Experimental Investigation of Performance and Emission Characteristics of Diesel Engine with Jatropha Biodiesel Blends

Amol Bharat Varandal, & Prof. Nitin Malviya

***Abstract*— The scarcity of reserves of petroleum and environmental pollution issues have led to the search for more environmental friendly and renewable fuels. This study evaluates the use of jatropha biodiesel blends as an alternative fuel for diesel engines. This experimental analysis is carried out to determine the effect of using biodiesel blends (i.e. B20 to B50) on the performance and exhaust emissions in a Variable Compression Ratio (VCR) diesel engine equipped with eddy current dynamometer. The thermal performance and emissions characteristics are evaluated by operating the engine at preset compression ratio 18, and varying loads in steps of 3 kg. The thermal performance parameters evaluated are brake thermal efficiency (BTHE), and brake specific fuel consumption (BSFC) and Exhaust Gas Temperature (ExGT). The emission constituents measured are carbon monoxide (CO), unburnt hydrocarbons (UHC) and Oxides of nitrogen (NOx). It was found that the performance parameters of the biodiesel blends did not differ greatly from those of diesel fuel. A slight decrease in thermal efficiency, with an increase in brake specific fuel consumption (BSFC), was noticed with the biodiesel blends. The CO and HC emissions were reduced for the blends while NOx was increased remarkably for the biodiesel blends.**

***Index Terms* — Biodiesel, Diesel Engine, Engine Performance, Emission Characteristics.**

I. INTRODUCTION

The continual rise in the prices of crude oil and depletion in the reservoirs of the crude oil, increasing hazard to environment due to exhaust emissions, the problem of global warming have adversely impacted the developing countries like India. From the point of view of long term energy security, it is necessary to develop new alternative fuels with properties comparable to petroleum based fuels. Jatropha biodiesel as an alternative fuel for diesel engine offers an advantage because of its comparable fuel properties with diesel fuel. It was described that engine parameters such as CR and Load were found to have major effect on performance and emissions of diesel engine when run with biodiesel and its blend with diesel [1–3]. Hence an experiment is carried out to study the performance of a diesel engine operated with biodiesel blends at varying load.

Manuscript received March 06, 2015.

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It is possible to use jatropha biodiesel in the diesel engines as a fuel if cleaned and properly converted to combustible diesel oil.

II. II. EXPERIMENTS

Experimental study is carried out on a Kirloskar make, 1C, 3.5 kW, constant speed 1500rpm Variable Compression Ratio (VCR) diesel engine. Performance tests are conducted on an engine at fixed compression ratio of CR18 and varying load (25%, 50%, 75% and 100%) using jatropha biodiesel with diesel blends (B20 to B50) to determine BSFC , BThE and ExGT. Engine emissions such as CO, HC and NOx were measured by using gas analyzer.

2.1. Experimental set-up

The specifications of the Kirloskar engine are given in Table 1. The engine with fixed compression ratio can be modified by providing additional variable combustion space. Tilting cylinder block method is one of the arrangements which can be used to vary the combustion space volume. The experimental study is conducted at various loads and hence an accurate and reliable load measuring system is a must. The load measuring system of this experimental test rig consists of a dynamometer of eddy current type, a load cell of strain gauge type and a loading unit. The load is applied by supplying current to the dynamometer using a loading unit. The load applied to the engine is measured by a load cell.

Table 1 Engine Specifications

Manufacturer	**M/s Kirloskar Oil Engines Ltd.**
Model	**TV 1**
Cycle	**4 Strokes**
Rated Power	**3.5 kW @**
Type of Combustion System	**Direct Injection**
No. of Cylinders	**1 Cylinder**
Bore/Stroke	**87.5 /110 mm**
Compression Ratio	**17.5 : 1 Modified to**
Swept Volume	**0.661 cc**
Type of Cooling	**Water Cooled**
Fuel Injection	**Inline**

2.2. Biodiesel

The biodiesel obtained from jatropha and its blend with diesel was considered in this study. The jatropha biodiesel is purchased from commercial supplier from Pune. The pure diesel is purchased from local petrol pump. The properties of the biodiesel blends are as given in table 2.

Table 2 Properties of Diesel and Jatropha Biodiesel Blends

Properties	Diesel	J20	J30	J40	J50
Density (Kg/m^3)	849	857	861	865	869
Viscosity (@ 40°C)	4.38	4.47	4.51	4.56	4.61
CV (KJ/Kg)	42100	41352	40984	40619	40257

III. RESULTS AND DISCUSSION

3.1. Engine performance

3.1.1 Brake Specific Fuel Consumption

After the engine reached the stabilized working condition for each test, fuel consumption, torque applied and exhaust temperature were measured from which BSFC, BTE were computed. The variations of these parameters with respect to load are presented in figure 1 to 3, at compression ratio of 18.

