Effect of Different Percentages of Biodiesel-Diesel Blends on Combustion, Performance and Emission Characteristics of 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. This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/references are appended. I hereby give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available outside organizations.

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LIST OF ABBREVIATIONS

DIT = Dynamic Injection Timing

PAH = Aromatic Hydrocarbon

ICE = Internal Combustion Engine

SI = Spark Ignition

IC = Internal Combustion

CI = Compression Ignition

TDC = Top Dead Centre

BDC = Bottom Dead Centre

CN = Cetane Number

ECU = Electronic Control Unit

BTE = Brake Thermal Efficiency

BSFC = Break Specific Fuel Consumption

HRR = Heat Release Rate

JTME = Jatropha Methyl Ester

WPOME = Waste Palm Oil Methyl Ester

COME = Camola Oil Methyl Ester

HC = Hydrocarbon

$\mathbf{CO_2}$ = Carbon Dioxide

PM = Particulate Matter

$\mathbf{O_2}$ = Oxygen

CO = Carbon Monoxide

NO = Nitrogen Oxide

ABSTRAK

Satu kajian perbandingan kesan peratusan yang berbeza campuran biodiesel-diesel (B20, B45 dan diesel asas) pada prestasi, pelepasan dan pembakaran pada sembilan kelajuan yang berbeza (1600, 1800, 2000, 2200, 2400, 2600, 2800, 3000 dan 3200) telah dijalankan. Tork enjin untuk B45 adalah yang paling tinggi berbanding dengan B20 dan asas diesel. Walau bagaimanapun, tork berkurang pada kelajuan tinggi untuk setiap campuran biodiesel-diesel dan diesel asas. Karbon monoksida (CO), hidrokarbon (HC) dan pelepasan asap menurun untuk semua campuran biodiesel-diesel. Walau bagaimanapun, nitrogen oksida (NO) meningkat pada 2600 rpm untuk semua campuran biodiesel-diesel dan diesel asas disebabkan oleh bahan api oksigen, suntikan masa dinamik automatik (DIT), penembusan yang lebih tinggi dan suhu yang tinggi. Tempoh lengah pencucuhan menurun semasa peningkatan peratusan biodiesel disebabkan bilangan setana yang tinggi. Selain itu, kenaikan tekanan adalah rendah kerana bilangan setana meningkat jadi enjin akan berjalan dengan lancar.

ABSTRACT

A comparative study of effect of different percentages of biodiesel-diesel blends (B20, B45 and base diesel) on performance, emission and combustion at nine different speed (1600, 1800, 2000, 2200, 2400, 2600, 2800, 3000 and 3200) was carried out. The engine torque for B45 shows the highest compared with B20 and base diesel. However, the torque reduce at high speed for every biodiesel-diesel blend and base diesel. Carbon monoxide (CO), hydrocarbon (HC) and smoke emissions decreased will all biodiesel-diesel blends. However, nitrogen oxide (NO) emission increase at 2600 rpm for all biodiesel-diesel blends and base diesel due to oxygenated fuel, automatic dynamic injection timing (DIT), higher penetration and higher temperature. The ignition delay period decreased as increase the biodiesel percentage due to high cetane number. Besides, the pressure rise was low as cetane number increased so engine running smoothly.

CHAPTER 1

1.1 Introduction

Nowdays, Diesel engine is widely increase of demand compared to spark ignition engines according to it cost, performance and complexity. Diesel engine has high compression ratio compared to spark ignition engines [1]. Most of the vehicles nowdays are using conventional mechanical fuel injection system. The fuel injection timing and injection quantity are hard and not precisely controlled under operating conditions. Besides, engine performance, break specific fuel consumption and emissions level is not easily achieved [2].

Next, the increasing of vehicles give concern of global warming and depletion of fossil fuel resources [3]. Therefore, the demand of diesel engines is increase because diesel engine is more better in term of economy, durability and renewable fuel. Research also was made using biodiesel fuel that blend with diesel which can affected the combustion, performance and emission of the engine. Besides, by implement the biodiesel in diesel engines it also can enhancement of fuel quality, self reliance of energy need and boosting economy. The engine is more improved in term of emission, ignition delay, knocking and engine running depending on cetane number compared to base diesel fuel. The chemical properties in biodiesel are lower than base diesel that would effect on formation of particulate matter in diesel engines. However, the bulk modulus is higher with biodiesel than base diesel as this properties indicates the compressibility of the fuel that effect on injection characteristics of diesel engines. In a diesel engine, the fuel spray characteristics which deal the interaction of the injected fuel with the surrounding hot air during ignition delay period and combustion, is mainly dependent on injection characteristics such as injection delay, in-line fuel injection pressure, dynamic injection timing (DIT), in-cylinder injection duration and injector nozzle configuration. The combustion and engine performance can be improve depending on fuel spray because it influences the mixtures formation process of fuel with air in engine cylinder [17].

- Combustion characteristics of a diesel engine using biodiesel-diesel blends.

The performance and emission characteristics of engine is depending on combustion characteristics. Combustion characteristics will be different for biodiesel and diesel fuels because has different properties. Improvement of mixture formation process that influences ignition and combustion process in engines [18,19]. Biodiesel fuel consist of 10-11% oxygen which would enhance heat release rate during combustion and reduce emission except NOx [20,21]. Biodiesel combustion diesel engine will start earlier at advanced dynamic injection timing due to higher bulk modulus. The peak of pressure is lower for biodiesel due to shorter ignition delay [22]. If ignition delay is high it leads to high rate of pressure rise, some extend to knocking, noise and NOx emission, it is necessary to lower the ignition delay. So, for the further improvement of the performance and emission reduction the combustion characteristics such as ignition delay, start of combustion, rate of pressure, etc of the diesel engine need to studied.

- Performance and emission characteristics of diesel engine using biodiesel-diesel blends.

Biodiesel has low carbon content than diesel fuel. Hence, biodiesel fuelled diesel engines will emit lower carbon based emissions than base diesel. Graboski and McCormick [23] studied the performance and emission characteristics of a diesel engine fuelled with biodiesel–diesel blends (B10, B20, B30, B50 and B100) as compared to base diesel. The results indicated that CO, HC, PM, smoke and Poly-Aromatic Hydrocarbon (PAH) emissions decreased with the biodiesel–diesel blends whereas brake specific fuel consumption (BSFC) and NOx increased significantly [24,25]. Rakopoulos et al. [26] reported that the BSFC increases with the oxygen enrichment in the fuel but it does not affect with oxygen enrichment in the intake air. The percentage of torque reduction was reported as 0.85%, 1.25%, 2.33% and 5.90% with B20, B35, B65 and B100 respectively. Experimental investigation was carried out to study the performance and emission characteristics of a diesel engine fueled with different percentages of karanja biodiesel–diesel blends (B5, B10, and B15) [27].

