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Emission of Diesel Engine Running on Emulsion Fuel Made from Low Grade Diesel Fuel

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Abstract – *As to achieve sustainable greening transportation, researchers has agreed that emulsion fuel could be an alternative fuel for diesel engine as it is useful for heavy transportation. Emulsion fuel is well-known in reducing the exhaust emission that had been produced by vehicles. This research has been conducted in order to investigate the exhaust emission in diesel engine such as, Nitrogen Oxides (NO_x), Carbon Dioxide (CO_2), Carbon Monoxide (CO) and Particulate Matter. There are two types of emulsion fuel tested as it differs in water percentage. E10 is an indicator for emulsion fuel with 10% of water and another one is E20 with 20% of water. To assure the stability of emulsion fuel, 1% of surfactant had been added. Test engine results shows that NO_x and PM for emulsion fuels reduced by 60% and 14.11% respectively compared to D2. Meanwhile, CO_2 and CO for emulsion fuels are increased compared to D2 by about 27.76% and 102.20% respectively.*

Keywords: Emulsion fuel, Exhaust emission, Nitrogen Oxides, Carbon Dioxide, Particulate Matter

1.0 INTRODUCTION

An engine or so called motor is a mechanical machine that can convert a form of energy to mechanical energy. Thus, the mechanical energy will burn the fuel to generate heat, which then produces power. Diesel engine is one of the types of engine. It is also known as compression ignition engine. Usually, heavy vehicle or transportation will use this kind of engine due to high power output and diesel is one of the economical fuels. However, a diesel engine causes more hazardous emissions especially Nitrogen Oxides (NO_x) and Particulate Matter (PM) which contributing to global warming on earth.

Greenhouse gasses in our atmosphere have been increasing day by day. Over 90% of the causes of the climate change come from human activities [1] of which the biggest cause of this catastrophe is contributed from atmospheric emission, especially gasses and aerosols that are being stored in the atmosphere.

The largest growth in this emission has come from industry and transportation [2] which is not only harmful to the environment but are also hazardous to human's health like Nitrogen Oxides (NOx) and Particulate Matter (PM) gas emissions. The effects of these hazardous emissions include a serious damage to the health like lung cancer, asthma, cardiovascular issues and other fatal illness that would cause to death.

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Due to the strict emission regulations that have been implemented, many devices are being invented in order to reduce the formation of these exhaust emissions but it is difficult to simultaneously reduce both Nitrogen Oxides (NO_x) and Particulate Matter (PM) and at the same time, maintain or improve the performance of the engine.

However, one method has been successfully introduced to reduce the formation of NO_x and PM emissions simultaneously and it is known as water into diesel engine or the other name is emulsion fuel.

Emulsion of diesel and water is one of numerous conceivable methodologies to diminish diesel motor contamination. Researchers discovered that the material science and synthetic energy of ignition are some of the vicinity of water vapour in reactants impacts. Water vapour has additionally gainful impacts on the rate of hotness discharge and contamination outflows.

Amid ignition, water that had been vaporized might decreases the temperature and the substance structure of the reactants bringing about higher concentration of hydrogen oxide (OH) also changes. Thus, the nitrogen oxides (NOx) development rate and ash oxidation would be controlled. Also, the rich zones in the burning chamber could be weakens [3].

Emulsion can be defined as two or more immiscible liquids which cannot be blended naturally. One is present as a dispersed droplet throughout the other liquid, which is present in a continuous phase. The dispersed droplet is called the internal phase, and the other liquid is the external phase [4].

One of the reasons on why emulsion fuel can be said could affect the exhaust emissions of the vehicle is micro-explosion phenomenon. Ivanov and Nevedov [5] are the first persons that explored about the micro-explosion process in 1965. They discovered that during combustion process, the dispersed droplets in an emulsion fuel will undergo an explosion spontaneously. In the improvement of greener exhaust emission and combustion efficiency, micro-explosion became one of the huge impacts.

Micro-explosion has various meaning, but in the end all of the meaning has been referred as the same meaning. The general meaning of micro-explosion is the initial spray secondary atomization's which resulting from the water evaporation process that rapidly occurs in oil droplets. Micro-explosion is the research that widely explored and it has become favourable research among the researcher and expertise.

In combustion chamber has a high environment temperature. The heat will spread to the emulsion droplet surface as the emulsion is sprayed into the combustion chamber. Water will be the inner phase in the emulsion fuel because the content is lower than the diesel.

Because of the different in boiling temperature and volatility between water and diesel, water will be covered and kept inside the diesel droplets. Water droplet will explode first as the water temperature had reached to the maximum temperature. Thus, it will cause the diesel droplets be tearing up into a very fine particle [6].

