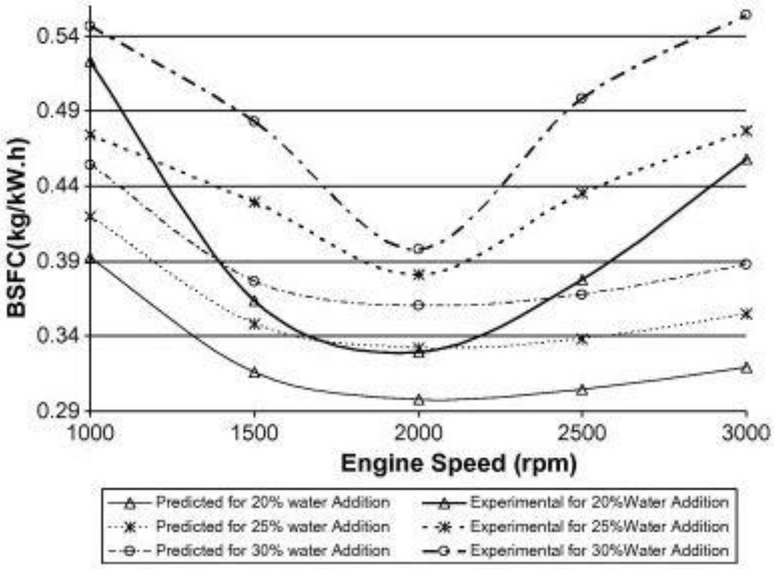

Figure 2.6 Comparison between experimental and theoretical values (DIESEL-RK software) of brake specific fuel consumption for 20%, 25% and 30% water addition.

At higher speeds increases the percentage of water in the emulsion, the BSFC increases. However, at lower speeds here is no significant change in BSFC with the amount of water added. For BSFC is increasing as a percentage of water in the emulsion raise a significant amount of diesel is displaced by the same amount of water. This means less diesel fuel in fact contained in each volume of the emulsion.

2.1.4 Engine Brake Thermal Efficiency

Value experimentally obtained engine brake thermal efficiency compared with the theoretical value in Figure 2.7 and Figure 2.8. As shown in these figures, the increase in thermal efficiency when the engine speed increases until it reaches the maximum value. Apart from this, the thermal efficiency of the engine speed decreases. Due to the low speed, the time available for heat transfer to the cylinder walls, and the number is important for a greater proportion of heat loss occurs. Speed increases braking power increase, which means a higher thermal efficiency is obtained. Higher speeds, however, accompanied by a rapid increase frictional force and by greater inertia in moving parts, this leads to a decrease in thermal efficiency.

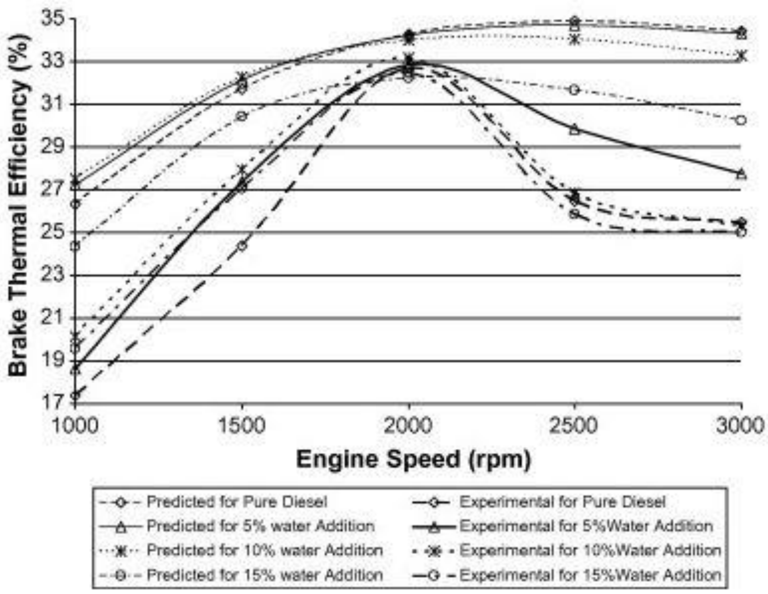

Figure 2.7 Comparison between experimental and theoretical values (DIESEL-RK software) of brake thermal efficiency for pure diesel, 5%, 10% and 15% water addition.