1.2 Problem statement

This study would like to compare effect of biodiesel-diesel blends on combustion, performance and emission characteristics with base diesel of diesel engine. There are few problems identify in this study, which are:-

- PME or palm biodiesel are abundant in Malaysia and can be produced in large quantity. The current biodiesel fuel available at petrol station are B10. For the future the government is going to increase the blend ratio. However, engine operating with biodiesel blend will usually cause higher NOx, lower engine pressure and higher BSFC. Thus, this has motivated us to discover the feasibility of use palm biodiesel blend in CI engine.

1.3 Research objective

The objectives of this study, which are:-

i. To compare engine performance and emission characteristics of CI engine fuelled with biodiesel-diesel blends.
ii. To investigate combustion characteristics of CI engine using biodiesel-diesel blends and compare with those of baseline petroleum diesel.

1.4 Scope project

This scope of project mainly focuses on study how to design the system of the common rail injection on the single cylinder engine. The scopes of study are:

- ✓ Study about type of engine used in this project.
- ✓ Diesel engine combustion parameter (injection pressure, HRR & ignition delay).
- ✓ Performance characteristics.
- ✓ Emission characteristics.
- ✓ Study the properties diesel and biodiesel fuel.
- ✓ Using LabVIEW and Dewesoft software.

1.5 Thesis outlet

In this thesis consists of five (5) chapters that fully describe the overall information and details from the introduction to conclusion of this project where the publishing of this thesis signify the completion of Final Year project.

In a chapter 1, it is the introduction of the project to the research background, problem statement, objectives and scope of the project.

Chapter 2 is the fundamental component of the project structure and in this chapter it is about the literature review and mainly about the research related to this project from the past journal, articles, books and webpages as references in completing this project. Detail explanation about the research is described in this chapter.

In chapter 3, it's explained about the methodology for carried out the project in discussed here for more detail. The procedure, experiment and calculations will be explained briefly on how they conducted and needed to be included in the project.

After that in a Chapter 4, it discussed about the results and the discussion has been obtained after complete chapter 3.

Lastly, the chapter 5 is the final chapter in this thesis which is the conclusion of the project. The summary of the project implementation and achievement are included. The limitation of this project also included for next research to improve this system to be better in future.

CHAPTER 2

LITERATURE REVIEW

2.1 Type of engine

An engine is a device designed to transforms one form of energy into mechanical work. However, while transforming process energy from one to another, the efficiency of conversion plays an important role. Normally, most of the engine covert thermal energy to mechanical work called 'heat engines' which is meant a device that transform the chemical energy of a fuel into thermal energy and utilizes this thermal energy to perform useful work [9]. They also can be divided into four-stroke engine and two-stroke engines then by means of working process such as fuel ignition they are divided into gasoline engines, carburetor engines and diesel engine. Fig.2 below shows the classification of heat engines.

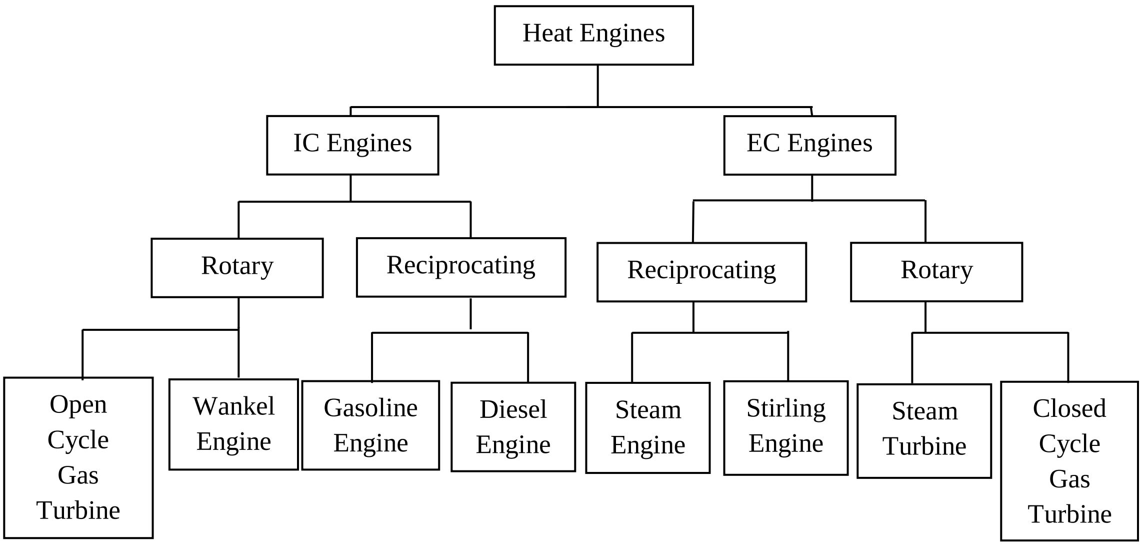


Figure 1: Classifications of Heat Engines

<u>Internal Combustion Engine (ICE)</u>

Internal combustion engine (ICE) is a heat engine where the combustion of a fuel occurs in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine the expansion of the high-temperature and high-pressure gases produced by combustion apply direct force to some component of the engine. Heat produced due to combustion between air and fuel mixtures is then help moved the piston. There are two type engines that can be classified in IC engine:

a) Spark Ignition (SI) engine

Spark ignition (SI) engine, combustion occurs due to the triggering of a spark between the spark plug electrodes, which gives rise to the propagation of a flame front. In this category of IC engines, the combustion is said to be normal if it is triggered by the spark plug and propagates "gradually" in the entire combustion chamber. The combustion stage strongly affects engine power, fuel consumption and noise emissions [11]. However, an abnormal combustion can be occurred due to auto-ignition of the air/fuel mixture when retained at high temperature and pressure for a long time. This knocking phenomenon due to sudden increase of cylinder temperature followed by pressure waves inside the cylinder that transmitted through the engine structure to the surrounding that can cause damage to the piston [10].

b) Compression Ignition (CI) engine

Compression (CI) engine, the fuels used is relatively higher reactivity such as diesel. These fuels cannot be mixed with air and then compressed into the cylinder because the combustion can be igniting spontaneously during compression stroke. Therefore, before the combustion started, the fuel immediately injected as a high pressure liquid spray into the already compressed air [10].

