BACHELOR THESIS & COLLOQUIUM – ME1841038

THE PERFORMANCE ANALYSIS OF A SINGLE CYLINDER DIESEL ENGINE WITH GREEN DIESEL FUEL OF PALM OIL AS FEEDSTOCK USING SIMULATION METHOD

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Departemen Teknik Sistem Perkapalan
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Institut Teknologi Sepuluh Nopember
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DOUBLE DEGREE PROGRAM OF
DEPARTMENT OF MARINE ENGINEERING
FACULTY OF MARINE TECHNOLOGY
SEPULUH NOPEMBER INSTITUTE OF TECHNOLOGY
SURABAYA
2020

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SKRIPSI – ME1841038

ANALISA PERFORMA PADA MOTOR DIESEL SILINDER TUNGGAL DENGAN BAHAN BAKAR GREEN DIESEL DARI BAHAN BAKU MINYAK KELAPA SAWIT DENGAN METODE SIMULASI

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2020

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SUPERVISOR APPROVAL SHEET

PERFORMANCE ANALYSIS OF A SINGLE CYLINDER DIESEL ENGINE WITH THE GREEN DIESEL FUEL OF PALM OIL AS FEEDSTOCK USING SIMULATION METHOD

BACHELOR THESIS

Submitted To Comply One Of The Requirements To Obtain A Bachelor Thesis
Engineering Degree
On

Laboratory of Marine Power Plant (MPP)
Bachelor Program Departement of Marine Engineering
Faculty of Marine Technology
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PERFORMANCE ANALYSIS OF A SINGLE CYLINDER DIESEL ENGINE WITH THE GREEN DIESEL FUEL OF PALM OIL AS FEEDSTOCK USING SIMULATION METHOD

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PERFORMANCE ANALYSIS OF A SINGLE CYLINDER DIESEL ENGINE WITH THE GREEN DIESEL FUEL OF PALM OIL AS FEEDSTOCK USING SIMULATION METHOD

BACHELOR THESIS

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I hereby who signed below declare that:

This bachelor thesis, as a final project, has written and developed independently without any plagiarism act. All contents, data, concepts, design, and ideas drawn directly from internal and external sources are indicated, such as cited sources, literature, and other professional sources.

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Departement	:	Marine Engineering

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Surabaya April 2020

Fathin Muhammad Mahdhudhu

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PERFORMANCE ANALYSIS OF A SINGLE CYLINDER DIESEL ENGINE WITH THE GREEN DIESEL FUEL OF PALM OIL AS FEEDSTOCK USING SIMULATION METHOD

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ABSTRACT

Green diesel is an alternative fuel to reduce dependence on petroleum. Green diesel is fuel for further innovation from biodiesel, which is both derived from vegetable oils. The process of making green diesel using hydrotreating by adding hydrogen aimed at removing the element of oxygen. This study focused on analyze performance of green diesel fuel compared with biodiesel B30. The method used in this research process was an simulation. Data of the fuels obtained from the journal. In this study engine validation was carried out according to the engine catalog at two points, 2200 rpm and 1600 rpm. Data collection in this study was in full load and load variations of 50%, 60%, 70%, 75%, 80%, 90% , 100%. At full load conditions, the HSD (High speed diesel) fuel data is added for supporting data from the biodiesel B30 and green diesel fuel analysis and the engine speed is varied from 1000-3300 rpm, this is calculated so that the peak point of each parameter to be tested is seen (power, torque, SFOC, BMEP). The results obtained by the power produced by green diesel are far better than the B30 biodiesel, the torque produced is higher than the diesel engine at the same engine speed than the biodiesel B30, the SFOC produced by green diesel is much smaller than the biodiesel B30, and the BMEP value of green diesel is better than biodiesel B30.

Keywords*: Perfomance analysis, Green diesel, Palm Oil, One Cylinder Diesel Enginel.Simulation Method*

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ANALISA PERFORMA PADA MOTOR DIESEL SILINDER TUNGGAL DENGAN BAHAN BAKAR GREEN DIESEL DARI BAHAN BAKU MINYAK KELAPA SAWIT DENGAN METODE SIMULASI

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ABSTRAK

Green diesel adalah bahan bakar alternatif untuk mengurangi ketergantungan pada minyak bumi. *Green Diesel* adalah bahan bakar untuk inovasi lebih lanjut dari biodiesel yang keduanya berasal dari minyak nabati. proses pembuatan *Green Diesel* dengan menggunakan hydrotreating dengan menambahkan hidrogen yang bertujuan menghilangkan unsur oksigen. dalam penelitian ini difokuskan pada kinerja bahan *Green Diesel* dibandingkan dengan biodiesel B30. Metode yang digunakan dalam proses penelitian ini adalah simulasi. pada penelitian ini dilakukan kalibrasi engine sesuai dengan engine katalog pada dua titik, rpm 2200 dan rpm 1600. Pengambilan data pada penelitian ini pada keadaan full load dan variasi beban dari 50%, 60%, 70%, 75%, 80%, 90%, 100%. Pada kondisi full load,ditambahkan data bahan bakar HSD (High speed diesel) untuk data pendukung dari analisa bahan bakar biodiesel B30 dan green diesel dan putaran engine divariasikan dari rpm 1000-3300, hal ini dilakukan agar titik puncak dari setiap parameter yang akan diuji terlihat (daya, torsi, SFOC, BMEP). Hasil yang didapatkan power yang dihasilkan green diesel jauh lebih baik dari pada biodiesel B30, torsi yang dihasilkan lebih tinggi green diesel pada putaran engine yang sama dari pada biodiesel B30, SFOC yang dihasilkan green diesel jauh lebih kecil dari pada biodiesel B30, dan nilai BMEP dari green diesel lebih baik dari pada biodiesel B30. .

Kata Kunci: Uji Performa, Green diesel, Minyak Kelapa Sawit, Mesin Diesel Satu Silinder. Metode Simulasi

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PREFACE

All the gratitude towards Almighty Allah for all the blessings and gifts so that the author can complete the final project to fulfill the requirements to obtaining the bachelor's degree program at Marine Engineering Department, Faculty of Marine Technology Institut Teknologi Sepuluh Nopember Surabaya.

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Surabaya, May 2020

Author

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CHAPTER 1
INTRODUCTION

1.1. Background

In our daily lives, we are undoubtedly familiar with diesel engines. Began to be applied in cars, on trains, on ships, and other industrial equipment. A diesel engine is an internal combustion engine as well as a gasoline engine whose working principle uses compression to blast fuel into a dynamic force. Therefore, the diesel engine's increased production will have an impact on the availability of diesel fuel in nature, which we know is that diesel fuel is diesel taken from distilled petroleum. In 2015, Indonesia produced 825,000 barrels per day and was ranked 24th for oil-producing countries in the world. In Indonesia, fossil fuels are used as favourite fuel which is used like 33% oil most of them are used to fuel motor vehicles, trains and ships.As much as 28% of coal used for electricity generation. The other 23% is natural gas used for home needs and dual fuel diesel engine. (BP , 2016)

Therefore, to answer the needs of fuel compared with the availability of fuel oil which has begun to deplete already many technologies and alternative fuels such as biodiesel. Biodiesel is fuel come from the vegetable oil that use the transesterification process. However, in making biodiesel, there are still many shortcomings including the use of FAME (Fatty acid methyl ester) which is still relatively expensive, which causes the price of biodiesel production to become even more expensive. To cope with expensive production prices, an idea was created about making green diesel. Green Diesel is an environmentally friendly fuel which is made with a hydrotreating process which in the process is added hydrogen which will later eliminate the oxygen element in the fuel content. Therefore green diesel is more stable. There is still little research that examines the performance of green diesel used in single cylinder engine 0.5 L four strokes. One of the journals published by Energies, discusses the performance of green diesel in a compression ignition engine. when compared to petroleum diesel, green diesel decreases both the maximum cylinder pressure and the rate of pressure increase. The lower maximum pressures and the lower rates of pressure increase are attributed to the higher cetane number of green diesel which shortens the ignition delay period and the premixed combustion phase. Also, a possible lower viscosity of green diesel allows a better mixing of the liquid fuel droplets with air and reduces the ignition delay.

This study will discuss the effect of Green Diesel on diesel engines' performance compared to the biodiesel performance on single cylinder diesel engine 0.5L. It is expected that in this research green diesel fuel can be used and commercialized publicly, and reduce the dependence on petroleum fuel which is increasingly reduced.

1.2. Research Problem

There is some problem occurs based on the background above, there is :

a. How the effect performance of green diesel on one cylinder diesel engine.
b. How the effect performance of biodiesel B30 on one cylinder diesel engine.
c. How is the performance comparison of green diesel and biodiesel on one cylinder diesel engine.

1.3. Research Limitation

A limitation is made so that the study is not too broad to aspects that are not far from relevance so that research can be more focused to do; the limitation of this study is as follows:

a. Limitation of the analysis of the use of green diesel on performance are power, torque, SFOC, and BMEP.
b. The comparison of the fuel with Biodiesel B30.
c. The research was conducted using the Yanmar TF 85 MH Diesel engine.

1.4. Research Objective

The objective of this final project based on the problem occur are :

a. To understand the performance of green diesel engine to power, torque , SFOC, and BMEP.
b. To understand the diesel engine's performance using biodiesel B30 to power, torque , SFOC, and BMEP.
c. To compare between green diesel and biodiesel B30 in one cylinder diesel engine.

1.5. Research Benefit

The desired benefit from the results of this research are:

a. Understanding the performance of green diesel to a diesel engine.
b. Understanding the performance of biodiesel B30 to a diesel engine.
c. Enhance insight related to green diesel and the process

CHAPTER 2
LITERATURE STUDY

Conventional energy sources like fossil fuel, petroleum, coal and methane are non renewable sources. These are primary sources of energy at present time and due to more massive consumption shortage is about to happen. From 1970 to 2015 energy supply has increased from 6 Gtoe to 15 Gtoe and the consumption of fossil remains high for the primary energy supply. The consumption of fossil fuel was around 86% for production of primary energy in 1973 and in the year 2015, this consumption is about 78%. Oil production will reach to a maximum limit by 2020 and also the consumption will continue to rise, pulled primarily by China and India. Rapid industrialization leads to decrease of fossil fuel reserves. Petroleum, nuclear, wind, coal, solar, etc. produced a significant part of energy for different sectors, for example, in the agriculture transport and industry sectors. For these sectors oil consumption in year 1973 is 42% and in 2014 it is 64.5% of total world's oil consumption. The consumption of fossil fuel is increased by 43.33% from last 41 year. therefore, many researchers have developed fuels derived from vegetable oil to reduce the tendency to use fossil fuels. one of them by using biodiesel and green diesel. both of these fuels are from vegetable oil. (Singh, et al., 2020)

Previously several research journals discussed green diesel. one of which was published by energies regarding green diesel, which includes how to produce green diesel, test the properties of the fuel that has been produced, and test the performance of the compression ignition internal combustion engine. (L.Douvartzides, et al., 2019)

The difference between biodiesel and green diesel is one of them from how it is made. In biodiesel, it produced by the transesterification of triglycerides contained in biomass matter such as vegetable oils. where Transesterification is the process of exchanging organic groups on an ester with an organic group from alcohol with the help of a catalyst such as KOH or NAOH. while for green diesel the way it is made is using hydroprocessing from biomass. (L.Douvartzides, et al., 2019)

From the different fuel produce, green diesel has a higher cetane number (above 70) than biodiesel. Cetane number is a measure of the quality of ignition of diesel fuel in an Combustion ignition internal combustion engine. After that, the performance tests include cylinder pressure, pump delivery, injection rate, and heat release rate curves on a typical CI internal combustion engine (L.Douvartzides, et al., 2019)

Because of that, the authors took the initiative to research performance analysis more resulting from green diesel fuel including power, torque, SFOC, and BMEP with the hope to add more information and knowledge about green diesel and performance of green diesel.

2.1. Green Diesel

The diesel fuel crisis is increasingly decreasing, and the need for energy sources is increasing, one of which is diesel fuel is an energy problem that must be resolved. Green diesel is an alternative solution to solve the problem of energy needs, namely by replacing diesel from petroleum with oil equivalent to diesel which is processed from vegetable oils such as used waste cooking oil, kapok seed oil, palm oil and others.

Classify green diesel in sofar consists of four generations. According to the raw triglyceride material used (first generation is edible vegetable oils, the second generation is non-edible vegetable oils, the third generation is residual vegetable oils and animal fats, and fourth-generation is algal oils). In most of the studies, fresh edible vegetable oils are used as sources of natural triglycerides. However, the use of such oils completes the production of foods. (Nikolopoulos, et al., 2019)

The process that can be carried out to convert vegetable oil into oil equivalent to diesel fuel is by hydrogenating vegetable oil to produce alkanes equivalent to diesel oil, propane, water and carbon dioxide. Alkanes resulting from the equivalent of diesel oil are called green diesel or generation 2 biodiesel (G2) with better quality than transesterified G1 biodiesel (Salamah & Setyawan, n.d.)

Figure 2.1 Palm as green diesel's feedstock
Source: (Qaim, et al., 2020)

The advantages of green diesel or G2 biodiesel can reach cetane number 55-90 far higher than the achievement of biodiesel G1 which is only 40-45, so that the oil produced can be directly used as diesel engine fuel without having to be added to diesel without even having to make engine modifications (Salamah & Setyawan, n.d.). The other advantage of green diesel is more stable when compared to biodiesel because in the element of green diesel no oxygen has corrosive properties, green diesel also has a better sulfur content than petroleum because it comes from vegetable oil.

