EXPERIMENTAL STUDY OF ALTERNATIVE FUEL PERFORMANCE OPERATING IN SINGLE CYLINDER DIESEL ENGINE

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

Faculty of Mechanical Engineering
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JUNE 2013

ABSTRACT

This report deals with the performance of waste plastic fuel acting on single cylinder YANMAR diesel engine. The objectives of this project are to analyze the performance of single cylinder YANMAR diesel engine in context of torque and power produced by using waste plastic fuel and compared it with the result obtain by using standard diesel fuel. Second objective is to analyze the consumption of waste plastic fuel compared to the result obtains by using standard diesel fuel available in market nowadays. The project used diesel engine with no load which means there is no force exerted on it. Details studies and research has been done to get knowledge on apparatus and set up for the project.

ABSTRAK

Laporan ini berkenaan dengan prestasi yang terhasil daripada penggunaan minyak diesel yang di perbuat daripada plastik terbuang ke atas enjin diesel YANMAR satu silinder. Objektif projek ini adalah untuk menilai ciri-ciri prestasi yang terhasil daripada penggunaan bahan plastik terbuang di dalam enjin diesel YANMAR satu silinder dalam konteks kuasa terhasil dan dibandingkan dengan penggunaan minyak diesel biasa. Laporan ini juga berkenaan analisis tentang kadar penggunaan minyak daripada plastik terbuang berbanding minyak diesel yang sedia ada di dalam proses pembakaran enjin diesel YANMAR satu silinder. Projek ini menggunakan enjin diesel tanpa beban yang membawa maksud tiada daya atau bebanan yang bertindak keatas enjin semasa kajian dijalankan. Kajian dan telaah yang secukupnya telah dilakukan dalam usaha menjayakan projek ini.

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LIST OF SYMBOLS

l/h	Litre per Hour
P	Power
kW	kiloWatt
T	Torque
N	Engine Speed

LIST OF ABBREVIATIONS

CC	Cubic Centimeters
BHP	Brake Horse Power
WPD	Waste Plastic Disposal
NOx	Nitrogen Oxides
PM	Particulate Matter
BTDC	Before Top Dead Center
TDC	Top Dead Center
Nil	Not Detected

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Management systems and techniques have been developed to reduce the environmental burden of waste production and at the same time to address possibilities of the conversion of waste to energy. Disposal of organic waste in landfills produces methane, which should be minimized via capture and subsequently used as a fuel for reducing greenhouse gas emissions. In addition, the by-products of incineration usually contain some toxic contaminants. However waste treatment still this can provide option needs a viable to be possibility analyzed for with energy specific production, tools its environmental impact. This chapter discussed about the project background, problem statement, objectives and the scope of this experimental study. This chapter shows the main and starting points for the progress of this study. The study will described and focused toward the performance of single cylinder diesel engine fueled by waste plastics fuel and the fuel consumption of both fuel.

1.2 PROJECT BACKGROUND

A fast-growing economic in emerging-developing countries, typically at the capital city, has encouraged an increased solid waste generation in that specific area. With the development inMalaysia country, along with the economic growth and business activity and consumption rate will accelerate the daily generation and volume rate of municipal solid waste. Government Board of Kuala Lumpur City has managed as many as 2.500 tons of municipal solid waste a day for the year 1998 for at least 912.500 tons. Generally, Malaysia generated around 18000 Mtons every day. In current investigations carried out by the Board of Government of Kuala Lumpur has record a samplefrom solid waste samples collection at certain location around 100 kg weights per sample, and the composition which could be found from the sample is as **Table 1.1**.

Table 1.1: Municipal Solid Waste Composition from Kuala Lumpur
Source: ChamhuriSiwar (2010)

Type of Solid Waste	Percentage of Total Solid Waste Sample
Food waste	74 percent
Plastics	21 percent
Paper	1 percent
Mixed Organic	1 percent
Wood	1 percent
Others	2 percent

This experiment is using single cylinder diesel engine as the main apparatus. It is a 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 system with radiator. This engine also uses direct fuel injection with a high pressure 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. It will generate 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. The specification of the engine can be seen clearly from **Appendix 3**. In this experiment, the condition used is zero loads which mean there is no load exerted on the engine.

1.3 PROBLEM STATEMENT

Millions of tons of waste plastics are generated every year worldwide. Municipal and commercial solid wastes contain a large amount of plastics and most of these plastics are not biodegradable. Hence the disposal of waste plastics has been an important concern for the society. The most common method is to use a landfill. Incineration, on the other hand, burns the plastics, but it can cause air pollution. Therefore, energy recovery from waste plastics is gaining importance because of its potential to eliminate plastics and at the same time generate energy using free feedstock, that is, waste plastics.

