1st International Conference on Engineering and Technology Development *ISSN 2301-6590*
(ICETD 2012)
Universitas Bandar Lampung
Faculty od Engineering and Faculty of Computer Science

Diesel Particulate Matter Distribution of DI Diesel Engine Using Tire Disposal Fuel

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Abstract— **Investigation on size distribution of Diesel Particulate Matter (DPM) of DI diesel engine running on tire disposal fuel was observed. The experimental project is comparison of size distribution of DPM between using tire disposal fuel and base diesel fuel. The engine experiment was conducted with YANMAR TF120M single cylinder four stroke diesel engine set-up at variable engine speed at 2400, 2100, 1800, 1500 and 1200 rpm. The data have been taken at each point of engine speed during the stabilized engine-operating regime. Measurement of size distribution of PM at different engine speed conditions have generally indicated bigger for tire disposal fuel compares to base diesel fuel.**

Keywords: **tire disposal fuel, Particulate Matter (PM), size distribution, diesel engine**

I. INTRODUCTION

Fossil fuels which include oil, coal and natural gas are non-renewable source of energy. Once the amount of fossil fuels in the Earth is used up, these fuels cannot be replaced. The depletion of the world resource, particularly the depletion of fossil fuels becomes the main focus among public and politician after global warming issue. Since the world energy resources have peaked in production and are exceeded by demand, it could cause skyrocketing oil prices and stampede the world into new recession. Historically, global economic growth has never occurred without a simultaneous increase in the use of fossil fuel energy. Without cheap oil, there is no cheap food, water, health care, travel, housing or recreation. (Leng, R.A., 2010). Because of that, there are many alternative fuels that have been developed today in order to replace these natural resources. One of the alternatives is by producing fuel from scrap tires called tire derived fuel or tire fuel.

The smoky black exhaust that is emitted by diesel engines has seen whether on highway or underground. Diesel engines are in common use in heavy duty trucks and buses because of their attractive performance characteristics and low operating cost. The incomplete combustion of diesel fuel results in the formation of solid and liquid particles in the exhaust called diesel particulate matter (DPM) that has been growing concern for over ten years. DPM contains elemental carbon, organic carbon, ash (metallic compounds and trace elements), sulphate, nitrates, adsorbed organic compounds and air toxins, and unidentified compounds. Other components of DPM are sulphuric acid and hydrocarbon or sulphate particles. (Sharp, J., 2003). However, particles in diesel engine exhaust must be concern due to their very small diameter and the mixture of the chemical contain in the particles are hazardous and can give bad effect to health such as lung cancer.

There is limited information about diesel particulate matter (DPM) that related to tire fuel. In this study, the diameter, concentration and size distribution of DPM of single cylinder diesel engine running on tire fuel were analyzed. The data analyses are compared with base diesel fuel.

II. EXPERIMENTAL METHOD

A direct-injection diesel engine (model TF120 YANMAR) with one cylinder was employed to the test. The engine specification is shown in Table 1. A schematic layout of the experimental setup is depicted in Fig. 1. The gross calorific value of waste plastic fuel is highest than diesel and tire plastic fuel as shown in table 2. The engine experimentally works on four-stroke cycle and was operated at 2400, 2100, 1800, 1500 and 1200 rpm with constant engine load. A hydraulic dynamometer was used to provide the constant engine load. The test was firstly started with diesel fuel, and when the engine reaches operating temperature, it was loaded with hydraulic dynamometer. The engine was tested at full load and various engine speeds. DPM was collected by a vacuum pump from downstream of the exhaust valve. Fig. 1 show the diagram of experimental engine setup. A composite filter was used to measure the DPM and analysis using SEM. At the end of the test, the engine was run with diesel fuel to flush out the tire disposal fuel from the fuel line and injection system.