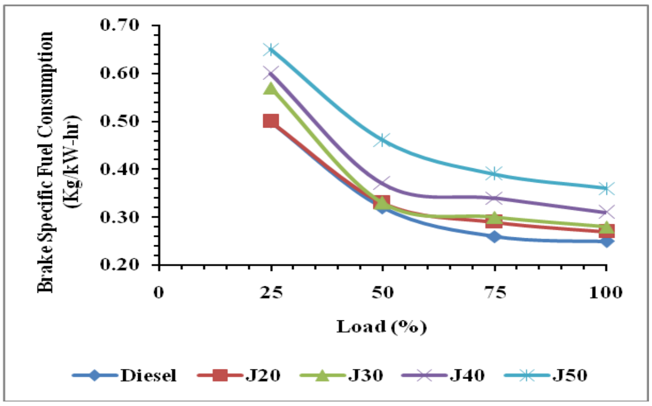

Figure 1 Variation of BSFC with Engine Load at Constant Speed 1500rpm at CR 18

It can be seen from Figure 1 that the BSFC lines for different blends came closer to each other as load was increased from 25 to 100%, indicating a comparable performance of the blends at higher load. The lowest BSFC values obtained using diesel, B20 and B30, for full load were 0.25, 0.27 and 0.28 kg/kW-hr respectively. The variation in BSFC of different blends was less at full load conditions than at part load; possibly due to increased temperatures and consequently increased efficiencies of the engine. Due to their low volatility and higher viscosity, biodiesel might be performing relatively better at higher compression ratios. The BSFC was observed to decrease sharply with increase in load for all fuels. The main reason for this could be that percent increase in fuel required to operate the engine is less than the percent increase in brake power due to relatively less portion of the heat losses at higher loads. From the above discussions it could be concluded that the BSFC is a function of biodiesel blend, and load.

3.1.2 Brake Thermal Efficiency

The variation of BThE of VCR engine obtained in this study is shown in Figure 2 as a function of load for compression 18.

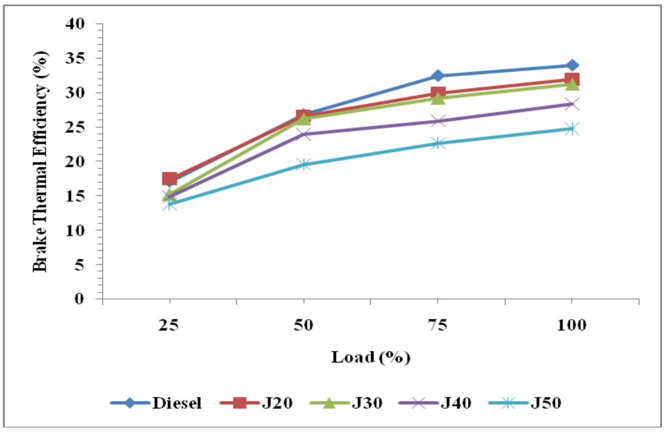

Figure 2 Variation of BThE with Engine Load at Constant Speed 1500rpm at CR 18

It can be observed from these figures that the parameters, which were responsible for giving best fuel economy, also resulted in showing maximum BThE.

The highest value of BThE using diesel was 34.02% whereas it was 31.99% and 31.27% in case of B20 and B30 respectively. B50 gives BThE of 24.87% which lowest for all blends at same load conditions. Based on these results it can be concluded that the performance of the engine with biodiesel blends is comparable to that with diesel, in terms of BThE. The change of load from 25% to full load resulted in increase in BThE for biodiesel blends. This could be due to the fact that biodiesel blends had lower volatility as compared to diesel and therefore the improvement in their combustion characteristics might have been relatively more at higher temperatures resulting from higher loads than the improvement in case of diesel with the same rise in load. The brake thermal efficiency of the engine was low at part loads as compared to the engine running on full load.

3.1.3 Exhaust Gas Temperature

The variation of exhaust gas temperature with the engine load for all the blends of jatropha biodiesel are shown in figure 3 at the constant speed of 1500rpm.

Figure 3 shows that as the load increases the exhaust gas temperature increases for the biodiesel blends. The diesel fuel shows less exhaust gas temperature as compared to all the biodiesel blends at all loads.