There are applications such as large marine vessels where fuel is scarce and expensive, and at the same time the waste plastics generated onboard are available at a negative cost. In a carbon-constrained world, the using of diesel fuel has contributed too much carbon pollution in world. Biodiesel is an alternate fuel that has lower net carbon emissions than fossil fuels.

1.4 PROJECT OBJECTIVES

The objectives of this project are to analyze the performance of single cylinder diesel engine by using waste plastic fuel and to analyze the consumption of waste plastic fuel compared to the result obtain by using standard diesel fuel available in market nowadays.

1.5 SCOPE OF STUDY

The following scopes of the project are determined to achieve the objectives of the project.

i. Analyzing the fuel consumption by using both fuel which are waste plastic fuel and standard diesel fuel in single cylinder diesel engine
ii. Analyzing the engine performance by using both fuel which are waste plastic fuel and standard diesel fuel in single cylinder diesel engine

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to review the information which related to this project such Internal Combustion Engine characteristics, characteristic of waste plastic disposal (WPD) fuel and diesel fuel, and the basic fundamental of diesel engine cycle.

2.2 DIESEL ENGINE

Almost all gasoline, spark-ignited engines run at stoichiometric conditions, which are the point where available oxygen from the air is completely consumed, oxidizing the fuel delivered to the engine. Stoichiometric spark-ignited engines use a homogenous air-fuel mixture with early fuel introduction for good fuel vaporization. Gasoline fuel delivery systemshave evolved from carbureted systems to throttle body injection, multipoint fuel injection and sequential. The latest evolutionary step, stoichiometric direct injection, represents a significant improvement for spark-ignited engines and when combined with turbocharging and engine downsizing makes them competitive with diesel engines in terms of fuel economyand performance.

Unlike gasoline spark-ignited engines, which always control both the amount of air and the amount of fuel close to complete combustion conditions, the diesel engine runs throttled with an excess of air (lean operation). Particulate matter (PM) and nitrogen oxides (NO_x) emissions are more challenging to control and are the main focus of diesel emissions control research, as well as the main source of technology costs.

Engine-out particulate matters emissions are also much higher than on spark-ignited engines due to direct in-cylinder fuel injection. The timing of fuel combustion is controlled when fuel is injected and the fuel ignites almost immediately after injection. This allows little time for the fuel to vaporize and mix with air, creating flame plumes. During this combustion process, carbonaceous particulates grow by aggregating with other organic and inorganic particles. Thus, particulate matter (both mass and number) is also much more challenging to control in a diesel engine, Francisco Posada (2012).

Diesels are workhorse engines. That is why diesel is used powering heavy duty trucks, buses, tractors, and trains, not to mention large ships, bulldozers, cranes, and other construction equipment.In the past, diesels fit the stereotype of muscle-bound behemoths. They were dirty and sluggish, smelly and loud. That image does not apply to today’s diesel engines. However and tomorrow’s diesels will show even greater improvements. They will be even more fuel efficient, more flexible in the fuels they can use, and also much cleaner in emissions.

2.2.1 History

German engineer Rudolph Diesel patented the diesel engine in 1892. He first considered powdered coal as a possible fuel, but it proved difficult to inject into the cylinder and caused an explosion that destroyed the prototype engine. He later experimented with vegetable oils and successfully used peanut oil. Ultimately, Diesel settled on a stable byproduct of the petroleum refinement process that would come to be known as "diesel fuel."

In this engine, air was drawn into the cylinder and was compressed to 35-40 bar. Towards the end of the compression stroke, an air blast was introduced into the combustion space at a much higher pressure, about 68-70 bar, thus causing turbulence in the combustion chamber. A three-stage compressor driven by the engine (and consuming about 15% of the engine's gross power) supplied compressed air which was stored in a reservoir. This compressed air served both for starting the engine and for air-injection into the compressed air already in the cylinder - that is, for blasting air to atomize the oil fuel by forcing it through perforated discs fitted around a fluted needlevalve injector. The resulting finely divided oil mist ignites at once when it contacts the hot compressed cylinder air, and the burning rate then tends to match the increasing cylinder volume as the piston moves outwards-expansion will therefore take place at something approaching constant pressure.

