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RESEARCH ARTICLE

EXPERIMENTAL INVESTIGATION ON THE PERFORMANCE AND EMISSIONS OF A DIESEL ENGINE FUELLED WITH BUTEA MONOSPERMA BIODIESEL AND ITS BLEND WITH CONVENTIONAL DIESEL OIL

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ABSTRACT

In this study, the performance and emission characteristic tests have been carried out on a single cylinder direct injection diesel engine running under constant speed and variable Brake power. In this study, the engine tests have been conducted with Butea monosperma oil methyl ester (B100) and their blends with conventional diesel oil in the proportions of 10:90 (B10), 20:80 (B20) and 50:50 (B50). 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 BP (1, 2, 3, 4 and 5kW). The performance and emission characteristics of blends are analyzed and compared with conventional diesel oil. The experimental results obtained for BMSOME are comparable with conventional diesel oil with the increase in engine performance and reduction in engine exhaust emissions.

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INTRODUCTION

Energy is the critical factor for human welfare .Development of country and economic growth depends on energy. Energy in environment friendly and renewable form becomes important to search substitute for conventional fossil fuels (Singh *et al.*, 2015). To eliminate or to reduce the dependency of petroleum fuel for our energy requirements and also to reduce the pollutions caused by the combustion of conventional fuel, various researches are being carried out. Biodiesel is one such field where researches are being carried out to reduce the dependence on petroleum-fuel in transportation sector (Agrawal, 2007). The development of biodiesel may reduce worldwide dependence on fuels derived from imported petroleum. The increased use of biodiesel would eventually reduce environmental levels of CO_2 because more plants would need to be grown, which in turn would use atmospheric CO_2 for photosynthesis. Hence, biodiesel produces 78% less CO_2 than neat diesel (ND) at 2661 g per gallon, while ND produces 12,360 g per gallon (Rashid, 2009; U.S. Department of Energy, 2000; Patil *et al.*, 2008).

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In this study the production of biodiesel is carried out by the process of transesterification of Butea monosperma oil with methanol as a solvent, Nano Calcium oxide (CaO) pellets as a catalyst. The obtained Butea monosperma biodiesel (methyl ester) from transesterification process is blended with the petroleum diesel in required proportion such as B10, B20, B50 and B100 and their properties such as flashpoint, firepoint, kinematic viscosity, etc., are examined to study the performance analysis of CI engine fuelled with the Butea monosperma biodiesel and it's blends are used to run a 4-stroke compression ignition engine without any modification. These results are compared with the performance and emission features of the same engine when fuelled with conventional petroleum diesel and tabulated. Qi *et al.* (2009) on evaluating the combustion characteristics of soyabean oil biodiesel and diesel found that biodiesel exhibited a higher peak cylinder pressure and at a lower BMEP, whereas conventional diesel oil exhibited a higher peak pressure and a higher BMEP. They also found that biodiesel emitted a lower amount of CO, HC, NOx, and smoke than diesel oil. Tamilselvan and Nallusamy (2015) evaluated the performance and emission characteristics of blends of pine oil. They found that a 100% pine oil blend exhibited the highest BTE and NOx emissions and lowest CO and HC emissions. The 100% pine oil blend exhibited the highest BTE because it has a lower kinematic viscosity than diesel oil.

Tamilselvan *et al*. (2016) evaluated the methyl ester blends of chicha oil. They found that all biodiesel blends exhibited a higher BTE and EGT than diesel. They also found that an 80% biodiesel blend emitted the most CO, CO_2, and NOx, whereas a 20% biodiesel blend emitted more HC at higher loads. Tüccar *et al*. (2014) evaluated 0, 5, 10 and 20% blends of Citrus sinensis biodiesel. They found that an increase in the biodiesel content in blends reduced torque and power. A general trend of decreasing NOx emissions and increasing CO emissions was observed by Tüccar *et al*. (2009) with all tested fuels. They found that CO emissions reduced and NOx emissions increased with an increase in the biodiesel content.

Studies have shown that, with the use of this Butea monosperma methyl ester as a fuel for diesel engine results in increase in nitrogen oxides (NO_x) emission whereas, hydrocarbon (HC), carbon dioxide (CO_2) and carbon monoxide (CO) emission decreases as compared to the diesel

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 shows the diesel engine test rig with exhaust gas analyzer.

