Evaluation of Water-in-Diesel Emulsion Fuel Blended with Metal Additives in a Diesel Engine

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ABSTRACT

Diesel engines are highly preferred in transportation and industrial application as they are more efficient and durable in comparison to gasoline engine. However, they produce high Nitrogen Oxides (NO_x) and Particulate Matter (PM) emissions which contributed to major source of air pollution in the environment. Water-in-diesel (W/D) emulsion fuels are being introduced as alternative fuels to reduce NO_x and PM emissions respectively. But, the utilization of W/D emulsion fuels contributed to higher CO emissions. Supplementing metal additives into the fuel is the alternative way to reduce the CO emissions and improve performance. The test were carried out to evaluate the effect of organic based manganese blended with the emulsion fuel to the engine fuel consumption and exhaust emissions. Three different organic manganese (100ppm, 150ppm, and 200ppm) were blended with the emulsion fuel (E10: 89%, water: 10%, surfactant: 1%) and labelled as E10Mn100, E10Mn150, and E10Mn200. For performance and emissions tests, the engine were set to run at 3500 rpm for every 0 kW, 1 kW, 3 kW, and 5 kW. E10Mn200 which showed the maximum decrease of fuel consumption (FC) and the highest exhaust gas temperature at 1.53% and 62.86% respectively in comparison with E10. Whereas, E10Mn150 displayed the highest reduction of CO at 14.67%, showing maximum rate increase at 28.24% in NO_x emissions, and minimum hydrocarbon (HC) emissions in comparison with E10. NOx emissions start to reduce after addition of 200ppm additives. Organic-based manganese act as a catalyst that promotes improvement of the emulsion fuel performance and reduce the harmful emissions discharged.

ISSN 1823- 5514, eISSN 2550-164X

Received for review: 2017-08-02
Accepted for publication: 2018-03-30
Published: 2017-08-15

Keywords: *Diesel Engine, W/D Emulsion Fuel, Carbon Monoxide, Organic-Based Manganese Additive*

Introduction

Energy are vital and contribute to great influences towards the economy, improving the quality of life, and improve the social development of a country and its citizen. But due to rapid economic growth and increasing demand of fossil fuels as energy resources, the reliance on the source are currently expanded. Although it gives benefits to the consumer, it actually imposes negative effects towards the environment and human being. Water-in-Diesel emulsion fuel is one of the promising alternative fuel that able to reduce major exhaust emission; particulate matter (PM) and Nitrogen oxides (NOx) simultaneously at the same time improves the combustion efficiency. Water-in-Diesel emulsion fuel contained a mixture of two or more distinct materials of immiscible fluids which is water and diesel in which the water is in the form of dispersion and diesel as the continuous form [1]. Surfactant was added to improve the composition and provide a stable emulsion fuel [2].

Water-in-diesel emulsion fuel is mostly used in the compression ignition engine and able to improve the performances and reduced harmful emissions discharged from the engine [3]. However, these alternative fuels consume higher emission of CO [4]-[5]. In order to encounter this issue, metal-based nanoparticles are being introduced to the W/D emulsion fuels and are reported in many studies. Ignition delay is significant variable in the diesel combustion as it has strong interrelation to the amount of fuel that is burned in the premixed combustion. Practically, nano-sized metal particle have the characteristics of high specific surface area, high thermal conductivity, and they also has the potential to store energy which resulting in high reactivity. Kao et al. [6] reported that the metal oxide nanoparticles in W/D emulsion fuel function as a catalyst and indirectly promote the chemical reaction between water and air-fuel mixture. On the other hand, Wakefield et al. [7] reported that the nano-sized metal oxide that act as a catalyst in diesel fuel can increased the active surface and promoted better chemical reaction. Tyagi et al. [8] determined and observed that adding nanoparticles into the conventional fuels will causes the improvement of the mass transfer properties, ignition temperature and also shorten the ignition delay, when he conducted a hot plate ignition probability test using aluminium and alumina nanoparticles.

Meanwhile, Sadhik Basha and Anand [9] observed that there is significant increase in the brake thermal efficiency and reducing of the harmful pollutant in comparison with neat diesel because of better combustion characteristic of the nanosize of solid particle of the Carbon Nano Tubes (CNT) during their studied on the effect of mixed with diesel with different mass fractions (0.5, 1.0, and 1.5 g/litre) with no modification on the engine. Vellaiyan and Amirthagadeswaran [10] reported that high premixed combustion, internal combustion pressure, and rough engine operation in which it is undesirable can be occurred due to the longer ignition delay.