2.2.2 Fundamental of Diesel Engine

A diesel is aninternal combustion engine thatconverts chemical energy in fuel to mechanical energy that moves pistons up and down inside enclosed spaces called cylinders. The pistons are connected to the engine's crankshaft, which changes their linear motion into the rotary motion needed to propel the vehicle's wheels. To convert the chemical energy of the fuel into useful mechanical energy all internal combustion engines must go through four events: intake, compression, power, and exhaust. How these events are timed and how they occur differentiates the various types of engines. All diesel engines fall into one of two categories, two-stroke or four-stroke cycle engines. The word cycle refers to any operation or series of events that repeats itself, R. Diesel (1895).

2.2.2.1 Four-Stroke Diesel Engine Cycle

In a four-stroke engine the camshaft is geared so that it rotates at half the speed of the crankshaft (1:2). This means that the crankshaft must make two complete revolutions before the camshaft will complete one revolution. The following section will describe a four-stroke, normally aspirated, diesel engine having both intake and exhaust valves with a 3.5-inch bore and 4-inch stroke with a 16:1 compression ratio, as it passes through one complete cycle.

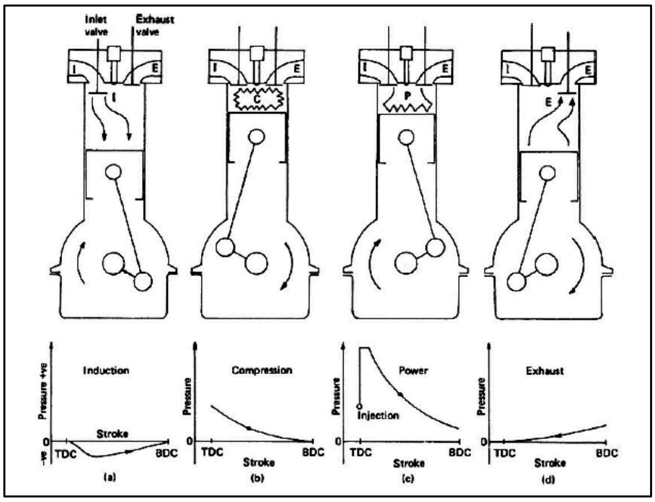

Figure 2.1: Four-Stroke Diesel Engine Cycle

Source: Gilbert (DOE)

<u>Intake / Induction</u>

As the piston moves upward and approaches before top dead center (BTDC), the camshaft lobe starts to lift the cam follower. This causes the pushrod to move upward and pivots the rocker arm on the rocker arm shaft. As the valve lash is taken up, the rocker arm pushes the intake valve downward and the valve starts to open. The intake stroke now starts while the exhaust valve is still open. The flows of the exhaust gasses will have created a lowpressure condition within the cylinder and will help pull in the fresh air charge.The piston continues its upward travel through top dead center (TDC) while fresh air enters and exhaust gasses leave. At about after top dead center (ATDC), the camshaft exhaust lobe rotates so that the exhaust valve will start to close. The valve is fully closed at ATDC. This is accomplished through the valve spring, which wascompressed when the valve was opened, forcing the rocker arm and cam follower back against the cam lobe as it rotates. The time frame during which both the intake and exhaust valves are open is called valve overlap and is necessary to allow the fresh air to help scavenge (remove) the spent exhaust gasses and cool the cylinder. In most engines, 30 to 50 times cylindervolume is scavenged through the cylinder during overlap. This excess cool air also provides the necessary cooling effect on the engine parts. As the piston passes TDC and begins to travel down the cylinder bore, the movement of the piston creates suction and continues to draw fresh air into the cylinder.

Compression

With both the inlet and the exhaust valves closed, the piston moves towards the cylinder head. The air enclosed in the cylinder will be compressed into a much smaller space of anything from 1/12 to 1/24 of its original volume. A typical ratio of maximum to minimum air-charge volume in the cylinder would be 16:1, but this largely depends on engine size and designed speed range.During the compression stroke, the air charge initially at atmospheric pressure and temperature is reduced in volume until the cylinder pressure is raised to between 30 and 50 bar. This compression of the air generates heat which will increase the charge temperature to at least 600°C under normal running conditions.

Power

Both valves are closed, and the fresh air charge has been compressed. The fuel has been injected and is starting to burn. After the piston passes TDC, heat is rapidly released by the ignition of the fuel,causing a rise in cylinder pressure. Combustiontemperatures are around 2336°F. This rise in pressure forces the piston downward and increases the force on the crankshaft for the power stroke.