Table 1. Engine Specifications

Engine specifications	
Make and model	Kirloskar TAF-1
No. of cylinders	Single cylinder
Rated power	4.4 kW
Rated speed	1500 rpm
Bore	87.5 mm
Stroke	110 mm
Injector opening pressure	200 bar (20 MPa)
Injection timing	23^0BTDC
No. of injector holes (diameter)	3 (0.3 mm)
Capacity	0.661 L
Cooling	Air-cooled

Plate 1. Engine Test Rig

Performance characteristics of diesel engine

The engine tests have been conducted with used Butea monosperma oil methyl ester (BMSOME) and their blends with conventional diesel oil. The test was conducted with B10 B20, B50, B100.

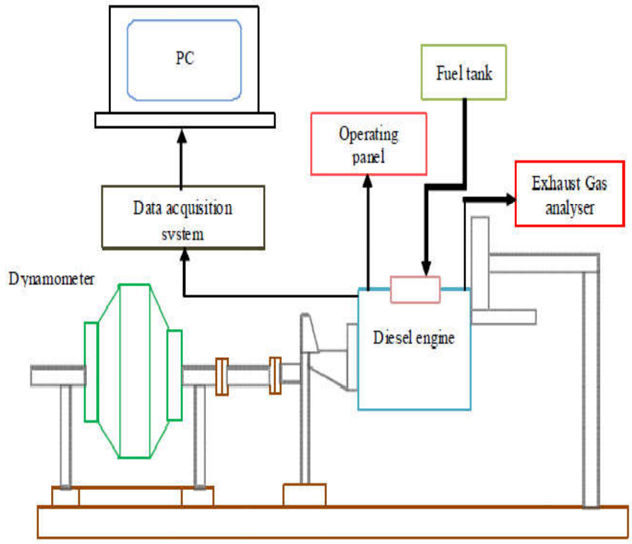

Figure 1. Block diagram of diesel engine

RESULTS AND DISCUSSION

Effect of Brake Power on Brake specific fuel consumption (BSFC) for all blends

Figure 2 shows the Brake Specific Fuel Consumption (BSFC) of B10, B20, B50 and B100. From figure 2 it is clear that BSFC decreases with the increase in BP and increases with the increase in methyl ester blend. For example B50 (0.44kg/kW-hr) of Butea monosperma oil methyl ester (BMSOME) consumes 1.1 times more fuel than B10 (0.4kg/kW-hr) at low BP of 1 kW and almost constant at maximum BP (5 kW). Compared to BSFC of 0.37 kg/ kW-hr at the same BP which is 1.08 times higher than B10. The maximum BSFC of 0.55 kg/ kW-hr were obtained for Diesel oil at minimum BP (1kW) compared to BSFC of B10 (0.4 kg/ kW-hr) at same load. The BSFC of Diesel oil which is 1.375 times higher than B10. The minimum BSFC of 0.4 kg/ kW-hr were obtained for B10 for maximum BP (5kW).

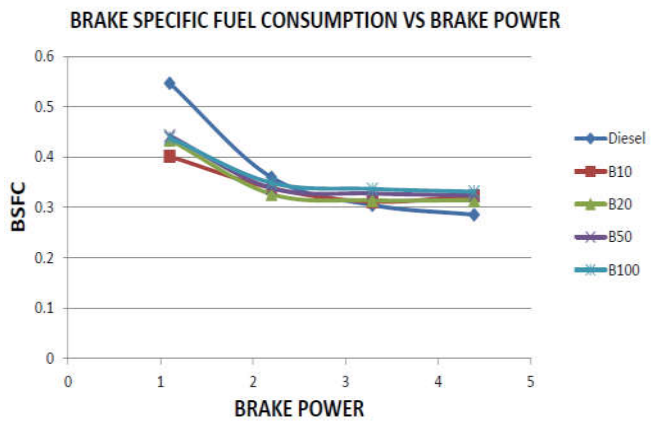

Figure 2. Effect of BP (kW) on BSFC (kg/ kW-hr) for all blends

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

Figure 3 shows the Brake Thermal Efficiency (BTE) for all B10, B20, B50, B100 blends. Figure 3 shows that brake thermal efficiency increases with the increase in load as well as increase in percentage of methyl ester. The maximum BTE of 37.5% were obtained for B100 at maximum load (5kW) compared to BTE of conventional diesel oil (33%) at same load, which is 12% higher than conventional diesel oil. The minimum BTE of 17.5% were obtained for diesel oil at minimum load (1kW) compared to BTE of B10 (22%) at the same load, which is 20.45% higher than conventional diesel oil.