Table 2.1 Comparation between FAME and Green Diesel
Source: (Piemonte, 2019)

Parameter	FAME (Biodiesel)	Green Diesel
Oxygen	11	0
Cetane number	50-65	80-90
LHV (MJ/Kg)	38	44

Sulphur content	<10	<10
Density (g/ml)	0.883	0.78
Nox Emission	+10	0-10

In Indonesia, public knowledge about green diesel still lacks because it is still in the research process and not yet commercialized. some people consider green diesel the same as biodiesel, but there are differences in the manufacturing process, even though green diesel and biodiesel come from vegetable oil. in Indonesia, there are no regulations governing green diesel because it is still in the process of research. However, for biodiesel, there are already available regulations namely from the Ministry of Energy and Mineral Resources of the Republic of Indonesia in 2019.

In general, the characteristics of vegetable oil is to have a higher cetane number than petroleum, containing low sulfur so that the resulting combustion emissions are more environmentally friendly than fuel from petroleum. (Cahyono, et al., 2019)

Table 2.2 Indonesian Standard Biodiesel

Source: (Ministry of Energy and Mineral Resources of the Republic of Indonesia, 2019)

No	Parameter Test	Requirement	Unit
1.	Density at 40˚C	850-890	Kg/m^3
2.	Kinematic Viscosity at 40˚C	2.3-6.0	Mm^2/s (cst)
3.	Cetane Number	51	Min
4.	Flash Point	130	˚C, min
5.	Copperplate corrosion	Number 1	
6.	Carbon residues in the original pilot or in 10% distillation pulp	0.05 0.3	%-mass, max
7.	Distillation temperature at 90 ˚C	360	˚C, max
8.	Sulfurized ash	0.02	%-mass, max
9.	Sulfur	10	mg/kg, max
10.	Phosphor	4	mg/kg, max
11.	Acid number	0.4	mg-KOH/g, max
12.	Free glycerol	0.02	%-mass, max
13.	Total glycerol	0.24	%-mass, max
14.	Levels of methyl esters	96.5	%-mass, min
15.	Iodine number	115	%mass(g-1_2/100 g), max
16.	Oxidation stability induction period rancimat method	600	Minute
17.	Oxidation stability induction period petroxy method	45	Minute
18.	Monoglyceride	0.55	%mass, max
19.	Colour	3	max
20.	Water content	350	Ppm, max
21.	CFPP (Cold Filter Plugging Point)	15	˚C, max

2.2. Green Diesel Production

Green diesel and biodiesel are derived equally from vegetable oils, but there are differences in the manufacturing process. Biodiesel is produced conventionally through transesterification of triglycerides in the presence of methanol and catalyst assistance. The reaction is catalyzed to produce FAME and glycerol as a byproduct. While the green diesel process uses a hydroprocessing system that uses hydrogen to remove oxygen from triglyceride molecules. Then, oxygen is easily removed through two competing reactions: decarboxylation and hydrodeoxygenation. The rate for each reaction depends on the catalyst and the process conditions. (Piemonte, 2019).

Green diesel production process in a standalone unit. Vegetable oil is combined with hydrogen and brought to the reaction temperature. Then the mixture is sent in the reaction unit where the vegetable oil is converted in Green Diesel. The last one is separated from the recycle gas in the separator unit while the liquid product is sent to a fractionation section. The design of the fractionation section can vary from a one-column system to produce diesel and unstabilized naphtha to a three-column system to produce propane, naphtha and diesel products. The recycle gas is treated in an amine system to remove CO_2. (Piemonte, 2019)

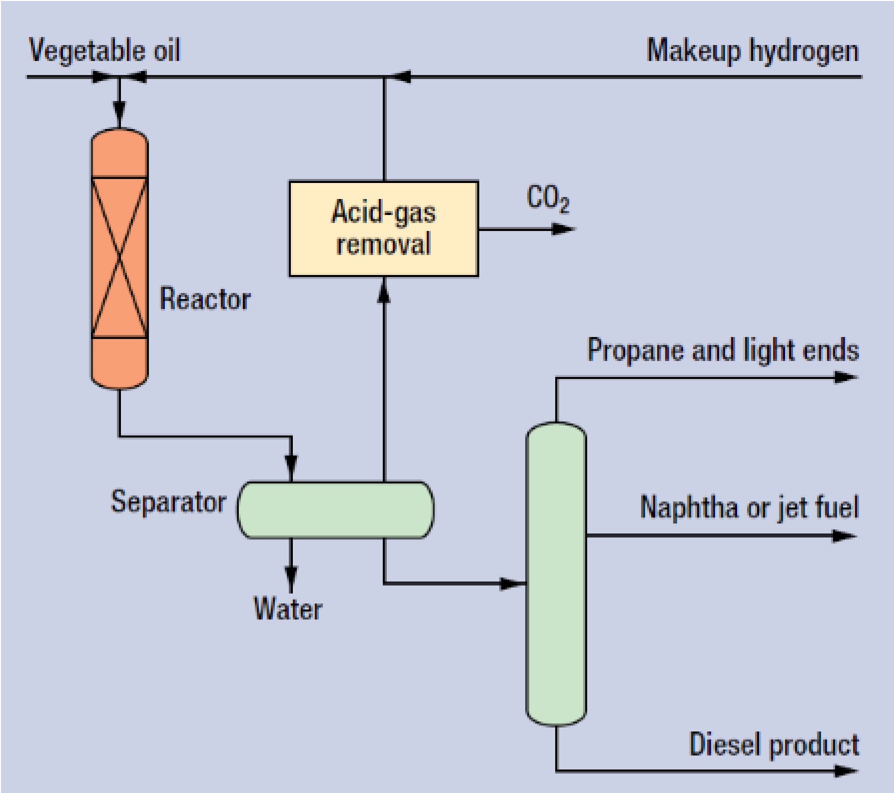

Figure 2.2 Green Diesel Production Flow
Source: (Piemonte, 2019)

2.3. Diesel Engine

Diesel engine, any internal-combustion engine in which air is compressed to a sufficiently high temperature to ignite diesel fuel injected into the cylinder, where combustion and expansion actuate a piston. It converts the chemical energy stored in the fuel into mechanical energy, which can be used to power freight trucks, large tractors, locomotives, and marine vessels. A limited number of automobiles also are diesel-powered, as are some electric-power generator sets. (Lafayette & Armstrong , 2013)

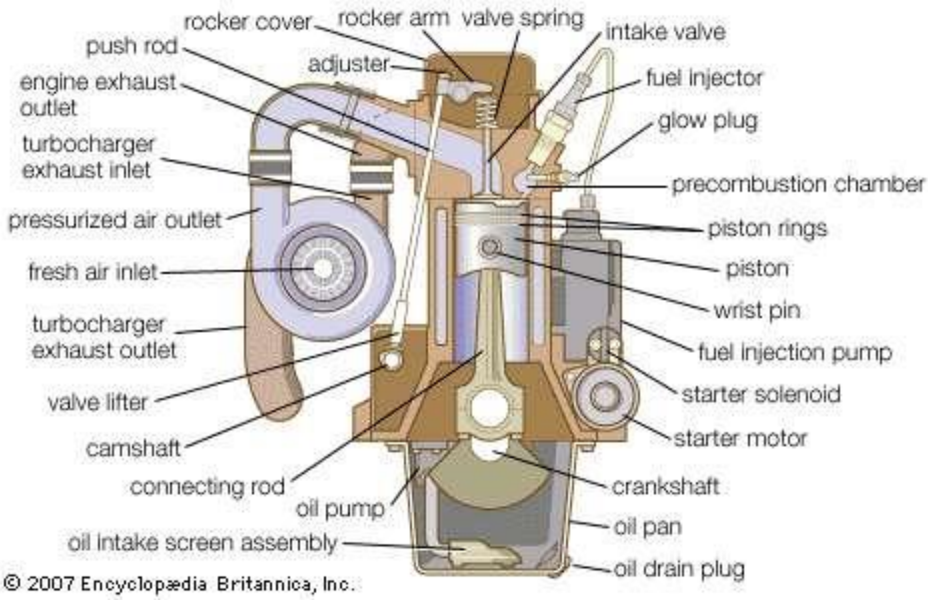

Figure 2.3 Diesel Engine with pre-combustion chamber
Source: (Lafayette & Armstrong , 2013)

The diesel engine is an intermittent-combustion piston-cylinder device. It operates on either a two-stroke or four-stroke cycle (see figure); however, unlike the spark-ignition gasoline engine, the diesel engine induces only air into the combustion chamber on its intake stroke. Diesel engines are typically constructed with compression ratios in the range 14:1 to 22:1. Both two-stroke and four-stroke engine designs can be found among engines with bores (cylinder diameters) less than 600 mm (24 inches). Engines with bores of greater than 600 mm are almost exclusively two-stroke cycle systems. (Lafayette & Armstrong , 2013)

The diesel engine gains its energy by burning fuel injected or sprayed into the compressed, hot air charge within the cylinder. The air must be heated to a temperature higher than the temperature at which the injected fuel can ignite. Fuel sprayed into air that has a temperature higher than the "auto-ignition" temperature of the fuel spontaneously reacts with the oxygen in the air and burns. Air temperatures are typically in excess of 526 °C (979 °F); however, at engine start-up, supplemental heating of the cylinders is sometimes employed, since the temperature of the air within the cylinders is determined by both the engine's compression ratio and its current operating temperature. Diesel engines are sometimes called compression-ignition engines because initiation of combustion relies on air heated by compression rather than on an electric spark. (Lafayette & Armstrong , 2013) Based on the motion of the piston to get one diesel engine process is divided into 2 types, namely:

2.3.1. Four Stroke Diesel Engine

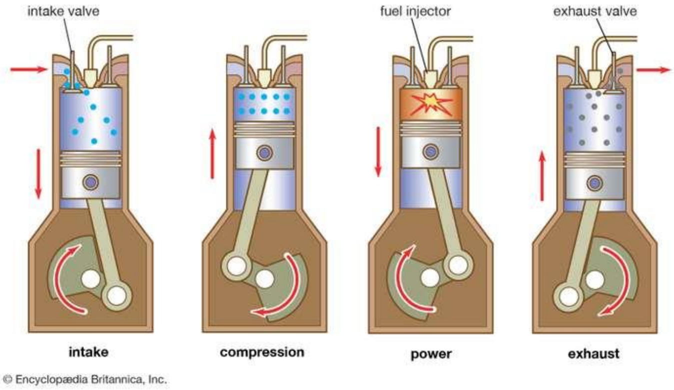

Figure 2.4 Four Stroke Diesel Engine Principal

Source : (Lafayette & Armstrong , 2013)

1. Intake

The piston moves from TDC to BDC. The suction valve is open and the exhaust valve is closed, because the piston moves down, the pressure in the cylinder becomes vacuum (under one atmosphere) so that pure air enters the cylinder. (Samlawi, 2018)

2. Compression

The piston moves from BDC to TDC. The suction valve is closed and the exhaust valve is closed, the air in the cylinder is pushed (pressed) so that heat and pressure arise. The final compression of the fuel is atomized (sprayed with very high pressure through a very small hole) resulting in combustion (in the form of an explosion). (Samlawi, 2018)

3. Power

Combustion produces high pressure in the combustion chamber, this pressure pushes the piston from the TDC to the BDC , doing power. (Samlawi, 2018)

4. Exhaust

The end of the effort of the exhaust valve is open, so the exhaust gas exits through the valve, because it is driven by a piston moving from BDC to TDC. (Samlawi, 2018)

2.3.2. Two-Stroke Diesel Engine

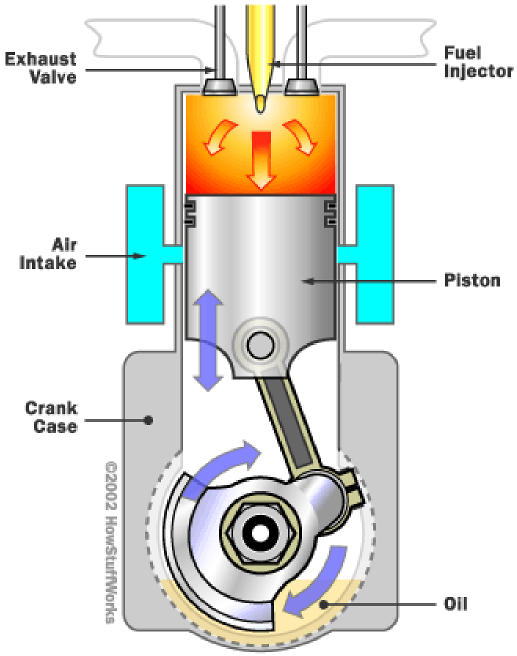

Figure 2.5 Two-Stroke Diesel Engine Principal

Source: (Lafayette & Armstrong , 2013)

1. Intake and compression steps

The piston moves from the BDC to the TDC, the filling air enters through the suction hole, then followed by compression, the end of the compression fuel is injected into the combustion chamber so that combustion occurs. (Samlawi, 2018)

2. Power and Exhaust

As a result of the combustion in the combustion chamber, high pressure pushes the piston from the TDC to the BDC doing power followed by the exhaust. (Samlawi, 2018)

2.4. Combustion

Combustion in the diesel engine differs fundamentally from combustion in the gasoline engine. In the gasoline engine, a more or less homogeneous mixture of air and fuel vapour is compressed and ignited by a spark shortly before top dead centre (TDC); then a flame develops and propagates across the combustion chamber. In the diesel engine, on the other hand, only air is compressed by the piston and the fuel is injected into the chamber towards the end of the compression stroke. At this point the temperature of the air is high enough to cause the fuel to ignite spontaneously. Combustion, with rare exceptions, is a complex chemical process involving many steps that depend on the properties of the combustible substance. It is initiated by external factors such as heat, light, and sparks. The reaction sets in as the mixture of combustibles attains the ignition temperature. The combustion spreads from the ignition source to the adjacent layer of gas mixture; in turn, each point of the burning layer serves as an ignition source for the next adjacent layer, and so on. (Tindal & Uyehara , 1988)

The mixing process between air and fuel is therefore of critical importance to combustion: this mixing is obviously dependent on the characteristics of the fuel spray, If the movements of fuel and air are not matched satisfactorily, then the efficiency of combustion will suffer, with a consequent deterioration in power output and fuel consumption and an increase in the levels of exhaust emissions, both particulate (smoke) and gaseous.