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2.0 METHODOLOGY

2.1 Fuel preparation and Engine specification

The methodology started by make an emulsion fuel for E10 and E20. The percentage for each solution to make emulsion fuel is measured by the volume. D2 was selected as a diesel fuel, tap water as water and SPAN 80 as a surfactant. The emulsion fuel for E10 is by 10% water, 89% diesel, 1% surfactant and E20 is by 20% water, 79% diesel, 1% surfactant. The mechanical mixer is used to mix the water and diesel at rotation 3000 rpm for 5 minutes. SPAN 80 is a type of the nonionic surfactant and commonly use in the food industry and the HLB number is 4.3 which are suitable to produce water-in-diesel type emulsion. After mixed, the emulsion fuels were become milkfish colour as shown in Figure 1.

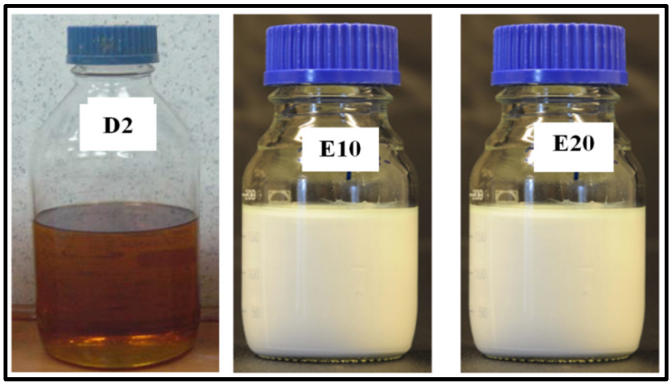

Figure 1: Fuels sample that were used in the experiment

The type of engine used is a DI diesel engine. It is a four stroke engine and is fixed to an alternator as generator. The engine utilizes air as the cooling system and the cooling system by the fan is needed when the test is done. The specifications of the engine are listed down in the Table 1. The combustion system of the engine is a toroidal combustion crown and the intake port type is helical. It is equipped with a high pressure pump. The fuel injector has four 0.2 mm diameter holes with an opening pressure of 220 bars.

Table 1: Specifications of Mr Mark SU186FAG diesel engine

Engine Type	DI
Number of cylinder	Single Cylinder
Aspiration	Naturally Aspiration
Bore	86mm
Stroke	72mm
Compression Ratio	18.7
Displacement	400cc

2.2 Engine testing

The diesel engine was directly coupled to an alternator equipped with a load controller. The alternator is a device which allows the engine to give a load by resisting the rotation of the engine crankshaft. The alternator outputs an electrical load in single phases at 240 volts and 50

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Hz utilizing a permanent magnet with carbon brush rotating field. The frequency of the alternator was kept constant by the constant 3000 rpm of the engine.

To determine the revolution speed of the engine, a handheld tachometer is used. The unit of measurement is rpm. The wide measuring range from 5 to 100 000 rpm with a resolution is 1rpm.

The load to the engine is controlled by voltage regulator for 5kW of load bank with the Philip QVF 137 Halolite lamp as a load. The maximum voltage for voltage regulator is 240V and the lamp is 230V. Load will be varied to 1kW, 2kW, 3kW and 4kW.

2.3 Emission testing

Engine emissions test will be run to record the exhaust emission for Nitrogen Oxides (NO_x), Carbon Dioxide (CO_2), Carbon Monoxide (CO) and Particulate Matter (PM). In this test, 3 set 5kW generator diesel engine will be used for each type of fuel. All the engine testing parameters were recorded based on the constant engine speed mode. The engine operating conditions have been selected based on the 3000 rpm, where engine loads were varied for 1kW, 2kW, 3kW and 4kW in order to represent the actual application of the generator set. The schematic diagram of the engine emissions test setup is on the Figure 2. By comparing the emissions made by emulsion fuel and diesel only the conclusion can be made to prove that emulsion fuel could lower the exhaust emission.