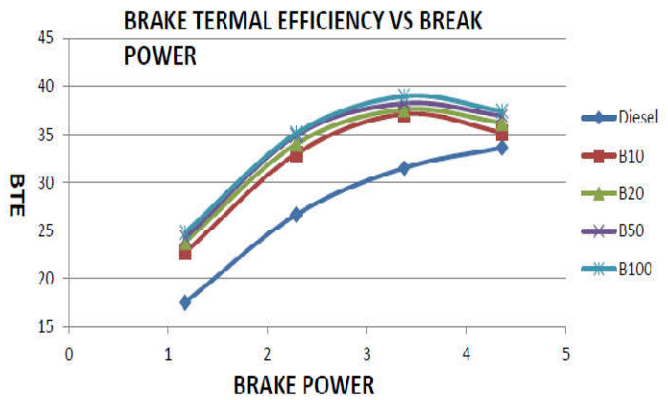

Figure 3. Effect of BP (kW) on BTE (%) for all blends

Effect of Brake Power on Exhaust gas temperature (EGT) for all blends

The variation of Exhaust gas temperature with respect to brake power is presented in figure 4 for different blends & diesel. The engine starts running with low temperature at low brake power. As the brake power increases the temperature inside the engine increases exponentially till it reaches full brake power. This rise of temperature is because of continuous flow of exhaust gas through outlet port. The max EGT of 450^0 obtained for conventional diesel oil for max BP of 5kW. The min EGT of 200^0 obtained for B10 at min BP of 1kW.

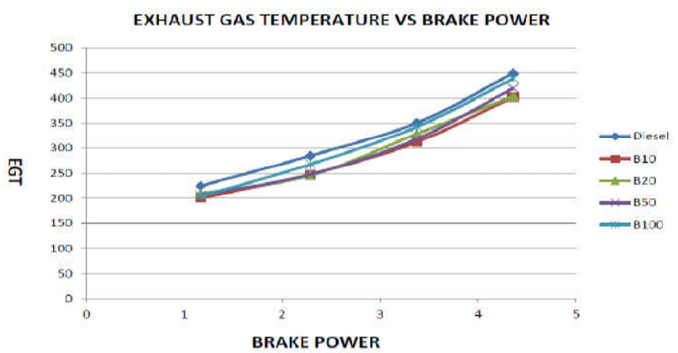

Figure 4. Effect of BP (kW) on EGT (^{0}C) for all blends

Exhaust Emission Characteristics

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

The percentage of CO in exhaust varies from 0.1% to 0.75% which is acceptable level.

From Figure 5 it is concluded that the CO emission increases with the increase in brake Power 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 (1.17, 2.29, 3.375 and 4.36kW) due to higher oxygen content in the methyl ester 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 5 that with increase in brake Power CO emission of B10 at minimum load (1.17kW) is 0.02% compared to diesel (0.05%) at same load. CO emission of B10 is 2.5times lower than conventional diesel oil.

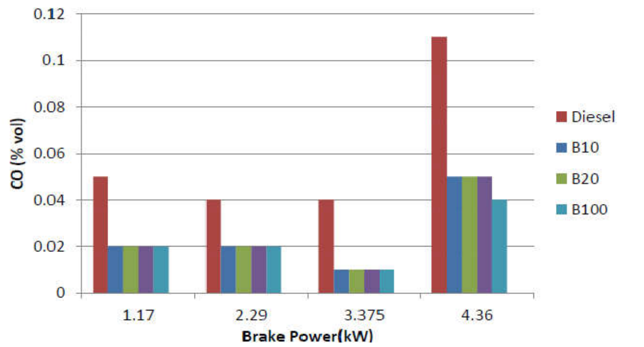

Figure 5. Effect of BP on CO emissions for all blends

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

A 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 6 shows the variation of unburned hydrocarbon emission with brake Powers for B10, B20, B50, B100, Diesel. The min HC emission obtained for B100 at min BP of 1.17 kW and the max HC emission of 21% for diesel oil at a max load of 4.36 kW which is 3.5 times higher than B100.