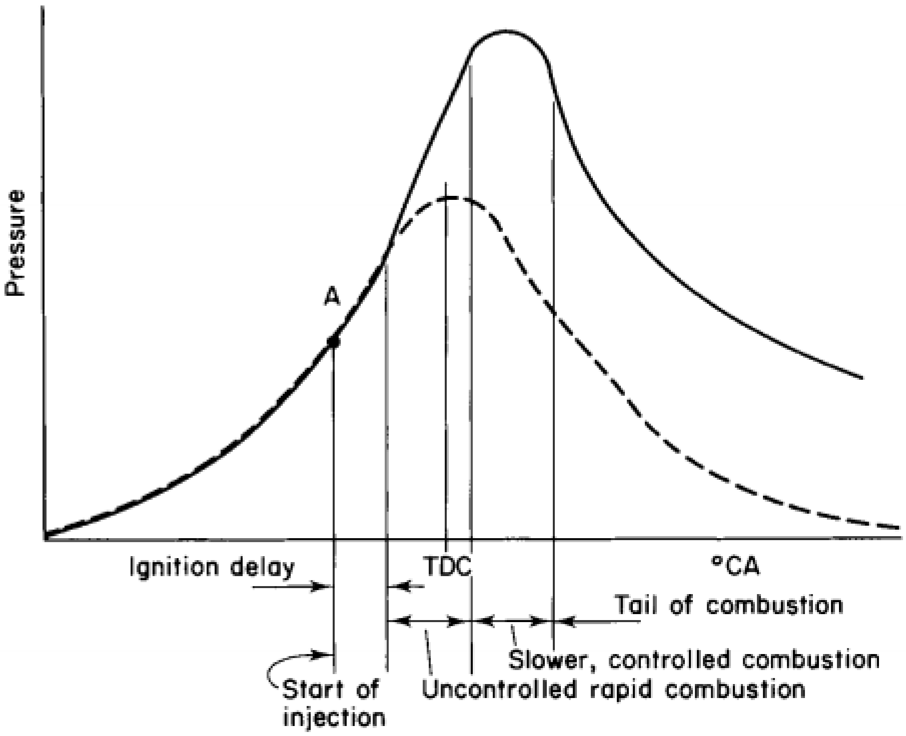

Figure 2.6 typical cylinder pressure for diesel engine
Source: (Tindal & Uyehara , 1988)

2.5. Performance of Diesel Engine

Engine performance is a measure of the performance of the engine, where the performance is closely related to the engine power generated and the usability of the engine. The performance of a vehicle engine is generally shown in three quantities, namely the power that can be produced, the torque produced, and the amount of fuel consumed. The net power generated from the engine's exit shaft is called "brake horsepower" (Bhp). The total power that can be produced from the engine piston is called "indicated horsepower" (IPHP). Some of this indicated horsepower is lost due to friction and moisture energy from the moving mass called "friction horsepower" (Cahyono, et al., 2019).

In determining the performance of the engine, there are several indicators that are closely related to engine performance, such as :

2.5.1. Power

Engine power is the amount of work of the machine during a certain time. In the combustion engine, the useful power is the shaft power, because the shaft moves the load. Shaft power is generated by the power indicator, which is the combustion gas power which moves the piston and then moves all the mechanisms, some of the indicator power is needed to overcome mechanical friction such as piston and cylinder walls and friction between the shaft and bearing. The performance of a combustion motor depends first of all on the power it can generate. The higher the turning frequency of the motor, the higher the power that is given, this is due to the higher frequency, the more work steps are experienced at the same time. (Cahyono, et al., 2019)

2.5.2. Torque

Torque is the multiplication of force and distance. Torque, also called moment or force moment, is the equivalent form of rotation of linear force. During the power process, the pressures that occur in the motor cylinder creates an unusually strong force on the piston. The force is transferred to the crank pen through the connecting rod resulting in a moment of turning or torque on the crankshaft.

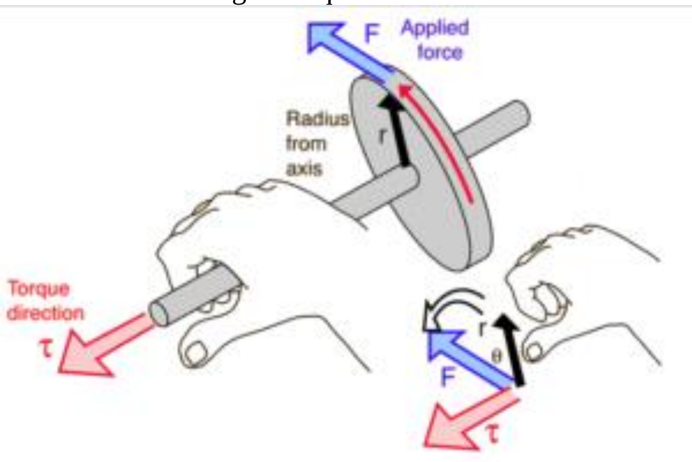

Figure 2.7 Torque principal
Source: (Collins, 2017)

To find out the amount of torque, a dynamometer is used. Usually, the combustion motor is connected to the dynamometer with the intention of getting the output torque from the combustion motor by connecting the shaft of the combustion motor with the dynamometer shaft using an elastic clutch.

2.5.3. Specific Fuel Oil Consumption (SFOC)

Fuel consumption is the amount of fuel per time to produce power of 1 HP. So fuel consumption is a measure of the economy of fuel use. For fuel consumption only the volume of fuel per unit time (kg / hour). (Cahyono, et al., 2019)

2.5.4. Brake Mean Effective Pressure (BMEP)

Average effective pressure is defined as the effective pressure of the working fluid against the piston along with its steps to produce a cycle of work.

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CHAPTER 3
METHODOLOGY

In this research using simulation method. In making it, a structured process is needed to simplify the steps to make it clearer. The processing of this research is described in a flow chart which will be presented in figure 3.1

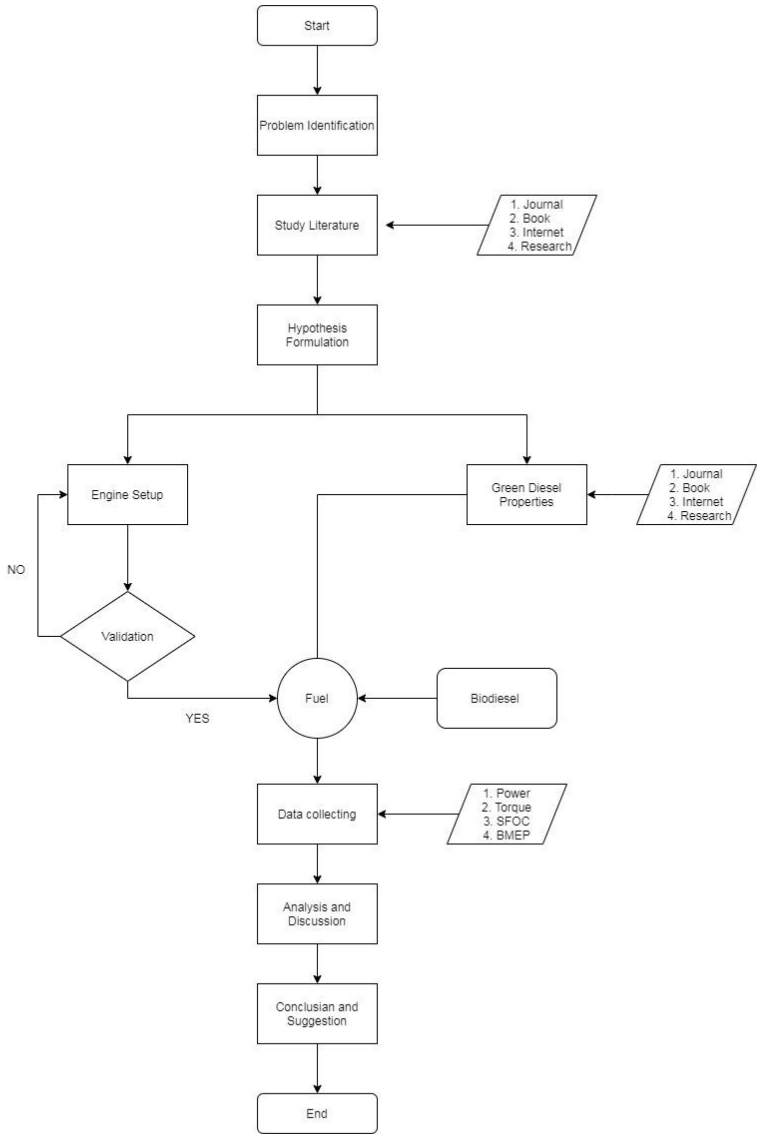


Figure 3.1 research flow chart

3.1. Problem Identification

The first process is to identify the possible problem that may happen during the process of this research, such as:

a. Knowing the performance of green diesel fuel on one cylinder diesel engine, including power, torque, SFOC, and BMEP.
b. Knowing the performance of biodiesel B30 fuel on one cylinder diesel engine including power, torque, SFOC, and BMEP.
c. Comparison of performance between green diesel and biodiesel B30.

3.2. Study Literature

Study Literature is carried out to determine the extent of this problem examined previously. Study Literature obtain from the journal, book, internet, and previous research.

3.3. Hypothesis Formulation

The hypothesis in this study is :

1. Green Diesel has higher power than biodiesel B30.
2. Green Diesel has higher Torque than biodiesel B30.
3. Green Diesel has less SFOC than biodiesel B30.
4. Green Diesel has better BMEP than biodiesel B30

3.4. Engine Set Up

Engine set up is a series that is used to test the performance of green diesel and biodiesel B30. In this reasearch using simulation with type the engine is Yanmar TF85 MH. Firstly, build the engine setup from reading the tutorial. The component on this simulation such as:

1. Inlet environment
2. Intake runner
3. Intake port
4. Intake and exhaust valve
5. Cylinder
6. Fuel injector
7. Exhaust port and runner
8. Outlet environment
9. Engine crank train
10. Dynamometer

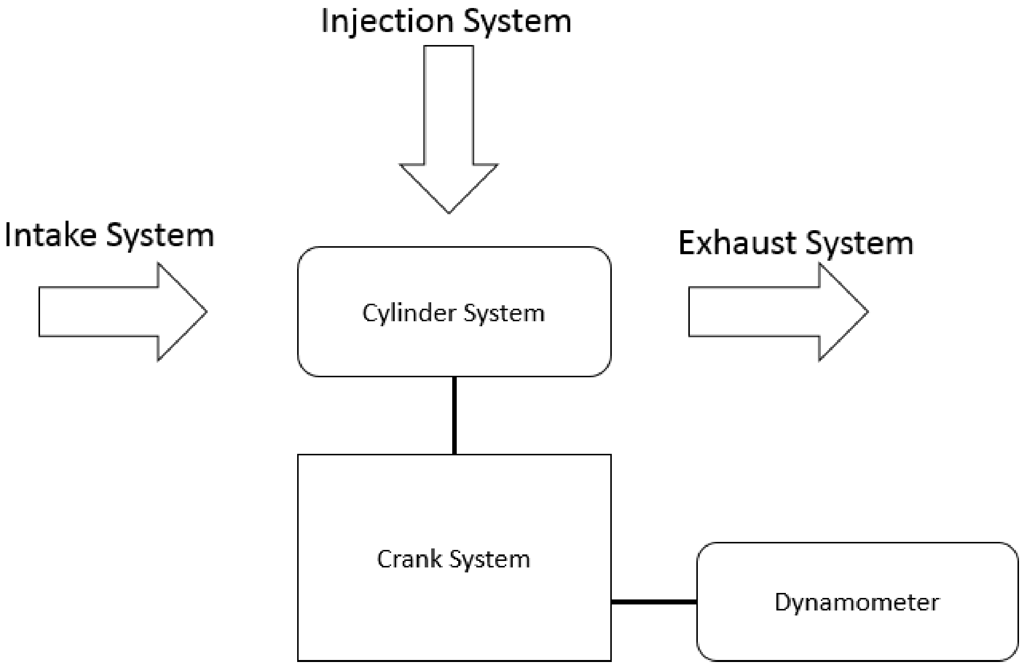


Figure 3.2 Engine Setup on simulation

From figure 3.1, it can be seen that the engine setup in simple explanation. Engine setup consist of 3 main part, from figure above shown in block figure, there are **cylinder system** which use to place for mixing between fuel and air and then it occurs internal combustion, **crank system** which use to change the mechanical motion into rotation motion, and last is **dynamometer** which use as load in this simulation.

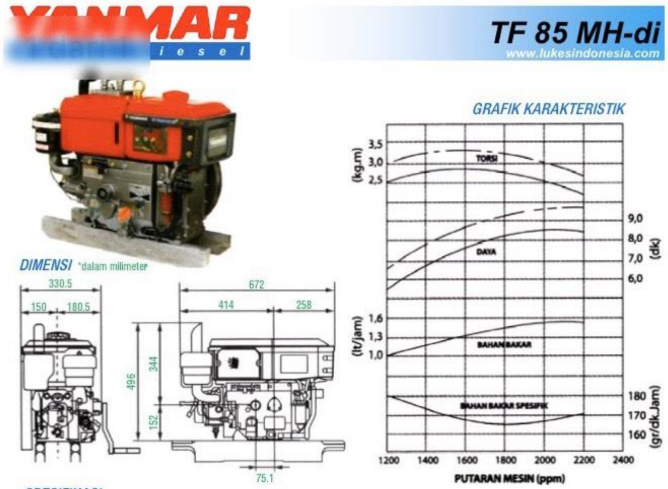
Furthermore, other component shown in arrow figure, there are **intake system** which consist of inlet environment, intake runner, intake port, and intake valve. **Injection system** which use to injection the fuel into the cyclinder for combustion process, and last is **exhaust system** which consist of exhaust valve, exhaust port, exhaust runner, outlet environment.

