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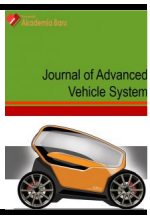

Investigation on Exhaust Emission Characteristic of Diesel Engine Using Water in Diesel Emulsion as Fuel

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ABSTRACT

In this study, experiment has been conducted to analyze the emission characteristics of diesel engine using water in diesel emulsion made from low grade diesel (D2) as fuel. Four different water percentage of emulsion fuels were compared with diesel fuel. Surfactant used at the same amount for each emulsion fuel. Engine was operated at 4 different loads with constant 1500 rpm. Particulate matter (PM) , nitrogen oxides (NOx) and carbon monoxide (CO) has been measured. The result show significant reduction of PM and NOx when operated using emulsion fuel. CO emission for emulsion fuel deteriorates at low and high loads.

1. Introduction

Research of internal combustion engines requires further improvement to achieve strict emissions regulations. Exhaust emissions that are emitted from diesel engine often change into poisonous substances that can damage our environment and human health [1]. Water in diesel emulsion fuel are capable to improve diesel emissions [2].

In the case of water in diesel emulsion fuel, water is mixed homogeneously with the diesel fuel and at the presence of surfactant that helps to produce stable emulsion fuel. Emulsion fuel is a convenient renewable fuel option as the existing engine does not require modification. Moreover, the presence of tiny water droplet in the particles may lead to micro explosion, which also enhance fuel atomization [3].

At a given fuel injection rate, the use of emulsion fuel leads to an increase of the total injected mass, of which a consequence is an increase of the mixing rate between fuel and air, thus reducing local fuel air ratios and consequently particulate matter (PM) production [4]. The results indicate consistent reductions in nitrogen oxides (NOx) and PM emissions. Reductions in NOx and PM emissions are in the ranges 9–70% and 16–60%, respectively. As for unburned hydrocarbons and carbon monoxide (CO), results are contradictory with some tests showing reductions while others

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indicating increases. The main mechanism causing the reduction in NOx is the decrease in temperature of the combustion as a result of vaporization of the liquid water in diesel [5].

Emulsion fuel has the ability to produce comparable in cylinder pressure and heat release rate like base diesel fuel. In addition, lower exhaust gas temperature and lower NOx emission is experienced at all load and engine speed condition for emulsion fuel as compared to diesel fuel. It is found that emulsion fuel suffers from higher CO at low load and low engine speed condition. However, at higher engine speed for a particular load, the CO emission reduces significantly [6].

This research measure exhaust emission such as PM, NOx and CO emitted from diesel engine operated on various percentage of water in diesel emulsion made from low grade diesel (D2).

2. Experimental Setup

Figure 1 shows the engine testing setup diagram which constructed based on the SAE standard for engine testing as the guideline [7]. The diesel engine that will be used in the testing is Yanmar L100 diesel generator which shown in Table 1.

Table 1
Engine specification detail

Engine Model	Yanmar L100 Diesel engine
Engine Type	4-stroke, single cylinder
Fuel supply system	Direct injection
Air Intake	Naturally aspirated
Coolant system	Air-cooled
Continuous Power [KW]	5.7
Max. Power [KW]	6.3
Bore x Stroke [mm]	86 x70
Displacement [L]	0.406
Rated Revolution [RPM]	3000

The project attached electric generator to the spotlight lamp as the load bank and controller. The load coming to the engine is being controlled by voltage regulator. The total load that exerted to the diesel generator is up to 5kW.

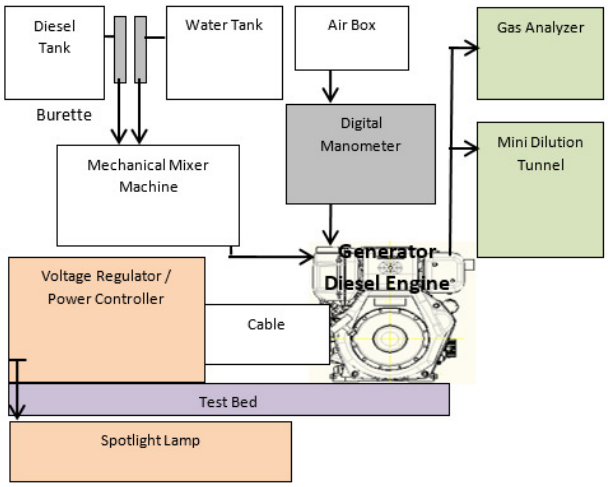

Fig. 1. The engine testing setup diagram

In order to measure the formation of NOx, and CO, Testo 350 emission analyzer is used. The probe of the emission analyzer are placed inside the exhaust tail pipe of the engine in order to sample the exhaust emission. The measured data either can directly display in the control unit or transfer to the software.

As for the measurement of the PM, a mini dilution tunnel need to be used. A small percentage of exhaust gas from the engine will be introduced into the dilution tunnel with the dilution ratio of 10. The diluted gas will be absorbed by uniform velocity of diaphragm pump and the particulate will be trapped on the Teflon filter. The particulate concentration will determine by measuring the filter weight before and after sampling.