<u>Working Principle of Internal Combustion Engine</u>

There are two basic working principle in SI engine and CI engine which is two stroke engine and four stroke engine.

1. Two Stroke Engine

A two stroke diesel engine shares the same operating principles as other internal combustion engines . It has all of the advantages that other diesel engines have over gasoline engines. A two-stroke diesel engine does not produce as much power as a four-stroke diesel engine; however, it runs smoother than the four-stroke diesel. This is because it generates a power stroke each time the piston moves downward; that is, once for each cranks haft revolution. The two-stroke diesel engine has a less complicated valve train because it does not use intake valves. Instead, it requires a supercharger to force air into the cylinder and force exhaust gases out, because the piston cannot do this naturally as in four-stroke engines. The two-stroke diesel takes in air and discharge exhaust through a system called scavenging. Scavenging begins with the piston at bottom dead center. At this point, the intake ports are uncovered in the cylinder wall and the exhaust valve is open. The supercharger forces air into the cylinder, and, as the air is forced in, the burned gases from the previous operating cycle are forced out [16].

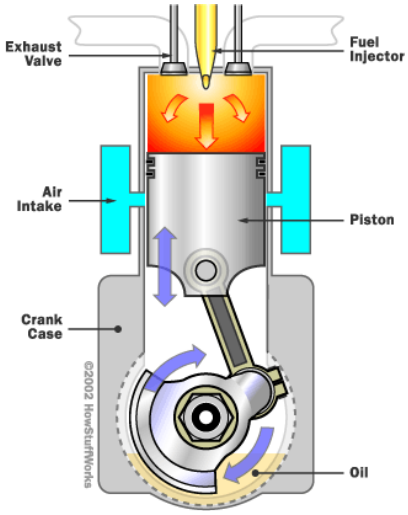


Figure 2: Two Stroke Diesel Engine

2. Four Stroke Engine

In 1892, a German specialist named Rudolf Diesel developed the pressure start motor that bears his name. The diesel motor uses warm made by pressure to light the fuel, so it requires no spark ignition system. Approaching air is compressed until its temperature comes to around 1000°F (540°C); This is called heat of compression. .As the cylinder achieves the highest point of its pressure stroke fuel is infused into the barrel, where it ignites by the hot air [1].

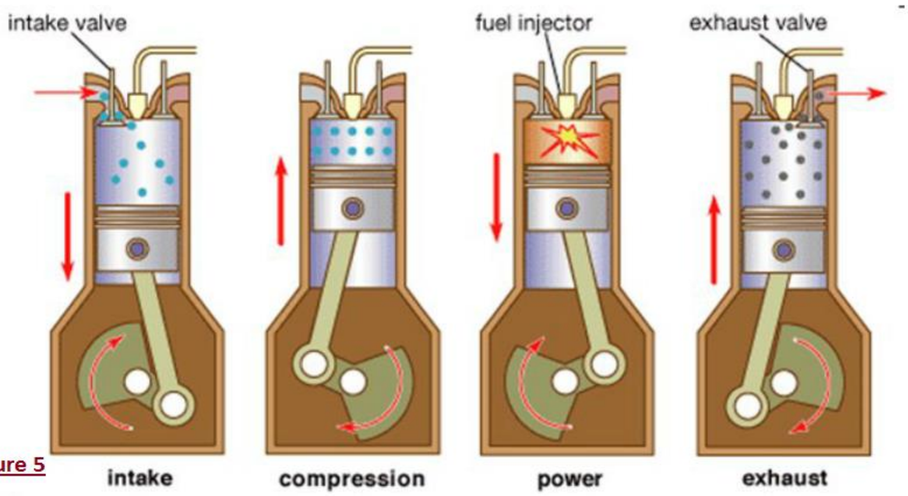


Figure 3: Four Stroke CI Engine Mechanism

<u>Four Stroke mechanism</u>

i. Intake stroke

- The air from outside is sucked in when the intake valve open while exhaust is closed. This process happen when piston moves from TDC to BDC.

ii. Compression stroke

- At this phase the piston moves from BDC to TDC. Then the air is start to compressed while both valves is closed.

iii. Power stroke

- The temperature just before point 4 is sufficiently high to cause fuel to ignite and combustion continues until injection stops at cut off (point 1). Both the valves Remain closed. The gases expand from 1 to 2.Piston moves from TDC to BDC. During the process before piston reaches BDC the exhaust valve opens.

iv. Exhaust stroke

- Exhaust valve open just before the end of expansion i.e. slightly before piston reaches BDC. The piston moves from BDC toward TDC pushing gases go through the exhaust valves. The inlet valve opens at the end of exhaust stroke i.e. when the piston is at TDC. The exhaust valve closes slightly after that.

2.2 Blend properties

The operation of engine is depending on number of fuel properties. Viscocity, density, CN, heating value, flash point, and pour point are the most significant properties of the fuel. The proper combustion, performance and emission are affecting with these. In this section, the properties of diesel and the most widely used diesel blend, that is, biodiesel–diesel blend, in CI engines are discussed. Biodiesel can be blended with diesel in any proportion to improve the qualities of the fuel. However, with regard to the differences in the physical and chemical properties of various types of biodiesel, biodiesel–diesel blends may have different physicochemical properties, which in turn affect the engine performance and pollutant emissions produced [30].

2.2.1 Kinematic viscosity

To get the better performance of engine the kinematic viscosity must be lower. This is because the higher viscosity will cause higher fuel pump power consumption and poor spray and atomization which increases fuel consumption. [28] Diesel fuel is less viscous than biodiesel. Then, by blending the diesel and biodiesel fuel it will increases viscosity than diesel fuel. But for B30 biodiesel-diesel blend, the viscosity can be lowered and reach similar range to that diesel. With analyses of Benjumea et al. and Tat and Garpen, who observed kinematic viscosities of 3.0–4.5 mm2/s for palm oil biodiesel–diesel blend and 2.8–4.10 mm2/ s for soybean biodiesel–diesel blend [29].