Then after all compoent has been input, now time to place parts on the project map and connect the components together. Setting the plot setup to checklist what datas want to be simulated. Moreover, setting the case setup for the what paramaters want to be vary.

There are 4 example of parameters in simulation. First is **RPM**, which use to test the simulation at what engine speed will be tested. **Injected mass** is the amount of fuel injected into the combustion chamber in units of gram. **Fuel** is type of fuel will be tested, in this simulation the fuel to be tested is biodiesel B30 and green diesel. And the last is **AFR** or air fuel ratio. Afr is comparison between air and fuel inside cylinder where to complete the great combustion

3.5. Validation

Validation is a series of activities that form the relationship between the value indicated by a measuring instrument or measurement system, or the value represented by a measuring material, with known values relating to the amount measured under certain conditions. (ISO/IEC, 2005). validation that we use is to compare the data according to the Yanmar TF85 MH-di engine catalog. the data being compared is torque at RPM 1600 and Power at RPM 2200.



SPESIFIKASI

1	Jenis Mesin	Motor diesel horizontal 4 (empat) langkah berpendingin air
2	Sistem Pembakaran	Pengabutan langsung (direct injection)
3	Jumlah Silinder	1 (satu) silinder
4	Saat Pengabutan	18^0 sebelum TMA
5	Diameter x Panjang Langkah	85 mm x 87 mm
6	Volume Silinder	493 cc
7	Daya Kontinyu	7.5 dk / 2200 ppm
8	Daya Maksimum Sesaat	8.5 dk / 2200 ppm
9	Torsi Maksimum	3.44 kg.m / 1600 ppm
10	Perbandingan Kompresi	18
11	Arah Putaran Poros	Berlawanan dengan arah putaran jarum jam (dilihat dari sisi roda gaya)
12	Pemakaian Bahan Bakar	171 gr / dk.jam
13	Pompa Bahan Bakar	Tipe Bosch
14	Tekanan Injektor	200 kg/cm^2
15	Sistem Pelumasan	Pelumasan paksa menggunakan pompa & katup regulator hidrolik (pompa jenis trochoidal)
16	Kapasitas Tanki Bahan Bakar	10.5 liter
17	Kapasitas Minyak Pelumas	2.2 liter
18	Jenis Minyak Pelumas	SAE 40 kelas CC atau CD
19	Sistem Pendinginan	Hopper
20	Kapasitas Tanki Pendingin	8.9 liter
21	Cara Menghidupkan	Manual (engkol)
22	Dimensi Mesin (P x L X T)	672 mm x 330.5 mm x 496 mm
23	Lampu	
24	Berat Kosong	93 kg
25	Ukuran Kemasan (P X L X T)	780 mm x 480 mm x 700 mm
26	Berat Kotor	123.5 kg

www.lukesindonesia.com

Figure 3.3 Specification Yanmar 85MH-di
Source: Yanmar catalog engine

3.5.1. Validation at RPM 2200

Firstly,calibrates at 2200 RPM. validation at this point to match the power, torque, and SFOC in accordance with the Yanmar 85 TF MH-di engine catalog. At this sample point, this simulation uses an injected mass of 1 g with a comparison of air fuel ration 14.6 with diesel to combust fuel (HSD) in accordance with the specifications of the engine catalog. After that run the simulation and retrieves data from the table that we have previously set the plot of what we will take out.

Table 3.1 Validation at RPM 2200

	Validation	Manual book
Daya (HP)	8.59	8.5
Daya (kW)	6.41	6.33
Torsi (kgf-m)	-	-
SFOC (g/HP-h)	171.38	171

From the table 3.1, the simulation results show the power value is 8.59 [HP] and SFOC 171.38 [g/HP-h]. After that, it is compared with the engine catalog where it has power is 8.5 [HP] and SFOC is around 171 [g/HP-h]. From this comparison, we can calculate the error margin between the simulation and the machine catalog. And the error value for power is 1.04 % , and margin eror for SFOC is 0.22%.

3.5.2. Validation at RPM 1600

Secondly, Calibrates at 1600 RPM. validation at this point to match the torque in accordance with the Yanmar 85 TF MH-di engine catalog. At this sample point uses an injected mass of 1 gram with a comparison of air fuel ration 14.6 with diesel to combust fuel (HSD) in accordance with the specifications of the engine catalog. After that run the simulation and retrieves data from the table that we have previously set the plot of what we will take out.

Table 3.2 Validation at RPM 1600

	Validation	Manual book
Daya (HP)	-	-
Daya (kW)	-	-
Torsi (kgf-m)	3.21	3.4
SFOC (g/HP-h)	-	-

From the table 3.3, the simulation results show the torque value is 3.21 [kgf-m], After that, it is compared with the engine catalog where it has torque is 3.4 [kgf-m]. Next step is to find the error margin between the simulation and the engine catalog. And the error value is 5.5%.

3.6. Green Diesel Properties

This process is the stage where we looking for the properties from green diesel fuel. Normally green diesel properties is tested on a laboratory scale. But in this reaserach, we use journal as source of the properties test. Property test has several parameters in accordance with the provisions of SNI (Indonesian standard). For example parameters will be tested in general properties test such as :

a. Density
   The density of an object is one of its most important and easily-measured physical properties. Densities are widely used to identify pure substances and to characterize and estimate the composition of many kinds of mixtures.Density is a measurement of the mass of each unit volume of an object. density denoted by ρ (rho). The higher the density of an object, the greater the mass of each volume. Density functions to determine substances. Each substance has a different density. And one substance, whatever its mass, whatever its volume, will have the same density. (Lower, 2020)
b. Viscosity
   Viscosity is a measure of resistance to flow . Viscosity is a measure of the thickness of a fluid which shows the size of the fluid's internal friction. (Bono, et al., 2006)
c. pH
   The degree of acidity used to express the acidity or basicity of a solution. fuels that have acidic pH will have corrosive properties, which means they will make components rust faster. (Trick, et al., 2018)
d. Flash Point
   The flashpoint is the lowest temperature at which the fuel expels enough steam to form a mixture with air, and can catch fire. Flash point is the temperature at which the ignition source will ignite the testing sample. The flash point is determined by heating the sample of fuel in a container and passing the flame over the surface of the sample. (Babu & Anand , 2019)
e. LHV
   The lower heating value (also known as net calorific value) of a fuel is defined as the amount of heat released by combusting a specified quantity (initially at 25°C) and returning the temperature of the combustion products to 150°C, which assumes the latent heat of vaporization of water in the reaction products is not recovered. (Sarkar, 2015)

Table 3.3 Certain Fuel Properties
Source : (L.Douvartzides, et al., 2019)

No	Property	Green Diesel	Petroleum Diesel	Biodiesel
1	Carbon (wt%)	84.9	86.8	76.2
2	Hydrogen (wt%)	15.1	13.2	12.6
3	Oxygen(wt%)	0.0	0	11.2

4	Cetane Number (CN)	>70	44.5-67	45-55
5	Lower Heating Value (MJ/Kg)	43.7-44.5	43.1	37.2
6	Density at 150c (kg/m3)	770-790	796-841	880
7	Polycyclic Aromatic Hydrocarbons (wt%)	<0.1	1.5-4.4	
8	Sulfur Content(mg/kg)	<5	3.8-15	
9	Flash Point (oc)	>59	54-148	100-180
10	Ash Content(wt%)	<0.001	0.01	
11	Water Content(mg/kg)	<200		
12	Viscosity 40oc (mm	2 until 4	1.9-4.1	2.9-11

3.7. Data Collecting

At this process, the fuel will be tested using a one-cylinder engine in simulation, The performance test is carried out by comparing the two fuels namely green diesel and biodiesel B30, the parameter that wants to test is :

a. Power
b. Torque
c. SFOC
d. BMEP

3.8. Analysis and Discussion

The analysis was carried out based on simulation data taken between green diesel and Biodiesel B30. The analysis will be presented in the form of a comparison graph

3.9. Conclusion and Suggestion

After all the steps are carried out, the next step is the conclusion of data analysis. It is hoped that the conclusions will be able to answer the problem that is the purpose of this thesis. Besides that, critics and suggestions based on the results of the research are needed to improve the thesis so that it is more perfect.

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CHAPTER 4
DATA ANALYSIS AND RESULT

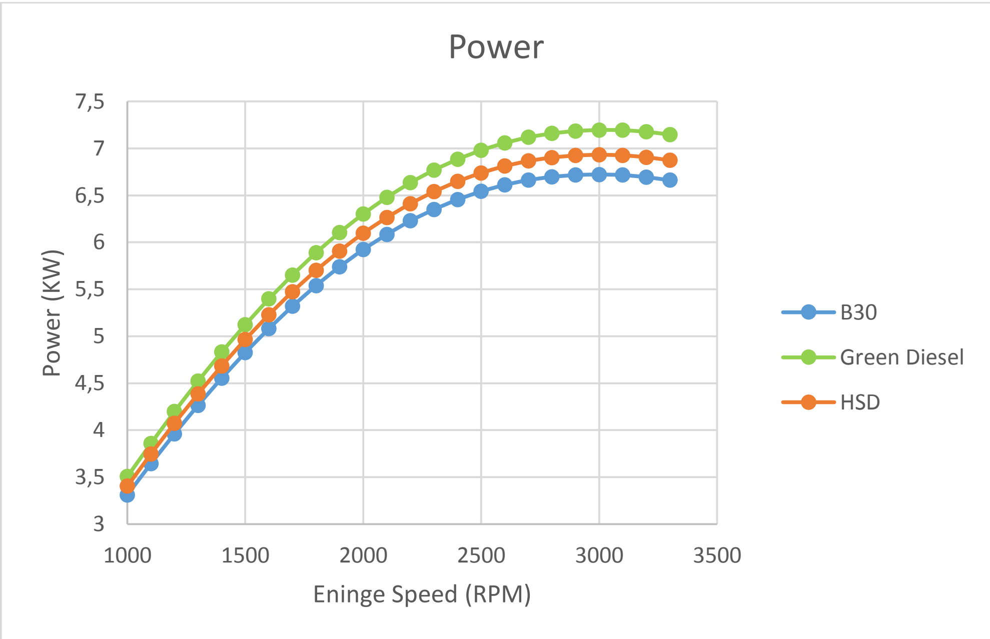
In this chapter will explain the results of the performance of each fuel and will compare the performance of the two fuels. From the results of the performance includes power, torque, specific fuel consumption (SFOC), BMEP. The performance data retrieval process is obtained from the performance simulation process from Green Diesel and biodiesel B30 diesel engines.

4.1. Performance of diesel engine with Biodiesel B30 and Green Diesel at full load

In this simulation there are three types of fuel that will be used. The first type of fuel uses biodiesel B30. The second type of fuel uses biofuels made from palm oil through a hydrotreating process called Green Diesel. And the last is HSD(High Speed Diesel), and HSD fuel in this research is only used as supporting data to analyze the comparison of biodiesel B30 and green diesel.

In this study, the variable RPM is determined at 1000 until 3300 so that the peak point of each fuel on each parameters in the diesel engine can be seen. Data taken includes power, torque, SFOC, BME.

4.1.1. Comparison between Power vs RPM at full load on Biodiesel B30 and Green Diesel



Graph 4.1 Graph of power and RPM at full load

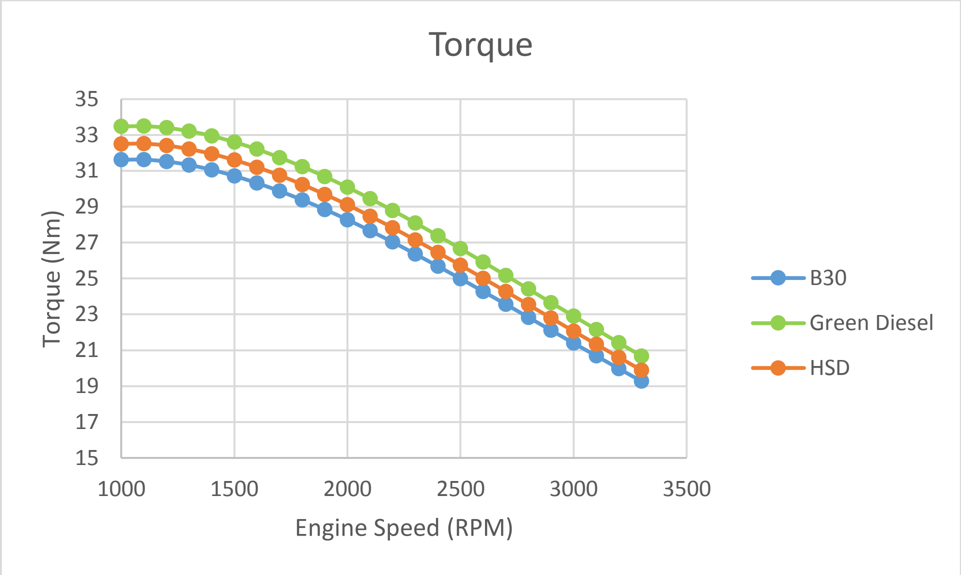
In graph 4.1 is a comparison graph of power at full load with engine speed on each fuel start from 1000 rpm until 3300 rpm.Tthe fuel being compared is biodiesel B30 (blue line) , green diesel (green line), and HSD (red line). On the X-axis shows the engine RPM, and on the Y-axis shows power. the full load power of B30 biodiesel green diesel, and hsd obtained shows quite high differences. the difference in power value of the two fuels (green diesel and biodiesel B30) between 1000-3300 rpm between the range 5.5% (0.194 kW) - 6.8% (0.485). And the difference power between green diesel and hsd is 2.9%-3.8%. from this differences, range margin between green diesel and hsd less than green diesel biodiesel B30.