Exhaust

When the burning of the charge is near completion and the piston has reached the outermost position, the exhaust valve is opened. The piston then reverses its direction of motion and moves towards the cylinder head. The sudden opening of the exhaust valve towards the end of the power stroke will release the still burning products of combustion to the atmosphere. The pressure energy of the gases at this point will accelerate their

expulsion from the cylinder, and only towards the end of the piston's return stroke will the piston actually catch up with the tail-end of the outgoing gases.

2.2.2.2 Two-Stroke Diesel Engine Cycle

The pump scavenge two stroke diesel engine designed by Sir Dugald Clerk in 1879 was the first successful two-stroke engine; thus the two-stroke-cycle engine is sometimes called the Clerk engine.

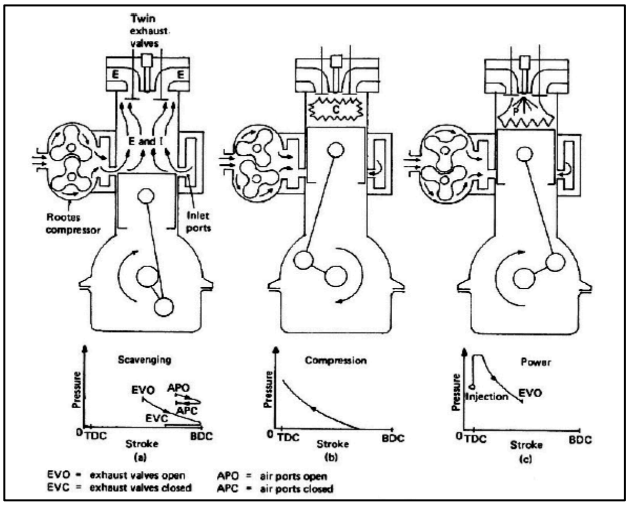

Figure 2.2: Two-Stroke Diesel Engine Cycle

Source: Gilbert (DOE

<u>Exhaust and Intake</u>

At 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; the rocker arm forces the exhaust valve off its seat. The exhaust gasses start to escape into the exhaust manifold, as shown in **Figure2.2**. Cylinder pressure starts to decrease. After the piston travels three-quarters of its (down) stroke 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.At ABDC, the camshaft starts to close the exhaust valve. The camshaft has rotated sufficiently to allow the spring pressure to close the exhaust valve. Also, as the piston travels past ABDC (after the exhaust valve starts closing), the intake ports are closed off by the piston.

Compression

Towards the end of the power stroke, the inlet ports will be uncovered. The piston then reaches its outermost position and reverses its direction of motion. The piston now moves upwards so that the piston seals and closes the inlet air ports, and just a little later the exhaust valves close. Any further upward movement will now compress the trapped air. Power phase as shown in **Figure 2.2**(c) shortly before the piston reaches the innermost position to the cylinder head on its upward compression stroke; highly pressurized liquid fuel is sprayed into the dense intensely heated air charge. Within a very short period of time, the injected fuel droplets will vaporize and ignite, and rapid burning will be established by the time the piston is at the top of its stroke. The heat liberated from the charge will be converted mainly into gas-pressure energy which will expand the gas and so do useful work in driving the piston outwards.

2.3 CHARACTERISTIC OF DIESEL FUEL

The components of diesel fuels are straight run fractions containing paraffinic and naphthenic hydrocarbons, naphtha and cracked gas oils. The atmospheric gas oils tend to have good ignition quality (cetane number) but many contain some high melting point hydrocarbons (waxes) that can result in high cloud and high pour points. These fractions are blended to produce different seasonal grades of diesel fuels required to meet a wide range of diesel engine uses.

Cetane number is a measure of the ignition delay of a diesel fuel. The shorter the interval between the time the fuel is injected and the time it begins to burn, the higher is its cetane number. It is a measure of the ease with which the fuel can be ignited and is most significant in low temperature starting, warm up, idling and smooth, even combustion. Cetane number requirements depend on engine design and size, nature of speed and load variations, and starting and atmosphere conditions.Some hydrocarbons ignite more readily than others and are desirable because of this short ignition delay. The preferred hydrocarbons in order of their decreasing cetane number are normal paraffins, olefins, naphthenes, iso-paraffins and aromatics.Cetane number is measured in a single cylinder test engine with a variable compression ratio.

Low-Temperature Flow: Unlike gasoline, which have freezing points well below even the most severe winter ambient, diesel fuels have pour points and cloud points well within the range of temperatures at which they might be used. This can be of particularconcern when using fuel delivered during the summer season. Seasonal blending to control cloud point (the temperature at which a cloud or haze of wax crystals first appears and separates from the fuel) is the refiner's assurance against field problems. In the winter, there is also an increasing tendency to use flow improvers, as well as polymeric additives that modify the wax structure as it builds up during cooling. These additives keep wax crystals small, so they can pass through the fine pores of fuel filters, enroute to the injector pump.