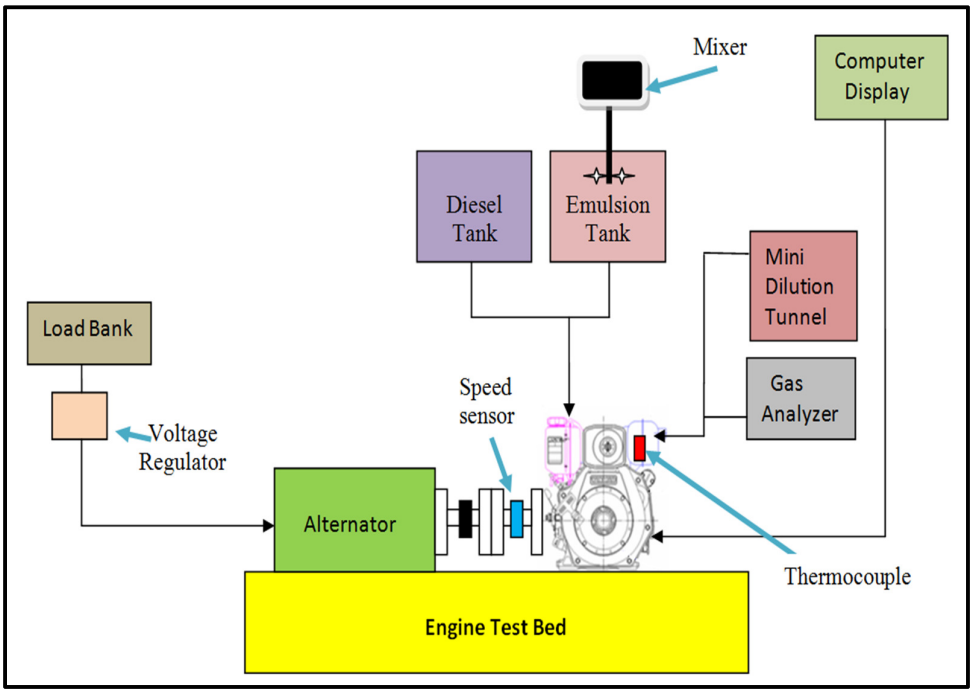

Figure 2: The schematic diagram of the engine emissions test setup

For the purpose of analyzing the measured gases produce by the diesel engine, a portable TESTO 350 Gas Analyzer was used. The probe of emission analyzer was placed inside the exhaust tail pipe in order to sample the exhaust emissions. All the emissions data was recorded into computer using TESTO PC logger software. A filter system was located in the sampling

line to remove solid particles from the sample gas to protect the emission analysis equipment from damage.

Mini-Dilution tunnel with a 70mm inner diameter and 680mm length was employed for sampling PM. Exhaust gas was diluted by clean air that was heated up to 50℃ at dilution rate of 10. Dilution ratio was controlled by the amount of CO2 between inside exhaust gas and inside dilution channel. CO_2 was measured with Rapidox 3100ZA CO_2 Analyser. This diluted gas for 60L measured by wet gas meter and was absorbed with uniform velocity by diaphragm pump, and particulate was trapped with Teflon filter (MILLIPORE FHLP04700, diameter 47mm, orifice 0.47 μm).

By measuring filter weight before and after the sampling, particulate concentrations were determined. Filter have been dehumidified inside the box with the silica gel to have a dry condition for 12 hour in order to remove the effect of moisture and then by using Quartz Crystal Microbalance, the filter was measured with reading accuracy of 0.01mg.

3.0 RESULTS AND DISCUSSION

3.1 Nitrogen Oxides (NO_x)

Figure 4 shows the NO_x emissions by the exhaust gas during engine loading. According to the results, the NO_x emissions increase with the increasing of load. The NO_x emission for E10 and E20 produce about 7.89% to 16.67% and 38% to 60.00% lower than D2.

