

Effects of Biodiesel and Engine Load on Some Emission Characteristics of a Direct Injection Diesel Engine

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ABSTRACT

In this research, experiments were conducted on a 4-cylinder direct-injection diesel engine using biodiesel as an alternative fuel and their blends to investigate the emission characteristics of the engine under four engine loads (25%, 40%, 65% and 80%) at an engine speed of 1800 rev/min. A test was applied in which an engine was fueled with diesel and four different blends of diesel/biodiesel (B20, B40, B60 and B80) made from waste frying oil and the results were analyzed. The use of biodiesel resulted in lower emissions of hydrocarbon (HC) and CO and increased emissions of CO₂ and NO_x. This study showed that the exhaust emissions of diesel/biodiesel blends were lower than those of the diesel fuels.

Key words: Emission, Biodiesel, Waste frying oil, Diesel.

INTRODUCTION

In recent years, the demands for energy have grown very quickly due to the rapid development of certain growing economies, especially in Asia and the Middle East. Biofuels such as alcohols and biodiesel have been proposed as alternatives for diesel engines^{1,2,3}. Especially, the environmental issues concerned with the exhaust gases emission by the usage of fossil fuels also encourage the usage of biodiesel, which has proved to be ecofriendly far more than fossil fuels. In particular, biodiesel has received wide attention as a replacement for diesel fuel because it is biodegradable, nontoxic and can significantly reduce toxic emissions and overall life cycle emission of CO₂ from the engine when burned as a fuel^{4,5}.

Biodiesel is known as a carbon neutral fuel because the carbon present in the exhaust was

originally fixed from the atmosphere⁶⁻⁷. This supply deficit will have serious implications for many non-oil producing countries which are dependent on oil imports. Furthermore, the extensive use of fossil fuels has increased the production of greenhouse gases, especially carbon dioxide (CO₂), thus exacerbating the greenhouse effect. The potential to both reduce fossil fuel reliance and the release of CO₂ to the atmosphere.

Biodiesel from waste cooking oil is a more economical source of the fuel. Kulkarni and Dalaj⁸ concluded that the engine performance of biodiesel obtained from waste frying oil is better than that of diesel fuel while the emissions produced by the use of biodiesel are less than those using diesel fuels except that there is an increase in NO_x.

Lapuerta *et al.*,⁹ tested two different biodiesel fuels obtained from waste cooking oils with different previous uses on diesel particulate

emissions. They found no important differences in emissions between the two tested biodiesel fuels.

Based on exhaustive engine tests, it can be concluded that bio-diesel can be adopted as an alternative fuel for existing conventional diesel engines without requiring any major modifications in the mechanical system of the engines. Bio-diesel emissions in a conventional diesel engine contain substantially less unburned HC, CO, sulfates, polycyclic aromatic hydrocarbons, nitrated polycyclic aromatic hydrocarbons and PM than conventional diesel emissions¹⁰⁻¹¹. The NOx emissions from bio-diesel blends of various origins are slightly lower than those of conventional diesel, and the difference is greater for blends with higher percentages of bio-diesel¹². Other researchers have observed the same behavior for all vegetable oil blends of various origins¹³⁻¹⁵. Various studies have shown that biodiesel made from waste cooking oil can be used in different types of diesel engines with no loss of efficiency¹⁶ and significant reductions in PM emissions¹⁷⁻²¹, Co emissions^{17,20} and total hydrocarbon (THC) emissions²⁰⁻²² when compared with emissions from conventional fossil diesel fuel. The performance and smoke results obtained from an engine used for generating electricity, when fueled with biodiesels of waste cooking oil origin, showed that the smoke reduction was about 60% for B100 and approximately 25% for B20¹². Dorado *et al.*,²³ used waste olive oil in a four-stroke, three-cylinder, and 2.5 L direct injection engine with a power rating of 34 kW through an eight mode test. They achieved 58.9% reduction in CO, 8.6% reduction in CO₂ and 57.7% reduction in SO₂ emissions. On the other hand, increases of 32 and 8.5% in the NOx emissions and specific fuel consumption were observed in the B100 and B20 mixtures, respectively. Murillo *et al.*, (2007)²⁴ tested a four-stroke diesel outboard engine running on conventional diesel, conventional diesel blended with certain amounts of waste cooking oil biodiesel (10, 30 and 50%), and pure bio-diesel and proved that the bio-diesel blends are environmentally friendly alternatives to conventional diesel. They found some reduction in power of approximately 5% with B10 and B30, and 8% with B50 and B100 with respect to the power obtained from conventional diesel.

The biodiesel from waste cooking oil was tested by Meng *et al.*,²⁴⁻²⁵ on an unmodified diesel engine, and the results showed that under all conditions, the dynamical performance remained normal. Moreover, B20 and B50 blend fuels created unsatisfactory emissions, while the B20 blend fuel reduced PM, HC and CO emissions significantly. In another study, wasted cooking oil from restaurants was used to produce neat biodiesel through transesterification, and this converted biodiesel was then used to prepare biodiesel/diesel blends. The authors of the study concluded that B20 and B50 are the optimum fuel blends in terms of emissions²⁶.

