EXHAUST EMISSION OF WASTE PLASTIC DISPOSAL FUEL ON SINGLE CYLINDER YANMAR DIESEL ENGINE

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JUDUL: **EXHAUST EMISSION OF WASTE PLASTIC DISPOSAL FUEL ON SINGLE CYLINDER YANMAR DIESEL**

SESI PENGAJIAN: **2010/2011**

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I certify that the project entitled "*Exhaust Emission of Waste Plastic Disposal Fuel on Single Cylinder YANMAR Diesel Engine*" is written by *Mohd Hazmie bin Hamdan*. I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

Engr. Zamri Bin Mohamed	....
Examiner	Signature

EXHAUST EMISSION OF WASTE PLASTIC DISPOSAL FUEL ON SINGLE CYLINDER YANMAR DIESEL ENGINE

MOHD HAZMIE BIN HAMDAN

Report submitted in partial fulfillment of the requirements
for the award of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
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NOVEMBER 2010

SUPERVISOR'S DECLARATION

I hereby declare that we have checked this project and in our opinion, this project is adequate in temrs of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

Signature :
Name of Supervisor : DR AGUNG SUDRAJAD
Position : SENIOR LECTURER
Date : 06 DECEMBER 2010

STUDENT'S DECLARATION

I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature :
Name : MOHD HAZMIE BIN HAMDAN
ID Number : MH 07056
Date : 06 DECEMBER 2010

“In **the name of ALLAH, the Most Beneficent, the Most Merciful**”

This work is dedicated to my beloved ones,

Hamdan bin Kasim

Zainon bte Manap @ Awang

Norhafiza bte Hamdan

Mohd Hazwan bin Hamdan

And

Allies…

Thank you for the endless support and encouragement.

You all always have a special place in my heart.

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ABSTRACT

This report deals with the exhaust emission of waste plastic disposal fuel on single cylinder YANMAR diesel engine. The objectives of this report are to analyze the fuel consumption and the emission characteristic of a single cylinder diesel engine that are using waste plastic disposal fuel compared to usage of ordinary diesel that are available in the market. This report describes the setups and the procedures for the experiment which is to analyze the emission characteristics and fuel consumption of YAMNAR diesel engine due to usage of the both fuels. The experiment used diesel engine with no load which means no load exerted on it. Detail studies about the experimental setup and components have been done before the experiment started. Data that are required for the analysis is observed from the experiments. Calculations and analysis have been done after all the required data needed for the thesis is obtained. The obtained data indicated that the diesel fuel is better than waste plastic disposal fuel in term of fuel consumption, emissions of carbon monoxide (CO) and emissions of carbon dioxide (CO_2). By the end of the report, the successful of the project have been stated which is YANMAR engine is able to run with waste plastic disposal (WPD) fuel but the engine needs to run by using diesel fuel first, then followed by waste plastic disposal fuel and finished with diesel fuel as the last fuel usage before the engine turned off.

ABSTRAK

Laporan ini berkaitan dengan hasil pembakaran bahan bakar dari bahan buangan sampah plastik menggunakan enjin diesel YANMAR silinder tunggal. Tujuan laporan ini adalah untuk menganalisis penggunaan bahan bakar dan ciri-ciri pembebasan gas ekzos enjin tersebut yang menggunakan bahan bakar dari bahan buangan sampah plastik berbanding dengan penggunaan minyak diesel biasa yang terdapat di pasaran. Laporan ini menjelaskan susunan radas dan prosedur untuk eksperimen yang dijalankan. Eksperimen ini menggunakan enjin diesel tanpa beban yang bermaksud tidak ada beban yang dikenakan ke atas enjin itu. Kajian terperinci tentang susunan telah dilakukan sebelum percubaan bermula. Data yang diperlukan untuk dianalisa adalah diambil dari eksperimen. Pengiraan dan analisa telah dilakukan selepas semua data yang diperlukan yang diperlukan untuk tesis tersebut diperolehi. Data yang diperolehi menunjukkan bahawa bahan bakar diesel lebih baik daripada bahan bakar pembuangan sisa plastik dalam hal konsumsi bahan bakar, pembebasan karbon monoksida (CO) dan pembebasan karbon dioksida (CO2). Pada akhir laporan tersebut, kejayaan projek telah dinyatakan bahawa enjin YANMAR dapat beroperasi dengan menggunakan bahan bakar dari pembuangan sisa plastik (wpd) tetapi enjin perlu dimulakan dengan menggunakan minyak diesel diikuti dengan minyak plastik dan diakhiri dengan minyak diesel semula sebelum enjin dimatikan.

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LIST OF ABBREVIATIONS

RPM	Revolution Per Minute
ppm	Percent Per Million
% vol	Percentage of Volume
O_2	Oxygen
CO_2	Carbon Dioxide
CO	Carbon Monoxide
NO	Nitrogen Monoxide
NO_x	Oxides of Nitrogen

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter discussed about the project background such as problem statement, objectives and scope of the project. All this information is crucial to give a starting point for the progress in this project. This project is focused on study exhaust emission of waste plastic disposal fuel on single cylinder YANMAR diesel engine.

1.2 PROJECT BACKGROUND

Now days, the amount of waste generated continues to increase in response to rapid increase in population, accelerated urbanization and industrialization process. In 2006, about 7.34 million tones of solid wastes were generated in Malaysia. Besides that, based on this data, the Ministry of Housing and Local Government says that Malaysia generates approximately 18,000 MT/day of solid waste. Table 1 showed the data of general composition of waste in Malaysia and Table 2 showed the data of waste composition for Kuala Lumpur from year 1975 until 2000. The quantity of waste generation in Kuala Lumpur alone is projected to increase from 2,620 tons in 1995 up to 4000 tons in year 2000.

The main apparatus for this project is a YANMAR TF120 single piston diesel engine with 638cc of displacement. This engine has 12 BHP of output and 10.5 BHP of continuous output. Its cooling system use water cooled cooling systems with radiator. This engine also uses direct fuel injection with a high pressure Bosch pump. The basic characteristics of this engine are it is a four stroke, compression-ignition engine which the fuel and air are mixed inside the engine. The air required for combustion is highly compressed inside the combustion chamber. This generates high temperatures which are sufficient for the diesel fuel to spontaneously ignite when it is injected to the cylinder. The diesel engine thus uses heat to release the chemical energy contained within the diesel fuel and convert it into mechanical forces.

In this experiment, the condition used is zero load which means there is no load exerted on the engine.

Table 1.1: General Composition of Waste in Malaysia

Materials	% by Weight
Organics	47.0
Paper	15.0
Plastics	14.0
Wood, garden waste	4.0
Metal	4.0
Glass	3.0
Textile	3.0
Other	10.0

Source: Prof. Tay Joo Hwa (2007)

Table 1.2: Kuala Lumpur's Solid Waste Composition (1975-2000)

Composition of waste\Year	1975	1980	1990	1995	2000
Organic	63.7	78.05	40.8	61.76	68.67
Paper	11.7	11.48	30.0	12.16	6.43
Plastic	7.0	0.57	9.8	5.27	11.45
Glass	2.5	0.57	3.0	5.27	1.41
Metals	6.4	3.16	4.6	6.89	2.71
Textile	1.3	3.16	2.5	2.84	1.50
Wood	6.5	2.58	3.2	0.00	0.70
Others	0.9	0.43	6.1	5.81	7.13

Source: Mohamed (2008)

1.3 PROBLEM STATEMENT

Plastics are durable and takes a long time degrade because of the molecular bonds in the plastic are so strong and it is resist to natural processes of degradation. In Malaysia, we still finding the best way to reduce trash and air pollution problems simultaneously. There are examples of pollution from plastic such as burning plastic can release toxic fumes, burning the plastic polyvinyl chloride (PVC) may create dioxin and the manufacturing of plastics often creates large quantities of chemical pollutants.

One of the solution that can help to solve the problems above is by using Waste Plastic Disposal (WPD) fuel as an alternative fuel for diesel engine. The production of this fuel is done by pyrolysis process. The result from using waste plastic as a raw material, it will help to reduce the total of waste plastics and will help to solve the problem that occur in Malaysia which is how to reduce trash and air pollution problems.

1.4 PROJECT OBJECTIVES

The objectives of this project are to analyze the fuel consumption and the emission characteristic such as oxygen(O_2), carbon dioxide(CO_2), carbon monoxide(CO), nitrogen dioxide(NO_2) and oxides of nitrogen(NO_x) of a single cylinder diesel engine that are using waste plastic disposal fuel compared to usage of ordinary diesel that are available in the market.

1.5 SCOPE OF STUDY

The following scopes of the project are determined in order to achieve the objectives of the project:

a) Analyzing fuel consumption
b) Analyzing the emission characteristic

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to provide information which related to the Internal Combustion Engine, Waste Plastic Disposal (WPD) fuel and also about characteristic of diesel fuel.

2.2 DIESEL ENGINE

DOE (1993) stated that a diesel engine is similar to the gasoline engine. Both engines are internal combustion engines which is means they burn the fuel-air mixture within the cylinders. Both are reciprocating engines, being driven by pistons moving laterally in two directions. The majority of their parts are similar. Although a diesel engine and gasoline engine operate with similar components, a diesel engine, when compared to a gasoline engine of equal horsepower, is heavier due to stronger, heavier materials used to withstand the greater dynamic forces from the higher combustion pressures present in the diesel engine.

The greater combustion pressure is the result of the higher compression ratio used by diesel engines. The compression ratio is a measure of how much the engine compresses the gasses in the engine's cylinder. In a diesel engine, compression ratios ranging from 14:1 to as high as 24:1 are commonly used. The higher compression ratios are possible because only air is compressed, and then the fuel is injected. This is one of the factors that allow the diesel engine to be so efficient. Compression ratio will be discussed in greater detail later in this module.

Diesel engines are not self-speed-limiting because the air (oxygen) entering the engine is always the maximum amount. Therefore, the engine speed is limited solely by the amount of fuel injected into the engine cylinders. Therefore, the engine always has sufficient oxygen to burn and the engine will attempt to accelerate to meet the new fuel injection rate. Because of this, a manual fuel control is not possible because these engines, in an unloaded condition, can accelerate at a rate of more than 2000 revolutions per second. Diesel engines require a speed limiter, commonly called the governor, to control the amount of fuel being injected into the engine. Unlike a gasoline engine, a diesel engine does not require an ignition system because in a diesel engine the fuel is injected into the cylinder as the piston comes to the top of its compression stroke. When fuel is injected, it vaporizes and ignites due to the heat created by the compression of the air in the cylinder.

2.2.1 History

Bosch (2005) stated that the modern diesel engine came about as the result of the internal combustion principles first proposed by Sadi Carnot in the early 19th century. Dr. Rudolf Diesel applied Sadi Carnot's principles into a patented cycle or method of combustion that has become known as the "diesel" cycle. His patented engine operated when the heat generated during the compression of the air fuel charge caused ignition of the mixture, which then expanded at a constant pressure during the full power stroke of the engine.

Dr. Diesel's first engine ran on coal dust and used a compression pressure of 1500 psi to increase its theoretical efficiency. Also, his first engine did not have provisions for any type of cooling system. Consequently, between the extreme pressure and the lack of cooling, the engine exploded and almost killed its inventor. After recovering from his injuries, Diesel tried again using oil as the fuel, adding a cooling water jacket around the cylinder, and lowering the compression pressure to approximately 550 psi. This combination eventually proved successful. Production rights to the engine were sold to Adolphus Bush, who built the first diesel engines for commercial use, installing them in his St. Louis brewery to drive various pumps.

2.2.2 Fundamental of Diesel Engine Cycle

Holt D. J (2004) stated that there are two basic types of diesel engines, two-cycle and four-cycle. An understanding of how each cycle operates is required to understand how to correctly operate and maintain a diesel engine.

2.2.2.1 Four Stroke Cycle

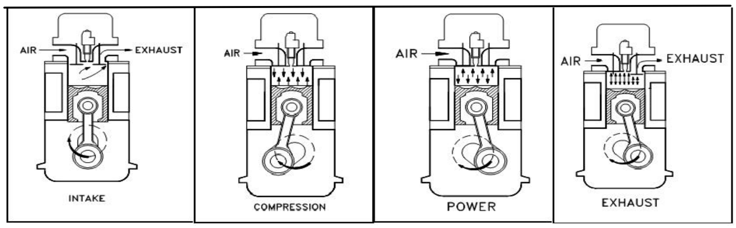


Figure 2.1: Four Stroke Cycle

Source: DOE (1993)

<u>Intake Stroke</u>

On the intake or induction stroke of the piston, the piston descends from the top of the cylinder to the bottom of the cylinder, reducing the pressure inside the cylinder. Air is forced by atmospheric (or greater) pressure into the cylinder through the intake port. The intake valve(s) then close.