From the graph 4.1, The highest power from 3 fuels is green diesel, the second is HSD, and last is biodiesel B30. Green diesel has maximum power at 3000 rpm with value is 7.194 KW and it happens overload in engine, while the lowest power on green diesel at 1000 rpm with value is 3.5 kW. Biodiesel B30 has the highest power at 3000 rpm with value is 6.72 KW also it happens overload, while the lowest power on biodiesel B30 at 1000 rpm with value is 3.31 KW. And highest point for HSD(High Speed Diesel) at 3000 rpm with value is 6.93 KW and it happens overload, while the lowest power on hsd at 1000 rpm with value is 3.403 KW.

In the graph above, the peak point is at 3300 rpm while in the Yanmar engine catalog the peak point is at 2200 rpm. This is because the friction data input is relatively small compared to the data taken during the experiment. So the smaller the friction used, the less power loses and the power produced is relatively bigger.

The conclusion from the graph if the use of green diesel in a one cylinder diesel engine has a higher power than using Biodiesel B30 and hsd in every engine speed. It cause higher the cetane number better it is in its ignition properties. Cetane number affects a number of engine performance parameters like combustion, stability, drivability, white smoke, noise and emissions. Green diesel has higher cetane number than petroleum diesel and biodiesel B30. This results in higher combustion efficiency and smoother combustion

4.1.2. Comparison between Tourque and RPM at full load on Biodiesel B30 and Green Diesel



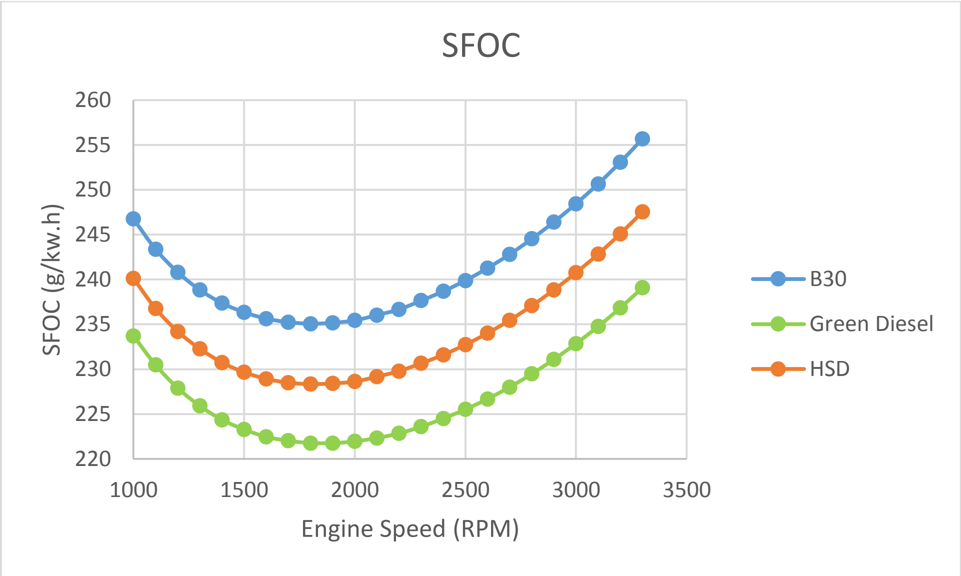
Graph 4.2 Graph of torque and RPM at full load

In graph 4.2 is a comparison graph of torque at full load with engine speed on each fuel. the fuel being compared is biodiesel B30 (blue line), green diesel (green line), and HSD (red line). On the X-axis shows the engine RPM, and on the Y-axis shows torquep[Nm]. The torque at full load of biodiesel B30 and green diesel obtained shows quite constantly differences. The difference in maximum tourque value of the two fuels (green diesel and biodiesel B30) at rpm 1100 is 5.57% (1.86 Nm). And difference maximum torque for green diesel and hsd at rpm 1100 is 2.9%(0.97 Nm). So from the graph above, the first maximum torque that has a high value is green diesel, second is hsd, and last is biodiesel B30.

In the 1000 rpm rotation it was seen that biodiesel B30 had increased to 1100 rpm by 0.007 Nm, green diesel had increased by 0.013 Nm, and hsd had inceased by 0.0139 Nm. And when at 1100 rpm, all fuels get a maximum torque value or can be called the torque peak point. the maximum torque value for biodiesel is 31.62 Nm , for green diesel is 33.49 Nm, and for hsd is 32.502 Nm.

After passing the torque peak point, the torque value will drop steadily on all fuels. And the lowest point of torque on biodiesel at 3300 rpm with a torque value of 19.27 Nm, lowest value of green diesel at 20.67 Nm, and lowest value of HSD is 19.88 Nm. The conclusion from the graph if the use of green diesel in a one cylinder diesel engine has a better torque in every RPM than using B30 biodiesel and hsd at full load.

4.1.3. Comparison between Spesific Fuel Oil Consumption (SFOC) and RPM at full load on Biodiesel B30 and Green Diesel



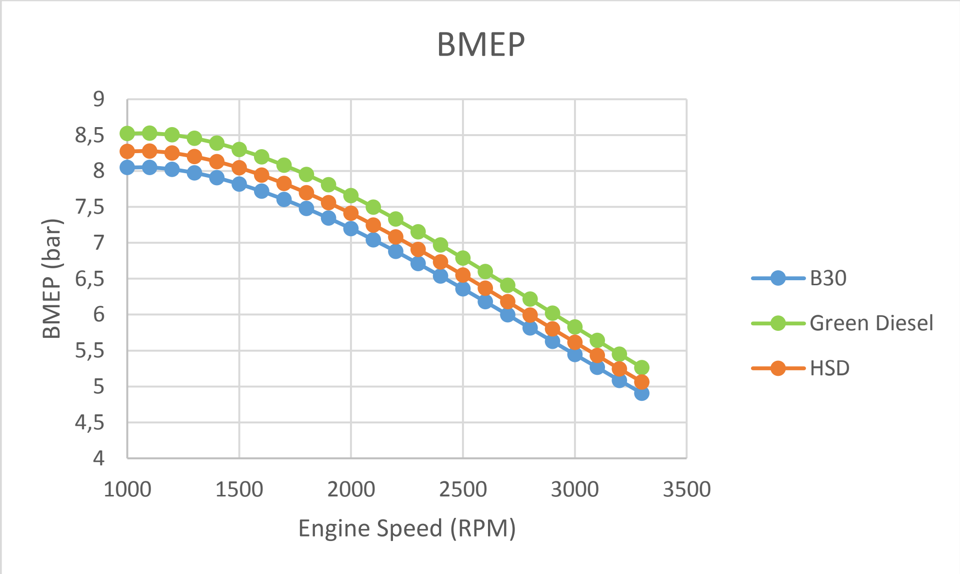
Graph 4.3 Graph of SFOC and RPM at full load

Based on Graph 4.3 shows the comparison between Engine Rotation to Specific Fuel Oil Consumption (SFOC) at full load conditions for all types of fuel. the fuel being compared is biodiesel B30 (blue line), green diesel (green line), and HSD (red line). On the X-axis shows the engine RPM, and on the Y-axis shows torquep[Nm]. SFOC obtained using green diesel and biodiesel B30 has a significant difference of around 5.58% at 1000 RPM and 6.9 % at 3300 RPM. And difference value of sfoc between green diesel and hsd around 2.74% at 100 RPM and 3.53 % at 3300 RPM. So from the graphic above, the highest sfoc value is biodiesel B30, second is hsd , and the lowest is green diesel.

Lower peak point is the best point for more efficiently Spesific fuel oil consumption. On the graph above, Lower peak point from each fuels is different, green diesel has lower peak point at 2000 rpm, biodiesel B30 at 1900 rpm , and for hsd at 1900 rpm. The lowest SFOC point on this case is green diesel fuel with value of SFOC is 221.75 gr / kWh, lowest for Biodiesel B30 with value of SFOC is 235.06 gr / kWh, and lowest value for hsd is 228.405 gr/kWh. Engine speed which has the largest SFOC point at 3300 rpm with B30 biodiesel fuel, with a value of 255.68 gr / kWh, for the largest SFOC point on green diesel is at 3300 rpm with an SFOC value of 239.08 gr / kWh, and the largest SFOC of hsd is 247.53 gr/kWh.

From simulation method using these three types of fuel, biodiesel B30, green diesel and high speed diesel (HSD), it was found that the best value of specific fuel oil contumption is green diesel that has a lower value than biodiesel B30 and hsd.

4.1.4. Comparson between Brake Mean Effective Pressure (BMEP) and RPM at full load on Biodiesel B30 and Green Diesel



Graph 4.4 Graph of BMEP and RPM at full load

Based on the graph 4.4 Comparison between Engine Speed and BMEP (Brake Mean Effective Pressure) in full load conditions for all types of fuel, biodiesel B30 (blue line) , Green diesel (green line), and high speed diesel (red line). From the graph it can be seen that the results are approximately the same as the torque vs. speed graph. From the graph above, the first maximum BMEP that has a high value is green diesel, second is hsd, and last is biodiesel B30.

From simulations using 2 types of these fuels (biodiesel B30 and green diesel), it was found that the largest BMEP produced green diesel fuel at a speed of 1100 rpm with a value of 8.52 bar, for Biodiesel B30 the largest point of BMEP at 1100 rpm with value is 8.05 bar, and for high speed diesel fuel has the largest point of BMEP at 1100 rpm with value is 6.27 bar. At this rpm too, biodiesel B30 and green diesel have the peak value. And after this rpm, the value of BMEP decrease constantly approximately 5.63 % to rpm 1200 and the value continous decrease every increasing the engine speed.

Then the lowest point and the lowest BMEP produced biodiesel B30 at a speed of 3300 rpm with a value is 4.905 bar , for green diesel has the lowest point at 3300 rpm with value is 5.26 bar, and for high speed diesel engine has lowest point at 3300 rpm with value is 5.06 bar. So From the simulation method using biodiesel B30, green diesel, and HSD, using green diesel has better value of BMEP than using biodiesel B30 and HSD.

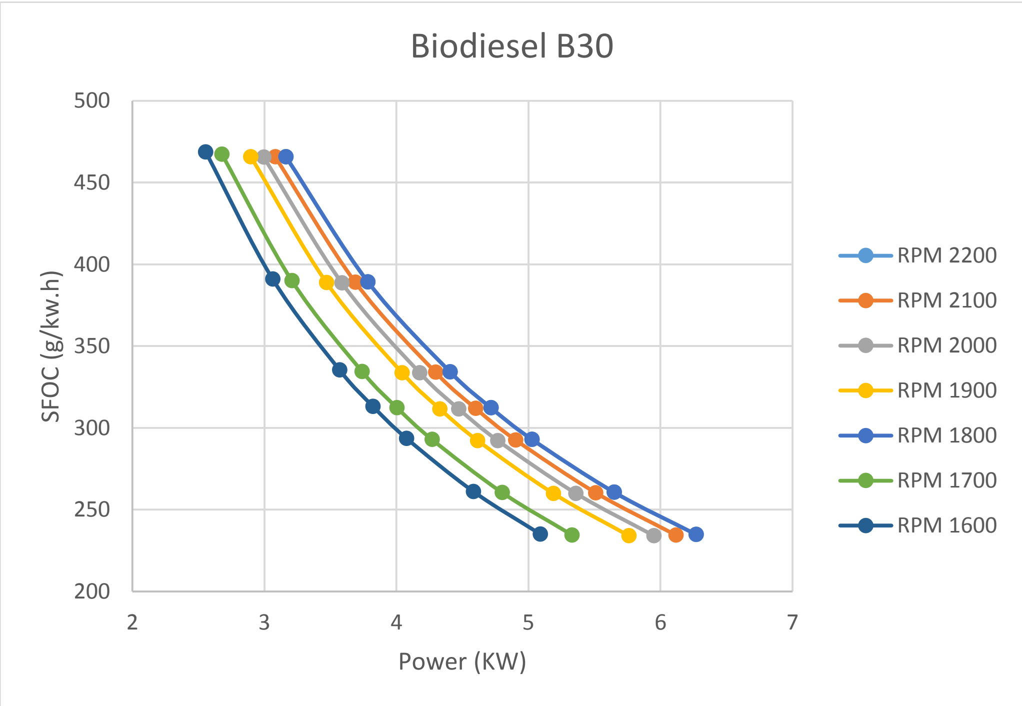
4.2. Performance of diesel engine with Biodiesel B30 and Green Diesel on load variations at each RPM

In this analysis, a performance test will be conducted to determine the effect of green diesel on diesel engines. This study uses a Yanmar TF85-MH diesel engine one cylinder with variations in load. The results of this simulation will determine the performance of diesel engines using green diesel fuel and will be compared with biodiesel B30. Limitation of the engine speed to be tested is at rpm 1600,1700,1800,1900,2000,2100and 2200.

The load used in this study uses torsimeter loading with torsion input [Nm]. Load variations are used between 50%, 60%, 70%, 75%, 80%, 90%, 100% at maximum torque at each engine speed.

In this experiment there are two types of fuel that will be used. The first type of fuel uses biodiesel B30 fuel, which is a standard diesel engine fuel in Indonesia. The second type of fuel uses green diesel.