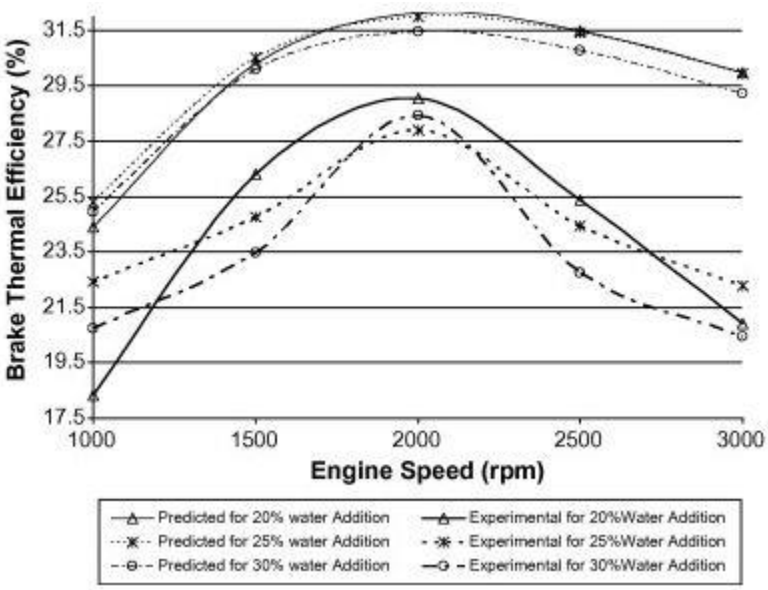

Figure 2.8 Comparison between experimental and theoretical values (DIESEL-RK software) of brake thermal efficiency for 20%, 25% and 30% water addition.

The maximum average increase in brake thermal efficiency occurs when 5% water in the emulsion used due to increase of brake power.

Therefore, experimental of fuel below the 5% water content must be conduct to measure the performance in diesel engine.

2.2 Principle of water-in-diesel emulsion

The introduction of water in the diesel engine combustion zone was first proposed by Prof. B. Hopkinson to improve thermal efficiency, reduce exhaust emissions and make the better cooling of the gas engine [7]. The micro-particle blasting of water during the combustion process helps to improve atomization and mixing of the air-fuel mixture. Figure 2.9 show the micro-explosion. The emulsion consists of two immiscible liquids.