2.2.2 Density

Higher density causes higher viscosity which decreases combustion, performance and emissions. Besides, higher density increase energy concentration of fuel and fuel atomization efficiency [28]. The biodiesel-diesel blends generally has higher density that base diesel. It is has an agreement from Zayed abd Ahmed, who mentioned that density of biodiesel-diesel blend varied from 838 to 896 kg/m3 when using difference percentages of biodiesel at different temperature. Besides, Alptekin and Canakci analysed the densities of six biodiesels (sunflower, canola, soybean, cottonseed, corn oils and waste palm oil). They found that blends of up to 20% with diesel provide a density very close to that of petrol diesel. The maximum differences were 0.97% and 1.24% of the density of the biodiesel-diesel blends [32]

2.2.3 Cetane number

The ignition delay is depending on CN. The higher CN the shorthen the ignition delay period. The biodiesel generally has higher CN than base diesel. Biodiesel has largely composed long chain HC group. For this reason, with increases in the biodiesel percentage in a biodiesel–diesel blend, the CN of the blend increases [33]. Table 1 shows that the CN of biodiesel–diesel blend is similar to that of diesel fuel. The CN of biodiesel ranges from 46.9 to 49.9, which is slightly lower than that of ordinary diesel, which ranges from 45 to 55. The reason for this is that the articles reviewed here investigated the CN of biodiesel–diesel blends with up to 30% biodiesel in the blend. When the percentage of diesel in the blend is higher, the blend has a lower CN than pure diesel.

Table 1: Fuel properties of Base Diesel and Biodiesel-Diesel Blend

Properties	Kinematic viscocity at 40°C	Density (kg/m3)	Cetane number	Calorific value (MJ/kg)	Flash point (°C)
ASTM limit	1.9 - 6	-	47 minimum	-	130 minimum
Diesel	2.5 – 5.7	816 - 840	45 – 55	43 - 47	50 - 98
Biodiesel-diesel blend (up to 30% blend)	2.77 – 4.80	835 - 896	46.9 - 49.9	35.6 – 44.16	75.5 - 140

2.2.4 Calorific value

Engine combustion characteristics and performance are influenced by the calorific value, which facilitates heat release during combustion and improves the power output [34]. The calorific value of biodiesel–diesel blends is generally slightly higher than that of biodiesel but lower than that of diesel fuel. With a reduction in the biodiesel percentage in the blend, the calorific value of the biodiesel increases. From the results presented in Table 1, it can be seen that the calorific value of biodiesel–diesel blend ranges from 35.6 to 44.16 MJ/ kg, which is slightly lower than that of ordinary diesel, which ranges from 43 to 47 MJ/kg. This result is in agreement with the results of Zayed and Ahmed [38], who observed a heating value of biodiesel–diesel blend that varied from 35.6 to 41.2 MJ/kg. Chen et al. [35] also found that the calorific value of biodiesel–diesel blend was lower than that of diesel. They investigated the calorific value of jatropha methyl ester (JTME) biodiesel blended with diesel in different percentages and found a value of 39.4 MJ/kg by using the lowest percentage of biodiesel.

2.2.5 Flash point

The flash point has great importance because it directly affects the transportation, storage, and handling of fuel. Fuel which has a higher flash point provides greater safety during storage and transport . The flash point of biodiesels is 50% higher than that of diesel, which represents an important safety asset for biodiesel [36]. Table 1 shows that the flash points of biodiesel–diesel blends are higher than that of ordinary diesel. The articles reviewed here revealed that the average flash points for all biodiesel–diesel blends are about 107.75 °C, showing a tremendous increase of 68.67% compared to diesel fuel. Shang et al. also obtained similar results when analysing the flash point of tung oil biodiesel blends. In recent scientific investigations, it was found that B20 (a mix of 20% biodiesel with 80% diesel fuel) is the most common blend. However, in Europe, the current regulation prescribes a maximum of 5.75% biodiesel [37].

2.3 Combustion characteristics

Diesel combustion can be manipulated by many parameters such as injection pressure, injection timing, injection profile and etc. All these parameters will affect the combustion process, which in turn determines the emissions levels [9]. Parameters which affect the combustion process are briefly explained below.

2.3.1 Injection Pressure.

The application of the high-pressure injection system increases the amount of fuel injection per crankshaft angle and it also lower the ignition delay. Naturally, this delay has a minimum value that cannot be breached. In these systems, the amount of the fuel injected into cylinder increases with the pressure until the ignition starts, which causes higher levels of NOx and mechanical noises. Additionally, high-pressure injection improves specific fuel consumption (SFC) and particle emission [19].

Injection pressure of diesel engines has important effects on engine performance and emissions. Previous study, observed the decline in torque caused by the increasing pressure in 4-stroke 4-cylinder indirect injection diesel engine. Besides the observation fine atomization with the increased injection pressure and this situation increased the heat output per crank angle in a single-cylinder direct injection engine however, increasing injection pressure improves the performance and emissions. Soybean oil methyl ester and tallow oil methyl ester are used as fuel on John Deere tractor engine at Yahya‟s study. These fuels were compared with Diesel fuel at different injection advances and pressures. When spray pressure was increased, it was noted that the fuel consumption decreased around % 6.4-7 [21].

2.3.2 Ignition delay

Most researchers observed that biodiesel–diesel blend provides a shorter ignition delay than diesel fuel. Rao et al. [38] investigated the combustion, performance, and emission characteristics of neat diesel, neat jatropha methyl ester (JTME) biodiesel, and a blend of JTME and diesel in a single-cylinder, four-stroke, naturally aspirated, direct-injection diesel engine. They observed that the ignition delay of the JTME and its blends was smaller than that of diesel under all loads and that the ignition delay decreased with increases in the amount of JTME in the blend under all loads. This is because of the oxygen content of JTME, which improves the ignitibility as well as splitting the heavier compounds of fatty acid present in JTME into smaller compounds, which produces more volatile matter, which in turn causes earlier ignition. A similar result was observed by Orkun Ozener et al. [39]. They analysed the combustion characteristics of soybean biodiesel and a blend of it with diesel in a single-cylinder, four stroke, naturally aspirated, direct-injection diesel engine and found that the ignition delay was shorter than that of diesel.