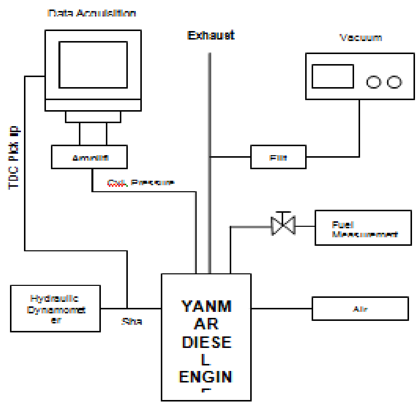


Fig. 1. Experimental Setup

 ISSN 2301-6590

TABLE 1.
EXPERIMENTAL ENGINE SPECIFICATION

	Specification
Engine Type	YANMAR TF120
Number of Cylinder	1
Bore x stroke (mm)	92 x 96
Displacement (L)	0.638
Continuous Output (HP)	10.5 HP at 2400 rpm
Rated output (HP)	12 HP at 2400 rpm
Cooling system	Hopper
Dry weight (kg)	102

TABLE 2.
FUEL CHARACTERISTIC

	Diesel Oil	Tire Disposal Fuel
Density @15^{0}C, kg/L	0.87	0.871
Viscosity @40^{0}C, cst	2.0	1.7
Flash Point , ^{0}C	91.0	42
Sulphur , wt%	0.3	2.6
Carbon Residue , wt%	<0.1	0.02
Cetane Index	55	---
Ash content, wt%	0.002	---
Gross Calorific Value (MJ/kg)	46.5	45.7

Table 2 show the comparison of fuel characteristics between diesel fuel and tire fuel. Based on result above, the diesel fuel has a better quality compare to the tire fuel. The diesel fuel has lower sulphur content and higher gross calorific value than tire fuel. Low sulphur content will produce low Soluble Organic Fraction (SOF) concentration of particulate matter. Meanwhile, higher gross calorific value contributes To less fuel consumption. For the cetane number, tire fuel does not have any value. This is because the cetane number of tire fuel is out of range which may have highest or lowest cetane number until it cannot produce any value.

III. RESULT AND DISCUSSION

Fig. 2 show the comparison of PM concentration for the tested fuel. Based on the graph, the PM concentration of the tire fuel is higher than the diesel fuel. At the minimum speed which is 1200 RPM, the value of PM concentration for diesel fuel is 0.14 g/m^3 meanwhile the tire fuel produced 0.335 g/m^3 of PM. At 2400 RPM which is the maximum speed, the PM concentration for the diesel fuel is 0.265 g/m^3 and for the tire fuel are 2.57 g/m^3. The average of PM concentration of tire fuel is higher than diesel fuel by 83.04 %. When the engine speed increase, the PM concentrations for both fuel also increase. The PM concentration of tire fuel is higher than diesel fuel because the tire fuels has not completely burned during the combustion and produces a lot of carbon. The carbon that not completely burned will flow through the exhaust valve and will be trapped to the filter. Moreover, tire fuel forms a lot of carbon black due to combustion during pyrolysis process.

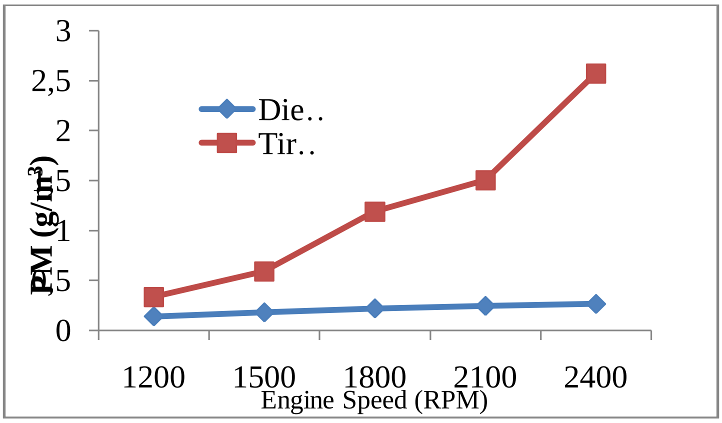


Fig. 2. Dpm Concentration

Fig. 3 show the comparison between tire fuel and diesel fuel for SOF concentration. The value of SOF concentration of tire fuel is higher than diesel fuel. At the minimum of engine speed which is 1200 RPM, the value of SOF concentration for diesel fuel is 0.11 g/m^3 and for the diesel fuel is 0.265 g/m^3. At the maximum engine speed which is 2400 RPM, the diesel fuel produced 0.21 g/m^3 of SOF concentration meanwhile the tire fuel produced 2.38 g/m^3 SOF concentration. The average of SOF concentration due to usage of tire fuel is higher than the diesel fuel by 84.71 %. The graph shows increasing value of SOF concentration for both fuels with increasing of speed. The SOF concentration for the tire fuel is high because the sulphur content of the tire fuel is 0.811 % higher than the diesel fuel which is 0.042 %. The higher the sulphur content, the higher the SOF concentration.

