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RESEARCH ARTICLE

AN EXPERIMENTAL INVESTIGATION OF THE PERFORMANCE AND GASEOUS EXHAUST EMISSIONS OF A DIRECT INJECTION DIESEL ENGINE USING USED COOKING OIL METHYL ESTER (UCOME) AND ITS BLEND WITH DIETHYL ETHER AND CONVENTIONAL DIESEL OIL

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ABSTRACT

The performance and emission characteristic tests have been carried out on a single cylinder direct injection diesel engine running under constant speed and variable loads. In the first part, the engine tests have been conducted with used cooking oil methyl ester (B100) and their blends with conventional diesel oil in the proportions of 20:80 (B20), 40:60 (B40), 60:40 (B60), and 80:20 (B80). In the second part, the engine tests have been conducted with blends of conventional diesel oil, used cooking oil methyl ester (UCOME), and diethyl ether in the proportions of 76:20:4 (BD20), 52:40:8 (BD40), 28:60:12(BD60), 4: 80:16 (BD80) and 0:83.33:16.67(BD100). A series of tests have been conducted for each of test fuel. The engine is allowed to run at constant speed at 1500RPM, but at different loads (0.4, 4, 6, 8 and 10kg). The performance and emission characteristics of blends are analyzed and compared with conventional diesel oil. The experimental results obtained for UCOME are comparable with conventional diesel oil with the increase in engine performance and reduction in engine exhaust emissions.

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INTRODUCTION

Limited reserves of fossil fuels, increasing demand for diesel oil and increasing stringent environmental regulations have motivated an intense search for alternative transportation fuels over the last three decades (Ministry of Petroleum and Natural gas, 2013-14; http://www.epa.gov/oms/climate/420f05001). Fluctuating prices of crude oil has posing severe burden on foreign exchange of oil importing countries like India (Ma and Hanna, 1999). Demand for petroleum products has expected to grow steadily to keep pace with industrialization and urbanization. Present survey indicates that known crude oil reserve could be exhausted in less than 50 years (Krawezyk, 1996; Mohibbe Azam *et al*., 2005; Van Gerpen, 2005). Use of non renewable diesel oil increases HC, CO, CO_2, NOx and PM emissions (Canakci, 2007; Connemann and Fischer, 1998; Demirbas, 2009). The world is facing two challenges; on one side known non renewable transport fuels are depleting at a faster rate, on other side there use is harming the quality of breathing air. The scarcity of diesel oil, growing emissions and fluctuating prices will make biodiesel more attractive (Ozsezn *et al*., 2009; Chang and Van Gerpen, 1997; Chang *et al*., 1996). Use of biodiesel increases the Brake Thermal efficiency (BTE) and reduces the emission of carbon monoxide (CO), hydrocarbons (HC) and particulate matter (PM) in the exhaust gas compared with conventional diesel oil because it contains 10% to 11% oxygen by weight (Graboski and McCormick, 1998; Meher *et al*., 2006; Murugesan *et al*., 2009). In this paper, an attempt has made to present the results obtained from tests conducted on diesel engine when it is fuelled with UCOME and its blends with conventional diesel oil and diethyl ether in different proportions.

Experimental set up

Table 1 shows the engine specifications. Figure 1 shows a schematic diagram of experimental set up. It is fitted with diesel engine, fuel tank, a data acquisition system, a computer, an operation panel and an exhaust gas analyzer. The Plate 1

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shows the computerized diesel engine test rig with exhaust gas analyzer.

Performance characteristics of diesel engine

The engine tests have been conducted with used cooking oil methyl ester (UCOME) and their blends with conventional diesel oil and Diethyl Ether (DEE) additive. The test was conducted with B20 blend and after that remaining blend like B40, B60, B80 and B100.

RESULTS AND DISCUSSION

Effect of load on BSFC for all blends

Figure 2 shows the Brake Specific Fuel Consumption (BSFC) of B20, B40, B60, B80 and B100. From Figure 2 it is clear that BSFC decreases with the increase in load and increases with the increase in methyl ester blend. For example B100 (5.16kg/kW-hr) of used cooking oil methyl ester (UCOME) consumes 1.03 times more fuel than B20 (5.01kg/kW-hr) at low load of 0.4kg and almost constant at maximum load (10kg).