Chemical properties of fuel such as the CN, engine speed, and engine load have an effect on the ignition delay of CI engines [40]. Fuels which have higher CNs usually have shorter ignition delay. Canakci found the CNs of No. 1 diesel fuel, No. 2 diesel fuel, and B100 to be 45.3, 42.6, and 51.5, respectively. He further investigated the ignition delay for each fuel and reported that the ignition delays of B100 and No. 1 diesel fuel were shorter than that of No. 2 diesel fuel. Other authors in the literature [41] observed the ignition delays of pure biodiesel and diesel against engine speed. They found that when the engine speed increased, the ignition delay also increased. The ignition delay for biodiesel and its blends containing 5%, 20%, and 50% biodiesel blend increased with increases in the engine speed . In the case of load, a shorter ignition delay was observed with increasing load according to the authors of [42]. A higher combustion chamber wall temperature and reduced exhaust gas dilution at higher loads may be reasons for this.

2.3.3 Heat release rate

The biodiesel–diesel blend from biodiesels of different origins provided a lower peak heat release than diesel fuel [43] The authors of also investigated the heat release rate of JTME biodiesel–diesel blend in their combustion characteristics analysis, as well as comparing the results with those for neat diesel fuel. They observed that the value of maximum heat release rate decreased with increases in the proportion of JTME in the fuel. In this study, the ignition delay was longer for diesel fuel than for biodiesel–diesel blend, which allowed more air and fuel to mix properly. Ultimately, this resulted in a higher heat release rate for diesel. Similarly, Sahoo and Das reported that the values of the maximum heat release rate were higher for biodiesel–diesel blends than for diesel fuel. Tesfa et al. [43] investigated the effects of biodiesel types and blend fractions on the combustion characteristics in a four cylinder, four-stroke, water-cooled, direct-injection diesel engine. They depicted the heat release rates for different biodiesel blends and normal diesel at a speed of 1300 rpm and at different load values of 105, 210, 315, and 420 N m. With increasing load, the peak heat release rate was shifted from diesel to biodiesel. The opposite result was found by Qi et al. [44]. They reported that the peak heat release rate of biodiesel is higher than that of diesel fuel under low engine loads (15% of full engine load), but the inverse is true under high engine loads (90% of full engine load). Moreover, Dhar and Agarwal as well as Gautam and Agarwal also reported the same finding [44].

Engine speed, engine load, and the oxygen content of fuels have an effect on the heat release pattern. Abu-Jrai et al. compared the heat release rate for biodiesel–diesel blend and diesel at 25%, 50%, and 75% of full engine load. The maximum heat release rate increases with the increase of load from low to medium, however, the opposite phenomenon occurs under high load. The maximum heat release rate occurs with increasing engine load slightly closer to the top dead centre (TDC). An increase in the maximum heat release rate and the fraction of fuel burned in the premixed combustion phase with an increase in the oxygen fraction of the injected fuel at high engine speed. The maximum heat release rate decreased, and advanced crank angle with the percentage of biodiesel in the blend increased [42]

2.3.4 Injection Quantity

In the case of a single injection, fuel quantity and injection duration as a function of injection pulse width could be measured through the application of this technique [2]. In addition, interference between injections could also be identified for two-stage or multiple injections, whereby substantial variations in the quantity and rate of fuel injection could be experienced.

It is important to note that there exists a time lag between the start of the injector current waveform and the start of fuel injection due to the inertia of the system as illustrated in Figure 6. The authors have previously reported on the hydraulic effects of two-stage injection on fuel injection quantity, combustion characteristics and emissions . It was identified that the fuel injection quantity during the second injection was substantially influenced by the first injection when they were closely spaced in time. Significant interactions were found between two closely spaced two-stage injections in a solenoid CR fuel injector, mainly due to the limitations of the injector utilised and the presence of pressure waves in the fuel line. Consequently, the FIE was thoroughly calibrated in order to achieve equal fuel injection quantities during the first and the second fuel injection events through the adjustment of the second injection duration. It should be noted that the twin split injections were obtained with the same energising time for the first and second injections and the difference in the fuel injection quantity in the second injection was mainly attributed to the design limitations of the injector utilised as well as the adverse effects of pressure waves in the high pressure fuel line, caused by the first injection. The quantity of fuel injected during the second injection had a significant impact on the rate of in-cylinder pressure rise [7]. The V1–4 strategies exhibited higher rate of pressure rise in comparison to those of single injection strategies, mainly due to higher degree of interaction between the first and the second injections. The results suggest that the combustion noise and also the mechanical stresses the engine parts are exposed to can be notably decreased with two-stage fuel injection. However, these aspects depend on the fuel injection strategy, fuel injection quantity and the engine speed, thus thorough assessment of such a phenomenon under various engine operating conditions is required in order to draw an explicit conclusion. In the case of the twin split strategies the substantial variations in the engine output and exhaust emissions were primarily caused by the inconsistency in the total fuel injection quantity, due to the effect of tow-stage injection and the DA, as well as the interaction between the first and second injection [7].

2.4 Emission characteristics

Emissions in CI engines consist of hydrocarbons (HCs), carbon monoxide (CO), NOx, and particulate matter (PM) [8]. The use of biodiesel–diesel blends in CI engines has been proven to lead to low emissions of PM, HC, and CO as well as higher emissions of NOx compared to diesel fuel. However, the emissions level varies from one engine to another and is dependent on the operating conditions of the engine, fuel quality, and engine design [45].

2.4.1 HC emission

HC emissions decrease when biodiesel-diesel blend is used as fue instead of diesel. For example, Ozsezen et al. [41] reported that unburned hydrocarbon emissions were about 40.3% lower for fresh oil biodiesel and biodiesel–diesel blends operation compared to baseline petroleum diesel fuel operation due to the improvement of the cetane value of the mixture. The increasing biodiesel percentage in the blend shortens the ignition delay, promotes reaction timing of the blends, and eventually reduces the level of unburned HC emission [38]. An et al. observed the HC emission in a Euro IV common-rail fuel-injection diesel engine fuelled by biodiesel–diesel blends with different percentages (10%, 20%, and 50%) of biodiesel. They found a lower level of HC emission under any load condition. The researcher used two different types of biodiesel, waste palm oil methyl ester (WPOME) and canola oil methyl ester (COME), in different percentages with diesel. They reported that the HC emission was decreased by 14.29% for WPOME and 72.68% for COME. Similarly, Lertsathapornsuk et al. [46] observed a decrease of 25.11% in HC emission compared to diesel No. 2. The authors of [38,41,42] found that properties of biodiesel such as the higher oxygen content are the reason for the lower level of HC emission. Engine load [47] and engine speed [41] have an impact on the HC emission of biodiesel–diesel blends. Gumus and Kasifoglu [47] observed the HC emission in a single-cylinder, four-stroke, direct injection diesel engine fuelled by biodiesel–diesel blend with different percentages (5%, 20%, and 50%) of biodiesel. They found that with an increase in the load, the amount of HC increases. Agarwal et al. [48] observed that HC emissions were lower under partial load but tended to increase under higher loads for all fuels due to a lack of oxygen at the time of engine operation. The HC emission of biodiesel–diesel blend