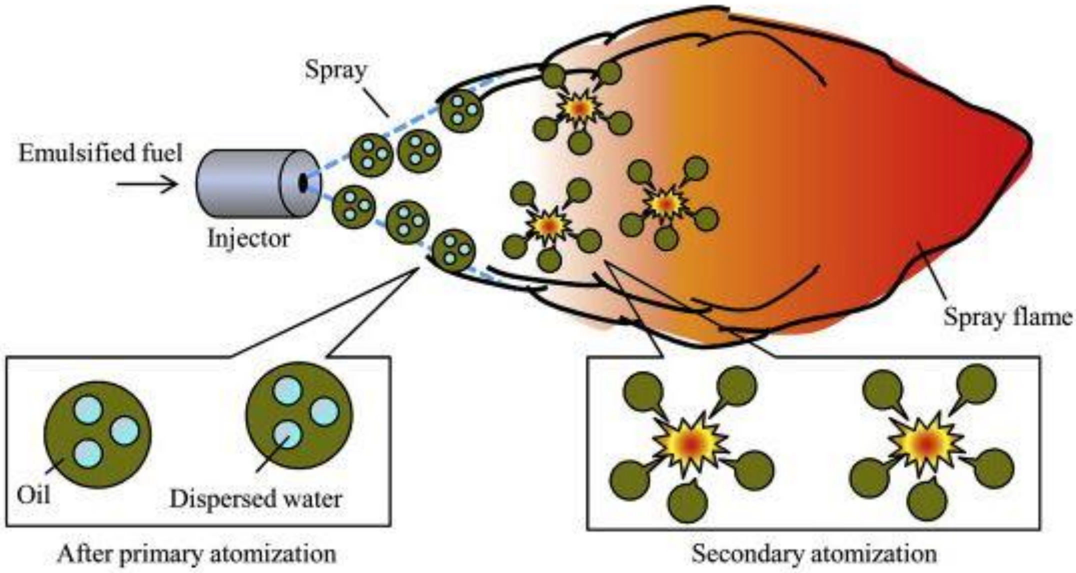

Figure 2.9 Schematic Diagram of Spray Flame of Emulsified Fuel

When compression happen in combustion chamber the heat transfer takes place from diesel to water in diesel engines, the low boiling point goes to unstable superheated state leading to micro-explosion resulting in better mixing of fuel with air. The onset of micro-explosion is caused by the evaporation of two or more liquid components with different fluctuations in high-temperature environments. Because of the finite velocity dispersion liquid, the less volatile component will cover the surface, this leads to rapid heating of the droplets. When the temperature reached the limit of superheat, micro-explosions occurs. The emulsions produced by high-energy emulsification methods in the presence of surface-active agents or surfactants. These methods include mechanical agitation of high-energy, high-pressure homogenizers, ultrasonic vibration and supersonic [8]. A research about how microstructure size of the fuel droplet will affecting the micro-explosion phenomena had been done. The micro-explosion phenomena will not occur if the droplet size is in the range of 20 –30 μm [7].

2.2.1 Role of surfactants

In general, the fuel emulsions are thermodynamically unstable systems. In a period of time, fuel emulsion gradually separated into two immiscible phases. To form a liquid fuel that kinetically stable, surfactants are used to reduce the surface tension between the water and diesel molecules. Surfactants contain polar (or) hydrophilic heads and non-polar (or) hydrophilic tail incorporated to weaken the surface tension of the medium in which it is dissolved.

The main factors to form a stable emulsion droplets are in accordance with the nominal value of hydrophilic-lipophilic balance (HLB) and the molecular structure of the surfactant. Low HLB has a tendency to create a stable water-in-oil emulsion while high HLB has a tendency to make a stable emulsion of oil in water [9].

2.2.2 Phases of emulsion fuel

Diesel water emulsions are classified based on the relative spatial distribution of diesel and aqueous phase. Generally, there are two different forms of the two-phase emulsion, first is water-in-oil (W / O) and second is oil in water (O / W). Emulsion consisting of droplets of water dispersed in the oil phase is known as emulsion W / O, and emulsion comprising oil droplets dispersed in the aqueous phase known as O / W emulsion (refer to Figure 2.10).

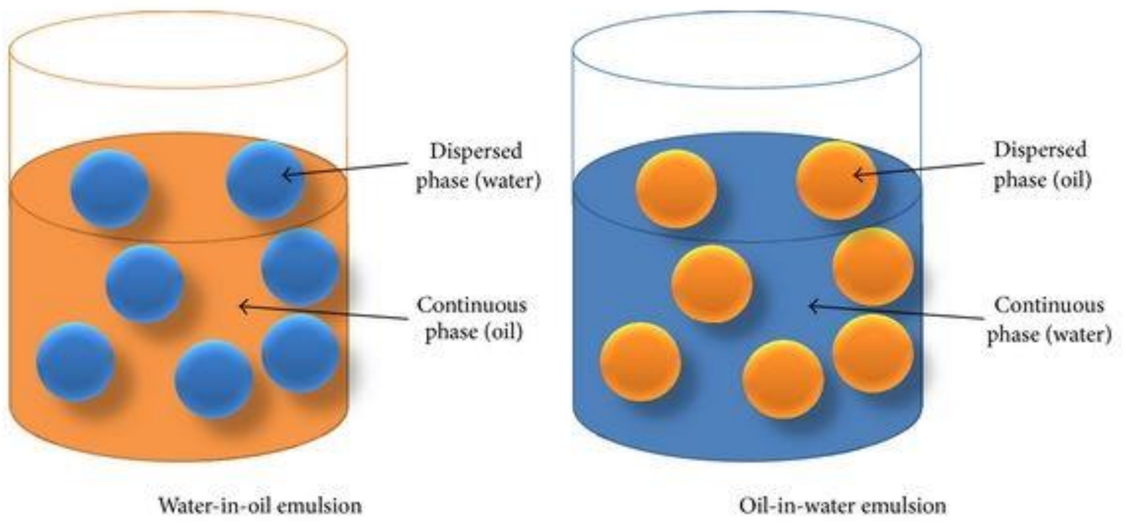

Figure 2.10 Concept of two-phase water-in-oil and oil-in- water emulsions.