From this motivation, the objective is to study and evaluate the effect of adding organic based Manganese additive into W/D emulsion fuel. The performance and emissions discharged by the engine was the real concern of conducting the experiment. Organic-based Manganese additive are being introduced into the W/D emulsion fuel in order to reduce the CO emission discharge towards the environment and to enhance the performance of the engine.

Methodology

Fuel Preparation

The D2 fuel was selected as the base fuel, tap water was used as the added water, and SPAN 80 with HLB 4.8 was used as the surfactant in the preparation of the emulsion fuel. Basically, the emulsion fuel consist of 89% of D2 fuel, 10% of water, and 1% of surfactant in volume. The emulsion fuel named as E10. Mechanical mixer at a speed of 2500 rpm used to well mix the emulsion fuel within 10 minutes. Meanwhile, 100 ppm, 150ppm, and 200ppm of organic-based Manganese oxide were being prepared as the additives to be added into the E10. Mass balance was used to get exactly the same amount of Manganese additive needed, and ultrasonic wave have been used for the mixing of the E10 with the manganese additives. Table 1 represents the D2 fuel characteristic. The samples labelled as E10, E10Mn100, E10Mn150, and E10Mn200 respectively.

Table 1: D2 fuel characteristic

Properties	**Unit**	**D2**
Calorific value	MJ/kg	45.28
Cloud point	^{o}C	18
Density @ 15 ^{o}C	kg/L	0.854
Total sulphur	mass%	0.28
Viscosity @ 40 ^{o}C	cSt	4.64
Distillation temperature, 90% recovery	^{o}C	368
Flash point	^{o}C	93
Pour point	^{o}C	12
Cetane number	-	54.6
Carbon	wt%	84
Hydrogen	wt%	12.8

Sulphur	wt%	0.2
Nitrogen	wt%	<0.1
Oxygen	wt%	3.9

Engine Performance and Emission Test

The engine was being set up as shown in the Figure 1. The engine was run at constant speed of 3500 rpm at different engine loads of 0 kW, 1 kW, 3 kW, and 5 kW. The loads and rpm are controlled by the LABVIEW software. A glass burette is used to measure the specific volume of tested fuels consume under certain load which were 0 kW, 1 kW, 3 kW, and 5 kW respectively. During the conducted experiment, time taken for every 10 ml drop of the volume of the tested fuels were recorded. The recorded of the time taken for the drop of 10 ml of the tested fuels inside the class burette were being taken three times and the average of all the recorded values were calculated. The formula for calculating the flow rate using the burette method is as follows:

$$\dot{m}_f = \frac{v}{t \times \rho_f} \quad (1)$$

Where; $\dot{m}_f$ is the mass flow rate of fuel, V is the specific volume in the burette, t is the time taken, and ρ_f is the density of the fuel. The specification of the engine are given in Table 2. The gas emission analyser used was E – instrument E4500.

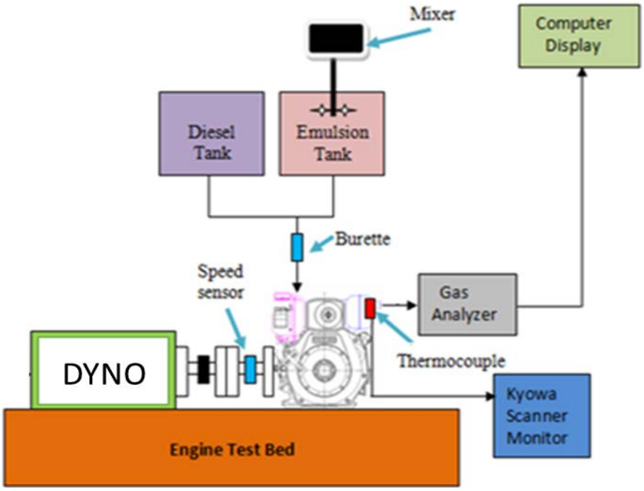

Figure 1: Schematic diagram of the engine emission test set up

Table 2: Test engine specifications

Parameter	Specification
Engine Type	4-Stroke, single cylinder, DI, air cooled
Bore/ Stroke (mm)	86/70
Rated revolution (rpm)	3100
Compression ratio	19.3
Displacement (L)	0.406
Fuel injection pressure (Mpa)	19.6