2.4.2 CO emission

It is a typical conclusion that CO emission decrease when diesel is replaced by biodiesel–diesel blends [2,5] Rakopoulos et al. [2] explored the emission characteristics of pure diesel and additionally mixes of diesel with vegetable oils and biodiesels of various beginnings. They found that the CO emission was lower than that of diesel fuel, and the reduction become bigger as the rate of biodiesel in the mix imcrease. Ozsezen and Canakci found a huge differences in CO emission roughly 57% between biodiesel–diesel blend and mineral diesel fuel when tests were executed in a four-cylinder, four-stroke, water-cooled, indirect ignition diesel motor. Gumus and Kasifoglu observed the CO emission in a direct ignition single cylinder–diesel blends in various rates (5%, 20%, and half) of biodiesel at a consistent speed of 2200 rpm under different loads. They found a critical decrease in CO exhaust emission with diesel fuel.[41] Researcher have discovered that properties of biodiesel, for example, higher oxygen content and higher CN are the explanations behind the lower level of CO emission. Most researcher agreed that engine load increase will decrease the CO emission and increment of engine speed will increase the CO emission. [42]

2.4.3 NOx emission

Most researchers agreed that the NOx emission of biodiesel–diesel blend is higher than that of ordinary diesel fuel [5,34,38–41,44,47,49]. For example, Murillo et al. [5] investigated the performance and emissions of neat diesel, neat biodiesel, and biodiesel–diesel blend in marine outboard diesel engines without major modification to the engines. They found that blend containing up to about 25% biodiesel gave a lower NOx emission than neat diesel. When the biodiesel percentage increased above 25%, the NOx emission increased, and for B100, it was found to be 16% higher than that of conventional diesel. Qi et al. [44] employed biodiesel–diesel blends with different percentages of biodiesel in a single-cylinder, four-stroke, water-cooled, naturally aspirated, direct-ignition diesel engine and found that the difference in the NOx emissions of diesel and blend was no more than 100 ppm. Chauhan et al. found that when the percentage of biodiesel in the blend increases, the emission of NOx increases.

Gokalp et al. [49] discovered 4.5%, 10%, and 15.5% increments in NOx emission for B20, B50, and pure biodiesel, individually, when tests were completed on a diesel tractor fuelled by marine diesel, soybean methyl ester, and mixes of them. Similar patterns were seen by the author of [34]. Some work revealed that NOx emission decrease when biodiesel–diesel mix was utilized. Kalligeros et al. investigated the exhaust emission of mixes of sunflower and olive oil with diesel in a stationary diesel motor and found that NOx emission was less in all cases. They presumed that the higher CN of biodiesel compared with marine diesel was the explanation behind this lessening. Pereira et al. discovered NOx discharges of 420, 452, 450, 419, and 460 ppm for B20, B50, B75, B100, and pure diesel, respectively. Engine load, engine speed, higher oxygen content and higher CN, and advances in injection and combustion have significant effects on NOx emissions for biodiesel. [5,42]

2.5 Performance characteristics

Engine performance is a one of the parameter that indicates whether or not an engine is acceptable. Brake power, brake specific fuel consumption (BSFC), and brake thermal efficiency (BTE) are the performance indicators for engines.

2.5.1 Power

Greater or smaller reductions in engine power when using biodiesel– diesel blends with biodiesel of different origins are reported in most research [5,41]. For example, Murillo et al. [5] investigated the engine performance characteristics of neat diesel and neat biodiesel as well as different percentages of biodiesel (10%, 30%, and 50%) with diesel in a single-cylinder, four-stroke, naturally aspirated, direct-injection diesel engine under variable load conditions. They reported that with increasing biodiesel percentage in the blend, the engine power output decreased. They also observed that when the engine was coupled to a specific propeller, the direct substitution of the fuel led to a reduction in the propeller speed, and therefore to a further reduction in the system's output. The waste cooking oil was compared with that for ultra-low sulphur diesel on a single-cylinder, four-stroke, water-cooled, direct-injection diesel engine under part load conditions. They reported that the average reduction from 1600 to 3600 rpm was 12.2% for B100. However, the maximum brake power with traditional diesel was found to be 25% higher than biodiesel from waste cooking oil and 52% higher than biodiesel with glycerin at 2500 rpm. On the other hand, Al-Widyan et al. [51] observed higher brake power output for 25%, 50%, and 75% biodiesel–diesel blends, relative to ordinary diesel fuel.

They completed tests on a single cylinder, naturally aspirated, water-cooled, direct injection motor coupled to an electric dynamometer. It had higher fuel mass flow in bigger mass flow, and utilized more thick blends in less internal leakage in the fuel pump. Usta et al. [52] additionally observed higher power for a hazelnut cleanser stock/waste sunflower oil blend and mixes (100%, 75%, and half) in a four-cylinder, turbocharged, indirect ignition diesel motor. Despite the fact that the increase of the biodiesel to the diesel fuel reduce its heat value, the presence of a higher oxygen level (10%) for mixes prompts complete combustion, a bigger mass flow rate for mixes, and higher viscosity for mixes, which means there is less interior leakage in the fuel pump. The motor speed, motor load, and rate of biodiesel–diesel blends guarantee impacts on the motor power output [5,41,51,52]. It is observed that the motor power reduce with increments in the rate of biodiesel in a mix and increase load. Thus, a similar pattern in the impact of motor speed on motor power, aside from uncommon special cases.