Compression Stroke

With both intake and exhaust valves closed, the piston returns to the top of the cylinder compressing the fuel-air mixture. This is known as the compression stroke.

Power Stroke

While the piston is at or close to Top Dead Center, the fuel is injected into the combustion chamber and ignited by the heat and pressure of compression (for a diesel cycle or compression ignition engine). The resulting massive pressure from the combustion of the compressed fuel-air mixture drives the piston back down toward bottom dead center with tremendous force. This is known as the power stroke, which is the main source of the engine's torque and power.

Exhaust Stroke

During the exhaust stroke, the piston once again returns to top dead center while the exhaust valve is open. This action evacuates the products of combustion from the cylinder by pushing the spent fuel-air mixture through the exhaust valve(s).

2.2.2.2 Two Stroke Cycle

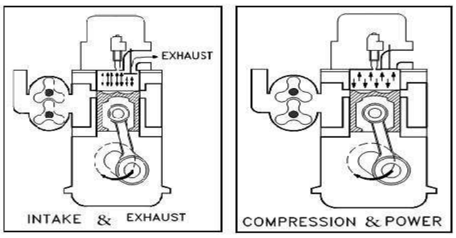


Figure 2.2: Two Stroke Cycle

Source: DOE (1993)

Intake And Exhaust Stroke

At 82° ATDC, with the piston near the end of its power stroke, the exhaust cam begins to lift the exhaust valves follower. The valve lash is taken up, and 9° later (91° ATDC), the rocker arm forces the exhaust valve off its seat. The exhaust gasses start to escape into the exhaust manifold. Cylinder pressure starts to decrease. After the piston travels three-quarters of its (down) stroke, or 132° ATDC of crankshaft rotation, the piston starts to uncover the inlet ports.

As the exhaust valve is still open, the uncovering of the inlet ports lets the compressed fresh air enter the cylinder and helps cool the cylinder and scavenge the cylinder of the remaining exhaust gasses. Commonly, intake and exhaust occur over approximately 96° of crankshaft rotation. At 43° ABDC, the camshaft starts to close the exhaust valve. At 53° ABDC (117° BTDC), the camshaft has rotated sufficiently to allow the spring pressure to close the exhaust valve. Also, as the piston travels past 48°ABDC (5° after the exhaust valve starts closing), the intake ports are closed off by the piston.

Compression And Exhaust Stroke

After the exhaust valve is on its seat (53° ATDC), the temperature and pressure begin to rise in nearly the same fashion as in the four-stroke engine. At 23° BTDC the injector cam begins to lift the injector follower and pushrod. Fuel injection continues until 6° BTDC (17 total degrees of injection). The power stroke starts after the piston passes TDC. The power stroke continues until the piston reaches 91° ATDC, at which point the exhaust valves start to open and a new cycle begins.

2.2.2.3 Major Advantages

The major advantages of the diesel engine are explained in the descriptions below (Bosch, 2005):

Diesel engines have several advantages over other internal combustion engines:

- They burn less fuel than a petrol engine performing the same work, due to the engine's higher temperature of combustion and greater expansion ratio. Gasoline engines are typically 25% efficient while diesel engines can convert over 30% of the fuel energy into mechanical energy.
- They have no high-tension electrical ignition system to attend to, resulting in high reliability and easy adaptation to damp environments. The absence of coils, spark plug wires, etc., also eliminates a source of radio frequency emissions which can interfere with navigation and communication equipment, which is especially important in marine and aircraft applications.
- They can deliver much more of their rated power on a continuous basis than a petrol engine.
- The life of a diesel engine is generally about twice as long as that of petrol engine due to the increased strength of parts used, also because diesel fuel has better lubrication properties than petrol.
- Diesel fuel is considered safer than petrol in many applications. Although diesel fuel will burn in open air using a wick, it will not explode and does not release a large amount of flammable vapor. The low vapor pressure of diesel is especially advantageous in marine applications, where the accumulation of explosive fuel-air mixtures is a particular hazard.
- For any given partial load the fuel efficiency (mass burned per energy produced) of a diesel engine remains nearly constant, as opposed to petrol and turbine engines which use proportionally more fuel with partial power outputs.
- They generate less waste heat in cooling and exhaust.

- With a diesel, boost pressure is limited only by the strength of the engine components, not predetonation of the fuel charge as in petrol engines.
- The carbon monoxide content of the exhaust is minimal; therefore diesel engines are used in underground mines.
- Biodiesel is an easily synthesized, non-petroleum-based fuel (through the Fischer–Tropsch process) which can run directly in diesel engines, while gasoline engines either need adaptation to run synthetic fuels or else use them as an additive to gasoline (e.g., ethanol added to gasohol), making diesel engines the clearly preferred choice for sustainability.

2.3 CHARACTERISTIC OF DIESEL FUEL

2.3.1 DIESEL FUEL FEATURES

Challen (1999) stated that high quality diesel fuels are characterized by the following features such as cetane number, boiling point, fuel's viscosity, cloud point, lubricity and sulfur content.

Cetane number (CN) expressed the ignition quality of the diesel fuel. High quality of diesel fuels must have high value of cetane number. The higher the cetane number, the greater the fuel's tendency to ignite. As the diesel engine dispenses with an externally supplied ignition spark, the fuel must ignite spontaneously (auto-ignition) and with minimum delay (ignition lag) when injected into the hot, compressed air in the combustion chamber.

Boiling point means the boiling range of a fuel is the temperature range at which the fuel vaporizes, depends on its composition. Good diesel fuels must have relatively low final boiling point. A low initial boiling point makes a fuel suitable for use in cold weather, but also means a lower cetane number and poor lubricant properties. This raises the wear risk for central injection units. If the final boiling point is situated at high temperatures, this can result in increased soot production and nozzle coking (deposit caused by chemical decomposition of not easily volatized fuel constituent on the nozzle cone, and deposits of combustion residues. For this reason, the final boiling point should not be too high.

Fuel’s viscosity is a measure of a fuel’s resistance to flow due to internal friction. Leakage losses in the fuel-injection pump result if diesel-fuel viscosity is too low, and this in turn results in performance loss. Much higher viscosity causes a higher peak injection pressure at high temperatures in non-pressure-regulated systems. For this reason, mineral oil diesel may not be applied at the maximum permitted primary pressure. High viscosity also changes the spray pattern due to the formation of larger droplets. Besides that, Diesel fuel with viscosity which is either too high or too low can cause serious damage to the engine’s injection system.

Cloud point is the temperature at which fuel turns cloudy to look at. When the fuel temperature drops to the fuel's cloud point, paraffin waxes that occur naturally in diesel fuel crystallize and cling together, making the fuel appear cloudy. This is known as “waxing” and, if not prevented, can clog filters and stop fuel flow to the engine. Clouding can be combated by using fuels with a lower cloud point, providing heat to the tanks, or including a cloud point improver to the fuel. This improver separates the clinging wax particles so they can pass through the fuel filters. Some oil companies produce special winter grade fuels for cold weather operation.

Lubricity is the other features of diesel fuels. In order to reduce the sulfur content of diesel fuel, it is hydrogenated. In addition to removing sulfur, the hydrogenation process also removes the ionic fuel components that aid lubrication. After the introduction of desulfurized diesel fuels, wear-related problems started to occur on distributor fuel-injection pumps due to the lack of lubricity. As a result, they were replaced by diesel fuels containing lubricity enhancers. Lubricity is measured in a High-Frequency Reciprocating Rig (HFRR method). A fixed, clamped steel ball is ground on a plate by fuel at high frequency. The magnitude of the resulting flattening are the Wear Scar Diameter (WSD) measured in µm, specifies the amount of wear, and thus a measure of fuel lubricity. Diesel fuels complying with EN 590 must have a WSD of ≤ 460 µm.

Sulfur content is the main problems of diesel fuels. Diesel fuels contain chemically bonded sulfur, and the actual quantities depend on the quality of the crude petroleum and the components added at the refinery. In particular, crack components mostly have high sulfur contents. Good diesels fuel must have low sulfur content. To desulfurize fuel, sulfur is removed from the middle distillate by hydrogenation at high pressure and temperature in the presence of a catalyst. The initial by product of this process is hydrogen sulfide (H_2S) which is subsequently converted into pure sulfur. Besides that, exhaust gas treatment systems for NO_x and particulate filters use catalysts. They must run on sulfur-free fuel since sulfur poisons the active catalyst surface.

Table 2.1: European Standard EN 590. Selected requirements for diesel fuels

Criterion	**Parameter**
Cetane number	≥55
Cetane index	≥46
CFPP in six seasonal categories, max	+5…-20 (˚C)
Flash point	≥55 (˚C)
Density at 15˚C	820…845 (kg/m^3)
Viscosity at 40˚C	2.00…4.50 (mm^2/s)
Lubricity	≤460 (µm [wear scale diameter])
Sulfur content	≤350 (until 12/31/2004) ≤50 (low)

Source: Daniel J. Holt (2004)

Table 2.2: Typical High And Low Heat Values for API (American Petroleum Institute) Rated Diesel Fuels

Gravity (°API)	Specific gravity at 60°F	Weight fuel (lb/gal)	High heat value		Low heat value	
			Btu/lb	Btu/gal	Btu/lb	Btu/gal
44	0.8063	6.713	19860	133500	18600	125000
42	0.8155	6.790	19810	134700	18560	126200
40	0.8251	6.870	19750	135800	18510	127300
38	0.8348	6.951	19680	137000	18460	128500
36	0.8448	7.034	19620	138200	18410	129700
34	0.8550	7.119	19560	139400	18360	130900
32	0.8654	7.206	19490	140600	18310	132100
30	0.8762	7.296	19420	141800	18250	133300
28	0.8871	7.387	19350	143100	18190	134600
26	0.8984	7.481	19270	144300	18130	135800
24	0.9100	7.578	19190	145600	18070	137100
22	0.9218	7.676	19110	146800	18000	138300
20	0.9340	7.778	19020	148100	17930	139600
18	0.9465	7.882	18930	149400	17860	140900
16	0.9593	7.989	18840	150700	17790	142300
14	0.9725	8.099	18740	152000	17710	143600
12	0.9861	8.212	18640	153300	17620	144900
10	1.000	8.328	18540	154600	17540	146200

Source: Daniel J. Holt (2004)

Table 2.3: Diesel in Malaysia-Typical (2004)

	Unit	A	B	C	D	E	F
Density	Kg/L	0.8500	0.8257	0.8491	0.8180	0.8499	0.8526
Cetane Number	-	55.4	66.8	55.1	65.3	55.7	55.4
Distillation, T90	˚C	358.4	357.2	364.9	352.4	366.6	368.8
Distillation, T95	˚C	376.2	376.9	384.1	370.9	383.0	384.0
Sulphur Content	ppm	2800	300	500	200	260	260

Source: Harlina (2006)

2.4 WASTE PLASTIC DISPOSAL (WPD) FUEL

From M. Mani et al. (2009), explained about the increasing of energy demand, and depletion of oil resources have led the researchers to find alternative fuels for internal combustion engines. Plastics are produced from petroleum derivates and are composed primarily of hydrocarbons but also contain additives such as antioxidants, colorants and other stabilizers. The purpose of this experiment is to study the performance, emission and combustion characteristics of a single cylinder, four-stroke, air cooled DI diesel engine run with waste plastic oil. The kinds of plastic materials use in the experiment are Polyethylene, Polypropylene, Teflon, Nylon and Dacron. The process that is included is crushing, cutting, shredding and pyrolysis process which produced hydrocarbons with small molecular mass such as ethane that can be separated by fractional distillation and used as fuels and chemicals. The experimental results have showed a stable performance with brake thermal efficiency similar to that of diesel. Carbon dioxide and unburned hydrocarbon were marginally higher than that of the diesel baseline. The toxic gas carbon monoxide emission of waste plastic oil was higher than diesel. Smoke reduced by about 40% to 50% in waste plastic oil at all loads.