Table 1. Engine Specifications

Make	Kirloskar
Model	TV1
Number of cylinders	One
Number of strokes	Four
Fuel	High Speed Diesel
Rated power	5.2 kW at 1500 RPM
Cylinder diameter	87.5mm
Stroke length	110mm
Compression ratio	17.5:1
Orifice diameter	20mm
Dynamometer arm length	185mm

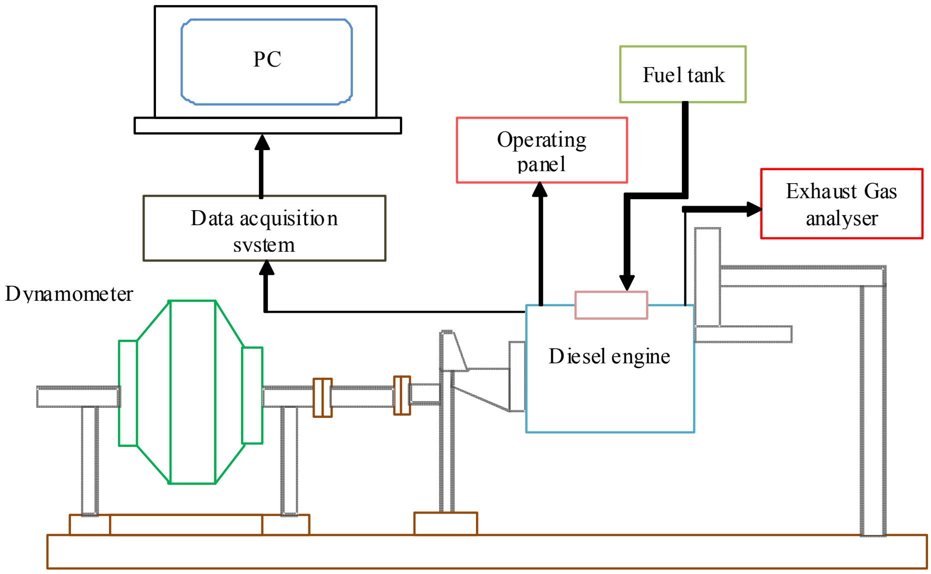

Figure 1. Block diagram of computerized diesel engine test rig

Plate 1. Computerized diesel engine test rig with exhaust gas analyzer

The maximum BSFC of 5.16 kg/ kW-hr were obtained for B100 at minimum load (0.4kg) compared to BSFC of conventional diesel oil (3.61 kg/ kW-hr) at same load. The BSFC of B100 which is 30.04% higher than conventional diesel oil. The minimum BSFC of 0.37 kg/ kW-hr were obtained for B20 for maximum load (10kg) compared to BSFC of 0.31 kg/ kW-hr at the same load which is 16.21% higher than conventional diesel oil. Figure 3 shows the Brake Specific Fuel Consumption (BSFC) of BD20, BD40, BD60, BD80 and BD100 blends. From Figure 3 it is clear that the maximum BSFC of 5.04 kg/ kW-hr were obtained for BD20 at minimum load (0.4kg) compared to BSFC of conventional diesel oil (3.61 kg/ kW-hr) at same load. The BSFC of B20 which is 28.37% higher than conventional diesel oil. The minimum BSFC of 0.36 kg/ kW-hr were obtained for BD40 for maximum load (10kg) compared to BSFC of 0.31 kg/ kW-hr at the same load which is 13.89% higher than conventional diesel oil. From the above data it is clear that the maximum BSFC of UCOME without additive is 2.71 % greater than the UCOME blended with diethyl ether as an additive for B100. Also the minimum BSFC of UCOME without additive is 2.70 % greater than the UCOME blended with diethyl ether additive for B40.