In this research, the performance of waste frying oil methyl ester blended with diesel fuel in ratios of 20% (B20), 40% (B40), 60% (B60) and 80% (B80) was investigated and compared with that of regular diesel in terms of emissions in diesel engine under four engine loads at an engine speed of 1800 rev/min.

The experiments were conducted on a four cylinders, four-stroke, turbocharged direct injection diesel engine. The engine specifications are given in Table 1.

The test engine was coupled to a hydraulic dynamometer providing a maximum engine power of 110 KW with a ± 0.1 KW of uncertainty to control engine speed and load. The test engine was operated at different torques when different fuels were tested. The load on the dynamometer was measured by using a strain gauge load sensor that was calibrated by using standard weights just before the experiments. An inductive pickup speed sensor was used to measure the speed of the engine, and it was also calibrated by an optical tachometer. An AVL DICOM4000 gas analyzer was used to measure CO, CO₂, NOx and HC emissions.

In the experiments, diesel fuel no. 2 and four diesel fuel/biodiesel blends were tested. Waste frying oil methyl ester was blended with diesel fuel in 0%, 20%, 40%, 60% and 80% proportions by volume. The blends were prepared just before the experiments. In the tests, wasted frying oil was supplied from Modares university biodiesel institute.

The specifications of the waste frying oil methyl ester are shown in Table 2.

All fuels were tested at 1800 rpm and four engine partial loads (25%, 40%, 65% and 80%). The general testing procedure can be summarized as follows. The engine was run with the diesel fuel. After completion of standard warm-up duration, the engine speed was increased to 3000 rpm. The tests and data collection were performed at four different engine loads. The engine was kept running to flush out the diesel/biodiesel blend from the fuel lines, injection pump and the injectors for a while before shutting down.

RESULTS

Experiments were performed at the rated torque speed of 1800 rev/min, and at 25%, 40%, 65% and 80% engine loads.

At each engine load, experiments were carried out for diesel and each blended fuel. In this paper, the effects of engine load and biodiesel on emissions included HC, CO, CO₂ and NO_x were investigated.

As shown in Fig. 1, for Diesel, the HC emission decreases with increase of engine load, due to the increase in combustion temperature associated with higher engine load. For biodiesel blended fuel, the HC emission is lower than that of diesel and decreases with increase of biodiesel in the fuel. However, for the biodiesel blended fuel, the HC emission, instead of decreasing straightly with engine load, has a peak value at the 40% engine load. The reduced HC emission with

biodiesel blended diesel can be accounted for by several reasons as stated in Lapuerta *et al.* (2008)[8]. However, the lower volatility of biodiesel compared with diesel contributes to the larger difference in HC emission at low engine loads. The maximum concentrations of HC are 35 ppm, 29 ppm, 27 ppm, 26 ppm and 25 ppm, respectively, for diesel, B20, B40, B60, B80, indicating that the maximum HC emission declines with the addition of biodiesel.

The characteristics of CO emission are shown in Fig. 2. For each fuel, there is a decrease of Co emission on increase of the engine load. The peak concentrations at the 25% engine load are 0.04%, 0.037%, 0.036%, 0.035% and 0.035%, respectively, for diesel, B20, B40, B60, B80. The higher combustion temperature at higher engine load contributes to the general decreasing trend. With the addition of biodiesel, CO emission also decreases. It is possible that the oxygen contained in the fuel enhances complete combustion in the cylinder and reduces CO emission²⁷⁻²⁹. Fig.3 compares the CO₂ emissions of various fuels used in the diesel engine. The CO₂ emission increases with increases in load, as expected. The lower percentage of biodiesel blends emits very low

Table 1: Specifications of the test engine

Cylinder number	4
Displacement(Lit)	3.9
Compression ratio	17:1
Power (kW/rpm)	85:2800
Torque (Nm/rpm)	340:1800
Cooling system	Water cooled

Table 2: Specifications of diesel and biodiesel fuels

Property	Method	Biodiesel	Property
Flash point, closed cup	D 93	64 ° C	182 ° C
Pour point	D 97	0 ° C	-3 ° C
Kinematical viscosity	D 445	4.03 mm ² /s	4.15 mm ² /s
Sulfated ash	D 874	-	0 wt. %
Total Sulfur	D 5453	0.05 wt. %	0.0018 wt. %
Copper strip corrosion	D 130	1a	1a
Cloud point	D 2500	2 ° C	0 ° C

amount of CO₂ in comparison with diesel. B20 emits very low level of CO₂ emissions. Using higher concentration biodiesel blends as the fuel, CO₂ emission is found to increase. But, its emission level

is lower than that of the diesel mode. B80 emits more amount of CO₂, as compared to that of biodiesel blends. More amount of CO₂ in exhaust emission is an indication of the complete