Table 2.4: Comparison of Waste Plastic Oil and Diesel Fuel Characteristic

Property	Waste plastic oil	Diesel
Density @ 30 ˚C in (g/cc)	0.8355	0.840
Ash content (%)	0.00023	0.045
Gross calorific value (kJ/kg)	44,340	46,500
Kinematic viscosity, cst @ 40 ˚C	2.52	2.0
Cetane number	51	55
Flash point (˚C)	42	50
Fire point (˚C)	45	56
Carbon residue (%)	82.49	26
Sulphur content (%)	0.0030	0.045
Distillation temperature (˚C) @ 85%	344	328
Distillation temperature (˚C) @ 95%	362	340

Source: M. Mani (20090

From Guang-Hua Zhang et al. (2006), explained about current situation of recycling waste plastics and technology of converting waste plastics into oil in China. In a review of environmental protection and reduction of non-regeneration resource, recycling technology for converting to oil from plastic wastes has drawn much attention in China. The process of pyrolysis and pyrolysis-catalytic upgrade method has been evaluated in terms of technology and economics. The purpose of pyrolysis is to produce the paraffin and crude oil from the plastic wastes in the 1990s in China. The small-scaled process is featured by facilitation, convenience and low equipment investment. The system consists of feed-supply, pyrolysis reactor, fractionating tower, heating and temperature controller and device for filling the plastics into the pyrolysis reactor. The purpose of pyrolysis-catalytic upgrade method is to upgrade by catalyst for the crude products gained. This is because total yield of fuel oil with pyrolysis is still lower and the quality of oil is not satisfied as gasoline and diesel oil. To constructed a plant for converting waste plastics to oil, the are the conditions that must to investiged such as collecting system, transportation distance of waste plastics, sorting method and controlling over secondary pollution. In addition, the commercialization and area of research on this technology in China are proposed.

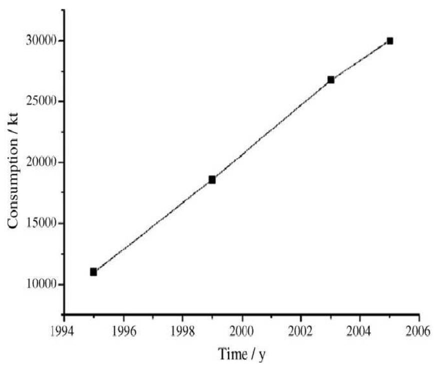


Figure 2.3: Consumption of plastics in China

Source: Guang-Hua Zhang (2006)

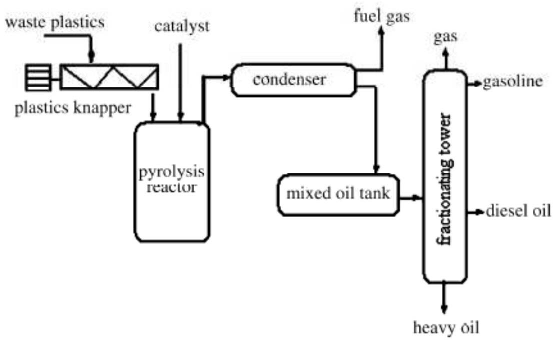


Figure 2.4: Pyrolysis process of generating fuel oil from the waste plastics

Source: Guang-Hua Zhang (2006)

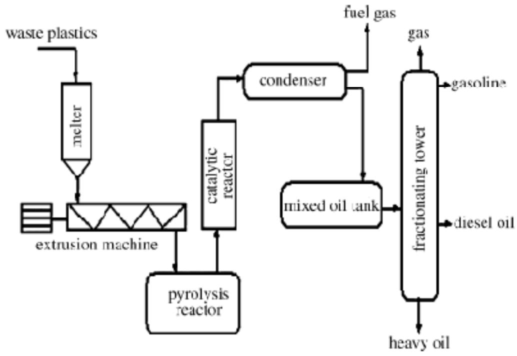


Figure 2.5: Pyrolysis-catalytic upgrades technique of plastic wastes in China

Source: Guang-Hua Zhang (2006)

Ejaz Ahmad et al. (2009) explained that the process involves catalytic degradation of waste plastic into fuel range hydrocarbon like petrol, diesel and kerosene. Catalytic degradation offers considerable benefits as compared to thermal degradation and other methods used. A catalytic cracking process in which waste plastic were melted and cracked in the absence of oxygen and at very high temperature, the resulting gases were cooled by condensation and resulting crude oil was recovered. From this crude oil, various products petrol, diesel and kerosene can be obtained by distillation. This process mainly consists of four units which is **reacting vessel or reaction chamber**, **condensation unit**, **receiving unit** and **distillation unit**. The degradation of waste plastic except polyvinyl chloride (PVC) and polyethylene terephthalate (PET) over two commercial grade cracking catalysts, containing 20% and 40% ultra stable Y zeolite was studied in a semi-batch reactor. Also the effect of polymer catalyst ratio was studied on the formation of liquid hydrocarbons. The best results were obtained when polymer catalyst ratio was 4:1 and after this ratio the liquid yield decreases. Furthermore alternate method for disposal of waste plastic is also studied. And the results of this process are found to be better than other alternate methods which are used for the disposal of waste plastic.

Table 2.5: Properties of crude oil obtained **(**when zeolite type 5A is mixed with catalyst & kept in receiver and product is filtered)

Properties	Regular gasoline	Fuel extracted from waste plastic
Color, Visual	Orange	Pale Yellow
Specific Gravity at 280 ˚C	0.7423	0.7254
Specific gravity at 150 ˚C	0.7528	0.7365
Gross Calorific Value	11210	11262
Net Calorific Value	10460	10498
API Gravity	56.46	60.65
Sulphur Content	0.1	0.002
Flash Point (Abel) ˚C	23.0	22.0
Pour Point ˚C	< -20	< -20
Cloud Point ˚C	< -20	< -20
Existent Gum, gm/m^3	40	36
Reactivity with MS	Nil	Nil
Reactivity with Cl	Nil	Nil
Reactivity with Al	Nil	Nil

Source: Ejaz Ahmad (2009)

Osami Nishida et al. (2001) explained that waste plastic disposal oil or blending pyrolitic oil produced from household and industrial plastic wastes with marine heavy fuel oil reduces the viscosity of the heavy oil significantly. Till now, the fuel oil used aboard sea going vessels has low grade heavy fuel oil (HFO) which is have (density = 1.0g/cm3, kinematic viscosity = 177 cSt at 50) which requires complicated heating systems and excessive heating energy. This study proposes a new use for the heavy fuel oil, on which the engine could operate without heating. It is the mixing of heavy fuel oil with oil thermally processed from waste plastics or called Waste Plastic Disposal or WPD. This paper reports the result of application of nonheated WPD-mixed HFO to diesel engines including inspection of the engine performance and exhaust gas characteristics. From the experiment, the result showed that WPD mixing ratio of 20% volume reduces the experimental heavy fuel oil viscosity 90 % from 177 cSt to 20 cSt at 50. The blended oil has been applied to a 4 stroke diesel engine (16 horsepower, 2200rpm) without preheating the oil. The experiment on the engine with non-preheated blended oil has proved the stable performance of the engine. This would lead to the significant reduction of fuel heating cost. Although NO_x emission slightly increases, the emission of particulate matters (PM), dry soot (DS) and soluble organic fraction (SOF) decreases by half at the mixing ratio of 30% volume.

Table 2.6: WPD Properties

Item		Unit	Value
Density		g/cm^3	0.939
Kinematic Viscosity		mm^2/s (cST)	1.189
Ignition Point		˚C	30.5
Component	Styrene Monomer	%	63.9
	Styrene Dimer	%	11.5
	Styrene trimer	%	5.7
	Toluene	%	2.2
	Ethyl benzene	%	1.4
	α Methyl styrene	%	2.2
	Others	%	13.1

Source: Osami Nishida (2001)

From E. Sugiyama et al. (1999), explained about develop system for oil reclamanation with municipal waste plastic material. Since 1997, they have collected data commercial plant. In the process of this system, it can dechlorine polyvinyl chloride and produce oil. From the fact, it is known that by thermal cracking, thermoplastic can be recovered to oil. This is because thermal degradation has been regarded as one of the measures. This system consist of seven process. The process is pelletizing, dechlorination, degradation, oil refining, HCI treatment, exhaust gas treatment, and waste water treatment. In pelletizing process, shredded and dried waste plastic pelletized to dia 6 x 10mm of pellets whose bulk density is approximately 0.4. In dechlorination process, chlorine contain in PVC becomes gaseous HCL at the extruder and the vessels. In degradation process, dechlorinated plastics is heated up to approximately 450^{o}C and changed to gaseous products and residue. In oil refining process, acidic gas derived from the top of fractiometer is send to the offgas scrubber where it is neutralized and treated. In HCI treatment process, quenching water absorb gaseous HCL and circulated until the purity of HCL is in design. In exhaust gas treatment process, exhause gas from the other processes is disposed to the air through a burner, In waste water treatment process, waste water of each process is carried to this process and disposed to a sewerlijne after proper treatments.

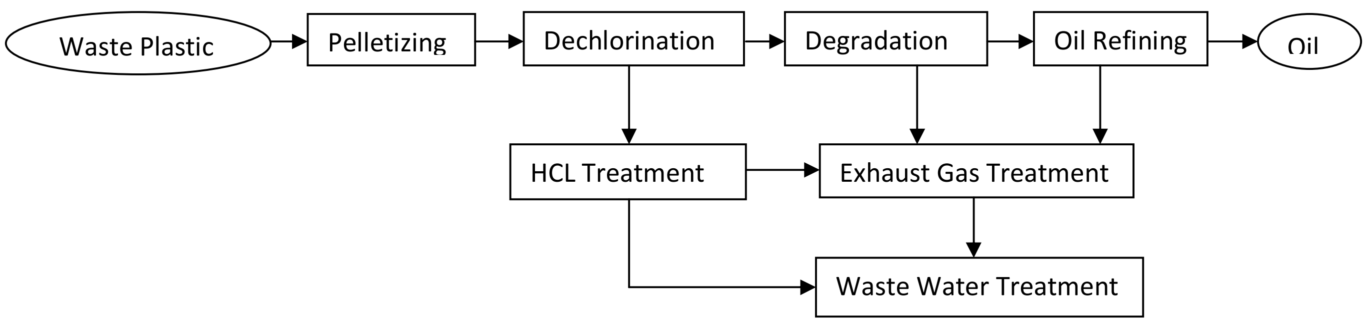


Figure 2.6: Process Flow Chart

Source: E. Sugiyama (1999)

2.5 EXHAUST EMISSION CHARACTERISTICS

Pulkrabek W.W (2003) stated that during the 1950s, the smog problem increased along with the population density and automobile density. It was recognized that the automobile was one of the major contributors to the problem, and by the 1960s emission standards were beginning to be enforced in California. During the next decades, emission standards were adopted in the rest of the United States and in Europe and Japan. By making engines more fuel efficient, and with the use of exhaust aftertreatment, emissions per vehicle of HC, CO and NO_x were reduced by about 95% during the 1970s and 1980s. Lead, one of the major air pollutants, was phased out as a fuel additive during the 1980s. More fuel-efficient engines were developed, and by the 1990s the average automobile consumed less than half the fuel used in 1970s. However, during this time, the number of automobiles greatly increased, resulting in no overall decrease in fuel usage. In 1999, petroleum consumption in the Unites States amounted to 16500 L/sec, a large percentage of which was fuel for internal combustion engine.

2.5.1 Oxides of Nitrogen (NO_x)

Exhaust gases of an engine can have up to 2000ppm of oxides of nitrogen. Most of this will be nitrogen oxide (NO), with a small amount of nitrogen dioxide (NO_2), and traces of other nitrogen-oxygen combinations. These are all grouped together as NO_x which x representing some suitable numbers. NO_x is a very undesirable emission, and regulations that restrict the allowable amount continue to become more stringent. Released NO_x reacts in the atmosphere to form ozone and is one of the major causes of photochemical smog.

NO_x is created mostly from nitrogen in the air. Nitrogen can also be found in fuel blends, which may contain trace amounts on NH_3, NC, and HCN, but this would contribute only to a minor degree. There are number of possible reactions that form NO, all of which are probably occurring during the combustion process and immediately after. These include but are not limited to,

$$O + N_2 \longrightarrow NO + N$$
$$N + O_2 \longrightarrow NO + O$$
$$N + OH \longrightarrow NO + H$$

NO, in turn, can then further react to form NO_2 by various means, including the following:

$$NO + H_2O \longrightarrow NO_2 + H_2$$
$$NO + O_2 \longrightarrow NO_2 + O$$

Atmospheric nitrogen exists as a stable diatomic molecule at low temperatures, and only very small trace amounts of oxides are found. However, at the very high temperatures that occurs in the combustion chamber of an engine, some diatomic nitrogen (N), which is reactive:

$$N_2 \longrightarrow 2\,N$$

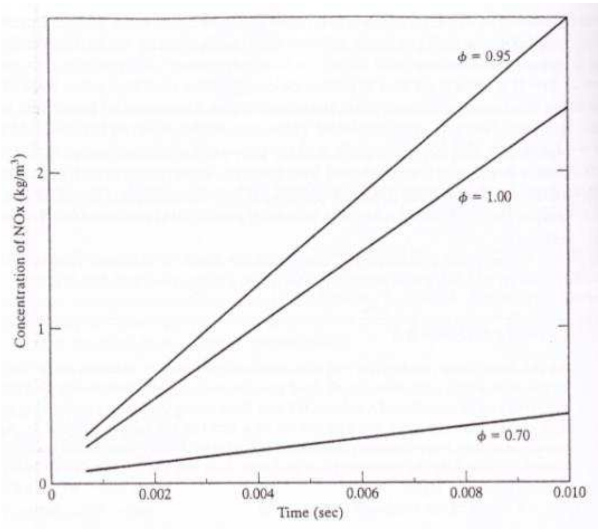


Figure 2.7: Generation of NO_x in an engine as a function of combustion time

Source: Pulkrabek W. W (2003)

2.5.2 Carbon Monoxide (CO)

Carbon monoxide, a colorless, odorless, poisonous gas, is generated in an engine when it is operated with a fuel-rich equivalent ratio. When there is not enough oxygen to convert all carbon to CO_2, some fuel does not get burned and some ends up as CO. Typically, the exhaust of a spark ignition engine will be about 0.2% to 5% carbon monoxide. Not only is CO considered an undesirable emission, but it also represents lost chemical energy that was not fully utilized in the engine. CO is a fuel that can be combusted to supply additional thermal energy:

$$CO + \frac{1}{2} O_2 \longrightarrow CO_2 + \text{heat}$$

Maximum CO is generated when an engine runs rich, such as when starting or when accelerating. Even when the intake air-fuel mixture is stoichiometric or lean, some CO will be generated in the engine. Poor mixing, local rich regions, and incomplete combustion will create some CO.