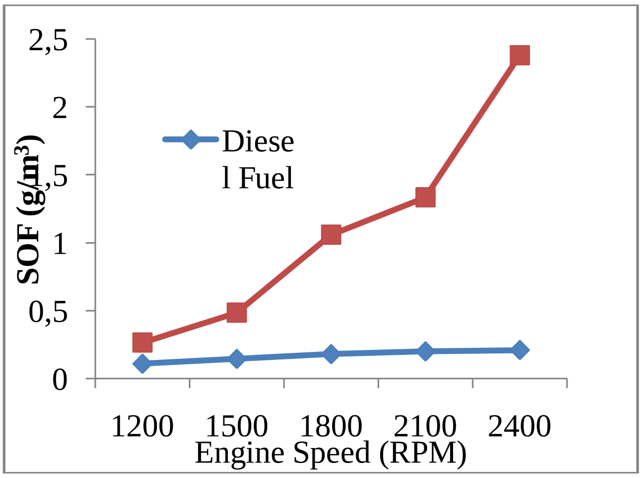


Fig. 3. Sof Concentration

Fig. 4 shows the comparison of DS concentrations for the tested fuel. The value of DS concentration due to usage of tire fuel is higher than diesel fuel. At the minimum engine speed which is 1200 RPM, the value of DS concentrations for the diesel fuel is 0.03 g/m^3 and for the tire fuel is 0.07 g/m^3. At 2400 RPM which is the maximum engine speed, the diesel fuel has been produced 0.055 g/m^3 of DS concentrations whereas the tire fuel had produced 0.19 g/m^3 of DS concentrations. The average of DS concentrations for diesel fuel is lower than tire fuel by 69.17 %. The trend of the graph shows that the DS concentrations increase with increasing of engine speed. Dry soot is the solid particles that have been trapped on the filter. The DS concentration of the tire fuel is higher than diesel fuel because the carbon content in the tire fuel is high. The increasing of the engine speed has been contributed to the formation of the dry soot rapidly.

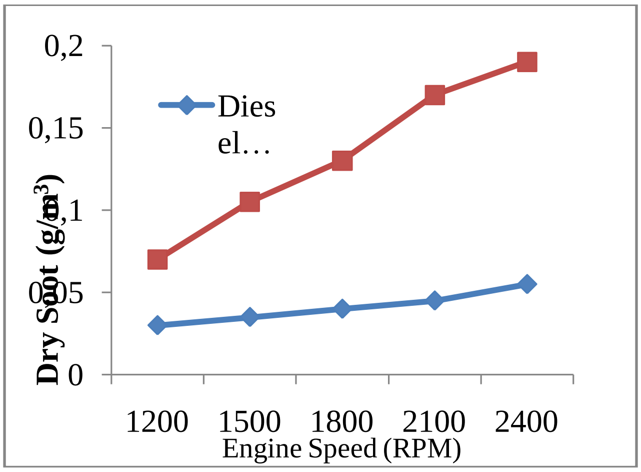


Fig. 4. Ds Concentration

Fig. 5 show the bar chart of size distribution of DPM diameter for the diesel fuel and the tire fuel at 1200 RPM. For diameter range 50 to 100 nm, the size distributions for the tire fuel is 46.7 % higher than diesel fuel which is 13.3 % only. The both fuel consists most of diameter range 101 to 150 nm and approximately have the same amount of size distributions which is 40 % for diesel fuel and 46.7 % for the tire fuel. For the diameter range more than 150 nm, the diesel fuel is higher than the tire fuel which is 46.7 %. Meanwhile, the tire fuel only have 6.7 % of size distribution of DPM diameter. From the bar chart, the tire fuel have consisted more small particle which below 100 nm compared to the diesel fuel that consisted more large particle which above 150 nm.