2.5.2 Brake-specific fuel consumption, BSFC

According to most researchers [41] BSFC increases with an increase in the percentage of biodiesel in the biodiesel–diesel blends when it is used as a fuel in conventional CI engines compared to diesel. For example, Cetinkaya and Karaosmanoglu investigated the performance of a diesel engine with various percentages of biodiesel in a biodiesel–diesel blend. They found that with increases in the biodiesel percentage, the BSFC increased; for example, a 4% increase was found for B20 and a 10% increase was found for B100 compared to neat diesel. Stringer et al. found 2.17%, 5.78%, 9.42%, and 16.76% increases in BSFC for B5, B20, B50, and B100, respectively, compared to diesel. In , the authors used neat diesel, four different percentages of biodiesel in biodiesel–diesel blend, and neat biodiesel. They found an similar pattern from before that is, BSFC increase with increase biodiesel rate in the biodiesel–diesel mix. Lertsathapornsuk et al. [46] observed increments of 5.60% for B50 and 12.73% for B100 in their experiment. The different pattern was seen by Liu [52], who found that the mean estimations of BSFC of 10%, 20%, 30%, 40%, and 50% mixes for different motor velocities were 4.0, 0.8, 0.6, –2.2%, and 1.4% higher individually than that of diesel fuel. Researchers [41] found several reasons for the higher BSFC when using biodiesel–diesel blend, such as the lower heating value, higher viscosity, and higher density of biodiesel compared to diesel. On the other hand, other researchers found decreased values of BSFC for biodiesel–diesel blends.

Pramanik investigates the performance of a diesel motor fuelled by jatropha biodiesel and a mix of it with diesel. He watched enhanced motor performance, for example, reduction in the BSFC for biodiesel–diesel blends compared with neat vegetable oil. The creator concluded that the reduction in viscosity of jatropha oil was the explanation behind the decreasing in the BSFC. Ramadhas et al. discovered that blends containing up to 80% biodiesel can give decreasing estimations of BSFC when tried in a single cylinder, direct injection diesel motor. Motor speed, motor load, and biodiesel containing a few deposits, for example, glycerin, corrosive, or water have impacts on BSFC [50]. Most specialists agreed that as the speed and load increment, the BSFC reduce and those negatively affect BSFC.

2.5.3 Brake thermal efficiency, BTE

The BTE for biodiesel–diesel blend decreases slightly or remains the same compared to diesel fuel according to the authors of [2,5,46,48] Agarwal et al. [48] investigated the combustion, performance, and emission characteristics of neat diesel and neat biodiesel as well as different percentages of biodiesel (10%, 20%, 50%, and 75%) with diesel in a single-cylinder, four-stroke, water-cooled, direct-injection diesel engine under variable load conditions. They found that with increments in the biodiesel percentages in the biodiesel–diesel blends, the BTE of the motor decreased. Stringer et al. researched the BTE for PBDF, B100, B50, B20, and B5 under full load conditions and found that it decreased when biodiesel–diesel blends was compared with diesel. Rakopoulos et al. [2] and Murillo et al. [5] discovered comparative outcomes for the BTE when biodiesel–diesel blends was utilized. Researchers have observed some properties of biodiesel which are responsible for the lower BTE, such as higher viscosity, lower cetane index, smaller ignition delay [42], lower heating value [52], higher lubricity, and higher BSFC. However, very few works [53] have reported a higher BTE for biodiesel blend compared to diesel.

Utilizing experimental information, Di et al. [88] clarified that the BTE of biodiesel and its blends is increase compared with diesel under test loads of 0.08, 0.20, 0.38, 0.55, and 0.67 MPa. It was observed in that ultra-low sulphur diesel, had the lowest BTE compared to pure biodiesel, biodiesel with 10% blended methanol and biodiesel with 10% fumigation methanol at constant speed and variable load. The maximum BTEs obtained were 37.2%, 39.1%, 39.6%, and 37.5%, respectively, for the ultra-low sulphur diesel, biodiesel, biodiesel with 10% fumigation methanol, and biodiesel with 10% blended methanol. As indicated by the opinions of researchers [53], biodiesel's higher oxygen content enhances ignition, and higher lubricity decreases friction lose due to the higher BTE. Motor speed, motor load, and rates of biodiesel–diesel mixes have both positive and negative effects on BTE, as appeared by the authors of [42,53] .