A well-designed SI engine operating under ideal conditions can have an exhaust mole fraction of CO as low as 10^{-3}. CI engines that operate in a lean manner overall generally have very low CO emissions.

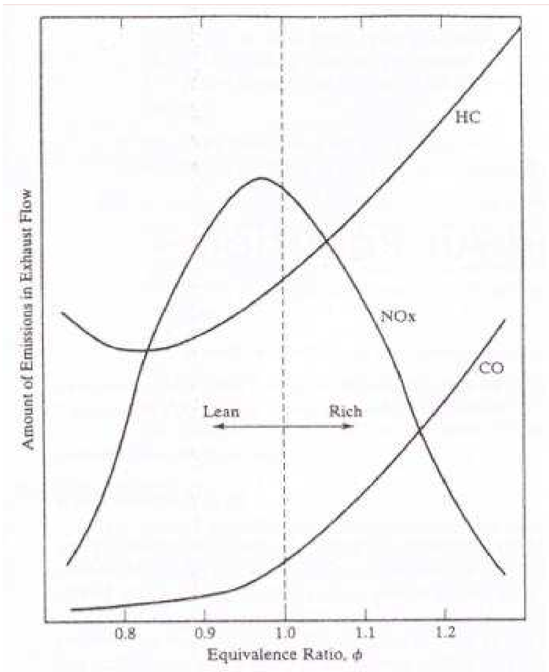


Figure 2.8: Emissions from SI engine as a function of equivalence ratio

Source: Pulkrabek W.W (2003)

2.5.3 Carbon Dioxides (CO_2)

At moderate levels of concentration, carbon dioxide is not considered an air pollutant. However, it is considered a major greenhouse gas and, at higher concentrations, is a major contributor to global warming. CO_2 is a major component of the exhaust in the combustion of any hydrocarbon fuel. Because of the growing number of motor vehicles, along with more factories and other sources, the amount of carbon dioxide in the atmosphere continues to grow. At upper elevations in the atmosphere, this higher concentration of carbon dioxide, along with other greenhouse gases, creates a thermal radiation shield. This shield reduces the amount of thermal radiation energy allowed to escape from the earth, raising slightly the average earth temperature. The most efficient way of reducing the amount of CO_2 is to burn less fuel (i.e., use engines with higher thermal efficiency)

2.5.4 Formation of Sulfur

Many fuels used in CI engines contain small amounts of sulfur, which, when exhausted contributes to the acid rain problem of the world. Unleaded gasoline generally contains 150-600ppm sulfur by weight. Some diesel fuels contain up to 5000 ppm by weight, but in United States and some other countries sulfur content is restricted by law to a tenth of this value or less.

At high temperature, sulfur combines with hydrogen to form H_2S and with oxygen to form SO_2:

$$H_2 + S \longrightarrow H_2S$$

$$O_2 + S \longrightarrow SO_2$$

Engine exhaust can contain up to 20ppm of SO_2 then combines with oxygen in the air to form SO_3:

$$2\,SO_2 + O_2 \longrightarrow 2\,SO_3$$

These molecules combine with water vapor in the atmosphere to form sulfuric acid (H_2SO_4) and sulfurous acid (H_2SO_3), which are ingredients in acid rain:

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

$$SO_2 + H_2O \longrightarrow H_2SO_3$$

Many countries have laws restricting the amount of sulfur allowed in fuel, and these laws are continuously being made more stringent. During the 1990s, the United States reduced acceptable sulfur levels in diesel fuel from 0.05% by weight to 0.01%. The amount of sulfur in natural gas can range from small (sweet) to large (sour) amounts. This can be a major emissions problem when this fuel is used in an IC engine or any other combustion system.

When the allowable sulfur level in diesel fuel was lowered, a new problem surfaced in CI engines. It was found that the fuel with very low levels of sulfur lost its lubricating ability, resulting in sticking fuel pumps and injectors. In addition, there was abnormal wear on cylinder surfaces and rapid pressure buildup in some particulate traps. To overcome these problems, additives are put into low-sulfur fuels. These additives include aliphatic ester derivatives and carboxylic acids.

A more serious effect of sulfur, in addition to being harmful emission, is that it poisons most emissions after treatment systems. Catalyst materials in catalytic converters and regenerating particulate traps deteriorate in the presence of sulfur, lead of phosphorus.

2.5.5 Particulates

The exhaust of CI engines contains solid carbon soot particles that are generated in the fuel-rich zones within the cylinder during the combustion. These are seen as exhaust smoke and are an undesirable odorous pollution. Maximum density of particulate emissions occurs when the engine is under load at WOT. At this condition, maximum fuel is injected to supply maximum power, resulting in a rich mixture and poor fuel economy. This can be seen in the heavy exhaust smoke emitted when a truck or railroad locomotive accelerates up a hill from a stop.

Soot particles are clusters of solid carbon spheres. These spheres have diameters from 10nm to 80nm (1nm = 10^{-9} m), with most within the range of 15-30 nm. The spheres are solid carbon with NC and traces of other components absorbed on the surface. A single soot particle will contain up to 4000 carbon spheres.

Carbon spheres are generated in the combustion chamber in the fuel rich-rich zones where there is not enough oxygen to convert all carbon to CO_2:

$$C_xH_y + z\,O_2 \longrightarrow a\,CO_2 + b\,H_2O + c\,CO + d\,C\,(s)$$

Then, as turbulence and mass motion continue to mix the components in the combustion chamber, most of these carbon particles find sufficient oxygen to further react and consumed to CO_2:

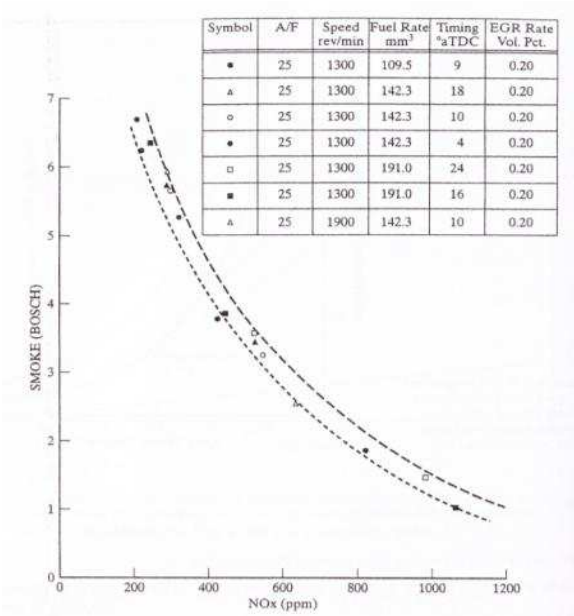
$$C\,(s) + O_2 \longrightarrow CO_2$$

Over 90% of carbon particles originally generates within an engine are thus consumed and never get exhausted. If CI engines were to operate with an overall stoichiometric air-fuel mixture, instead of the overall lean mixture they do operate with, particulate emissions in the exhaust would far exceed acceptable levels.

Up to about 25% of the carbon in soot comes from lubricating-oil components, which vaporize and then react during combustion. The rest comes from the fuel and amounts to 0.2-0.5% of the fuel. Because of the high compression ratios of CI engines, a large expansion occurs during the power stroke, and the gases within the cylinder are cooled by expansion cooling to a relatively low temperature. This causes the remaining high-boiling components found in the fuel and lubricating oil to condense on the surface of the carbon soot particles. This absorbed portion of the soot particles is called the soluble organic fraction (SOF), and the amount is highly dependent on cylinder temperature.

At light loads, cylinder temperatures are reduced and can drop to as low as 200°C during final expansion and exhaust blow down. Under these conditions, SOF can be as high as 50% of the total mass of soot. Under other operating conditions when the temperatures are not so low, very little condensing occurs and SOF can be as low as 3% of total soot mass. SOF consists mostly of hydrocarbon components with some hydrogen, SO_2, NO, NO_2 and trace amounts of sulfur, calcium, iron, silicon and chromium, while lubricating-oil additives contain zinc, phosphorus and calcium.

Particulate generation can be reduced by engine design and control of operating conditions, but quite often this will create other adverse results. If the combustion time is extended by combustion chamber design and timing control, particulate amounts in the exhaust can be reduced. Soot particles originally generated will have a greater time to be mixed with oxygen and combusted to CO_2. However, a longer combustion time means a high cylinder temperature and more NO_x generated. Dilution with EGR lowers NO_x emissions, but increase particulate and HC emissions. Higher injection pressure gives a finer droplet size, which reduces HC and particulate emission, but increases cylinder temperature and NO_x emissions. Engine management systems are programmed to minimize NO_x, HC CO and particulate emissions by controlling ignition timing, injection pressure, injection timing and/or valve timing. Obviously compromise is necessary. In most engines, exhaust particulate amounts cannot be reduced to acceptable levels solely by engine design and control.



Symbol	A/F	Speed rev/min	Fuel Rate mm^3	Timing °aTDC	EGR Rate Vol. Pct.
●	25	1300	109.5	9	0.20
▵	25	1300	142.3	18	0.20
○	25	1300	142.3	10	0.20
●	25	1300	142.3	4	0.20
□	25	1300	191.0	24	0.20
■	25	1300	191.0	16	0.20
▵	25	1900	142.3	10	0.20

Figure 2.9: Nitrogen oxide (NO_x)-smoke (particulates) trade-off at various engine operating conditions

Source: Pulkrabek W.W (2003)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will describe further on the experiment which is analyzing the exhaust emission due to usage of waste plastic disposal (WPD) fuel compared to diesel fuel for diesel engine. In order to complete the experiment, methodology is one of the most important things that need to be considered. The objective for methodology is to make sure that the project will run according to schedule and the data obtained can be analyzed properly.

In this chapter, all the details and related discussions on the process that involve in the project are described. There is a flow chart or more specifically Gantt chart that shows all the process timeline. Both charts explained every single step that is followed to ensure that the objective of the project can be successfully achieved. The steps will start with literature finding until submitting the complete report.