Table 2 shows the specification of procedure to produce emulsion fuel base on water percentage. Span 80 type as surfactant to stabilize emulsion fuels. Span 80 is the most effective surfactant while the optimum mixing condition to produce emulsion fuel in approximately 5 minutes with the mixing speed of 5000 rpm [8].

Table 2
Emulsion fuels specification

Fuel	Diesel [%]	Water [%]	Surfactant, Span 80 [%]	Mixing time [min]	Mixing speed [rpm]
Diesel	100	0	0	0	0
E 5	94	5	2	5	5000
E 10	89	10	2	5	5000
E 15	84	15	2	5	5000
E 20	79	20	2	5	5000

3. Results and Discussions

Figure 2 shows particulate matter (PM) concentration of test fuels at different engine load condition. At all loads, diesel fuel emits significantly higher PM than emulsion fuels. Emulsion fuel when injected into combustion chamber produced a finer fuel droplets due to micro explosion phenomenon. Smaller fuel droplets will easily consumed and lead to complete combustion, thus reduce formation of PM. Among emulsion fuels at 3kW and 4kW, E5 show highest PM concentration while the lowest is E20. Strength of the micro explosion is not merely depend on water percentage. It is also affected by size of dispersed water particle, droplet size emulsion as well as temperature and pressure in the combustion chamber [9]. Higher PM concentration of using E15 compared with E10 might due to weak micro explosion, however no specific reason can be provided.

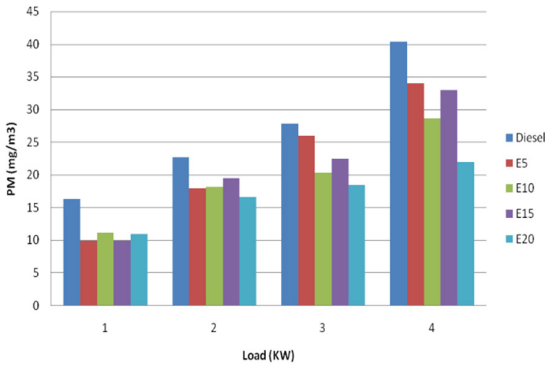

Fig. 2. Particulate matter (PM) versus engine load

Figure 3 shows nitrogen oxides (NO_x) concentration for each test fuel at different engine load conditions. Diesel fuel shows significantly high NO_x concentration compared with emulsion fuels. In average, emulsion fuels are able to reduce NO_x concentration about 20% compared with diesel engine. Almost at all loads, emulsion fuel with higher water percentage can suppressed more NO_x emission. The heat absorbed by water content in the form of latent and sensible heat decrease the combustion temperature and thus NO_x formation will decrease [10].

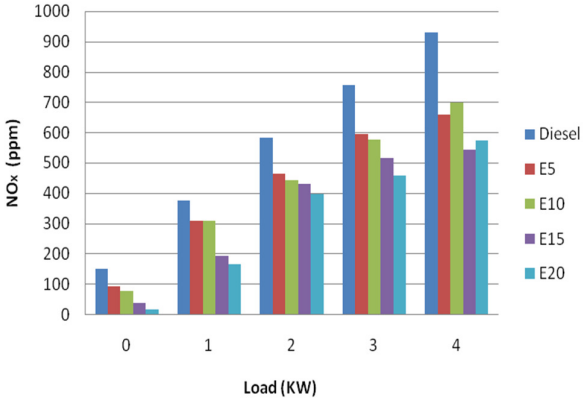

Fig. 3. Nitrogen oxides (NO_x) versus engine load

Carbon monoxide (CO) concentration versus various engine load condition are shown in Figure 4. Diesel fuel emit the lowest CO concentration at all loads. CO concentration deteriorates at low and high loads of using emulsion fuels. Higher water concentration in emulsion fuel proportionally increase CO concentration at high loads.

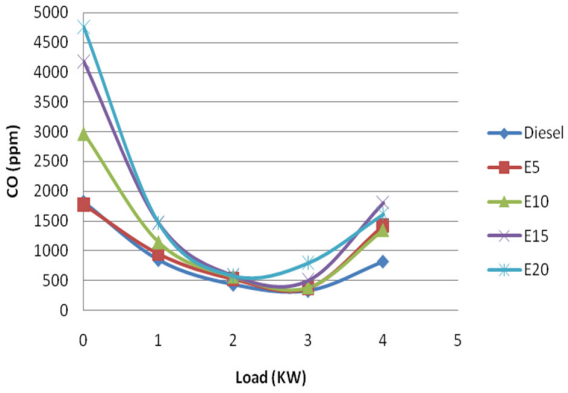

Fig. 4. Carbon monoxide (CO) versus engine load

4. Conclusion

Emulsion fuels made from low grade diesel (D2) have been tested in this study. It can be concluded that:

1. Diesel engine fuelled with emulsion fuels emits lower PM compared with diesel fuel.
2. Water percentage in emulsion fuel is not the only factor that can effect PM emission concentration.
3. Emulsion fuels are effectively able to suppressed NO_x formation.
4. CO concentration for emulsion fuel deteriorates at low and high loads.

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