Results and Discussions

Figure 2 presents fuel consumption (FC) of the tested fuel. It is significant and important parameter in the indication of the engine performance as it determined the consumed quantity of fuel. Overall, the trend of FC from D2, E10, E10Mn100 and E10Mn150 showed almost the same trend at all load whereas the load increased, the FC for all fuel increased. Maximum decreased in FC was obtained from the fuel E10Mn200. Under 5kW load, E10Mn200 achieved maximum decreased of FC by 1.53% when compared with E10. While, for E10Mn150 and E10Mn100 reduced to 0.98%, and 0.54% of the fuel consumption. It was observed that the FC after 3kW the improvement start to cease. The more quantity of additive being added increased the reduction of FC. Therefore, supplementing additive which was organic-based manganese promotes better combustion of the injected fuel since the additive act as an oxidation catalyser. The additive enables the improvement of the fuel properties which positively affect the atomization and penetration of the fuel which improve the combustion of the fuel [11].

Figure 3 presents the CO emissions of tested fuel. It was observed that the increase in the load caused decrease in the CO emissions. Compared to E10, all tested fuels with additive added showed reduction except E10Mn200 at full load of 5kW. The maximum CO emission reduction was observed to be obtain from E10Mn150. Under full load, E10Mn150 reduced up to 14.76% of CO emissions in comparison of E10. E10Mn100 reduced to 11.5% of CO emissions while E10Mn200 increased to 19.04% of CO emissions discharged under the full load. It was observed that the improvement of the CO emission starts to decrease after 3 kW. Organic-based manganese additives promote better combustion of the injected fuel as the additives act as an oxidation catalyzer. Oxidation catalyzer decrease the oxidation temperature and gives better fuel combustion. E10Mn200 also observed to has high remarkable increased in the CO emission after the improvement start to cease at 3kW [12].