2.2.3 Ultrasonic Homogenizer

Biodiesel is produced by two liquid immiscible. High speed stirring often used to enhance the relationship between the two phases. It uses a lot of energy, and it's not an effective way to contact the two phases. Effect of ultrasonic parameters on biodiesel yield depends on amplitude, pulse of vibration, diameter of the ultrasonic probe, irradiation distance and reactant flow rate [10]. Ultrasonic assisted biodiesel reactor is a practical solution to increase the level of mixing [11].

2.3 Significance of Various Properties of Biodiesel

There are various thermodynamic and physical properties of the food oil is very important for the process modelling and simulation tools. Thermo physical properties used for the characterization of biodiesel and they also required for combustion modelling. Physical properties of biodiesel [12] and their values or ranges given below in Table 2.1. Table 2.2 show the properties comparison between biodiesel and diesel.

Table 2.1 Physical Properties of Biodiesel

Common name	Biodiesel (bio-Diesel)
Common Chemical name	Fatty Acid Methyl Ester (FAME)
Chemical Formula Range	C14–C24 methyl esters
Kinematic viscosity range (mm2 /s, at 313 K)	3.3–5.2
Density Range (kg/m3 , at 288 K)	860–894
Boiling point range (K)	>475
Flash point range (K)	420–450
Distillation range (K)	470–600
Vapor pressure (mm Hg, at 295 K)	<5
Solubility in water	Insoluble in water
Physical Appearance	Light to dark yellow, clear liquid
Odor	Light musty
Biodegradability	More biodegradable than petroleum Diesel
Reactivity	Stable, but avoid strong oxidizing agents

Table 2.2 Properties of Biodiesel and Diesel.

Fuel Properties	Biodiesel	Diesel
Density at 15°C, g/cm³	0.8834	0.8340
Viscosity at 40°C, mm²/s	4.47	2.83
Sulfur content, %	< 0.005	0.034
Carbon, %	76.1	86.2
Hydrogen, %	11.8	13.8
Oxygen, %	12.1	---
Flash point, °C	178	62
Cetane Number	56	47
Net Calorie value, kJ/kg	37,243	42,588

2.3.1 Kinematic Viscosity, Dynamic Viscosity and Viscosity Index

Kinematic viscosity is defined as the resistance of the liquid flow. It refers to the thickness of the oil, and is determined by measuring the amount of time it takes to move a given oil to pass through the orifice of a certain size. Kinematic viscosity is the most important property of biodiesel because it affects the operation of the equipment and the fuel injection spray atomization, especially at low temperatures when the viscosity increases affect fuel instability [13]. Moreover, the high viscosity can lead to the formation of engine deposits of soot and fuel atomization is not enough. Kinematic viscosity is measured according to ASTM D445. Dynamic viscosity known as absolute viscosity. It can be calculated by multiplying the kinematic viscosity with the density of the fuel. Viscosity index (VI) is an arbitrary measure viscosity changes with temperature. It is used to characterize the lubricating oil in the automotive industry.

2.3.2 Flash point

Flash point is another important property for any fuel. It is the temperature at which it will ignite when exposed to a flame or spark. Flash point varies inversely with fluctuating fuel. Generally, crude oil has a higher flash point than diesel, which is usually more than 150 ° C, whereas conventional diesel fuel having a flash point 55-66 ° C are safe for transport, handling and storage purposes [13].

2.3.3 Density

Density is the relationship between mass and volume of liquid or solid and can be expressed in units of grams per litre (g / L). The density of diesel fuel is important because it gives an indication of the delay between the injection and combustion of fuel in a diesel engine (ignition quality) and energy per unit mass (specific energy). This can affect the efficiency of atomization of fuel to the combustion system airless [14].