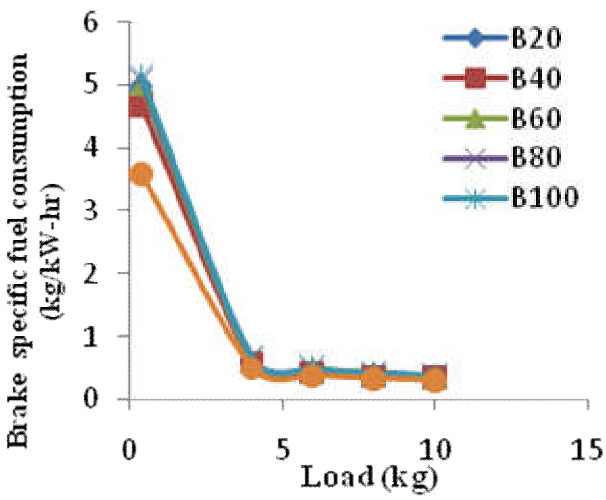

Figure 2. Effect of Load on BSFC for all blends without additive

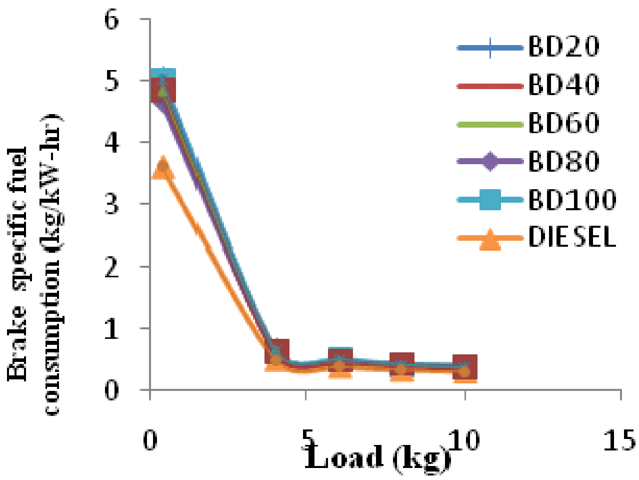

Figure 3. Effect of load on BSFC for all blends with additive

Effect of load on brake thermal efficiency (BTE) for all blends

Figure 4 shows the Brake Thermal Efficiency (BTE) for all B20, B40, B60, B80 and B100 blends. Figure 4 shows that brake thermal efficiency increases with the increase in load as well as increase in percentage of methyl ester. The maximum BTE of 25.54% were obtained for B100 at maximum load (10kg) compared to BTE of conventional diesel oil (26.25%) at same load, which is 2.82% lower than conventional diesel oil. The minimum BTE of 1.66% were obtained for B20 at minimum load (0.4kg) compared to BTE of conventional diesel oil (2.23%) at the same load, which is 3.43% lower than conventional diesel oil.

Figure 5 shows brake thermal efficiency of BD20, BD40, BD60, BD80 and BD100 blends. From Figure 5 it is clear that the maximum BTE of 26.59% were obtained for BD100 at maximum load (10kg) compared to BTE of conventional diesel oil (26.25%) at same load, which is 1.27% higher than conventional diesel oil. The minimum BTE of 1.66% were obtained for BD20 at minimum load (0.4kg) compared to BTE of conventional diesel oil (2.23%) at the same load, which is 3.43% lower than conventional diesel oil. From these data it is clear that the maximum BTE of UCOME without additive is 1.29 % lower than the UCOME blended with diethyl ether additive for B100. Also the minimum BTE of UCOME without additive is equal to the UCOME blended with diethyl ether additive for B20.