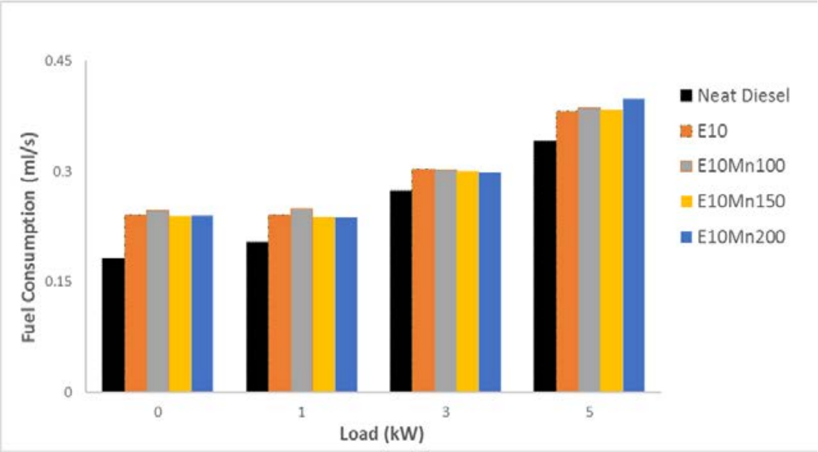

Figure 2: Fuel consumption (FC) of tested fuel

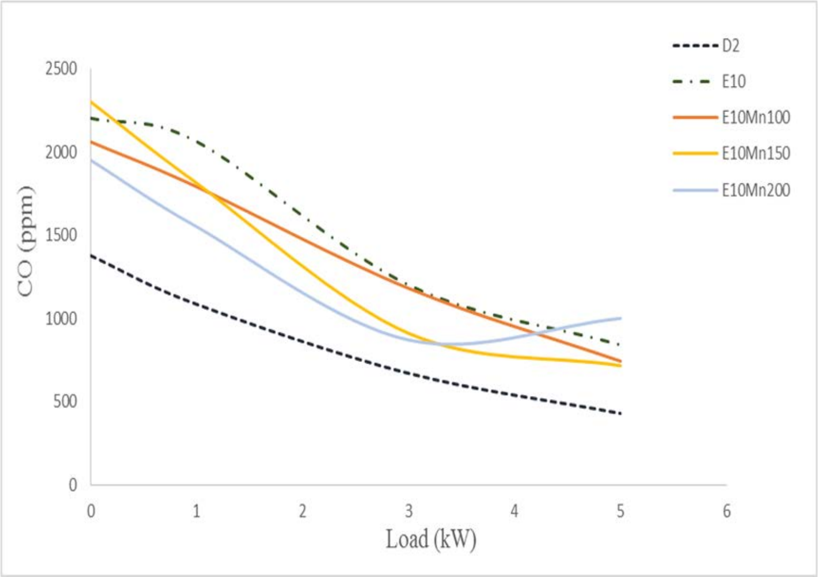

Figure 3: CO emission graph of tested fuel

Figure 4 presents the NO_x emissions of tested fuel. The NO*x* emissions increased in line with the increased of load. It was observed that adding of the manganese additive up to 200 ppm into the emulsion fuel indirectly increased the NO*x* emissions. E10Mn150 give the maximum rate of increase of NO*x* emissions. All metal additive emulsion fuels produced higher as compared to neat emulsion fuel E10 at 5kW load, however the said fuels still emit lower NO*x* than neat diesel. E10Mn200 showed 12.99% reduction of NO*x* emissions compared with D2. The NO*x* emissions of the neat diesel, E10, E10Mn100, E10Mn150, and were determined to be 302 ppm, 177 ppm, 190 ppm, 227 ppm, and 200 ppm respectively under full load of 5kW.

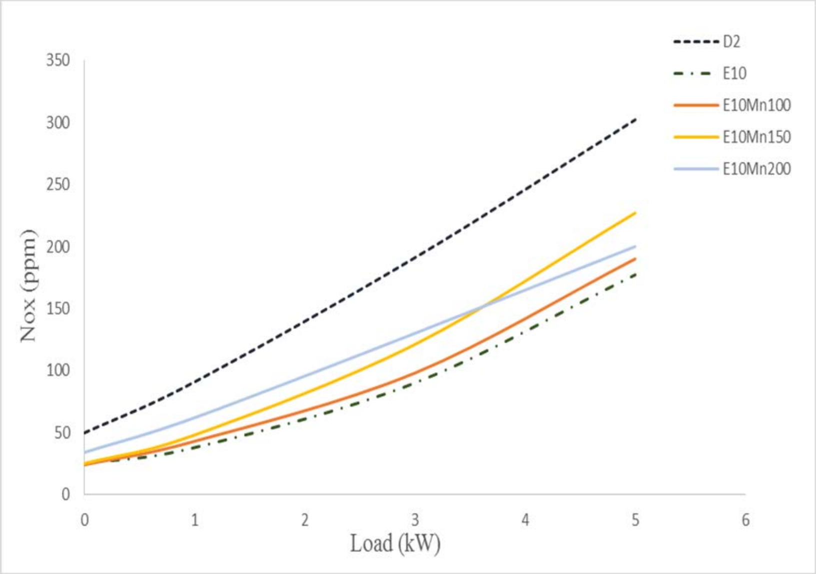

Figure 4: NOx emission graph of tested fuel

Figure 5 presents the HC emissions of tested fuel. The HC emissions decrease in line as the load increased. The lowest HC emission was obtained from E10Mn100 at full load which is 40% reduction compared to D2. HC emission obtained at maximum load from the fuels D2, E10, E10Mn100, E10Mn150, and E10Mn200 were 700 ppm, 500 ppm, 300 ppm, 633.33 ppm, and 500 ppm respectively. Supplementing organic based manganese which act as additive able to decrease the HC emissions discharged [13].