4.2.1. Comparison between power and SFOC on Biodiesel B30

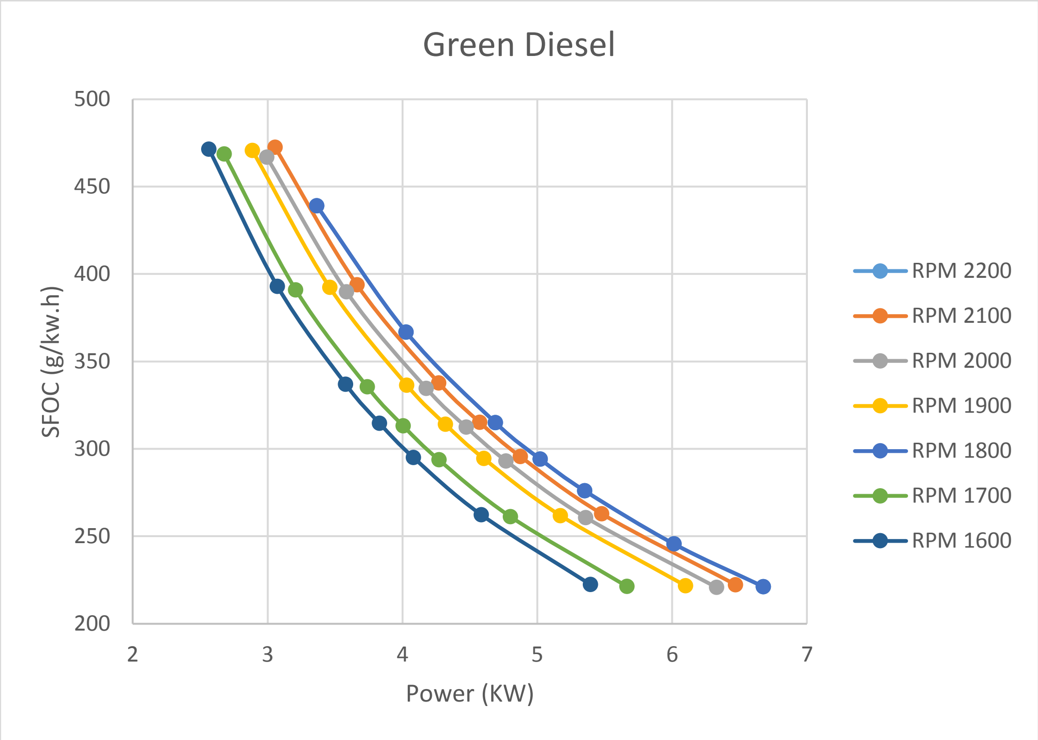


Graph 4.5 Graph of power and SFOC on Biodiesel B30

On the graph 4.5 explains that Comparison between power and SFOC on biodiesl B30 every engine speed from 1600 rpm-2200 rpm. X-axis power in KW unit and Y-axis shows SFOC in g/kwh unit. From the graph it can be seen At 1600 rpm has the biggest power is 5.09 Kw, at 17000 the biggest power is 5.33 Kw, at 1800 rpm, the biggest power is 6.2 kW, while at 1900 rpm it gets 5.76 kW. At 2000 rpm rotation, 2100 rpm, 2200 rpm obtained maximum power respectively of 5.95 kw, 6.11 kw, and 6.27 kW.

Meanwhile, the lowest SFOC point in this type of biodiesel B30 fuel is 1900 RPM with an SFOC value of 234.04 gr / kWh. The lowest SFOC point at each RPM is 1600 RPM with SFOC value is 235.02 gr / kWh, 1700 RPM with SFOC value is 234.48 gr / kWh, 1800 RPM with an SFOC value of 234.79 gr / kWh, 2000 RPM with an SFOC value of 234.112 gr / kWh, 2100 RPM with an SFOC value of 234.45 gr / kWh, and 2200 RPM with an SFOC value of 234.798 gr / kWh.

4.2.2. Comparison between power and SFOC on Green Diesel

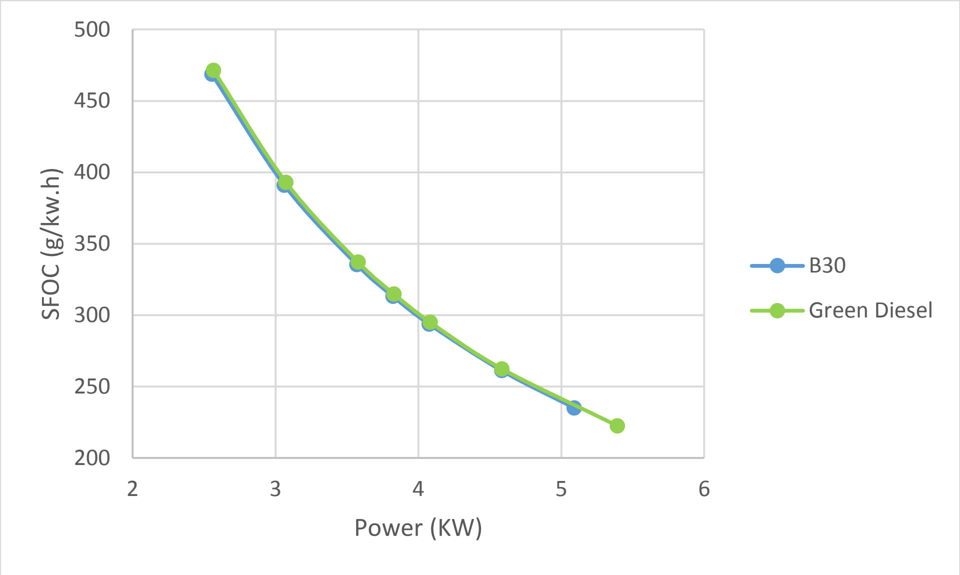


Graph 4.6 Graph of power and sfoc on green diesel

On the graph 4.6 explains that Comparison between power and SFOC on green diesel every engine speed from 1600 rpm-2200 rpm. X-axis power in KW unit and Y-axis shows SFOC in g/kwh unit. From the graph it can be seen At 1600 rpm has the biggest power is 5.39 Kw, at 17000 the biggest power is 5.663 Kw, at 1800 rpm, the biggest power is 6.675 kW, while at 1900 rpm it gets 6.09 kW. At 2000 rpm rotation, 2100 rpm, 2200 rpm obtained maximum power respectively of 6.329 kw, 6.470 kw, and 6.675 kW.

Meanwhile, the lowest SFOC point in this type of biodiesel B30 fuel is 2000 RPM with an SFOC value of 220.740 gr / kWh. The lowest SFOC point at each RPM is 1600 RPM with SFOC value is 222.437 gr / kWh, 1700 RPM with SFOC value is 221.359 gr / kWh, 1800 RPM with an SFOC value of 221.207 gr / kWh, 1900 RPM with an SFOC value of 221.741 gr / kWh, 2100 RPM with an SFOC value of 222.305 gr / kWh, and 2200 RPM with an SFOC value of 221.207 gr / kWh.

4.2.3. Comparison between Power and SFOC on Biodiesel B30 and Green Diesel at RPM 1600



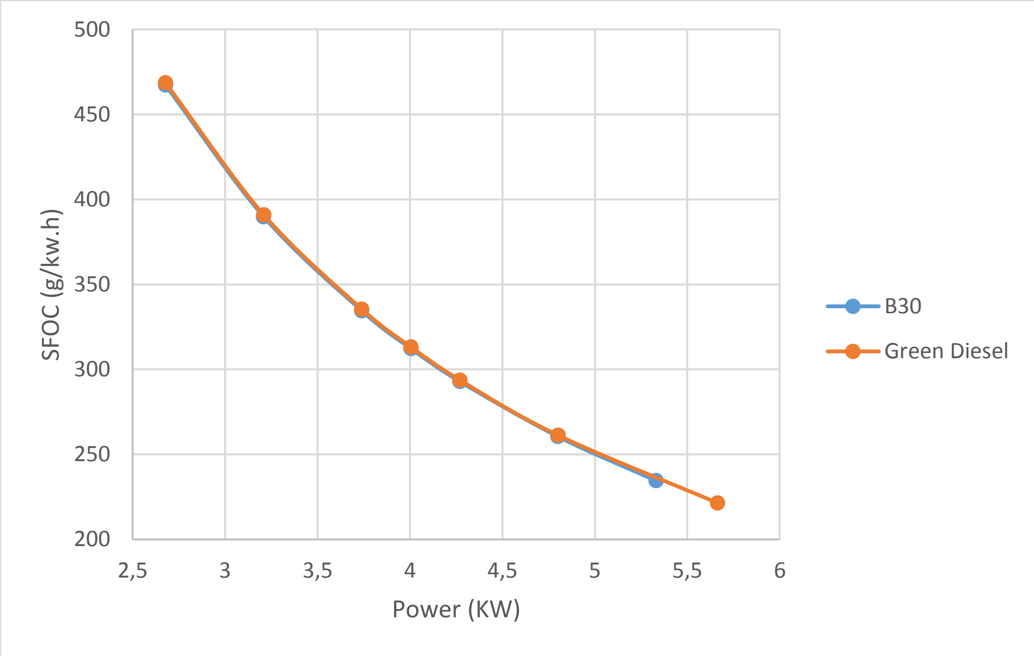
Graph 4.7 Graph of power and SFOC at RPM 1600

From the graph 4.7 explains that Comparison between power with specific fuel oil consumption (SFOC) at rpm 1600 on biodiesel B30(blue line) and green diesel (green line). X-axis shows power in Kw unit and Y-axis shows power in [g/kwh] unit. From the graph it can be seen that the results of comparison biodiesel B30 and green diesel are approximately quite difference and it shown graphic of decline constantly. From the graph above, it can be concluded that the SFOC value will decrease with the addition of power up to 100% load.

From simulations using 2 types of these fuels (biodiesel B30 and green diesel), it was found that the largest power produced green diesel fuel and also in this load is the optimum SFOC value, it means more ecomical and less cost. The largest power value is 5.39 kW with SFOC value is 222.43 g/kwh. For Biodiesel B30 the largest point is 5.09 kWwith SFOC value is 234.0211 g/kwh.

Then the lowest point of power produced biodiesel B30 and also in this load is the hisghest SFOC value, it means more cost. The lowest power with a value is 2.55 Kw and SFOC value is 468.682 g/kwh. And for green diesel has the lowest power value is 2.56 kW, with the SFOC value is 471.464 g/kwh. From the simulation method using biodiesel B30 and green diesel, using green diesel has better value of power and SFOC at 1600 RPM

4.2.4. Comparison between between Power and SFOC on Biodiesel B30 and Green Diesel at RPM 1700

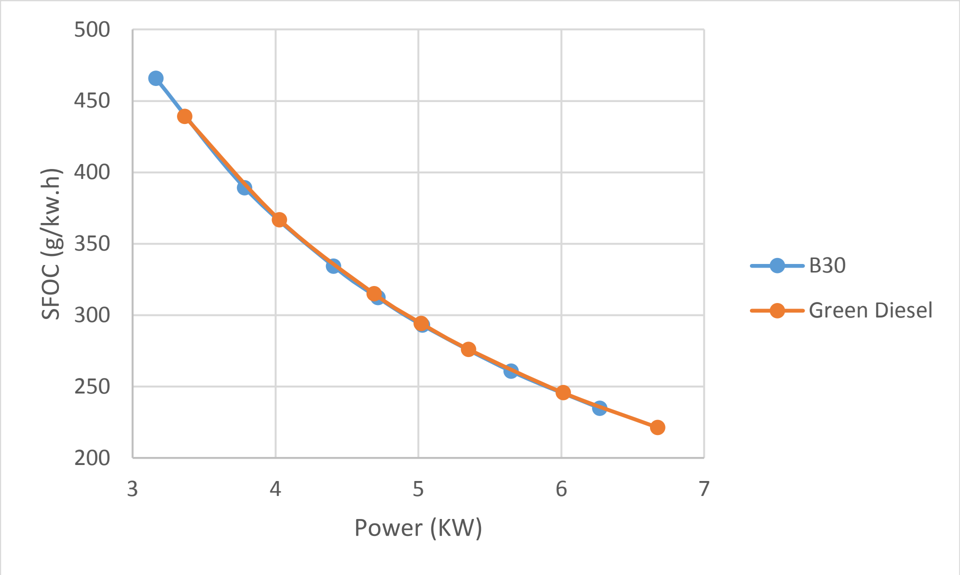


Graph 4.8 Graph of power and SFOC at RPM 1700

From the graph 4.8 explains that Comparison between power with specific fuel oil consumption (SFOC) at rpm 1700 on biodiesel B30(blue line) and green diesel (red line). X-axis shows power in Kw unit and Y-axis shows power in [g/kwh] unit. From the graph it can be seen that the results of comparison biodiesel B30 and green diesel are approximately same and it shown graphic of decline constantly. From the graph above, it can be concluded that the SFOC value will decrease with the addition of power up to 100% load. From simulations using 2 types of these fuels (biodiesel B30 and green diesel), it was found that the largest power produced green diesel fuel and also in this load is the optimum SFOC value, it means more ecomical and less cost. The largest power value is 5.663 kW with SFOC value is 221.259 g/kwh. For Biodiesel B30 the largest point is 5.331 kW with SFOC value is 234.484 g/kwh.

Then the lowest point of power produced biodiesel B30 and also in this load is the hisghest SFOC value, it means more cost. The lowest power with a value is 2.676 Kw and SFOC value is 467.343 g/kwh. And for green diesel has the lowest power value is 2.6771 kW, with the SFOC value is 468.690 g/kwh. From the simulation method using biodiesel B30 and green diesel, using green diesel and biodiesel B30 is same but at 100% load has the best value of green diesel than biodiesel B30.