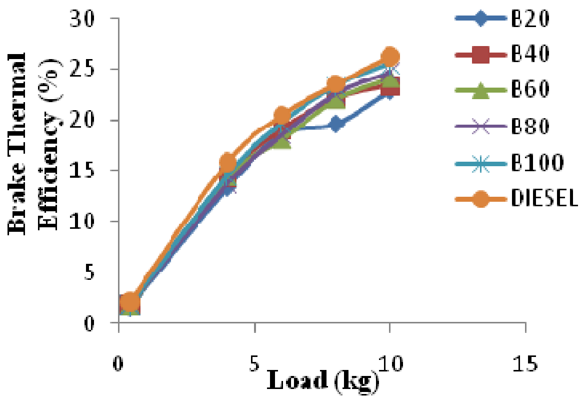

Figure 4. Effect of load on BTE for all blends without additive

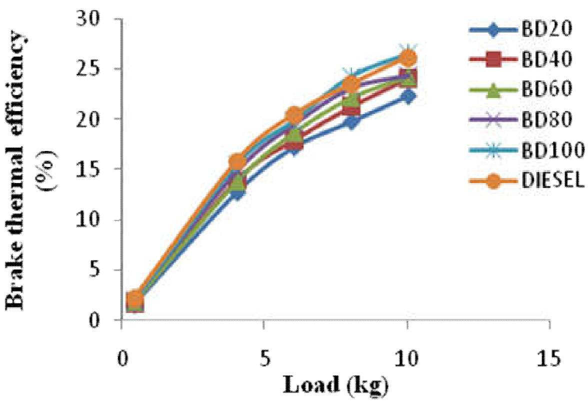

Figure 5. Effect of load on BTE for all blends with additive

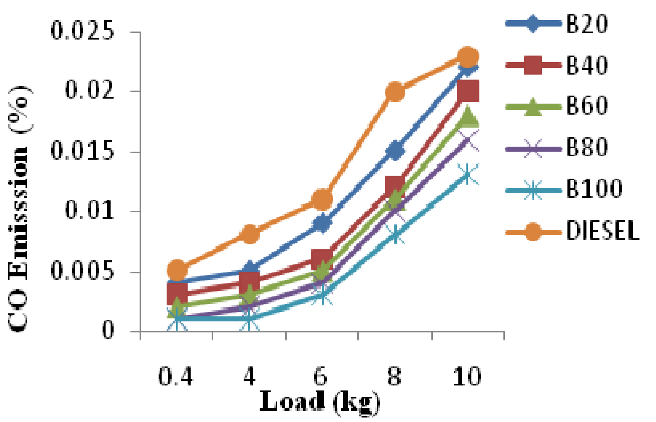

Figure 6. Effect of load on CO emission for all blends without additive

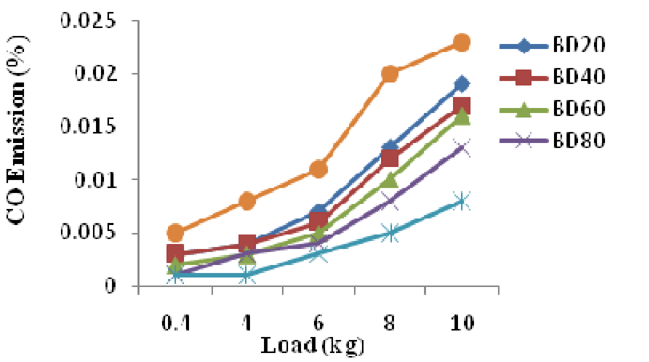

Figure 7. Effect of load CO emission for all blends with additive

Exhaust Emission Characteristics

Effect of load on Carbon Monoxide (CO) Emissions for all blends

CO is present in small quantities in diesel engine exhaust and this is possible because of the fact that the fuel injected during later part of injection does not find sufficient oxygen due to local depletion in certain parts of combustion chamber. The percentage of CO in exhaust varies from 0.1% to 0.75% which is acceptable level. From Figure 6 it is concluded that the CO emission increases with the increase in load and decreases with the increase in methyl ester volume percentage in the blends. The CO emission for all methyl esters and their blends are lower than conventional diesel oil at all loads (0.4, 4, 6, 8 and 10kg) due to higher oxygen content in the used cooking oil methyl ester (UCOME) and their blends with conventional diesel oil at different proportions which results in oxidation of CO during engine exhaust. It is also seen from the Figure 6 that with increase in load CO emission of B20 at minimum load (0.4kg) is 0.004% compared to diesel (0.005%) at same load. CO emission of B20 is 20% lower than conventional diesel oil. Similarly for all medium and high loads the CO emission is 37.5%, 18.18%, 25 and 4.54% for 4, 6, 8 and 10kg respectively. Figure 7 shows that CO emission of BD20 at minimum load (0.4kg) is 0.003% compared to diesel oil (0.005%) at same load. CO emission of BD20 is 40% lower than conventional diesel oil. Similarly for all medium and high loads, the CO emission is 50%, 36.36%, 35% and 17.39% for 4, 6, 8 and 10kg respectively. The maximum percentage of CO emission (0.022%) will be obtained at maximum load of 10kg for B20 and the minimum CO emission of 0.001% observed at minimum load of 0.4kg for B80 and B100 and by using diethyl ether additive CO emission can be reduced to some extent.