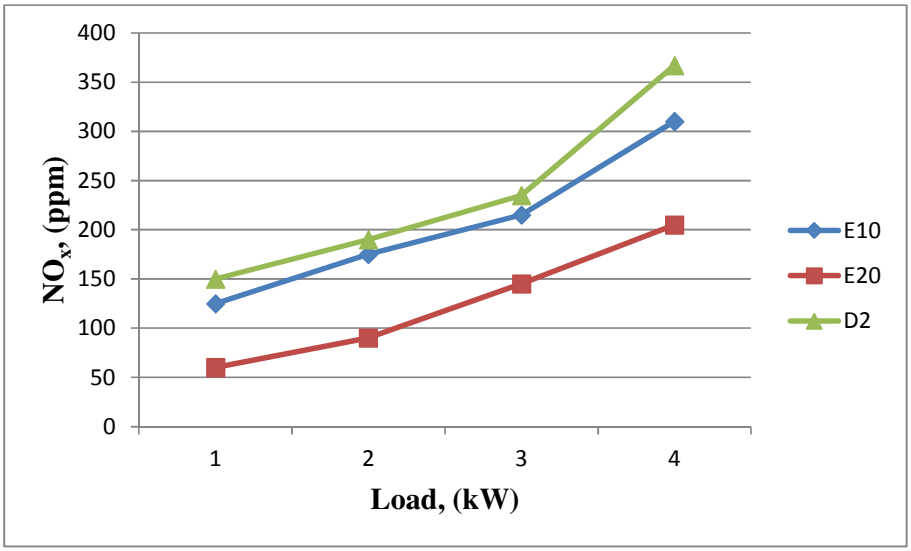

Figure 4: Nitrogen Oxides versus Engine Loads

The reductions of NO_x for both emulsion fuels are due to the water content inside the emulsion. During combustion, the presence of water decreased the peak temperature of the flame. The reduction of the temperature is due to the high latent heat from the evaporation of water in the emulsion that absorbs the heat during the combustion. The water content in the inner phase absorbs the calorific heat value of the emulsion. Hence, this reduces the burning gas temperature inside the combustion and restricts the generation of Nitrogen Oxides.

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3.2 Carbon Dioxide (CO_2)

Data analysis for CO_2 emissions at different engine loading is as shown in Figure 5. As can be seen in the graph, CO_2 emissions would increase with increasing load. CO_2 emissions for E10 and E20 are higher than D2 by about 5.09% to 13.50% and 12.5% to 27.76% respectively. The higher amount of oxygen atoms in the emulsion fuels carried by water component probably the main reason for the increasing amount of CO_2 emitted from using emulsion fuels compared with D2. Transformations of CO were promoted by excess oxygen in order to become CO_2 [7].

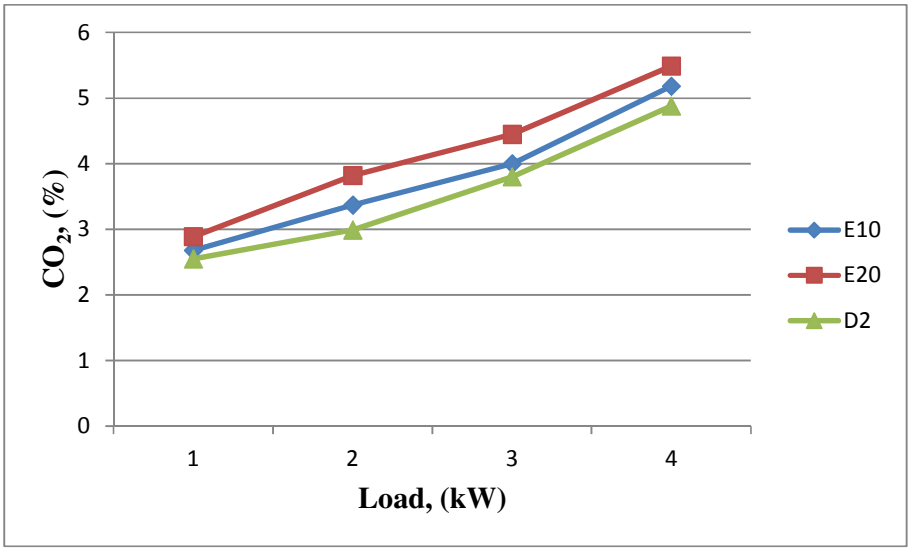

Figure 5: Carbon Dioxide versus Engine Loads

3.3 Carbon Monoxide (CO)

Figure 6 shows the amounts of CO emissions at different engine loading for emulsion fuels and D2. As shown, CO emissions would decrease with increasing load. CO emissions for E10 and E20 are higher than that from D2 by about 19.38% to 89.50% and 64.55% to 102.20% respectively.

Both emulsion fuels, E10 and E20 produces almost the same number of Carbon Monoxide emission as compare to diesel fuel D. This high formation of Carbon Monoxide at low load when using emulsion fuels is because of the water presence. The water contains inside the fuel lower the combustion temperature.

Study said that when the combustion temperature is lower than 1400K, the oxidation process of Carbon Monoxide will freeze. The temperature is insufficient to convert the CO to Carbon Dioxide, CO_2. Other factor is because of high concentration of OH radicals inside the water particle. This promotes the oxidation of Carbon to Carbon Monoxide.

Micro-explosion process works more effectively at high pressure and high temperature conditions; this explained the reduction of Carbon Monoxide formation from E10 and E20 at higher engine load. Better micro-explosion process resulting in the secondary atomization to vigorously explode the fuel into very fine fuel droplets thus improves the air-fuel mixing process.