CHAPTER 3

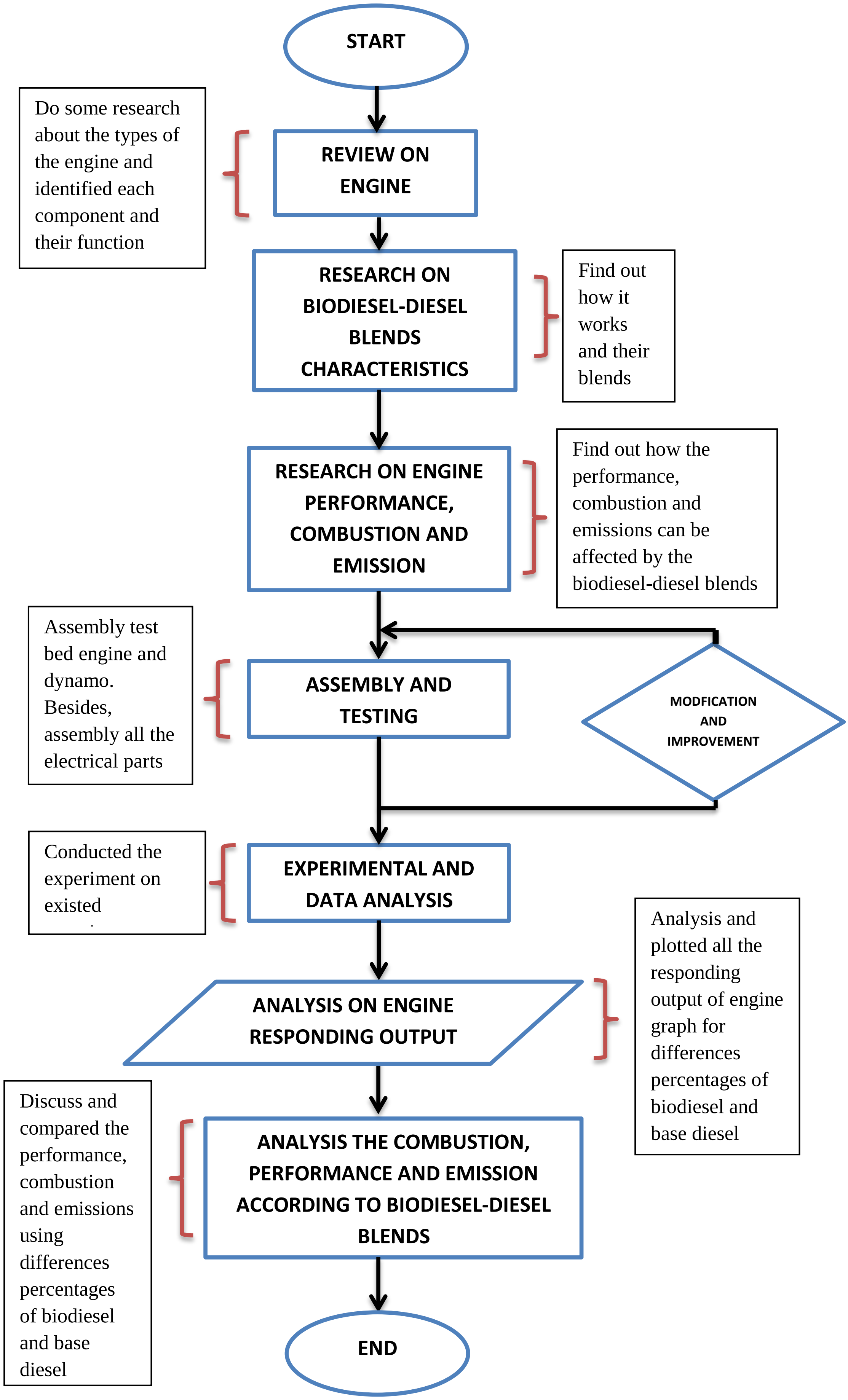
RESEARCH METHODOLOGY

3.1 Introduction

This project is done to investigate and compare the data from Yanmar L48N6 diesel engine that connected to 20kW eddy current dynamometer that load and measured torque and rotational speed produced by the engine. Engine was fuelled with different percentages of biodiesel which is B20, B45 and base diesel. The test was running at different engine speed for each percentages of biodiesel. Indicated data can be recorded by using LabVIEW and Dewesoft software. After the data was recorded, the comparison of data in term of performance, combustion and exhaust emissions was analysed.

Biodiesels are gaining more importance as a promising alternative energy resource due to the global fossil fuel crisis and emission problems. Thus, the use of a blend of biodiesel with conventional fuel was suggested to balance its usage, which could still provide a beneficial greenhouse effect. So, this is important to completing this experiment or project in order to study how biodiesel fuel can impact the performance, combustion and emissions of engine that can affect the economic and environmental

3.2 Project flow chart



3.3 Experimental setup

Firstly, the project more focussing on designing the structure of test bed. The dynamo and the test bed before this was at Prof Zainal lab. First we moving dynamo using fore lift to engine lab. Next assembly dynamo and test bed in the room with applying stud and nut through floor.

Second, after all the part was move and assemble in engine lab, CAD drawing using solidwork for structure of all the test bed (diesel engine, dynamo , engine pump and motor). Designing the base and plate for diesel engine. This is the critical part because the size and height of plate and base must align with dynamo and also must make it less vibration while running the engine. All the base, plate and clamping will be send out to outsource process to fabricate.

Figure 4: Assembly Test Bed in the Engine Lab

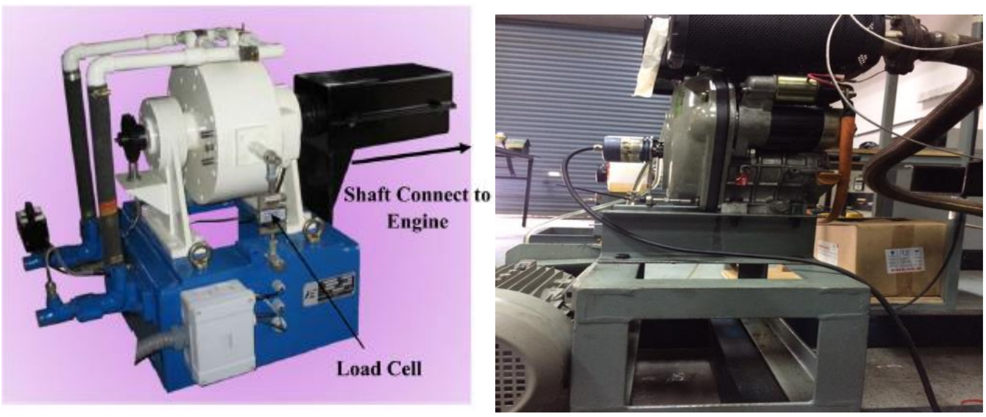


Figure 5: Assembly the Diesel Engine and Dynamo

Next step will be piping assembly between test bed and cooling tower.

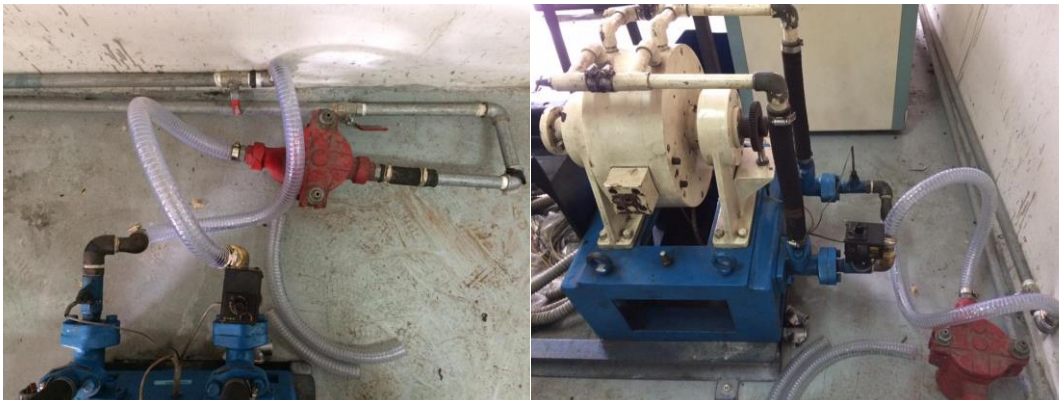


Figure 6: Connection between Flexible Pipe and Cooling Tower

Next, attached the rotary encoder to the crankshaft and mounted at diesel engine. Besides, the encoder is connected to Dewesoft data acquisition system.

Figure 7: Crankshaft Encoder

Next, the fuel tank was connected with automated volumetric type fuel flow measuring system using 50 mL burette and connected to the engine. The steel rack was fabricate in 4 height to located the fuel tank, engine battery and to attached the four photo-interuptor sensors around 50 mL burette.