Effect of load on Unburned Hydrocarbon Emissions (UNBHC) for all blends

The hydrocarbons in the diesel engine exhaust are composed of a mixture of many individual hydrocarbons in the fuel supplied to the engine as well as partly burned hydrocarbons produced during combustion process. A greater surface to volume ratio of combustion chamber leads to formation of greater fraction of hydrocarbon from the quenched zone. Unburned hydrocarbon emission is also a crucial factor in determining the emission behaviour of diesel engine because it is the direct result of incomplete combustion. Figure 8 shows the variation of unburned hydrocarbon emission with loads for B20, B40, B60, B80, B100, Diesel, BD20, BD40, BD60, BD80 and BD100. The UNBHC emissions of used cooking oil methyl ester (UCOME) and their blends are compared with conventional diesel oil. From Figure 8 it can be concluded that the unburned hydrocarbon emission increases with the increase in load and decreases with the increase in volume of methyl ester proportion in the blend. Also it is seen from the Figure 8, the UNBHC emission of used cooking oil methyl ester and their blends are lower than conventional diesel oil. This is because it contains more amount of oxygen to complete combustion of fuel than conventional diesel oil. From Figure 8 it is clear that the unburned hydrocarbon emission for B20 at minimum load (0.4kg) is 8 ppm compared to 10 ppm of conventional diesel at the same load, which is 20% lower than conventional diesel oil.

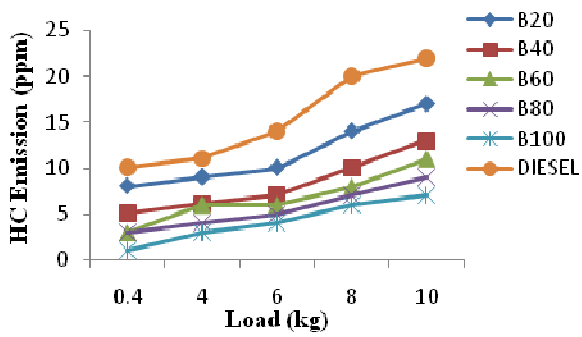

Figure 8. Effect of load on HC emission for all blends without additive

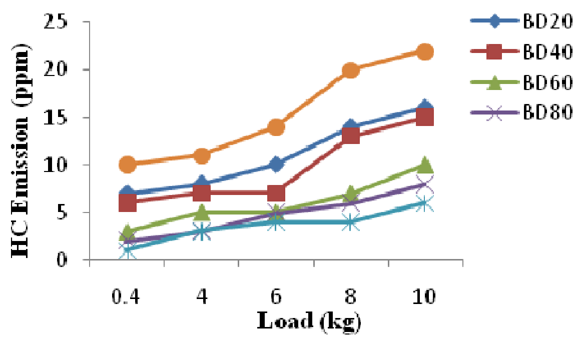

Figure 9. Effect of load on HC emission for all blends with additive

The HC emission increases with the increase in load from 0.4kg to 10kg for all blends and also the HC emission of all blends are lower than conventional diesel oil. Figure 9 shows the unburned hydrocarbon emission for BD20 at minimum load (0.4kg) is 7 ppm compared to conventional diesel of 10 ppm at the same load which is 30% lower than conventional diesel oil. The HC emission extremely increases with the increase in load from 0.4kg to 10kg compared to direct blend with diesel oil for all blends and also the HC emission of all blends marginally decreases with the increase in methyl ester volume and diethyl ether. The maximum amount of HC emission will be obtained at maximum load of 10kg is 17 ppm for B20 and the minimum HC emission of 1ppm for B100 observed at minimum load of 0.4kg. HC emission can be extensively reduced by blending methyl ester with diethyl ether.

Conclusion

Diethyl ether as an additive has less effect on BSFC when its percentage is kept low, but BSFC has decreased with the increase in the percentage of diethyl ether in the blend. This may be due to better utilization of biodiesel at lower percentage of conventional diesel oil and higher percentage of diethyl ether. For instance, BD80 has lower BSFC than B80 at all loads. BTE has increased with the increase in the percentage of diethyl ether. This is due to better utilization of air at lower percentage of conventional diesel oil and higher percentage of diethyl ether. For instance, BD80 has higher BTE than B80 at all loads. Diethyl ether has considerable effect on CO and HC emissions. DEE reduces CO and HC emissions at all load. It may be due to the fact that DEE improves the oxygen content of the blend. The experimental results prove that UCOME and its blends are potentially good substitute fuel for diesel engine in near future when scarcity of petroleum products occurs.

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