Various techniques have been attempted to modify the chemical compounds biodiesel and some researchers tried to adjust the configuration of the engine to comply with the requirements for biodiesel.

2.4 Introduction to the Guide Vanes Design

Compression ignition combustion theory says, when fuel is injected into the combustion chamber, the fuel molecules first will evaporate and then mix with the higher pressure and higher temperature air before combustion started. Anyway, the higher viscosity and molecular weight of the presence of biodiesel will increase the length of penetration and reduce the cone angle of the injected fuel causes a reduction in the combustion efficiency and engine performance. Preheating and blending biodiesel with diesel injection and advanced real-time help biodiesel evaporate more progressive and spread outside of the core fuel injected [2]. Therefore, in compliance with the hypothesis, if the biodiesel molecule can evaporate and move as fast as or faster than the diesel to improve the process of mixing with water, CI engines using biodiesel will produce the same performance or better.

When the fuel is injected into the air in the cylinder with the higher turbulence kinetic energy (TKE), velocity, swirl and tumble, will improve combustion and ultimately can improve engine performance and reduce emissions. Method guide vanes have been to improve the characteristics of the flow of air in the cylinder as it is the easiest method compared to using a changing the geometry of the piston head or modify the intake runners [15]. Modifying the geometry of the combustion chamber can improve combustion and reduce emissions. The investigation also shows that the geometry of the combustion chamber which increases swirl around TDC, will lead to more efficient combustion as show on Figure 2.11.

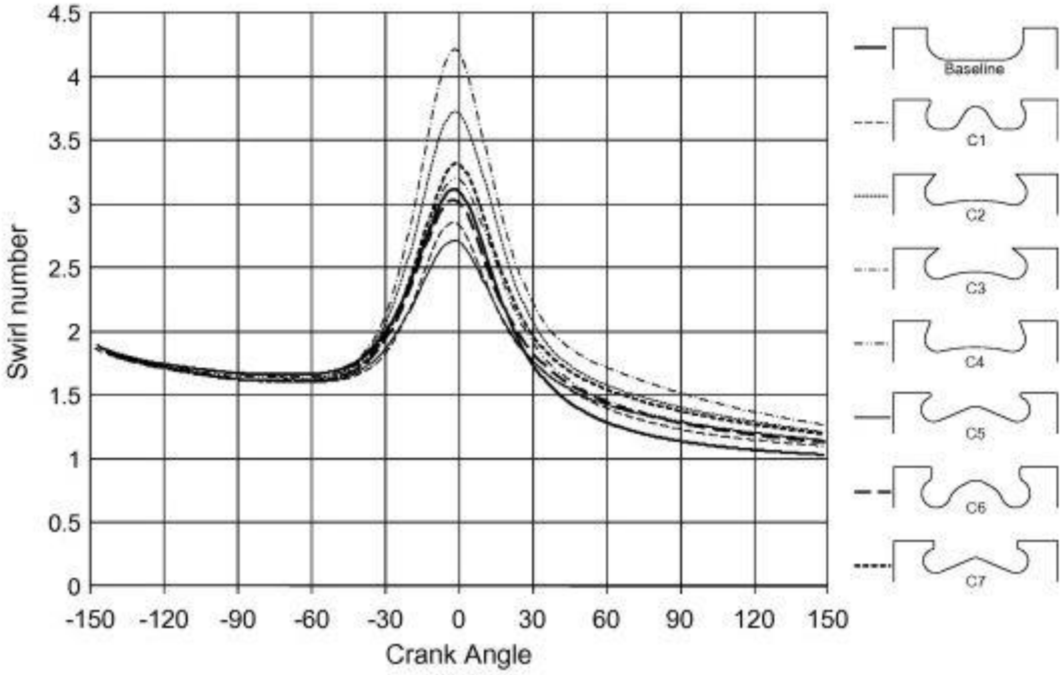

Figure 2.11 Swirl Number Variation during closed- vale duration for various bowl geometries

Velocity distributions in both configurations at different times around TDC are shown in Figure 2.12. Before TDC, the maximum velocity in C1 is more than that of baseline. But, at TDC and after TDC, the maximum velocity in the C1 configuration is less than that in the baseline case.