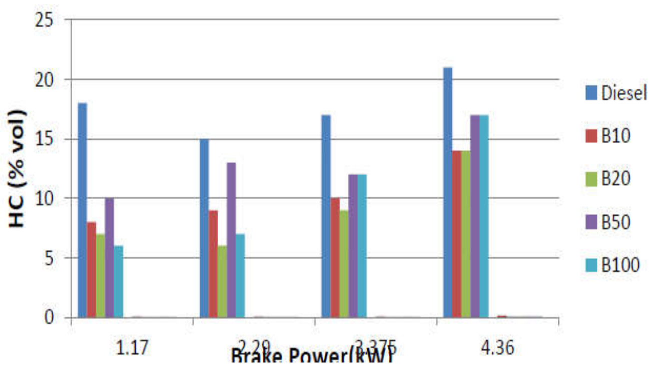

Figure 6. Effect of BP on HC emissions for all blends

Effect of Brake Power on Nitrogen oxides (NOx) for all blends

Oxides of nitrogen in the engine exhaust are a combination of nitric oxide (NO) and nitrogen dioxide (NO_2). Nitrogen and oxygen react at relatively high temperatures. Therefore, high temperatures and availability of oxygen are the two main reasons for the formation of NOx. The NOx emission for all the fuels tested followed an increasing trend with respect to brake power which is as shown in figure 7.

The NOx emission is higher for B100 at higher BP and lower for diesel at lower BP which is 3.28 times lower than B100.

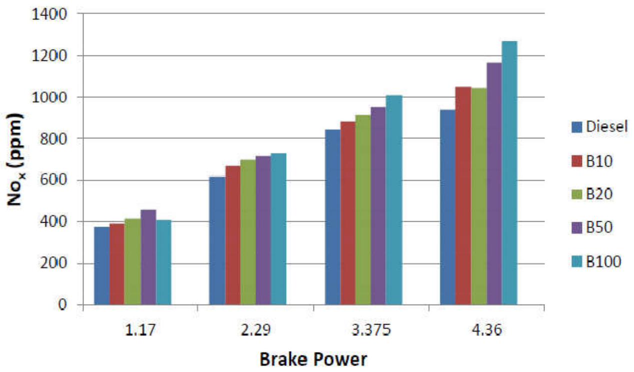

Figure 7. Effect of BP on NOx emission for all blends

Effect of Brake Power on Carbon dioxide (CO_2) for all blends

The CO_2 emission for biodiesel and its blends is lower than that of diesel at all values of brake power as shown in figure 8. As the brake power increases the supply of fuel increases which causes the emission of CO_2 at full brake power to increase. B100 emits least amount of CO_2 (7%) at higher BP of 4.36 kW compared to all the blends so it is preferred.

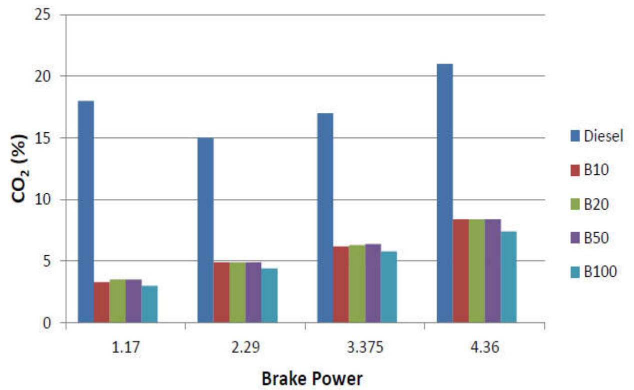

Figure 8. Effect of BP on CO_2 for all blends

Conclusion

Biodiesel has become more attractive to replace the petroleum fuels. As per reputed literature, most of the Transesterification studies have been done on edible oils like rapeseed, soybean, and sunflower etc. by using NaOH catalyst. The non edible oil like Butea Monosperma is the most potential species to produce biodiesel in India which could offer opportunity for the generation of rural employment. The process is based on the alkaline catalysed Transesterification and can be further improved to get high yield and good quality Biodiesel. Engine performance with biodiesel does not differ greatly from that of diesel fuel. The produced biodiesel has good break thermal efficiency in comparison with diesel. A little change in fuel consumption is often encountered due to the lower calorific value of the biodiesel. Most of the major exhaust pollutants such as CO, CO_2 and HC are reduced with the use of biodiesel and the blends as compared to diesel which is very much beneficiary. But NOx emission increase when fuelled with diesel-biodiesel fuel blends as compared to conventional diesel fuel. Among the blends, B50 shows the better performance at different loads

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