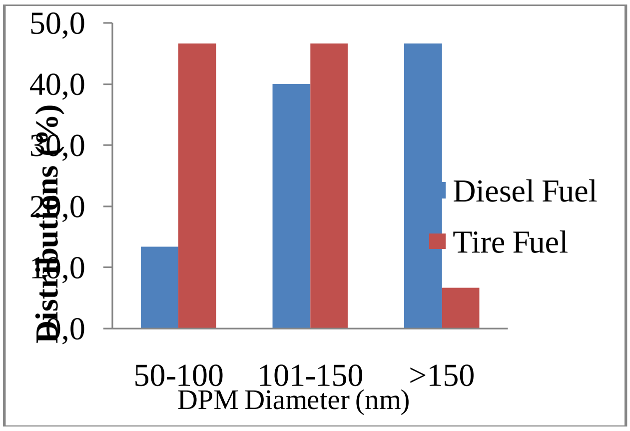


Fig. 5. Comparison of Size Distribution Dpm At 1200 Rpm

Fig. 6 show the bar chart of percentage distribution versus DPM diameter at 2400 RPM of engine speed. For the diameter range below than 100 nm and 101 to 150 nm, the tire fuel has higher percentage distribution compared to the diesel fuel. At range below than 100 nm, the percentage of distribution for tire fuel is 30 % and the diesel fuel is 13.3 % whereas for the range 101 to 150 nm the tire fuel recorded 56.7 % and the diesel fuel recorded 40 % of percentage distribution. For the diameter range more than 150 nm, the diesel fuel has the higher percentage than the tire fuel by 33.4 % difference. Based on the trends of bar chart for all speed have shown that the tire fuel produced many small particle which is the diameter below than 100 nm that very harmful to human health. This small particle can easily penetrate into human blood cells and also human lung that contribute to the lung cancer.

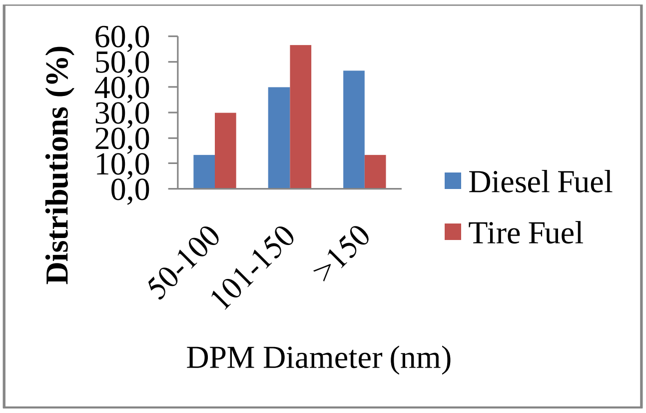
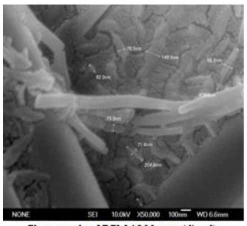
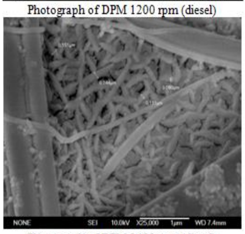
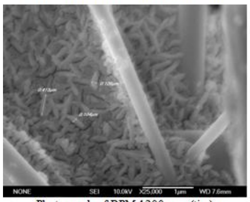


Fig. 6. Comparison Of Size Distribution Dpm At 2400 Rpm


Photograph of DPM 1200 rpm (diesel)


Photograph of DPM 2400 rpm (diesel)


Photograph of DPM 1200 rpm (tire)

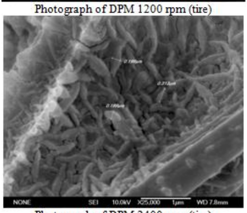

Photograph of DPM 2400 rpm (tire)

Fig. 7. Photographs Of Dpm By Sem

IV. CONCLUSIONS

The main objective of this project is to analyze the DPM concentrations, size distribution and size diameter of diesel particulate matter (DPM) of a single cylinder diesel engine by using tire fuel compared to diesel fuel. From the experiment, the average the DPM concentration of tire fuel is higher than diesel fuel by 83.04%. For SOF concentration, the average amount due to usage of tire fuel is also higher than the diesel fuel by 84.71%. Moreover, for DS concentration the tire fuel is higher than diesel fuel by 69.17%.

Based on analysis of size distribution, the tire fuel have produced many small particle which is range below 100 nm compared to the diesel engine that produced many large particle which more than 150 nm. As a result, the particle that produced when the engine run using the tire fuel is more harmful to the human health since the small particle is easy to penetrate into blood cells and lung.

In general condition, the engine running smoothly when the tire fuel was used in range of speed. Furthermore, the particulate matters that have been trapped at the filter become browner with increasing of the engine speed. The exhaust smoke causes irritation to the eyes as well as breathing difficulty.

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