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EMISSIONS AND FUEL CONSUMPTION OF SINGLE CYLINDER DIESEL ENGINE USING PLASTIC FUEL

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Graphical abstract

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Abstract

This paper deals with the exhaust emission of plastic fuel on single cylinder diesel engine. The objectives of this research are to analyze the fuel consumption and the emission characteristic of a single cylinder diesel engine that are using plastic fuel compared to usage of ordinary diesel that are available in the market. This paper describes the setups and the procedures for the experiment which is to analyze the emissions characteristics and fuel consumption of 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. 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). The successful of the project have been stated which is engine is able to run with plastic fuel but the engine needs to run by using diesel fuel first, then followed by plastic fuel and finished with diesel fuel as the last fuel usage before the engine turned off.

Keywords: plastic fuel, diesel engine, emissions, fuel consumption

Abstrak

Penelitian ini berfokus pada pengujian bahan bakar plastic pada mesin diesel satu silinder. Tujuan dari penelitian adalah mengetahui konsumsi bahan bakar dan emsisi gas buang mesin diesel dengan menggunakan bahan bakar plastic dibandingkan dengan penggunaan bahan bakar solar. Pelaksnaan uji mesin dilakukan dengan tidak menggunakan pembebanan pada mesin. Hasil penelitian menunjukkan bahwa bahan bakar plastic dapat digunakan pada mesin diesel dengan hasil emisi yang sedikit lebih rendah dibandingkan dengan bahan bakar diesel.

Keywords : bahan bakar plastic, mesin diesel, emisi, konsumsi bahan bakar

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1.0 INTRODUCTION

Now days, the amount of waste generated continues to increase in response to rapid increase in population, accelerated urbanization and industrialization process. Waste plastic is an-organic waste and need around 50-80 million years for the decompose in the soil. The data from the Plastics Industrial Association (INAPLAS) and Bureau Statistics (BPS) shows that from the 64 M Ton /Year waste in Indonesia around 3.2 M Ton is plastics waste dumped into the sea.

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

Plastics are durable and takes a long time degrade because of the molecular bonds in the plastic are so strong and it is resisted 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.

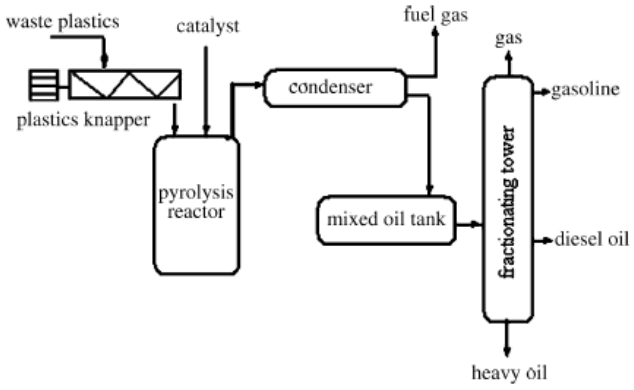

Figure 1. Process of Pyrolisis to produce plastic fuel [9]

One of the solutions 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.

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. 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

Table 1. Properties of fuel

Property	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

2.0 METHODOLOGY

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 losing energy and become heavier, and the particle will drop to the bottom of the beaker that act as a trap.

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

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 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 has been made at the engine's flywheel to enable the RPM sensor to detect the engine speed.

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.

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.

Figure 2. Setup of Experimental

3.0 RESULTS AND DISCUSSION

This part 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 single piston diesel engine.

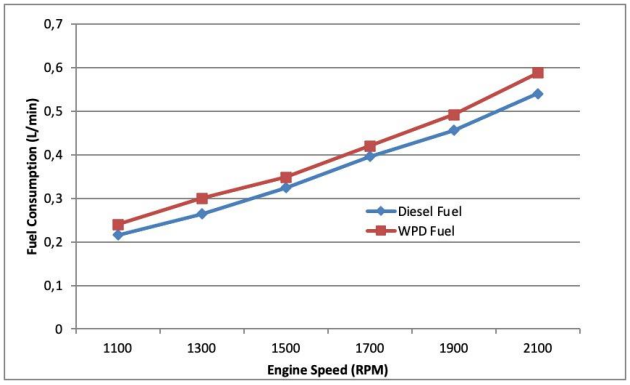

Figure 3. Fuel Consumption vs Engine Speed

Figure 3 clearly shows that the fuel consumption for waste plastic fuel usage is lower than diesel fuel. 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.

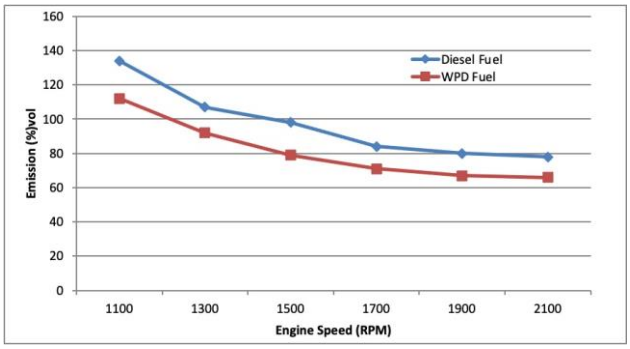

Figure 4. Emissions of NO_x vs Engine Speed

Figure 4 shows the graph of oxides of nitrogen (NO_x) emission versus engine speed. 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 19.26%. 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.