Viscosity influences the spray pattern when the fuel is injected into the cylinder. Low-speedmarine engines can use higher-viscosity fuels than high-speed road-transport and generator engines, and still run without excessive smoking. Minimum viscosity limits are imposed to prevent the fuel from causing wear in the fuel injection pump.

Volatility of a diesel fuel has little influence on its engine performance, except as it affects exhaust smoking tendencies. The distillation range of a diesel fuel does not allow much flexibility in this regard, because of the interdependence with other specification factors. Because diesel fuels are classified as nonflammable for freight purposes, minimum flash point restrictions are imposed.

Fuel lubricity also influences the characteristics of diesel fuel. Some processes used to desulphurize diesel fuel, if severe enough, can also reduce the natural lubricating qualities of the diesel fuel. Since engines require the diesel fuel to act as a lubricant for their injection systems, diesel fuel must have sufficient lubricity to give adequate protection against excessive injection system wear.

Sulfur content is the first diesel fuel property to be widely controlled by legislation, aimed at limiting exhaust emissions. Sulfur is present in all crude oils and as well as all refined products.During combustion, however, sulfur compounds burn to form acidic byproducts, $S0_2$ and S0, which form sulfates in the exhaust gas stream.

Sulfates are part of a diesel engine’s particulate emissions. Therefore, controlling fuelsulfur level reduces the level of sulfate pollutants. Depending on the crude source, sulfur compounds can also create corrosive sulfur oxides on combustion. These can cause high rates of engine wear and a rapid depletion of engine oil additives. Engine manufacturers often relate oil change intervals to the fuel sulfur content.

Table 2.1: Diesel and waste plastic fuel specification for selected requirement
Source: Fazil Mat Isa, PETRONAS SdnBhd (1999)

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Properties	Waste plastic fuel	Diesel
Density (g/cm^3)	0.7710	0.8416
Cetane number	64.4	68.2
Kinematic Viscosity (cP)	1.2	2.22
Flash point (^{0}C)	72	84
Gross clarify Value (MJ/kg)	34.7247	42.4915
Boiling Point (^{0}C)	186	193
Sulphur Content (%)	0.019	0.042

2.4 WASTE PLASTIC DISPOSAL FUEL

Panda, et.al described that production of liquid fuelfrom plastic waste would be a better alternative as the calorific value of the plastics is comparable to that of fuels, around 40MJ/kg. This option also reduces waste and conserves natural resources. It was also mentioned that mechanical recycling of plastic wastes is widely adopted method by different countries and the catalytic pyrolysis of plastic to fuel is gradually gaining momentum and being adopted in different countries recently due to its efficiency over other process in all respects.

Walendziewskicarried out two series of waste plastic cracking. The first series of polymer cracking experiments was carried out in a glass reactor at atmospheric pressure and in a temperature range 350-420°C, the second one in autoclaves under hydrogen pressure (~3-5MPa) in temperature range 380-440°C. They also concluded that the application of catalyst results in lowering of polymers cracking temperature, density of obtained liquid and increased the gas fuel yield.

Channdrasekar Murugesan, et.al described the hydrocracking of polymer waste typicallyinvolves reaction with hydrogen over a catalyst in a stirred batchautoclave at moderate temperatures and pressures. The work reported mainlyfocuses on obtaining a high quality gasoline starting from a wide range of feeds. Typicalfeeds include polyethylene, polyethylene terephthalate, polystyrene, polyvinyl chloride and mixed polymers, polymerwaste from municipal solid waste and other sources, co-mixing of polymers with coal, co-mixing of polymers with different refineryoils such as vacuum gas–oil and scrap tires alone or co-processedwith coal. To aid mixing and reaction, solvents such as 1-methylnaphthalene, tetralin and decalin have been used with somesuccess. Several catalysts, classically used in refinery hydrocracking reactions, have been evaluated and include transition metals such as Ferus (Fe) supported on acid solids (such as alumina, amorphous silica–alumina, zeolites and sulphatedzirconia). Thesecatalysts incorporate both cracking and hydrogenation activitiesand although gasoline product range streams have been obtained,little information on effect of metal and catalyst, surface areas, ratio or sensitivity to deactivation is quoted. **Table 2.2** shows the comparison between waste plastic fuels with the other conventional fuel in content of Calorific Value.