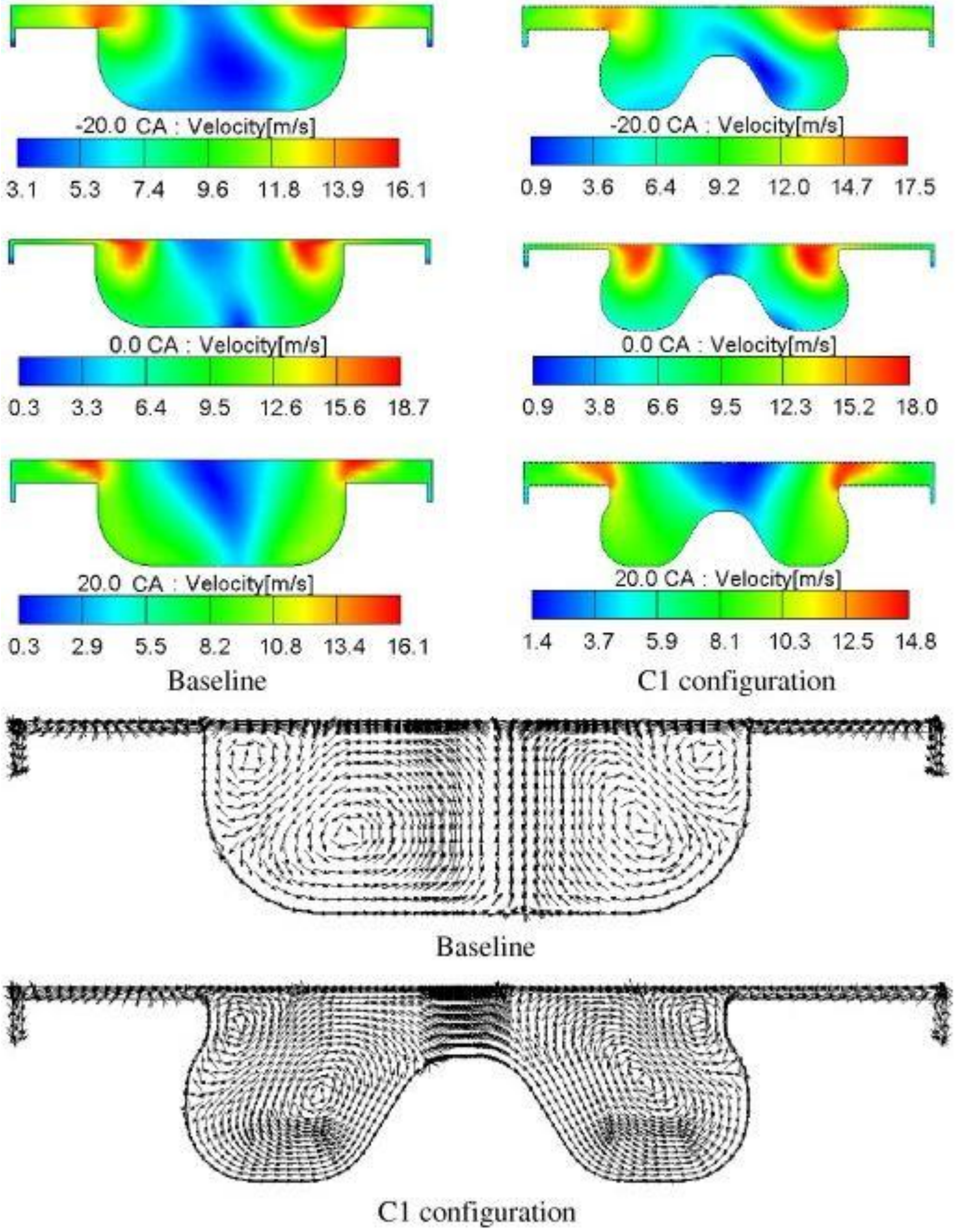

Figure 2.12 Distribution of velocity in the central plane of cylinder and velocity vectors in the central plane of cylinder at TDC.