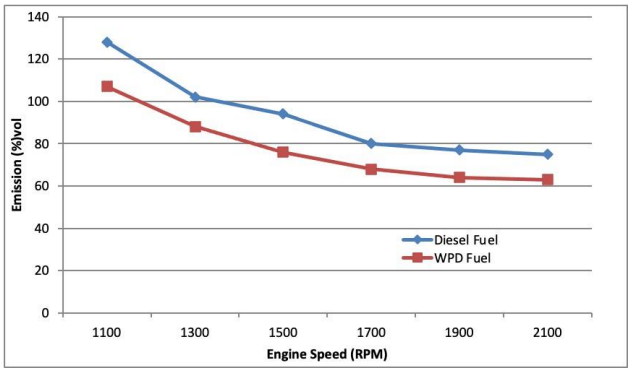

Figure 5. Emissions of NO vs Engine Speed

Figure 5 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%. 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.

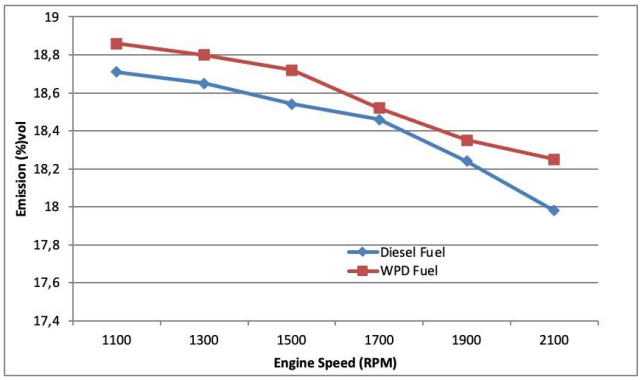

Figure 6. Emissions of O_2 vs Engine Speed

Figure 6 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. 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.

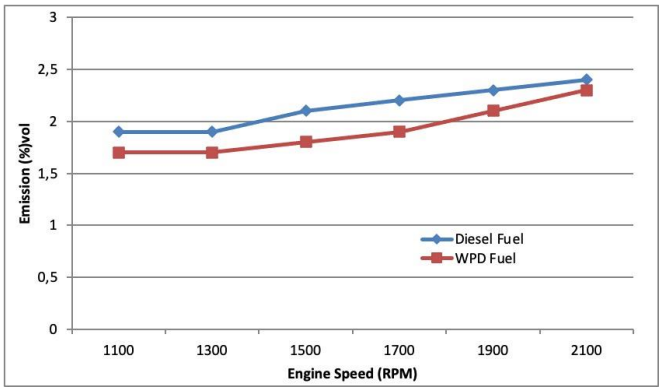

Figure 7. Emissions of CO_2 vs Engine Speed

Figure 7 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 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.

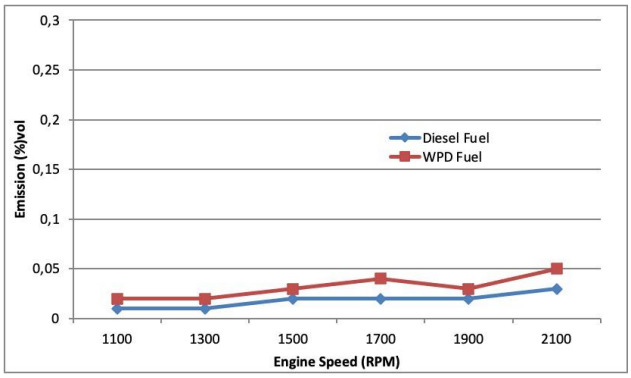

Figure 8. Emissions of CO vs Engine Speed

Figure 8 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 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.

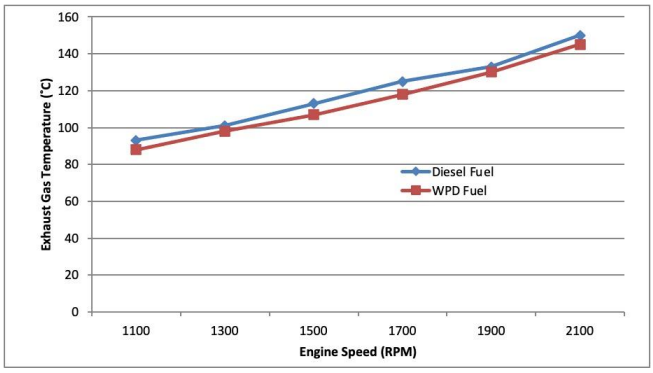

Figure 9. Exhaust Gas Temperature vs Engine Speed

From Figure 9, 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%. Number of combustions 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.

4.0 CONCLUSION

There are several conclusions that can be drawn which is engine is able to run with plastic disposal 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 plastic 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.

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