4.2.5. Comparison between between Power and SFOC on Biodiesel B30 and Green Diesel at RPM 1800

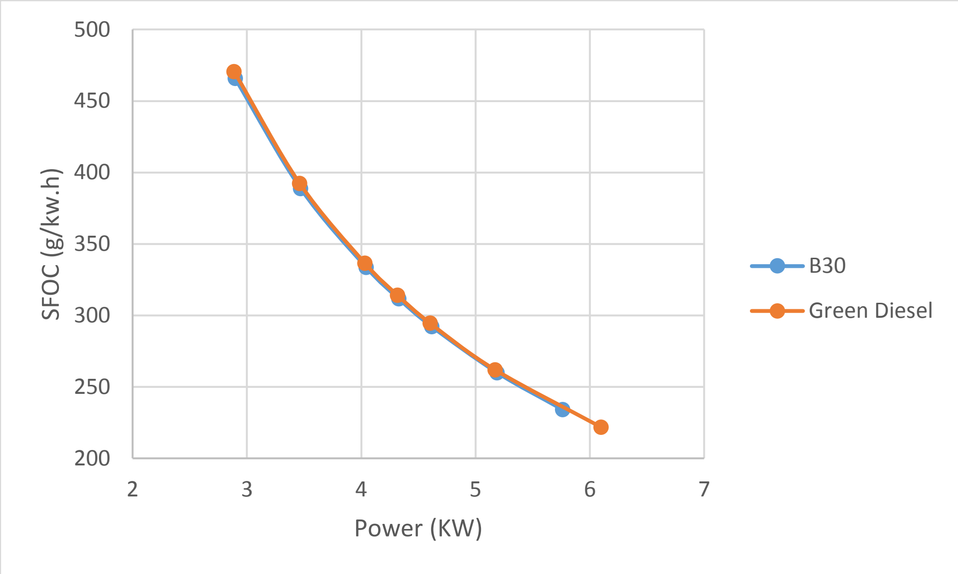


Graph 4.9 Graph of power and SFOC at RPM 1800

Based the graph 4.9 explains that Comparison between power with specific fuel oil consumption (SFOC) at rpm 1700 on biodiesel B30(blue line) and green diesel (red line). X-axis shows power in Kw unit and Y-axis shows power in [g/kwh] unit. From the graph it can be seen that the results of comparison biodiesel B30 and green diesel are approximately quite different and it shown graphic of decline constantly. From the graph above, it can be concluded that the SFOC value will decrease with the addition of power up to 100% load.

Simulations using 2 types of these fuels (biodiesel B30 and green diesel), it was found that the largest power produced green diesel fuel and also in this load is the optimum SFOC value, it means more ecomical and less cost. The largest power value is 6.67 kW with SFOC value is 221.207 g/kwh. For Biodiesel B30 the largest point is 6.27 kW with SFOC value is 234.798 g/kwh. Then the lowest point of power produced biodiesel B30 and also in this load is the highest SFOC value, it means more cost. The lowest power with a value is 3.1625 Kw and SFOC value is 465.745 g/kwh. And for green diesel has the lowest power value is 3.364 kW, with the SFOC value is 439.041 g/kwh. From the simulation method using biodiesel B30 and green diesel, using green diesel has better value of power and SFOC at 1800 RPM.

4.2.6. Comparison between between Power and SFOC on Biodiesel B30 and Green Diesel at RPM 1900



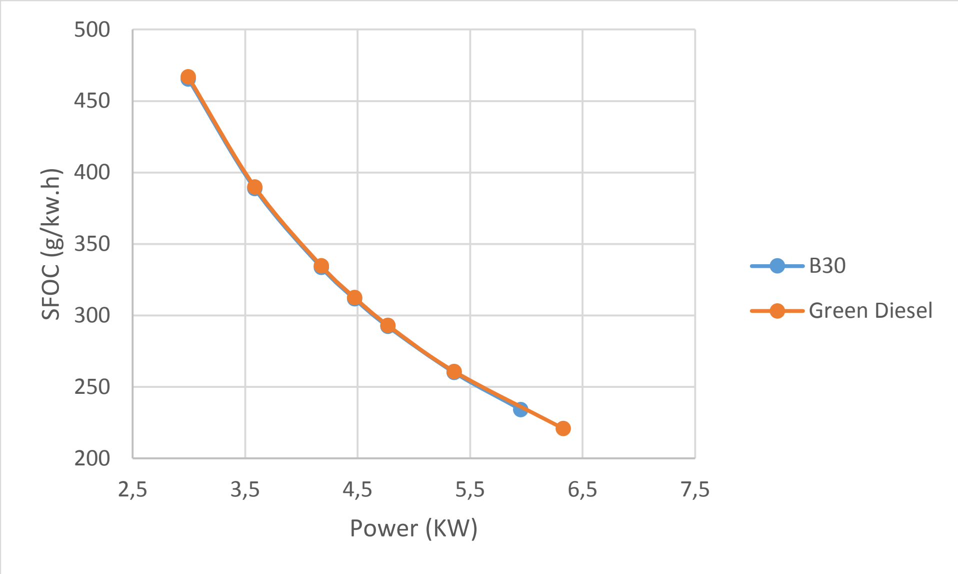
Graph 4.10 Graph of power and SFOC at RPM 1900

In the graph 4.10 explains that Comparison between power with specific fuel oil consumption (SFOC) at rpm 1900 on biodiesel B30(blue line) and green diesel (red line). X-axis shows power in Kw unit and Y-axis shows power in [g/kwh] unit. From the graph it can be seen that the results of comparison biodiesel B30 and green diesel are approximately same. From the graph above, it can be concluded that the SFOC value will decrease with the addition of power up to 100% load.

On the simulations using 2 types of these fuels (biodiesel B30 and green diesel), it was found that the largest power produced green diesel fuel and also in this load is the optimum SFOC value, it means more ecomical and less cost. The largest power value is 6.0988 kW with SFOC value is 221.741 g/kwh. For Biodiesel B30 the largest point is 5.761 kWwith SFOC value is 234.0499 g/kwh.

Then the lowest point of power produced green diesel and also in this load is the highest SFOC value, it means more cost. The lowest power with a value is 2.887 Kw and SFOC value is 470.619 g/kwh. And for biodiesel B30 has the lowest power value is 2.896 kW, with the SFOC value is 465.754 g/kwh. From the simulation method using biodiesel B30 and green diesel, using green diesel and biodiesel B30 is almost same but at 100% load has the best value of green diesel than biodiesel B30.

4.2.7. Comparison between between Power and SFOC on Biodiesel B30 and Green Diesel at RPM 2000



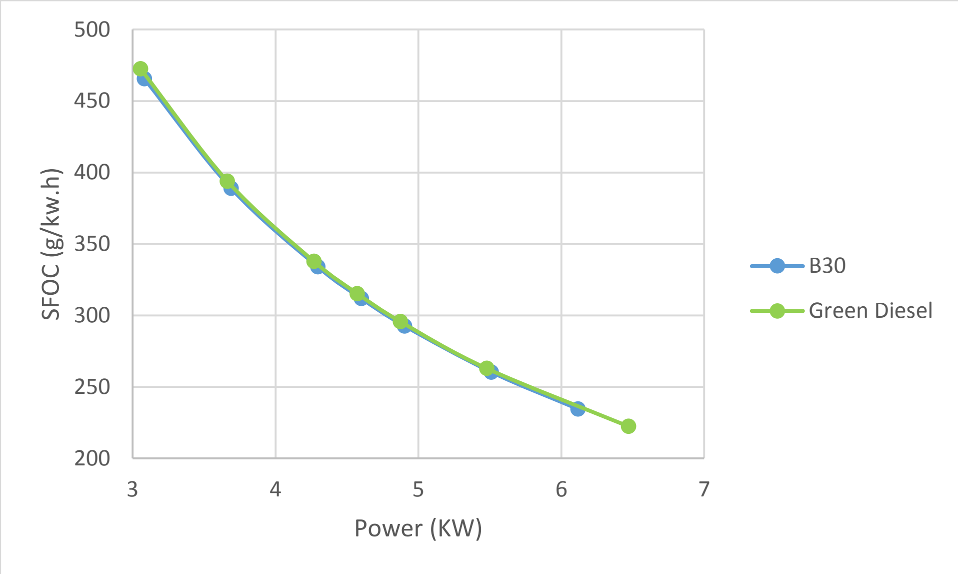
Graph 4.11 Graph of power and SFOC at RPM 2000

From graph 4.11 explains that Comparison between power with specific fuel oil consumption (SFOC) at rpm 20000 on biodiesel B30(blue line) and green diesel (red line). X-axis shows power in Kw unit and Y-axis shows power in [g/kwh] unit. From the graph it can be seen that the results of comparison biodiesel B30 and green diesel are approximately same except in last load ,100%load. From the graph above, it can be concluded that the SFOC value will decrease with the addition of power up to 100% load.

From simulations using 2 types of these fuels (biodiesel B30 and green diesel), it was found that the largest power produced green diesel fuel and also in this load is the optimum SFOC value, it means more ecomical and less cost. The largest power value is 6.329 kW with SFOC value is 220.74 g/kwh. For Biodiesel B30 the largest point is 5.95 kW with SFOC value is 234.112 g/kwh.

Then the lowest point of power produced is green diesel but the margin between these two fuels is very small and also in this load is the highest SFOC value, it means more cost. The lowest power with a value is 2,9953 Kw and SFOC value is 466.843 g/kwh. And for biodiesel B30 has the lowest power value is 2.99455 kW, with the SFOC value is 465.435 g/kwh. From the simulation method using biodiesel B30 and green diesel, using green diesel and biodiesel B30 is almost same but at 100% load has the best value of green diesel than biodiesel B30..

4.2.8. Comparison between between Power and SFOC on Biodiesel B30 and Green Diesel at RPM 2100

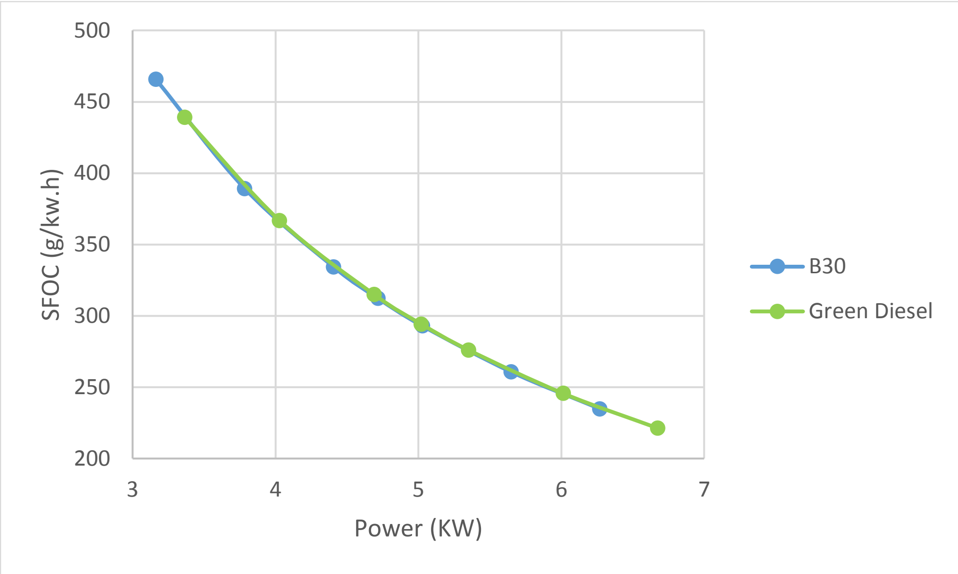


Graph 4.12 Graph of power and SFOC at RPM 2100

From the graph 4.12 shows that Comparison between power with specific fuel oil consumption (SFOC) at rpm 2100 on biodiesel B30(blue line) and green diesel (red line). X-axis shows power in Kw unit and Y-axis shows power in [g/kwh] unit. From the graph it can be seen that the results of comparison biodiesel B30 and green diesel are approximately quite different and it shown graphic of decline constantly. From the graph above, it can be concluded that the SFOC value will decrease with the addition of power up to 100% load. From the graph above, the simulations using 2 types of these fuels (biodiesel B30 and green diesel), it was found that the largest power produced green diesel fuel and also in this load is the optimum SFOC value, it means more ecomical and less cost. The largest power value is 6.4704 kW with SFOC value is 222.305 g/kwh. For Biodiesel B30 the largest point is 6.117 kW with SFOC value is 234.452 g/kwh.

Then the lowest point of power produced green diesel and also in this load is the highest SFOC value, it means more cost. The lowest power with a value is 3.055 Kw and SFOC value is 472.46 g/kwh. And for biodiesel B30 has the lowest power value is 3.081 kW, with the SFOC value is 465.626 g/kwh. From the simulation method using biodiesel B30 and green diesel, using green diesel has better value of power and SFOC at 2100 RPM.

4.2.9. Comparison between between Power and SFOC on Biodiesel B30 and Green Diesel at RPM 2200



Graph 4.13 Graph of power and SFOC at RPM 2200

Based the graph 4.13 explains that Comparison between power with specific fuel oil consumption (SFOC) at rpm 2200 on biodiesel B30(blue line) and green diesel (red line). X-axis shows power in Kw unit and Y-axis shows power in [g/kwh] unit. From the graph it can be seen that the results of comparison biodiesel B30 and green diesel are approximately quite different and it shown graphic of decline constantly. From the graph above, it can be concluded that the SFOC value will decrease with the addition of power up to 100% load.

From the graph above, the simulations using 2 types of these fuels (biodiesel B30 and green diesel), it was found that the largest power produced green diesel fuel and also in this load is the optimum SFOC value, it means more ecomical and less cost. The largest power value is 6.675 kW with SFOC value is 221.207 g/kwh. For Biodiesel B30 the largest point is 6.27 kW with SFOC value is 234.798 g/kwh. Then the lowest point of power produced biodiesel B30 and also in this load is the highest SFOC value, it means more cost. The lowest power with a value is 3.1625 Kw and SFOC value is 465.745 g/kwh. And for green diesel has the lowest power value is 3.364 kW, with the SFOC value is 439.041 g/kwh. From the simulation method using biodiesel B30 and green diesel, using green diesel has better value of power and SFOC at 1800 RPM.