From the figure, it can be noted that the high velocity vortex squish flow is almost the same in both configurations. Because vortex interaction, squish, two counter-rotating vortex is formed in the combustion chamber. Configuration C1 has a diameter that is less than the basic entry configuration. Therefore, the squish flow is expected to penetrate more toward the centre of the bowl. In this study, however, penetration squish flow to both C1 and basic geometry is the same. If the basic configuration, the larger vortex spread to the centre of the cylinder. But, in the C1 configuration, the projected central vortex causes the larger to move outwards, which in turn displaces a smaller vortex towards the outside. Thus, the central projection in the C1 block squish flow enters deep into the combustion chamber. These reasons explain some vortex is lower in the case of C1.

CHAPTER 3

METHODOLOGY

3.1 Overview

In emulsion between palm oil and water (water-in-oil), the microstructure of emulsion, micro-explosion in the cylinder (combustion chamber) and overall engine performance are related to the percentages of water content. The mixing of emulsified biofuel and air also related to the guide vane by create the swirl of air before enter the combustion chamber. The project is to study the design characteristic of inlet guide vane for application of emulsified biofuel in diesel engine. Some experiment procedure will described in this chapter in order to obtain the optimum percentage of water content in emulsified biofuel and the best design of inlet guide vane.

3.2 Preparation of Emulsified Biofuel

The emulsified biofuel is emulsion which consists three types of liquid. Emulsified biofuel consists of palm oil, water and surfactant. To produce water-in-oil emulsion, surfactant liquid is important. The equipment that had been used to blend the emulsion is Ultrasonic Homogenizer (UH) machine.

The basic procedure in order to prepare 1Litres emulsified biofuel with 1% of water content are as follow the instruction. First, the palm oil is filled into a measuring cylinder until 970ml of palm oil is obtained. Then, the palm oil is poured into an empty beaker. After that, 20ml of Triton X-100 surfactant is poured into the container that contain the palm oil as shown on Figure 3.1. As mention before, surfactant liquid is important. Surfactant is a substance that tends to reduce the surface tension of a liquid in which it is dissolved. So, it is used to make sure that the water and palm oil can be mixed together and forming a water-in-oil emulsion. The detail of Triton X-100 are as follow:

- Name: Octylphenol Ethoxylate
- Surfactant Type: Nonionic
- Chemical formula: $C_{14}H_{22}O(C_2H_4O)_n$ (n = 9-10)
- Molar mass: 647g mol^{-1}
- Density: 1.07 g/cm^3

Figure 3.1 Poured 20mL of surfactant (Triton X-100)

The container that contains Triton X-100 surfactant and palm oil is put into the Ultrasonic Homogenizer (UH) machine. The Ultrasonic Homogenizer machine is set with continuous mode, 40Hz frequency and 5 minutes of blending time as show on Figure 3.2.

Figure 3.2 Setup the Ultrasonic Homogenizer machine

The specifications of the Ultrasonic Homogenizer machine are as follows:

Features:

- Auto-tuning and power control convenience for user
- Timer control the total working time from 1 minute to 60 minutes
- Display the remaining time on countdown state
- On/OFF impulse timer
- continue setting from 1s , 4s or 8s
- Automatic amplitude compensation to make the amplitude not changed following the carrying.

The mixture of palm oil and surfactant is blended together and after 15 seconds of blending time, 5ml of water is added into the mixture to form an emulsion as show on Figure 3.3. After blending process is finished, take the emulsion out from the Ultrasonic Homogenizer machine and let it to be cooled at room temperature.

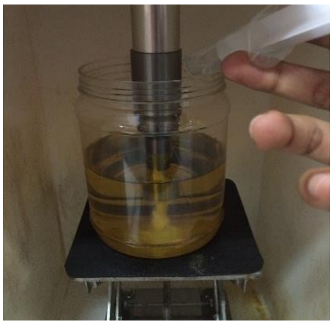

Figure 3.3 Water added into the Mixture

Use all of the steps above in order to prepare another emulsion with different percentages of water by following Table 3.1.