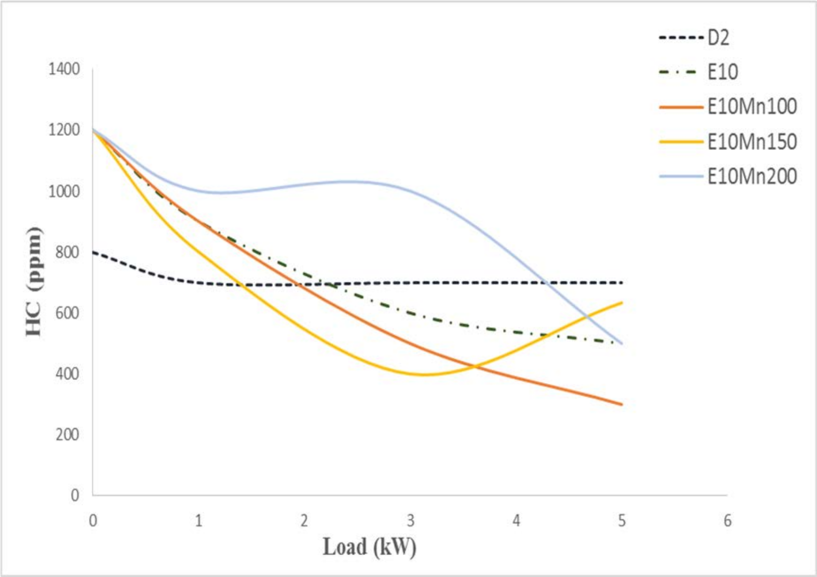

Figure 5: HC emission graph of tested fuel

Figure 6 presents the exhaust gas temperature of tested fuel. Ignition delay has strong correlation with the increase of the exhaust gas temperature. While, decreased in exhaust gas temperature may be considered is due to the reduction of long ignition delay time. As shown in the said figure, it is clearly shows that, as the percentage of metal additives increases, the exhaust temperature significantly increase. Maximum of exhaust gas temperature of E10, E10Mn100, E10Mn150, and E10Mn200 were 245 ^{o}C, 293 ^{o}C, 375 ^{o}C, and 399 ^{o}C respectively under full load. The highest exhaust gas temperature was observed to be obtained from E10Mn200. While E10Mn100, E10Mn150, and E10Mn200 were observed to increase by 19.56%, 53.06%, and 62.86% respectively. Among the emulsion fuel supplemented with the organic based manganese additives, the one with 200 ppm mixture rate was the highest of the exhaust temperature can increased. Thus, the exhaust gas temperature was affected by the concentration of manganese additives being added in which it reacts to the emulsion fuels to improve the fuel properties.

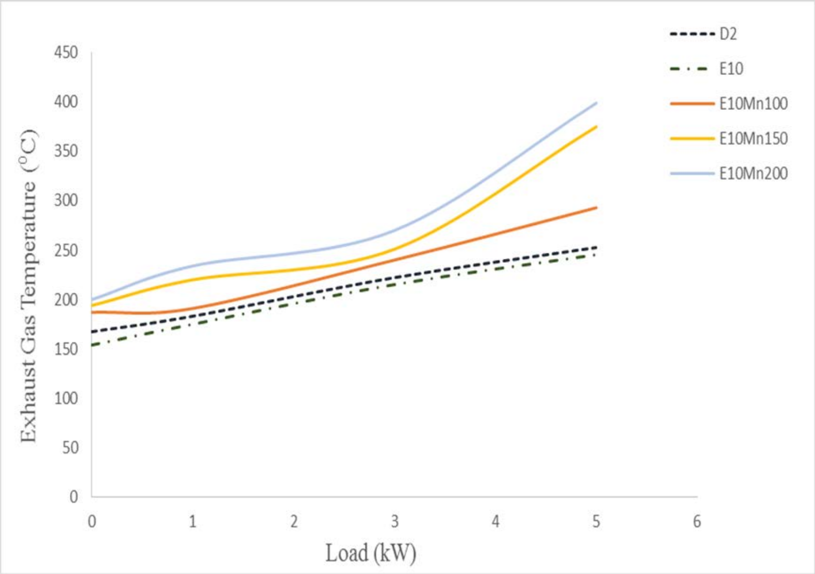

Figure 6: Exhaust gas temperature of tested fuel

Conclusion

The effect of adding metal additive into the water-in-diesel emulsion fuel in diesel engine has been evaluated with variation of 3 different volumes; 100, 150 and 200 ppm. All metal additives emulsion fuel showed an improvement of fuel consumption as compared with neat emulsion fuel where E10Mn200 achieved maximum decreased of FC by 1.53% followed by E10Mn150 and E10Mn100 where both fuels reduced 0.98% and 0.54% respectively compared to E10. As for the emissions test, all metal additives emulsion fuel produced lower CO as compared to E10, but slightly higher than D2. E10Mn150 under full load produced the lowest CO as compared to E10 with 14.67% reduction. However, the formation of NO*x* for all the metal additive emulsion fuels was slightly increased over the neat emulsion.

Supplementing organic based manganese additive into emulsion fuel able to reduce the fuel consumption, CO emissions, and THC emissions discharged from the engine. Somehow, it partially increases the formation of NO*x* emissions and promotes the higher in exhaust gas temperature. Organic based manganese which act as catalyst promotes the improvement of the emulsion fuel performance and reduced the harmful emissions discharged.

Acknowledgment

The authors would like to express their gratitude to the Malaysia-Japan International Institute of Technology, Universiti Teknologi Malaysia who provided the research with related facilities and equipment. Highest appreciation goes to the Universiti Teknologi Malaysia for their financial support (Q.K.130000.2743.02K53).

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