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CHAPTER 5
CONCLUSION AND SUGGESTION

5.1. Conclusion

Based on simulation of biodiesel B30 and green diesel , the following conclusions are :

1. The green diesel fuel has the highest power aat 2200 rpm full load with value is 6.675 kW, the highest torque at 1600 rpm full load with value is 32.206 Nm , the lowest SFOC value at 2000 full load rpm with value is 220.7408 gr/kwh, and has the largest BMEP value at 1600 full load rpm with value is 8.198 bar .
2. Biodiesel B30 fuel has the highest power aat 2200 rpm full load with value is 6.270 kW, the highest torque at 1600 rpm full load with value is 30.398 Nm , the lowest SFOC value at 2000 full load rpm with value is 234.112 gr/kwh, and has the largest BMEP value at 1600 full load rpm with value is 7.737 bar.
3. The results of the comparison of the performance of Biodiesel B30 and Green Diesel are as follows :
   a. Power produced from the use of green diesel fuel is better than biodiesel B30.
   b. Torque produced from the use of green diesel fuel is higher than biodiesel B30.
   c. SFOC produced from the use of green diesel fuel is more economical and less cost than biodiesel B30
   d. BMEP value produced from the use of green diesel fuel is better than biodiesel B30.

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5.2. Suggestion

The suggestion of this thesis are :

1. Further experiments were conducted to validate the data from this simulation.
2. Fix the validation of the engine setup data before retrieving analysis data
3. Collecting factual engine component data to be included in the simulation data

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APPENDIX

Biodiesel B30 fuel simulation data at full load:

RPM	Torque (Nm)	Power (kW)	SFC (g/kWh)	BMEP(bar)
1000	31.619274	3.3111625	246.7501	8.048496
1100	31.626879	3.6431549	243.36787	8.050432
1200	31.52186	3.9611537	240.81183	8.023701
1300	31.329828	4.2651076	238.83073	7.97482
1400	31.057968	4.553336	237.36792	7.90562
1500	30.717375	4.8250737	236.34277	7.8189235
1600	30.319542	5.080088	235.63306	7.717658
1700	29.872746	5.3180532	235.23857	7.6039286
1800	29.382557	5.5384817	235.06949	7.4791536
1900	28.846203	5.7394576	235.1593	7.342628
2000	28.277767	5.9224815	235.43625	7.197936
2100	27.660288	6.0828147	236.02794	7.0407605
2200	27.032278	6.22779	236.66502	6.8809047
2300	26.360525	6.349076	237.64024	6.7099137
2400	25.680288	6.45416	238.67767	6.5367637
2500	24.98604	6.54133	239.88074	6.360047
2600	24.277838	6.61016	241.25786	6.179778
2700	23.561604	6.661886	242.8016	5.9974647
2800	22.83564	6.6957593	244.52782	5.812675
2900	22.112822	6.715383	246.41023	5.6286864
3000	21.395027	6.721446	248.45035	5.4459763
3100	20.684875	6.7149568	250.66396	5.265211
3200	19.973885	6.693313	253.07558	5.084233
3300	19.272835	6.6602135	255.68413	4.9057846

Green Diesel fuel simulation data at full load:

RPM	Torque (Nm)	Power (kW)	SFC (g/kWh)	BMEP(bar)
1000	33.477577	3.5057635	233.70734	8.521517
1100	33.490826	3.8578663	230.4667	8.524889
1200	33.402954	4.1975393	227.88696	8.502522
1300	33.214863	4.521728	225.90488	8.454645
1400	32.950237	4.830757	224.35857	8.387286
1500	32.603935	5.121414	223.27913	8.299136
1600	32.206818	5.3963046	222.4551	8.198052
1700	31.74103	5.650652	222.01515	8.079489
1800	31.23458	5.8875794	221.7575	7.950575
1900	30.678545	6.1040344	221.75606	7.80904
2000	30.084583	6.3009005	221.94304	7.6578503
2100	29.451496	6.4767222	222.32605	7.4967017
2200	28.793827	6.6336217	222.83617	7.329296
2300	28.101072	6.768296	223.57912	7.1529593
2400	27.38441	6.8824534	224.50127	6.970538
2500	26.658691	6.979229	225.51607	6.7858105
2600	25.919378	7.0571046	226.67834	6.5976224
2700	25.171127	7.1169686	227.99727	6.40716
2800	24.413286	7.1583495	229.47145	6.214256
2900	23.656605	7.1842103	231.09099	6.021647
3000	22.902079	7.1949	232.85556	5.829587
3100	22.157661	7.193069	234.75883	5.6401
3200	21.413645	7.1757812	236.83746	5.450715
3300	20.678171	7.145863	239.0848	5.2635045

High speed diesel fuel simulation data at full load

RPM	Torque (Nm)	Power (kW)	SFC (g/kWh)	bmep
1000	32.50221	3.403623	240.11894	8.273242
1100	32.516163	3.7455928	236.75504	8.276794
1200	32.41471	4.073353	234.20306	8.25097
1300	32.215916	4.3857355	232.26967	8.200368
1400	31.946304	4.683573	230.74649	8.131741
1500	31.6052	4.964533	229.65587	8.044914
1600	31.203852	5.2282553	228.91995	7.9427533
1700	30.746378	5.4735804	228.48964	7.8263063
1800	30.239582	5.700027	228.33545	7.6973047
1900	29.688524	5.9070525	228.40565	7.557036
2000	29.108414	6.0964518	228.62164	7.4093723
2100	28.476408	6.262289	229.15605	7.248499
2200	27.827112	6.4109063	229.78528	7.0832243
2300	27.14376	6.537722	230.64552	6.9092817
2400	26.449234	6.6474175	231.60068	6.7324944
2500	25.736914	6.737908	232.72575	6.551177
2600	25.012888	6.810293	234.00906	6.366881
2700	24.279604	6.8648963	235.4566	6.1802278
2800	23.538551	6.901864	237.07143	5.9915977
2900	22.797522	6.9233174	238.83928	5.8029723
3000	22.062551	6.9311547	240.75586	5.61589
3100	21.332556	6.925214	242.83443	5.430074
3200	20.605846	6.905085	245.09572	5.245095
3300	19.888998	6.873144	247.53604	5.062625

Data simulation of Biodiesel B30 at variation load :

RPM 1600

B30	50	60	70	75	80	90	100
Torque (Nm)	15.24339	18.27452	21.30565	22.82121	24.33677	27.3679	30.39857
Power (kW)	2.554711	3.062191	3.569498	3.823087	4.076633	4.583593	5.090304
SFC (g/kWh)	468.6822	390.9436	335.3245	313.0555	293.5601	261.0469	235.0211
BMEP(bar)	3.880114	4.651669	5.423224	5.809002	6.19478	6.966335	7.737774

RPM 1700

B30	50	60	70	75	80	90	100
Torque (Nm)	15.0364	18.02349	21.00958	22.50313	23.99568	26.98177	29.96861
Power (kW)	2.67694	3.208257	3.739238	4.004758	4.270062	4.800726	5.331366
SFC (g/kWh)	467.3439	389.8895	334.4745	312.2752	292.8515	260.4414	234.4844
BMEP(bar)	3.827426	4.587772	5.347864	5.728037	6.107956	6.868048	7.628329

RPM 1800

B30	50	60	70	75	80	90	100
Torque (Nm)	13.73623	16.43841	19.1406	20.49169	21.84278	24.54496	27.24714
Power (kW)	3.16254	3.784369	4.406097	4.716924	5.027726	5.649254	6.270682
SFC (g/kWh)	465.7455	389.1852	334.2418	312.204	292.8926	260.6477	234.7985
BMEP(bar)	3.739506	4.487611	5.235461	5.609386	5.983312	6.731162	7.479154

RPM 1900

B30	50	60	70	75	80	90	100
Torque (Nm)	14.56425	17.44828	20.33131	21.77382	23.21533	26.09936	28.98259

Power (kW)	2.896943	3.470199	4.043125	4.329737	4.616117	5.188978	5.761548
SFC (g/kWh)	465.7549	388.7703	333.6417	311.538	292.1936	259.9057	234.0499
BMEP(bar)	3.707243	4.441355	5.175212	5.542395	5.909324	6.643436	7.377344

RPM 2000

B30	50	60	70	75	80	90	100
Torque (Nm)	14.30414	17.13114	19.95714	21.37064	22.78414	25.61113	28.4379
Power (kW)	2.99455	3.586013	4.177146	4.472773	4.768369	5.359471	5.950403
SFC (g/kWh)	465.4359	388.6292	333.5979	311.5331	292.2059	259.9518	234.1122
BMEP(bar)	3.641033	4.360629	5.079969	5.439767	5.799565	6.519161	7.238697

RPM 2100

B30	50	60	70	75	80	90	100
Torque (Nm)	14.02119	16.78617	19.55114	20.93363	22.31612	25.0811	27.84636
Power (kW)	3.081724	3.689106	4.296379	4.599974	4.903542	5.510594	6.117601
SFC (g/kWh)	465.6266	388.9298	333.9262	311.8733	292.5526	260.3012	234.4522
BMEP(bar)	3.56901	4.272819	4.976626	5.328531	5.680435	6.384243	7.088124

RPM 2200

B30	50	60	70	75	80	90	100
Torque (Nm)	13.73623	16.43841	19.1406	20.49169	21.84278	24.54496	27.24714
Power (kW)	3.16254	3.784369	4.406097	4.716924	5.027726	5.649254	6.270682
SFC (g/kWh)	465.7455	389.1852	334.2418	312.204	292.8926	260.6477	234.7985
BMEP(bar)	3.496475	4.1843	4.872124	5.216036	5.559948	6.247773	6.935597

Data simulation of green diesel at variation load :

RPM 1600

Green Diesel	50	60	70	75	80	90	100
Torque (Nm)	15.16	18.192	21.224	22.74	24.256	27.288	32.20698
Power (kW)	2.565286	3.072693	3.578207	3.830251	4.081818	4.583522	5.393417
SFC (g/kWh)	471.4642	393.0291	337.0407	314.6355	295.0201	262.3548	222.4377
BMEP(bar)	3.858887	4.630664	5.402442	5.788331	6.17422	6.945997	8.198093

RPM 1700

Green Diesel	50	60	70	75	80	90	100
Torque (Nm)	15.03555	18.02265	21.00875	22.5023	23.99485	26.98095	31.83519
Power (kW)	2.677176	3.208571	3.739631	4.005191	4.270533	4.801277	5.663724
SFC (g/kWh)	468.6903	391.0089	335.4325	313.1687	293.6887	261.1849	221.3593
BMEP(bar)	3.827209	4.587557	5.347652	5.727826	6.107745	6.867839	8.103457

RPM 1800

Green Diesel	50	60	70	75	80	90	100
Torque (Nm)	14.61441	17.49272	20.37104	21.81019	23.24935	26.12767	29.00598
Power (kW)	3.364913	4.027289	4.689552	5.020641	5.351701	6.013737	6.675659
SFC (g/kWh)	439.0412	366.7998	314.973	294.1894	275.9787	245.576	221.207
BMEP(bar)	3.739506	4.487611	5.235461	5.609386	5.983312	6.731162	7.950583

RPM 1900

Green Diesel	50	60	70	75	80	90	100
Torque (Nm)	14.423	17.308	20.192	21.635	23.077	25.962	30.67783
Power (kW)	2.887662	3.460955	4.032604	4.318083	4.603002	5.171948	6.098805
SFC (g/kWh)	470.6199	392.3257	336.4175	314.0415	294.4749	261.8507	221.7414
BMEP(bar)	3.671288	4.405648	5.139752	5.50706	5.874112	6.608471	7.808858

RPM 2000

Green Diesel	50	60	70	75	80	90	100
Torque (Nm)	14.30259	17.1296	19.9556	21.36911	22.78261	25.60962	30.24844
Power (kW)	2.99453	3.586055	4.177251	4.472909	4.768536	5.3597	6.329476
SFC (g/kWh)	466.8431	389.797	334.596	312.4634	293.0772	260.7249	220.7408
BMEP(bar)	3.640638	4.360236	5.079579	5.439378	5.799177	6.518776	7.699559

RPM 2100

Green Diesel	50	60	70	75	80	90	100
Torque (Nm)	13.83	16.596	19.362	20.745	22.128	24.894	29.45158
Power (kW)	3.055414	3.662898	4.269179	4.571868	4.874255	5.478124	6.47047
SFC (g/kWh)	472.464	393.8425	337.7098	315.2576	295.5988	262.8554	222.3057
BMEP(bar)	3.520344	4.224412	4.928481	5.280515	5.63255	6.336618	7.496724

RPM 2200

Green Diesel	50	60	70	75	80	90	100
Torque (Nm)	14.61441	17.49272	20.37104	21.81019	23.24935	26.12767	29.00598
Power (kW)	3.364913	4.027289	4.689552	5.020641	5.351701	6.013737	6.675659
SFC (g/kWh)	439.0412	366.7998	314.973	294.1894	275.9787	245.576	221.207
BMEP(bar)	3.72001	4.452667	5.185325	5.551654	5.917983	6.650641	7.383299

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AUTHOR BIOGRAPHY

The author's name is Fathin Muhammad Mahdhudhu, born on 04th January 1998 in Surakarta, Indonesia. Author is the youngest child from 2 siblings. Author is derived from a family with father named Ali Muhdi and mother named Sulasih. The author had formal studies at SD Muhammadiyah 1 Surakarta (2005-2010), SMPN 4 Surakarta (2010-2013), and SMAN 4 Surakarta (2013-2016). In 2016, the author went to Surabaya in order to continue the study at Department of Marine Engineering (Double Degree Program with Hochschule Wismar), Faculty of Marine Engineering, Institut Teknologi Sepuluh Nopember Surabaya specialized in Marine Power Plant. During the study period, the author is a member of MPP Laboratory of Marine Engineering. The author also has work experiences in two companies as engineering student intern e.g., PT. Industri Kapal Indonesia (2018) in Makassar and PT. Jakarta International Container Terminal (2019) in Jakarta. For further discussion and suggestion regarding to this research, the author can be reached through email and phone number stated as below.

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