Table 3.1 Composition of emulsified biofuel with different ranges of water content

Percentage of water content (%)	Volume of Triton X-100 (ml)	Volume of palm oil (ml)	Volume of water content (ml)
1	10	485	5
2	10	480	10
3	10	475	15
4	10	470	20
5	10	465	25

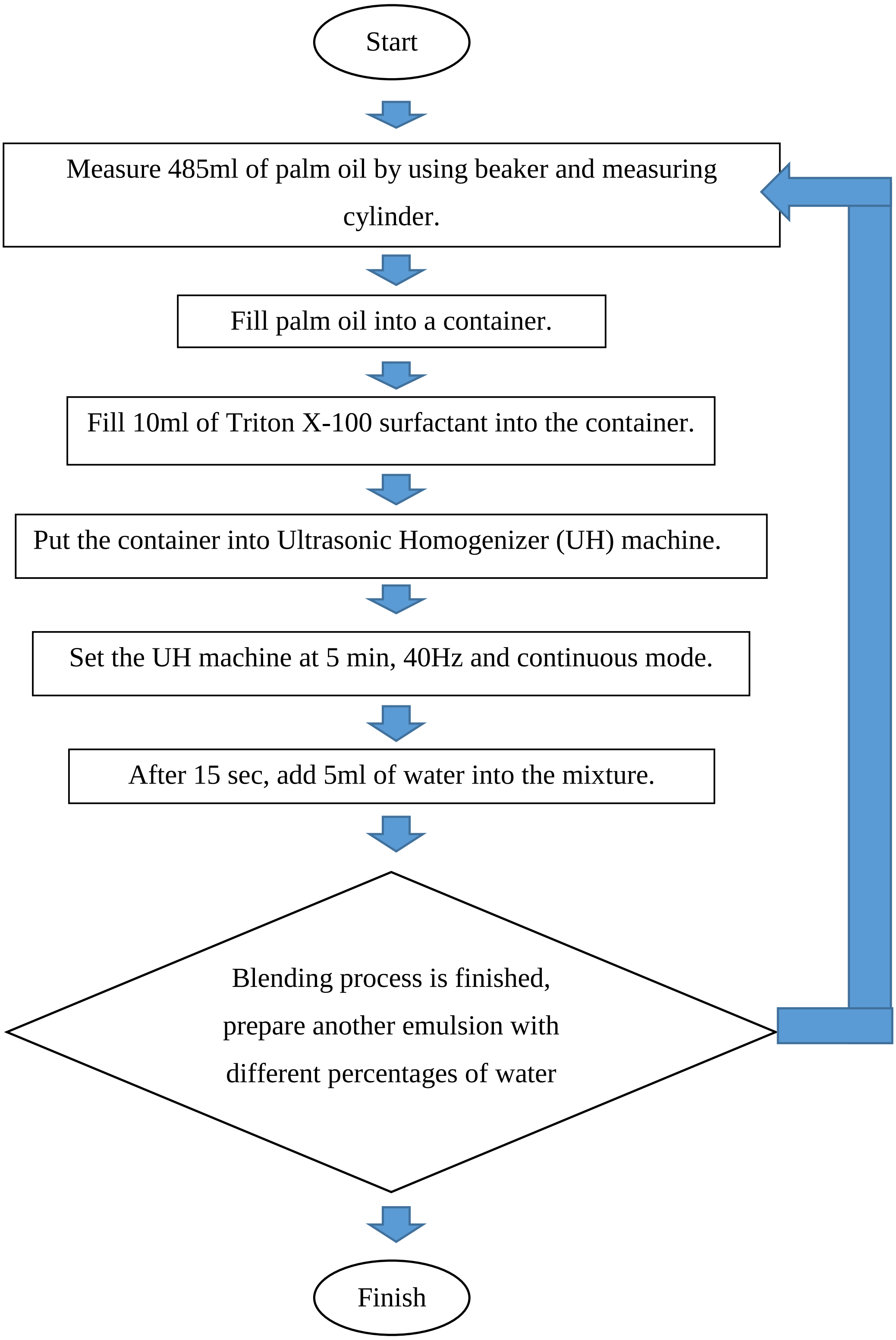

Figure 3.4 Emulsification process