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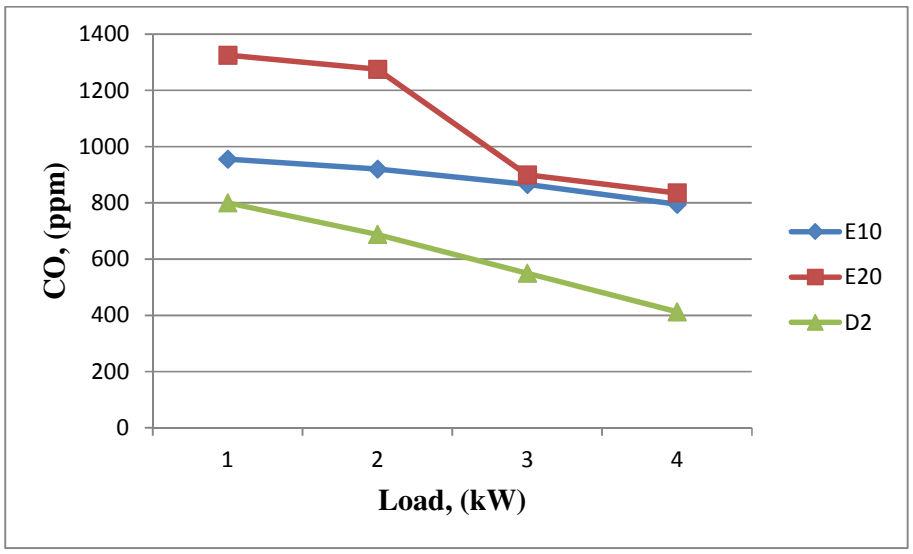

Figure 6: Carbon Monoxide versus Engine Loads

3.4 Particulate Matter (PM)

Figure 7 shows the data taken for particulate emissions, PM for three different fuels under 4 different loads. From the graph, it is clearly illustrates that the formation of Particulate Matter is reduce when applying both E10 and E20 emulsion fuels. The PM emissions from E10 and E20 were lower than D2 in a range of 4.90% to 10.50% and 9.50% to 14.11%, respectively.

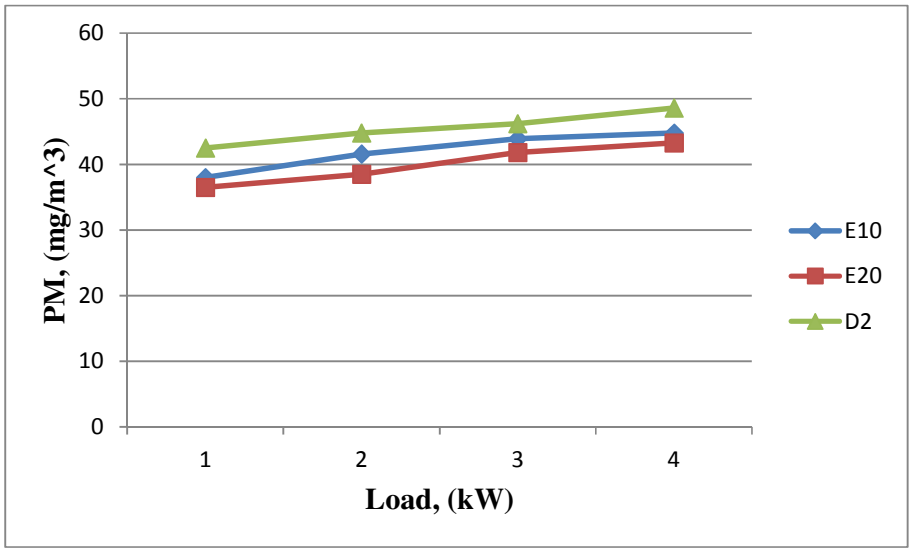

Figure 7: Particulate Matter versus Engine Loads

This happened because of the micro-machining phenomenon that resulted to enhance atomization thus better mixing of the air-fuel. In addition, the presence of water in the fuel increases the concentration of hydroxyl, OH radicals. Increasing of OH radicals will leads to the oxidation of soot precursors. Besides, there are also some studies that stated about the other factors of the Particulate Matter reduction which are lower flame temperature, rapid

evaporation of water, decreasing of pyrolysis reaction and the enhanced oxidation of soot precursor.

4.0 CONCLUSSION

This research concludes on how emulsion fuel affect to exhaust emission in diesel engine compared to neat diesel. The parameters that been tested are Nitrogen Oxides (NO_x), Particulate Matter (PM), Carbon Oxides (CO_2) and Carbon Monoxide (CO). The following conclusions are drawn based on the experimental results:

1. Nitrogen Oxide (NO_x) and Particulate Matter (PM) are found to be reduced for both types of emulsion fuels, E and ES when compared to neat diesel, D.
2. The emission of Carbon Monoxide (CO) and Carbon Dioxides (CO_2) are higher when the engine used E10 and E20 fuel comparing to neat diesel, D2.

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