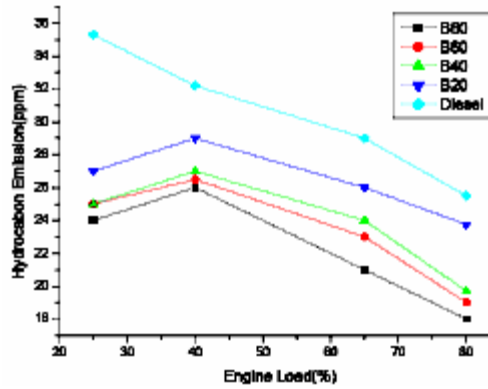


Fig. 1: Effect of biodiesel and engine load on hydrocarbon emission

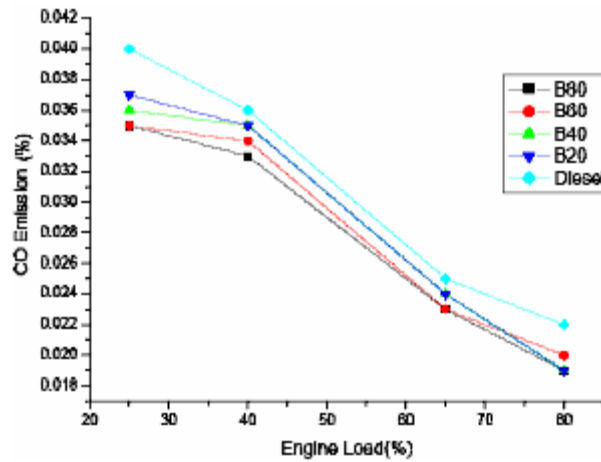


Fig. 2: Effect of biodiesel and engine load on CO emission

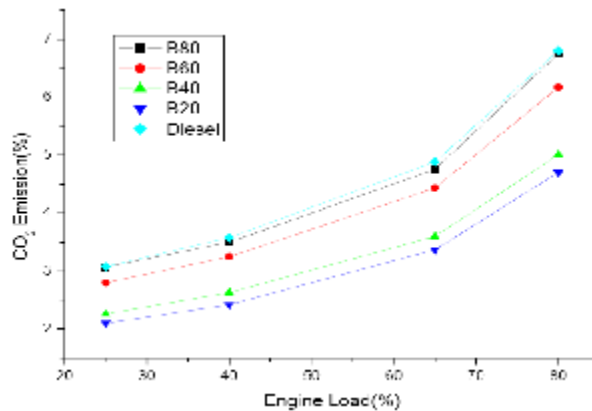


Fig. 3: Effect of biodiesel and engine load on CO₂ emission

combustion of fuel. This supports the higher value of exhaust gas temperature.

Fig.4 shows the variation of NO_x emission with engine load. The NO_x concentration increases with increase of engine load for all the fuels. Compared with diesel, NO_x emission of the

biodiesel blended fuel increases slightly at all tested engine loads and the increase is more obvious at higher engine loads. From diesel to B80, the NO_x emission increases. The peak concentrations at the 80% engine load are 670 ppm, 640 ppm, 640 ppm, 620 ppm and 600 ppm respectively, for diesel, B20, B40, B60, B80.

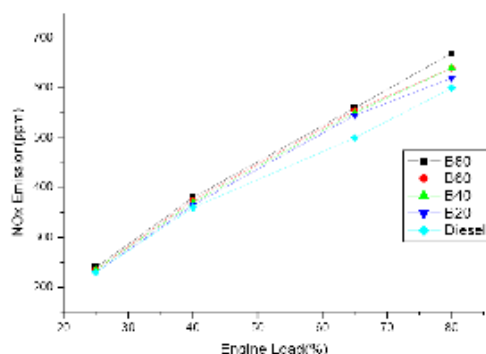


Fig. 4: Effect of biodiesel and engine load on NO_x emission

CONCLUSION

Experiments have been conducted on a diesel engine using diesel, diesel-biodiesel blended fuels. Biodiesel used in the present study was manufactured from waste frying oil. Blended fuels containing 20%, 40%, 60% and 80% by volume of biodiesel, were used in the tests. The effect of engine load and fuel mix on emissions was investigated. The use of diesel blended with biodiesel, compared with diesel on the emissions; in general, HC and CO emissions are higher at

low engine loads and lower at high engine loads while NO_x increase with engine loads. Also the CO₂ emission increases with increases in load, as expected. The lower percentage of biodiesel blends emits very low amount of CO₂ in comparison with diesel. After the addition of biodiesel in the blended fuel, HC and CO emissions decrease due to improved combustion with oxygen enrichment of the fuel. However, NO_x emissions increase due to the higher combustion temperature and the increased oxygen level in the combustible mixtures.

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