3.2 FLOW CHART

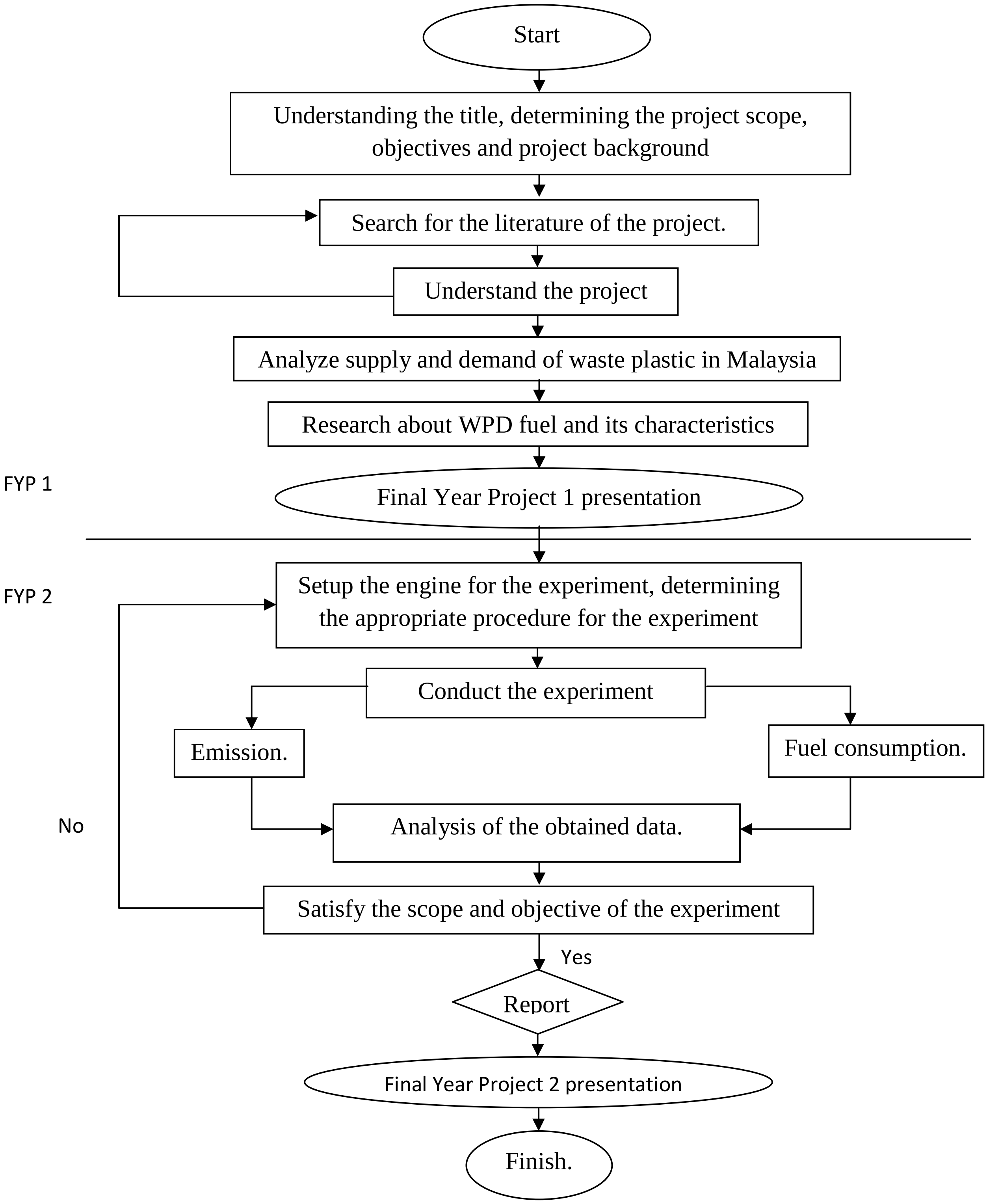


Figure 3.1: Flow chart

3.3 FLOW CHART DESCRIPTION

The flow chart shows every single step that required in order to complete this project and as a guideline. In the beginning, the projects start with receiving the title of the project, understanding the title, determining the project objectives, scopes and the project background. After that, literature review needs to be completed. All related source such as books, journals, research through internet are used to complete literature review. Based on literature review, all the related information about the project is understood about the project. Data and information that had been created before can be used to gain idea and additional information.

Then the methodology of the project which is started by analyzing the supply and demand of plastic waste in Malaysia begins. This process is to identify either supplying of plastic waste enough for this project or not. The data of waste plastic is obtained from journals and websites. The next procedure is research about alternative fuel which is WPD fuel. This study is based on the journals of converting plastic waste into diesel fuel. From the journals, the characteristics of WPD fuel which are derived from experimental data conducted by researchers are obtained. After completing the study about the characteristics of WPD fuel, the presentation slide for Final Year Project 1 presentation is prepared.

For Final Year Project 2, methodology continued with the setup of the engine for the experiment and determining the appropriate procedure for the experiment. After finishing the setup process, the experiment is conducted to analyze the exhaust emission and fuel consumption for the usage of both fuels. The data taken from the experiment are analyzed. If the results fulfill the scopes and objectives of the experiment, the next step which is compilation is preceded. If the results not satisfy the objectives and scopes, the experiment is repeated to get the desired result which is satisfied the scope and objective of the project. After completing the analysis of exhaust emissions and fuel consumption, compilation of the data must be done. This step includes compilation of data from chapter one until five which are introduction, literature review, methodology, analysis with discussion and conclusion. Then the presentation slide for Final Year Project 2 Presentation is prepared.

3.4 LITERATURE ANALYSIS

Literature analysis is a combination and elaboration of the literature review that are made according to journals and also the analysis that involved in the previous research. Before start the project is started, it is important to understand first the project objective which is analyzing the exhaust emission for the engine that using WPD fuel compared to diesel fuel. In order to understand that, the best and precise information must be gathered from the right source. So, there are several ways or methods of source to obtain all the information required such as internet, books / encyclopedia and Project supervisor.

3.4.1 Internet

Internet is the simplest and easiest way to get the information related to the project. By using internet, many journals in form of technical paper that have been written by previous researcher can be found. It is a responsible to choose the best among the journals to get the correct information needed since there are too many journals. Not all information from the internet can be trusted, so the data must be compared to the relevant books in order to get correct and accurate information.

3.4.2 Books / Encyclopedia

Books and encyclopedia are the most trustable and precise source of information. It is because the book is written by professional and officially qualified engineer which are very well-known in related course. To look for this kind of source, library or book shop is suitable place. All the data such as analysis, concepts and calculation method can be found in the book.

3.4.3 Project Supervisor

Not all the information that obtained from the internet, books and encyclopedia can be easily understood and precise to the project. So, project supervisor advice is very important to finalize the information obtained and make sure that all the information is correct to be put in the project report. So, discussion with supervisor which is lecturer that is specifically expert in the project scope will solve all problems that could not be found the answer in other reference. Furthermore, discussion with supervisor can generate new idea for the project research beside make the research more clear and understandable.

3.5 ENGINE RIG DESIGN

Before proceed to the experiment, there are several important part that need to be finished such as engine rig. The design must be finished first before proceed to fabrication process. For the design, SOLIDWORK software is used. The dimension must be larger than size of YANMAR single piston engine because it will be use as a base for that engine.

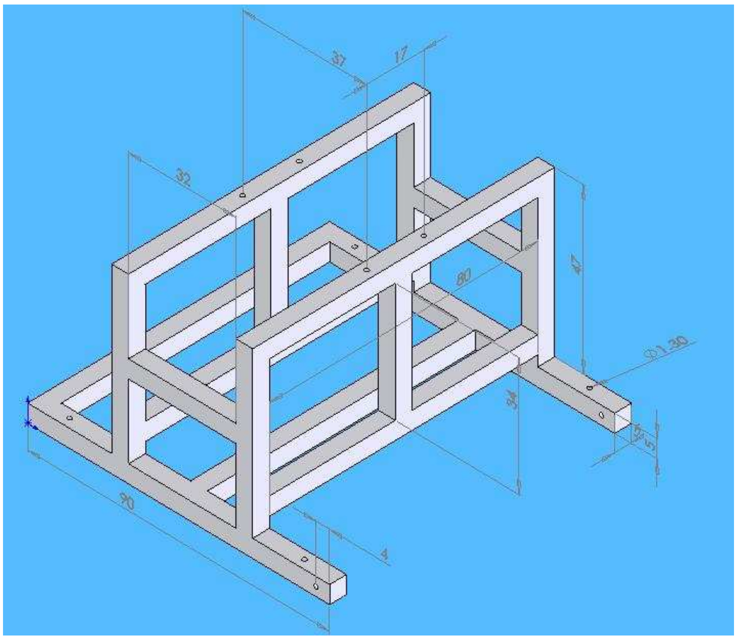


Figure 3.2: Engine Rig Design

3.6 TOOLS

This project based on experimenting method and focused on analyzing the exhaust emission and analyzing the fuel consumption using two different type of fuel which is diesel fuel and waste plastic disposal fuel. There are many tools that have been used in order complete the fabrication process such as disk cutter, MIG welding, hand drill and hand grinder. Disk cutter is used to cut all the materials such as hollow mild steel while MIG welding is used to assemble all the part that will be used in the experiment, hand drill is used to make a hole and hand grinder is used to remove the burr after cutting process.

Figure 3.3: Disk Cutter

Figure 3.4: MIG Welding

Figure 3.5: Hand Drill

Figure 3.6: Hand Grinder

3.7 FABRICATION

Fabrication is the important process that needs to be finished before proceeding to the next step. There are several parts that need to be fabricated in order to complete this experiment such as engine rig, display panel table, rack, exhaust manifold and exhaust gas trap.

3.7.1 Engine Rig

After finished the engine rig design, the fabrication process can be precede. The material used to fabricate this engine rig is hollow mild steel which the dimension is 2in x 2in.

Figure 3.7: Engine Rig

3.7.2 Table

This table is used as the base to put the display panel. The purpose of this table is to make sure that our reading can record properly. The material used is mild steel and plywood.

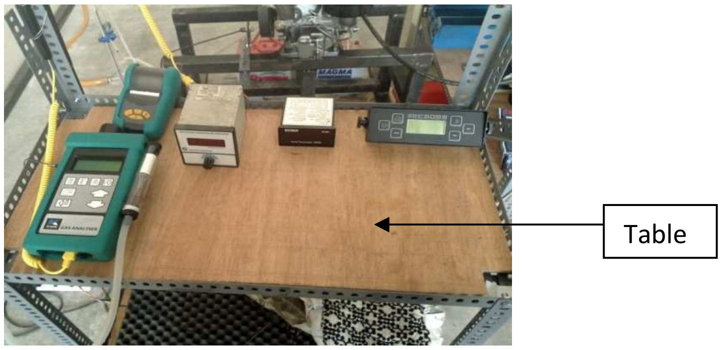


Figure 3.8: Table

3.7.3 Exhaust Manifold

Exhaust manifold have been modified to make sure a thermocouple hole and a valve can be installed, so that the exhaust gasses can be analyzed from the valve.

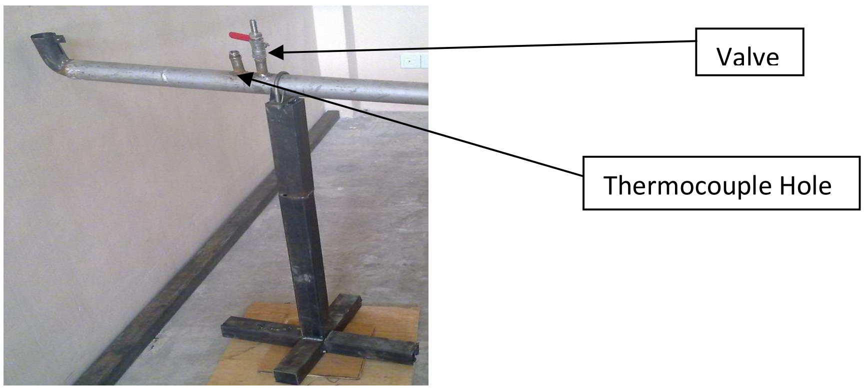


Figure 3.9: Exhaust Manifold

3.8 APPARATUS

3.8.1 YANMAR Engine

The engine that is used for this experiment is YANMAR TF 120. This is single cylinder diesel engine.

Figure 3.10: YANMAR Diesel Engine

3.8.2 Exhaust Gas Particle Trap

Diesel engine produces soot as a product of combustion. If this soot entered the exhaust analyzer, it will cause the exhaust analyzer to be damage. The exhaust gas particle trap functioned to avoid the soot from reaching the exhaust analyzer. It worked by cooling the exhaust gas through the “water jacket” along the tube that the exhaust gas going through, causing the particle in the exhaust gas loosing energy and become heavier, and the particle will drop to the bottom of the beaker that act as a trap. The diagram of the exhaust gas particle trap is shown below:

Figure 3.11: Water Reservoir Tank

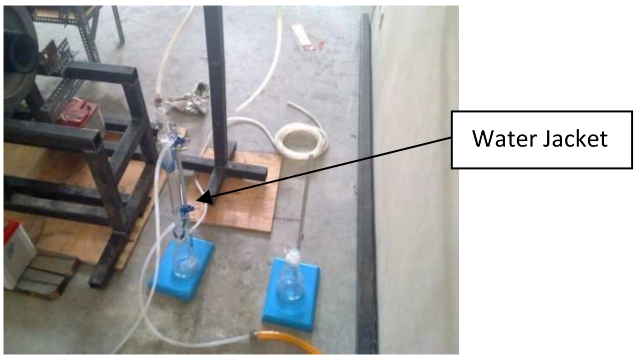


Figure 3.12: Exhaust Gas Particle Trap

3.8.3 Fuel Flow Rate Analyzer

The fuel flow meter that is used in this experiment is from AIC – 1204 HR 2000 model, with board computer from BC 3033 model. The picture is shown below:

Figure 3.13: Fuel Flow Rate Board Computer

3.8.4 Exhaust gas temperature sensor

The exhaust gas temperature is measured using thermocouple and the temperature is shown by the display unit. Thermocouple is placed at the exhaust manifold as shown below:

Figure 3.14: Thermocouple

Figure 3.15: Temperature Display Unit

3.8.5 Exhaust Gas Analyzer

The exhaust gas is analyzed using exhaust analyzer. The model that is used is Hand Held 4 & 5 Gas Analyzer Auto 4-2 & Auto 5-2 model. The picture of the exhaust gas analyzer is shown below:

Figure 3.16: Exhaust Gas Analyzer

3.8.6 Engine Speed Sensor

The engine speed sensor is used to measure the current engine speed. The model used is model 461957 photoelectric sensor and the display unit are from model 461950 panel tachometer. Photoelectric sensor is attached to the engine rig to enable the speed of the engine to be measured. A marking have been made at the engine's flywheel to enable the RPM sensor to detect the engine speed. The picture of the RPM sensor and the panel tachometer unit are shown below:

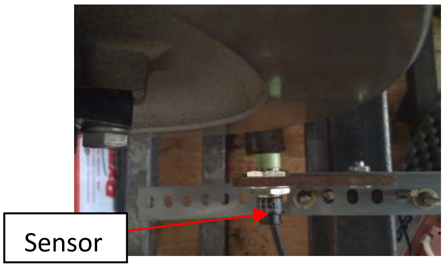


Figure 3.17: Photoelectric Sensor

Figure 3.18: Panel Tachometer

3.9 FUEL

There are two types of fuel used in this experiment which is diesel fuel and waste plastic fuel.

3.9.1 Waste Plastic Fuel

Figure 3.19: Waste Plastic Fuel

3.9.2 Diesel Fuel

Figure 3.20: Diesel Fuel

3.10 EXPERIMENT PROCEDURE

3.10.1 Fuel consumption analysis

At the beginning, the engine speed is set to be 1100 revolution per minute (rpm). The time taken for the engine to consume 100mL of fuel is taken and the fuel consumption can be determined manually by dividing the 100mL of fuel by the time taken to consume 100mL of fuel. Using flow rate meter, the amount of fuel consumed for 5 minutes can be determined directly from the board computer unit that displays the amount. The fuel consumption also can be determined by dividing the amount of fuel consumed by 5 minutes of time taken. The value that is obtained through both methods can be compared. The unit for the fuel consumption is liter/hour (L/hr)

The engine speeds then are variable to 1500rpm, 1700rpm, 1900rpm and 2100 rpm and the same procedures are repeated. The experiment then is continued with waste plastic disposal fuel. All the data obtained are filled in the table. The graph of fuel consumptions for both fuel usages are plotted and compared.

3.10.2 Emission analysis

At the beginning, the engine speed set to be 1100rpm. The exhaust gas that is come out from the exhaust valve is collected using pipe and the smoke is let through the exhaust particle trap. The water jacket around the exhaust pipe will cause the particle to fall at the bottom of the trap. The “clean” exhaust gas then will enter the exhaust analyzer and the content of the exhaust gas will be analyzed. The amount of the content can be measured directly from the exhaust analyzer display unit.

The engine speeds then are variable to 1500rpm, 1700rpm, 1900rpm and 2100rpm and the same procedures are repeated. The experiment then is continued with waste plastic disposal fuel. All the data obtained are filled in the table. The graph of exhaust gas emissions for both usages of fuel are plotted and compared.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter presents results of this project and further the results are discussed in detail. In this project, the results are obtained by using experimental method which analyze emission characteristics and fuel consumption on YANMAR single piston diesel engine. The recommendations for this project will be discussed in the next chapter.

4.2 FUEL CONSUMPTION

Table 4.1 shows the data of fuel consumption for both fuel usages which is diesel fuel and waste plastic fuel. From the data, it clearly shows that the maximum fuel consumption for both fuel usages is at the maximum engine speed which is 2100RPM and the minimum value of fuel consumption is at the minimum engine speed which is 1100RPM.

Table 4.1: Fuel Consumption

Engine Speed (RPM)	Diesel Fuel	Waste Plastic Fuel
	Flow Rate (L/h)	Flow Rate (L/h)
1100	0.216	0.240
1300	0.264	0.300

1500	0.324	0.348
1700	0.396	0.420
1900	0.456	0.492
2100	0.540	0.588

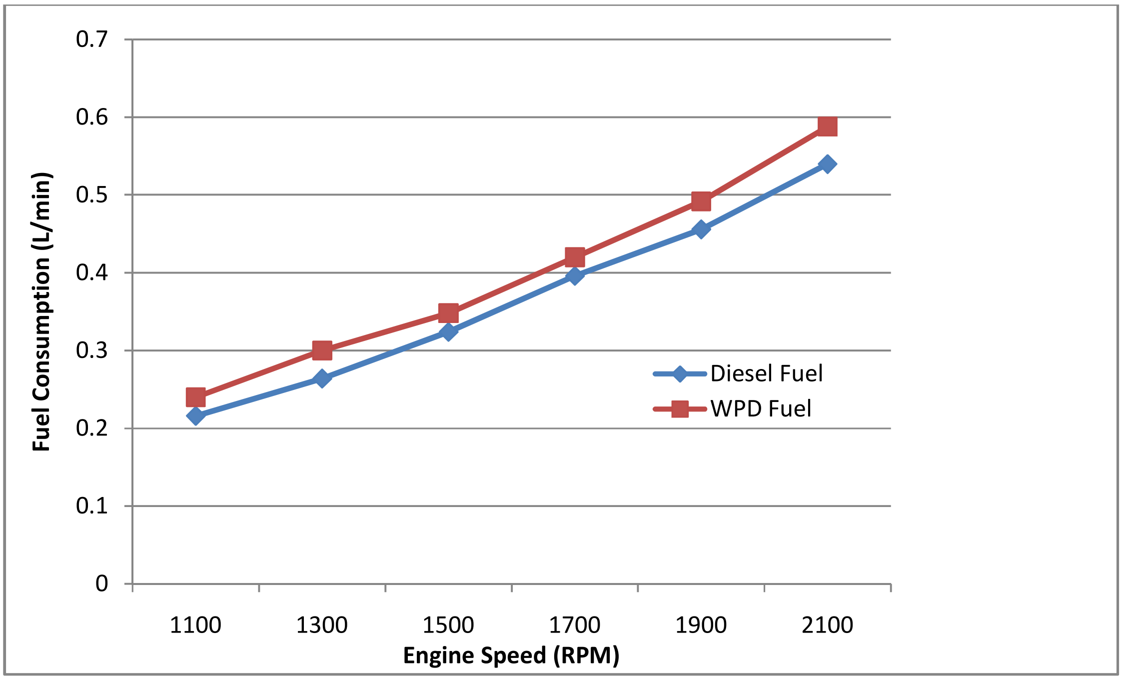


Figure 4.1: Graph of Fuel Consumption Vs Engine Speed

Figure 4.1 clearly shows that the fuel consumption for waste plastic fuel usage is lower than diesel fuel. The maximum and minimum value of fuel consumption for diesel fuel usage is 0.540L/h and 0.216L/h. The maximum and minimum value of fuel consumption for waste plastic fuel usage is 0.588L/h and 0.240L/h. The maximum value of fuel consumption for both fuel usages is at higher engine speed while the minimum value is at lower engine speed. The average fuel consumption for waste plastic fuel usage is higher than diesel fuel by 8.74%. It means diesel fuel is better in fuel consumption than waste plastic fuel. The value of fuel consumption is increase due to engine speed because higher engine speed produces more combustion that results more fuel needed to make sure combustion will occur properly.

4.3 EMISSION

4.3.1 NO_x

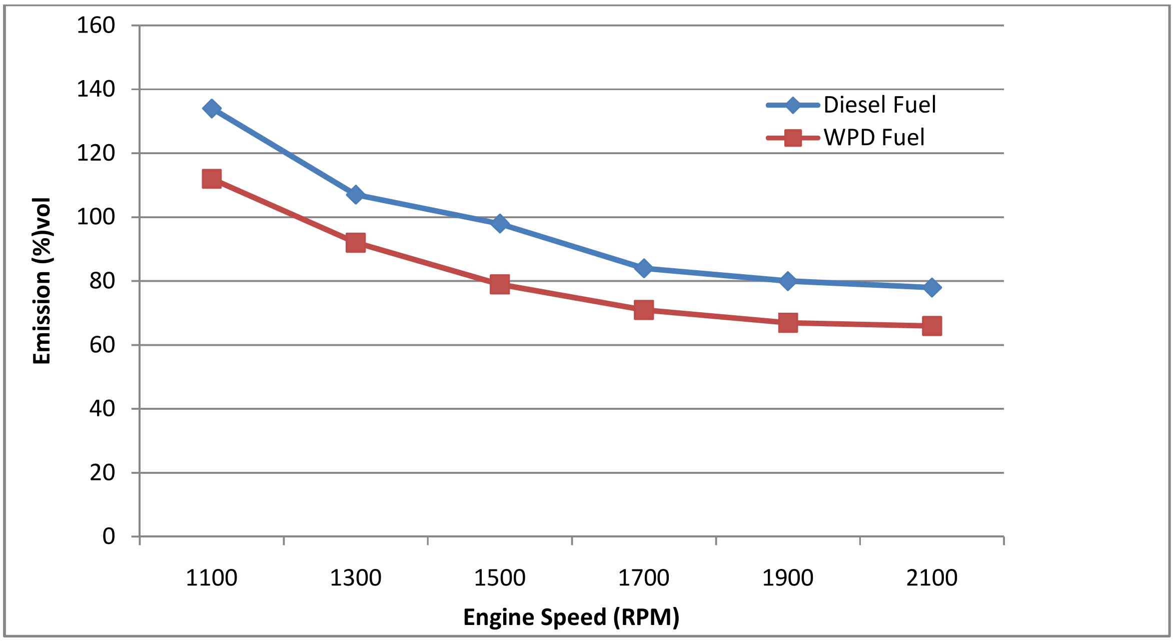


Figure 4.2: Graph of Emission (NO_x) Vs Engine Speed

Figure 4.2 shows the graph of oxides of nitrogen (NO_x) emission versus engine speed. At the maximum engine speed which is 2100RPM, the value of NO_x for diesel fuel is 78 parts per million (ppm) and 66ppm for waste plastic fuel. At the minimum engine speed which is 1100RPM, the value of NO_X for diesel fuel is 134ppm while for waste plastic fuel is 112ppm. It is clearly seen that the composition of NO_x due to diesel fuel usage is higher than waste plastic fuel. The average of NO_x emission from the usage of diesel fuel is higher than waste plastic fuel by 19.30%. The trend of the graph shows that when engine speed increases, the value of NO_x for both fuel usages is decreasing. This may caused by the experiment condition which is the engine is running without load exerted to it. NO_x emission is depending on the condition of air and fuel mixture which is lean or rich. If the stoichiometry of the combustion is lean, lower NO_x is formed. Graph shows that the value of NO_x for diesel fuel is higher than waste plastic disposal fuel. This may cause by higher exhaust temperature due to diesel fuel usage. When temperature is higher, higher NO_x is formed.

4.3.2 NO

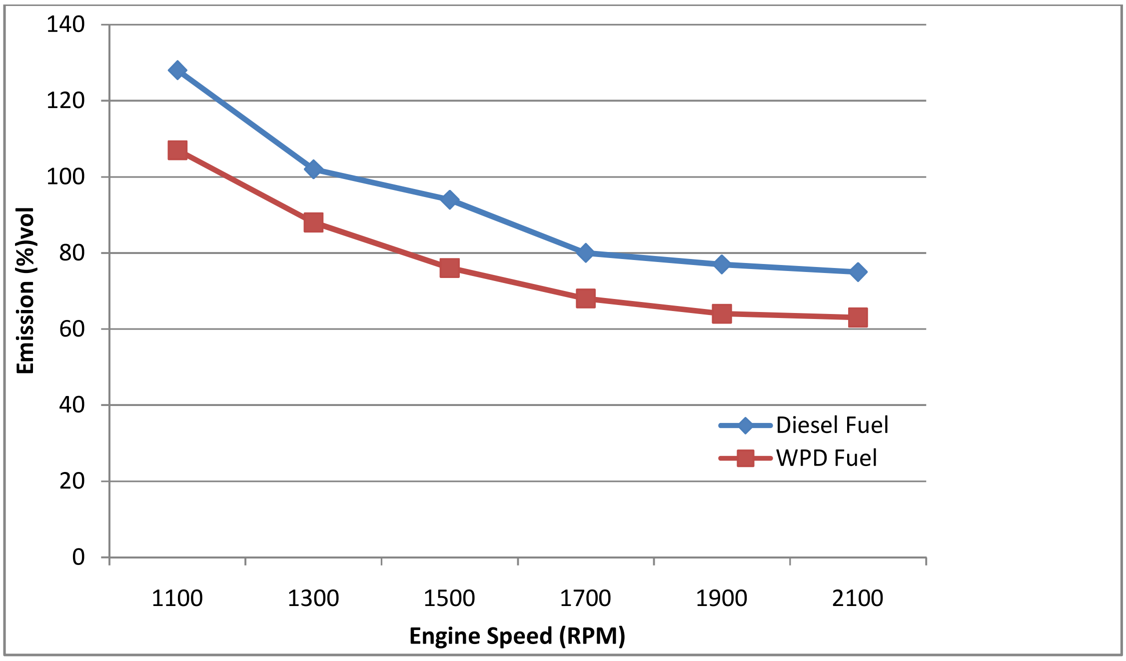


Figure 4.3: Graph of Emission (NO) Vs Engine Speed

Figure 4.3 shows the graph of Nitrogen dioxide (NO) versus engine speed. Graph above clearly shows that the fuel composition of NO for waste plastic fuel usage is lower than diesel fuel usage. The average NO composition for waste plastic fuel usage is higher than diesel fuel by 19.31%. At the minimum engine speed which is 1100RPM, the value of NO for diesel fuel usage is 128ppm while for waste plastic fuel usage is 107ppm. At the engine maximum speed which is 2100RPM, the value of NO emission for diesel fuel usage is 75ppm and for tire disposal fuel usage is 63ppm. The graph shows decreasing value of NO for both fuels with increasing of engine speed. This may caused by the condition of the experiment where the engine runs with no load exerted on it, so it will run in lean condition where that causes the NO emission that produced is lower.

4.3.3 O_2

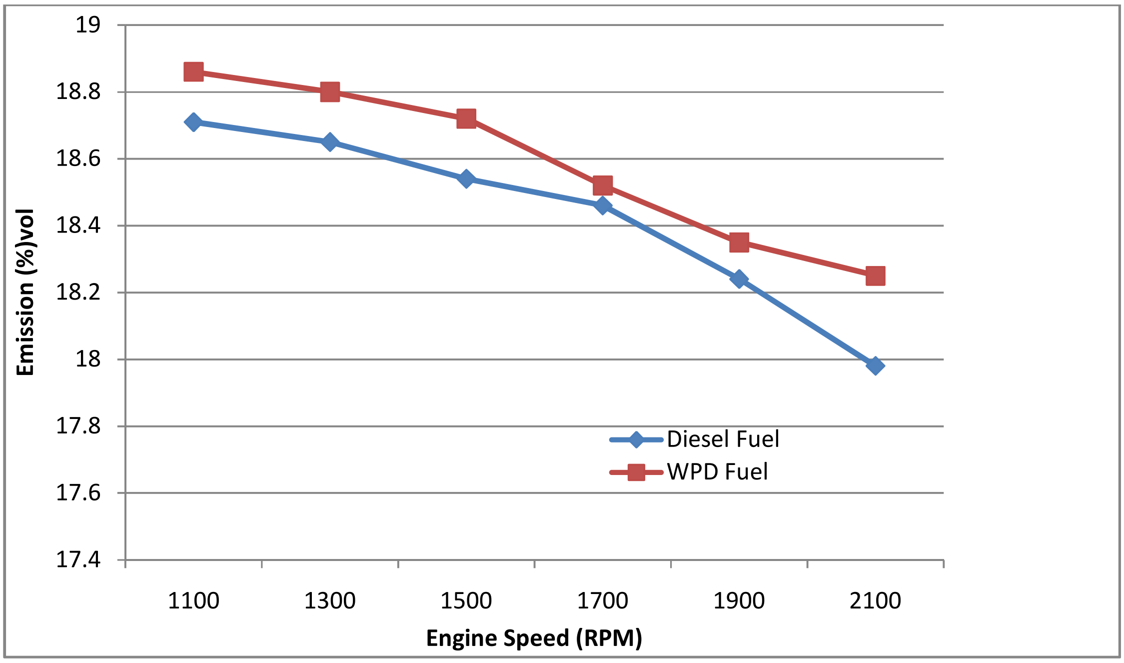


Figure 4.4: Graph of Emission (O_2) Vs Engine Speed

Figure 4.4 shows the comparison of oxygen (O_2) emission for tested fuels. Graph above clearly shows that the O_2 composition for waste plastic fuel usage is lower than diesel fuel usage. The maximum value of oxygen emission is at lower engine speed which is 1100RPM while the minimum value of oxygen emission is at higher engine speed which is 2100RPM. For diesel fuel, the maximum value of oxygen emission value is 18.71% volume and the minimum value is 17.98% volume. For waste plastic fuel, the maximum value of oxygen emission value is 18.86% volume and the minimum value is 18.25% volume. The average of O_2 composition for waste plastic fuel usage is higher than diesel fuel by 0.81%. The value of O_2 become lower when the engine speed increased probably because when the engine speed increased, more O_2 combines with the fuel to enable the combustion to occur.

4.3.4 CO_2

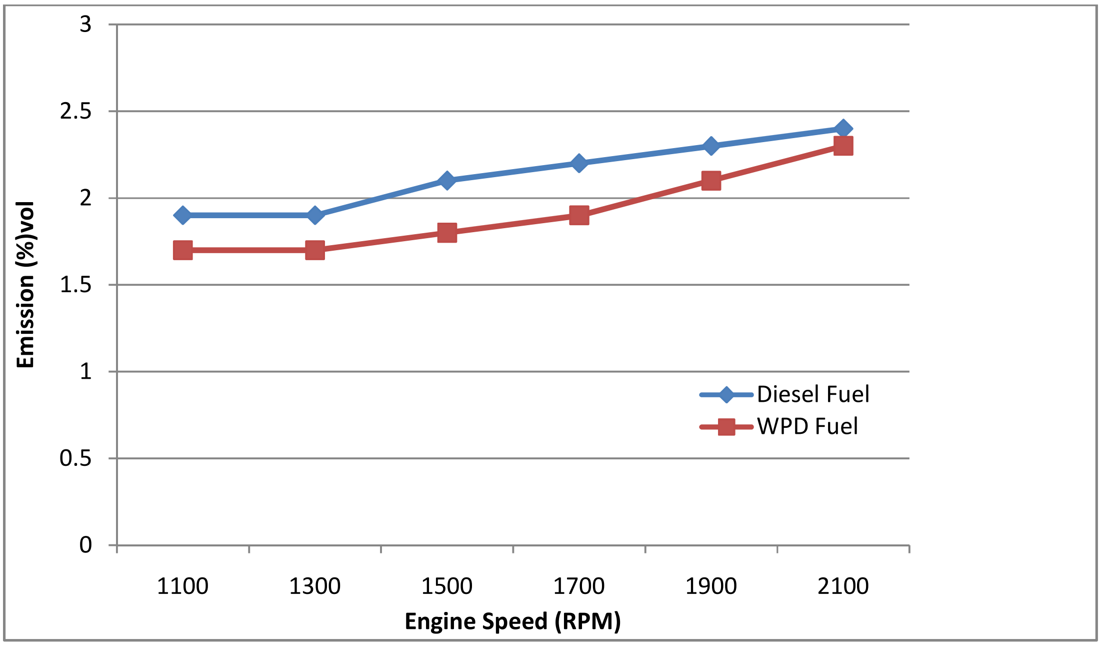


Figure 4.5: Graph of Emission (CO_2) Vs Engine Speed

Figure 4.5 shows the graph of carbon dioxide (CO_2) emission versus engine speed. The graph shows that the value of CO_2 for diesel fuel usage is higher than waste plastic fuel. The average of CO_2 composition for waste plastic fuel usage is lower than diesel fuel by 10.94%. At the minimum engine speed, the value of CO_2 emission for diesel fuel usage is 1.9% volume and for waste plastic fuel is 1.7% volume. At the maximum engine speed, the graph shows that the value of CO_2 emission for diesel fuel usage is 2.4% volume and for waste plastic fuel is 2.3% volume. The trend of the graph shows that the value of CO_2 is increase due to engine speed. This may caused by increasing of incomplete combustion occur at high engine speed because do not find time to undergo combustion.

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4.3.5 CO

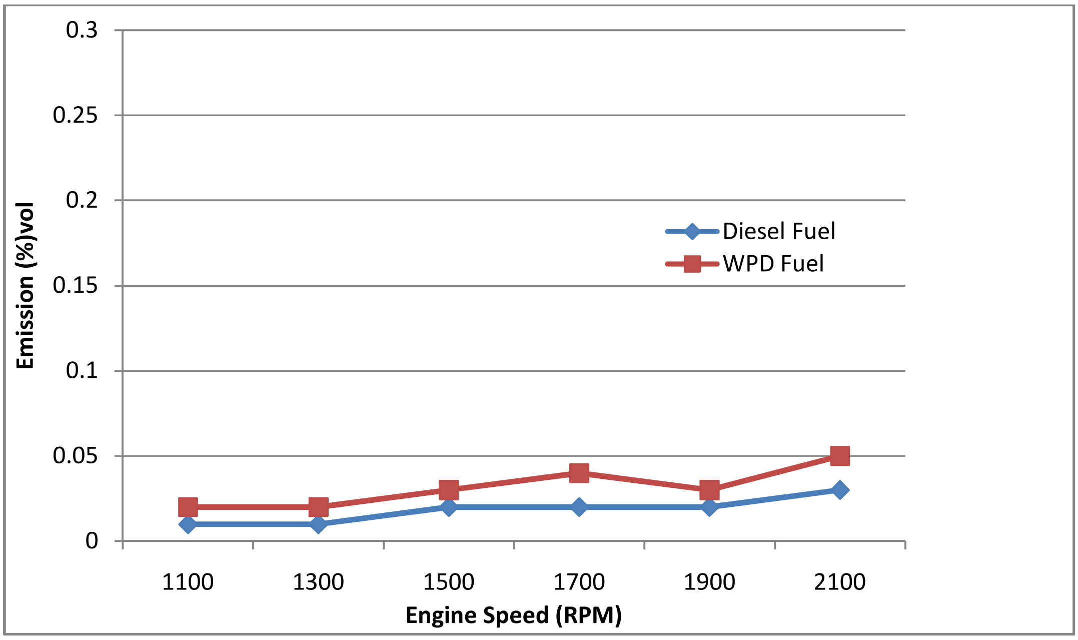

Figure 4.6: Graph of Emission (CO) Vs Engine Speed

Figure 4.4 shows the comparison of carbon monoxide (CO) emission for tested fuels. Graph above clearly shows that the CO composition for waste plastic fuel usage is higher than diesel fuel usage. From the graph above, it clearly shows that the maximum value of CO emission is at higher engine speed which is 2100RPM while minimum value is at lower engine speed which is 1100RPM. The maximum value of CO for diesel fuel usage is 0.03% volume and the minimum value is 0.01% volume while the maximum value of CO composition for waste plastic fuel is 0.05% volume and the minimum value is 0.02% volume. . The average of CO composition for waste plastic fuel usage is higher than diesel fuel by 77.8%. From graph above, it shows that the value of CO emission is low for both fuel which is diesel fuel and waste plastic fuel. This is because generally, diesel or compression ignition engines operate with lean mixtures and hence the CO emission would be low. Because of the condition of the engine runs with no load exerted on it, so it will run in lean condition. Therefore, they do not find time to undergo combustion which results higher CO emission for waste plastic fuel than that diesel fuel.

4.4 EXHAUST GAS TEMPERATURE

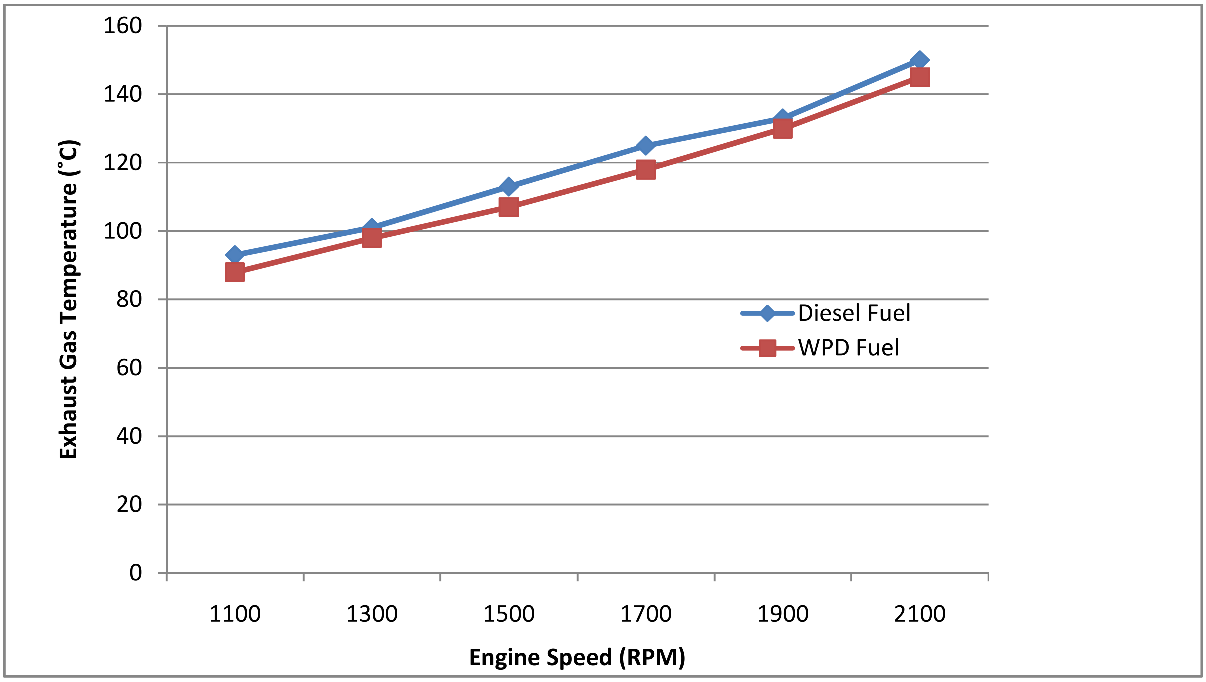

Figure 4.7: Graph of Exhaust Gas Temperature Vs Engine Speed

From Figure 4.7, it is clearly seen that the exhaust temperature due to waste plastic fuel usage is lower than diesel fuel. The average exhaust temperature due to diesel fuel higher than waste plastic fuel is by 4.23%. At the maximum engine speed which is 2100RPM, the value of exhaust gas temperature for diesel fuel usage is 150˚C while 145˚C for waste plastic fuel. At the lower engine speed which is 1100RPM, the value of exhaust temperature is 93˚C for diesel fuel usage and 88˚C for waste plastic fuel usage. The graph above shows that exhaust temperature is increase due to engine speed. Number of combustion is directly proportional to the engine speed. This is the answer why exhaust temperature is increase. Higher engine speed will produce higher heat release that will affect the exhaust temperature. Besides that, the reasons for lower exhaust gas temperatures for waste plastic fuel are due to lower viscosity which results a lesser penetration of the fuel into the combustion chamber and the lesser amount of heat is developed.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

There are several conclusions that can be drawn which is YANMAR engine is able to run with waste plastic disposal (WPD) fuel but the engine needs to run by using diesel fuel first, then followed by waste plastic disposal fuel and finished with diesel fuel as the last fuel usage before the engine turned off. In term of fuel consumption, waste plastic disposal fuel is slightly higher than diesel fuel by 8.74% but still suitable for daily used. This is because the price is lower than existed diesel fuel. The value of oxides of nitrogen (NO_x) and nitrogen monoxide (NO) for waste plastic disposal fuel usage is lower by 19.26% and 19.31% than diesel fuel and the value of carbon monoxide (CO) for waste plastic disposal fuel is by 77.8% higher than diesel fuel. This may caused by using engine with zero loads for the experiment which result the mixture of fuel and air is in lean condition. The value of exhaust gas temperature for waste plastic disposal fuel is lower by 4.23% than diesel fuel.

5.2 RECOMMENDATIONS

For further research, this experiment can be continued by install the dynamometer that will give loads to the engine which results the brake power, torque of the engine can be analyze. By installing the dynamometer, the comparison between diesel fuel and waste plastic disposal fuel can be analyze clearly in term of engine performance and emission characteristics. Besides that, in further research, it is better use more accurate gas exhaust analyzer complete with air fuel ratio (AFR) analyzer in order to improve this experiment.

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APPENDIX A

GANTT CHART FOR FINAL YEAR PROJECT 1

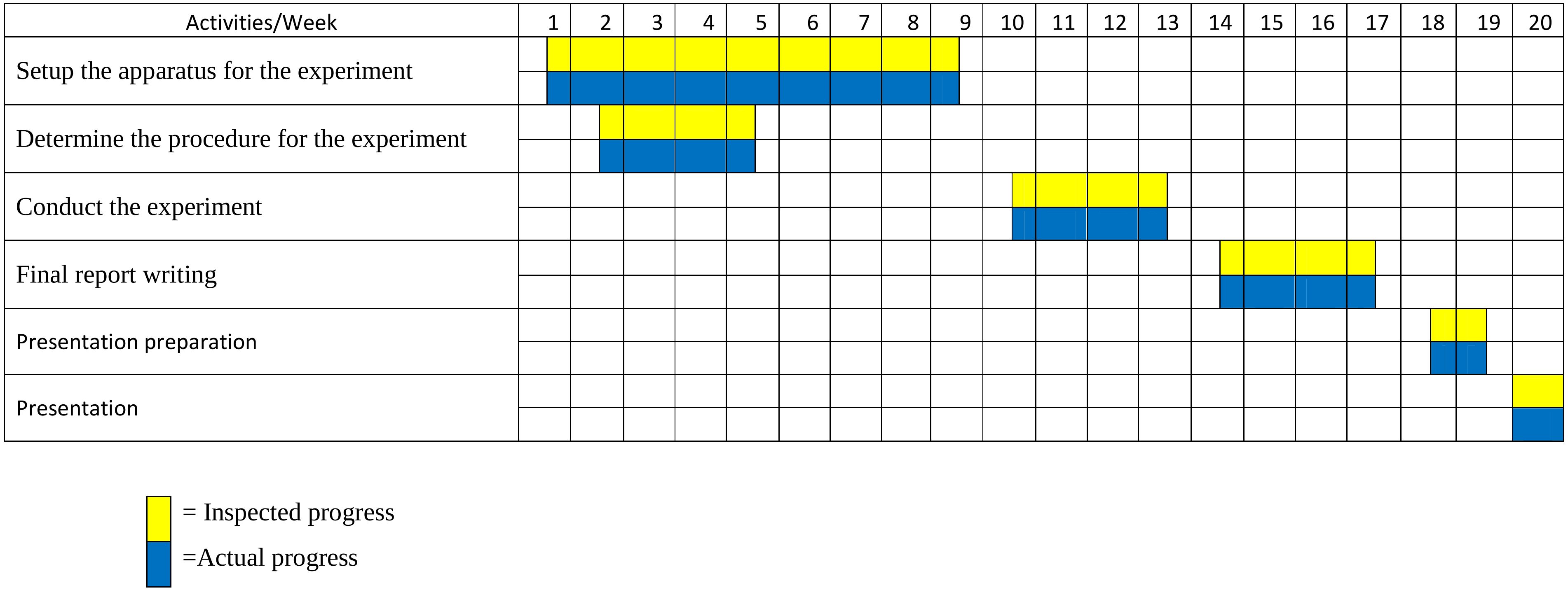
Activities/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Get the title and the logbook																
Determine the project objectives, scopes and background																
Determine the flow chart of the project																
Looking for the literature review																
Complete and send the proposal to the supervisor																
Presentation preparation																
Presentation																

= Inspected progress

=Actual progress

APPENDIX B

GANTT CHART FOR FINAL YEAR PROJECT 2



APPENDIX C

RESULT OF DIESEL FUEL

Engine speed (RPM)	Time taken to consume 100mL (minute)	5 minute average fuel consumption (L)	Exhaust gas temperature (°C)	Emission					Ambient Temperature (°C)	Throttle Opening (cm)
				NO_x (ppm)	NO (ppm)	CO (% vol)	CO_2 (% vol)	O_2 (% vol)		
1100	26	0.018	93	134	128	0.01	1.9	18.71	30.6	2.1
1300	22	0.022	101	107	102	0.01	1.9	18.65	30.6	2.3
1500	18	0.027	113	98	94	0.02	2.1	18.54	29.2	2.6
1700	15	0.033	125	84	80	0.02	2.2	18.46	29.2	2.9
1900	14	0.038	133	80	77	0.02	2.3	18.24	29.8	3.2
2100	12	0.045	150	78	75	0.03	2.4	17.98	29.8	3.7

APPENDIX D

RESULT OF WASTE PLASTIC DISPOSAL FUEL

Engine speed (RPM)	Time taken to consume 100mL (minute)	5 minute average fuel consumption (L)	Exhaust gas temperature (°C)	Emission					Ambient Temperature (°C)	Throttle Opening (cm)
				NO_x (ppm)	NO (ppm)	CO (% vol)	CO_2 (% vol)	O_2 (% vol)		
1100	26	0.020	88	112	107	0.02	1.7	18.86	29.5	2.1
1300	22	0.025	98	92	88	0.02	1.7	18.80	30.3	2.35
1500	18	0.029	107	79	76	0.03	1.8	18.72	30.1	2.6
1700	15	0.035	118	71	68	0.04	1.9	18.52	30.1	2.9
1900	13	0.041	130	67	64	0.03	2.1	18.35	30.1	3.3
2100	11	0.049	145	66	63	0.05	2.3	18.25	30.1	3.7

APPENDIX E

ENGINE SPECIFICATION

Brand	: YANMAR
Model	: TF 120
Displacement	: 636 cc
Max Output	: 12 Bhp @ 2400rpm
Continuous output	: 10 Bhp @ 2400rpm
Fuel tank capacity	: 11 liter
Cooling system	: Water cooled, radiator
Starting system	: Starter or manual cranking
Dimensions (L/W/H)	: 685cm/350cm/530cm
Weight	: 102 kg

APPENDIX F

BOARD COMPUTER AND FUEL FLOW METER SPECIFICATION

For board computer:

Voltage supply	: 11 to 30 VDC
Current consumption of system (U in = 24 V)	
- Normal operation and standby	: 40 MA
- With illumination	: 60 mA
- With sensors connected	: 100mA
- Supply for sensors	: U out 7 V
	I max 40 mA

For fuel flow meter:

- Dimensions	: 115 × 55 ×55 mm (incl. non-return valve)
-Weight	: 0.600 kg
- Measuring range	: 1 to 80 l/h
- Pulse rate	: 2000 ppm

APPENDIX G

TECHNICAL SPECIFICATION OF PANEL TACHOMETER AND PHOTOELECTRIC SENSOR

Model 461950 Panel Tachometer:

Range : 5 to 99 990 RPM
Accuracy : 0.1 (5 to 999.9); 1 (1000 to 9999); 10 (10.000 to 99.990)

Display : 0.5 "(13mm) 4 digit (9999 count) LED display

Display update rate: Once per second

Power : 110/220 VAC; 50/ 60 Hz ± 15%

Panel cutout dimensions: 3.62 × 1.77" (92 × 45mm)

Bezel dimensions : 3.78 × 1.89 × 2.36" (96 × 48 ×60mm)

Model 461957 Photoelectric sensor:

Range : Up to 6000 RPM (100 Hz)

Power : 12- 24 VDC ± 10%; Consumption: 40 mA max

Response time : < 1 ms

Output : NPN transistor; Max load 80 mA

Photo beam color : Green

Photo beam wavelength : 5500 Angstroms

Cable length : 1.8 meters

APPENDIX H

SPECIFICATION OF EXHAUST ANALYZER

Parameter	Resolution	Accuracy	Range
Carbon Monoxide	0.01%	±5% of reading	0-10%
Oxygen	0.01%	±5% of reading	0-21%
Hydrocarbon	1 ppm	±5% of reading	0-5000ppm
Carbon Dioxide	0.1%	±5% of reading	0-16%
Nitric Oxide	1 ppm	±4% of reading	0-5000ppm

APPENDIX I

DIESEL PLASTIC FUEL CHARACTERISTIC

Property	Diesel Fuel
Density @ 30 ˚C in (kg/m^3)	811.25
Kinematic viscosity, m^2/s	0.0000989
Cetane number	55
Flash point (˚C)	50
Fire point (˚C)	56
Carbon residue (%)	26
Sulphur content (%)	0.045
Distillation temperature (˚C) @ 85%	328
Distillation temperature (˚C) @ 95%	340

APPENDIX J

WASTE PLASTIC DISPOSAL FUEL CHARACTERISTIC

Property	**Waste Plastic Fuel**
Kinematic viscosity, (kg/m^3) @ 50 ˚C	0.0000866
Total Sulphur (%)	0.37
Density @ 15 ˚C in (kg/m^3)	924.1
Flash point (˚C)	64
Water by Distillation (Vol %)	7.9
Pour point (˚C)	N.D < -10
Gross Calorific Value (KJ/Kg)	49652

*N.D = Not Detected