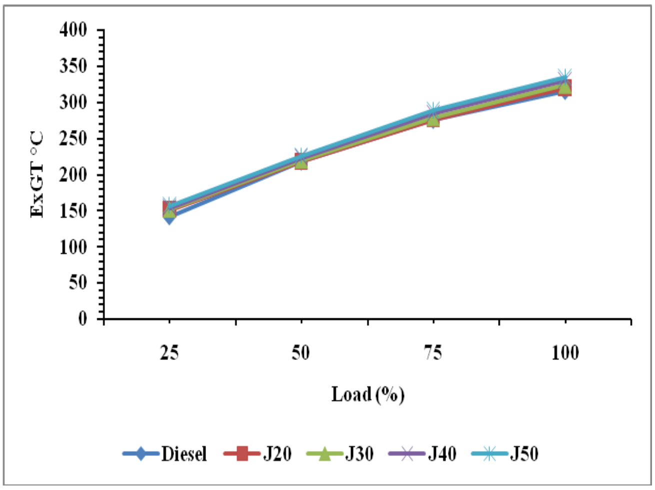

Figure 3 Variation of ExGT with Engine Load at Constant Speed 1500rpm at CR 18

The exhaust gas temperature for the diesel , J20, J30, J40 and J50 are 315 °C, 320°C , 324°C,331 °C and 335°C respectively. It can be seen from the above figures that as the biodiesel blend ratio increases the exhaust gas temperature also increases. This is because more oxygen content in the biodiesel blends as compared to diesel fuel which leads to complete combustion of biodiesel. It may be because of higher viscosity, late burning of fuel particles take place on the walls of cylinder which will lead to higher gas temperatures as compared to other blends.

3.2. Engine Emission Characteristics

3.2.1 Carbon Monoxide

Figure 4 shows that the CO emissions for biodiesel blends are lower when compared to diesel.

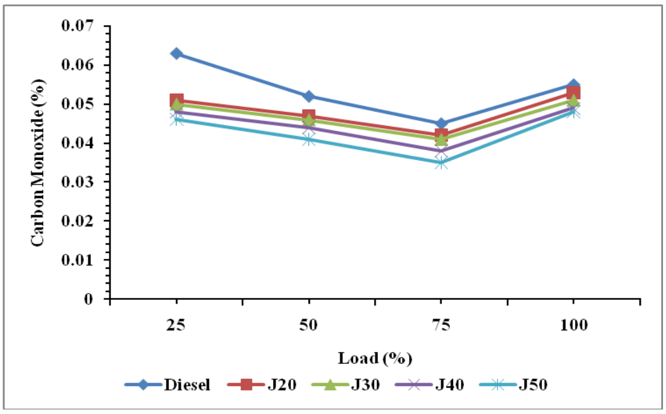

Figure 4 Variation of CO with Engine Load at Constant Speed 1500rpm at CR 18

The presence of CO in the exhaust gas of an engine is a representation of the chemical energy of the fuel which is not fully utilized. Generally, the CO emission is affected by the fuel type, combustion chamber design and atomization rate, engine load and engine speed. It is observed from the above figures that the CO emission decreases with the increase in load upto 75% load and at full load it sharply increases. The possible reason for this sudden increase may be incomplete combustion at full load. With percentage of biodiesel increasing in blend fuel, CO emissions of blend reduce. The reasons for this behavior might be to more oxygen in biodiesel and better oxidation reactions during the expansion stroke.

3.2.2 Hydrocarbons

Figure 5 shows the HC emission for biodiesel blends are lower that the diesel for all loads.

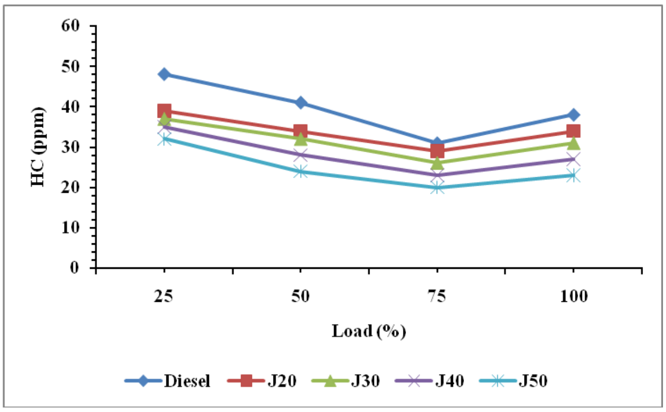

Figure 5 Variation of HC with Engine Load at Constant Speed 1500rpm at CR 18

B50 showed lower HC followed by the B40, B30 and B20 for all loads. The trend is similar to that noted in earlier studies. It is because of high hydrocarbon oxidation late in the expansion stroke. Complete combustion of blends takes place producing less amount of unburned HC. The HC emissions decreased as the oxygen in the combustion chamber increased, either with oxygenated fuels or oxygen-enriched air. On the other hand, although biodiesel is less volatile than diesel fuel, higher final distillation points have been reported for diesel fuel. This final fraction of diesel may not be completely vaporized or burnt, thereby increasing UHC emissions. Therefore, lower UHC emissions can be expected when biodiesel and biodiesel-diesel blended fuels are used in a diesel engine.

3.2.3 Oxides of Nitrogen

Figure 6 shows that the NOx emission for biodiesel blends and diesel at constant speed 1500rpm. The NOx emission for biodiesel blends is more compared to diesel. With increase in blend ratio the NOx emission increases. This can be attributed to the variation of the maximum combustion temperature inside the cylinder for both blends.

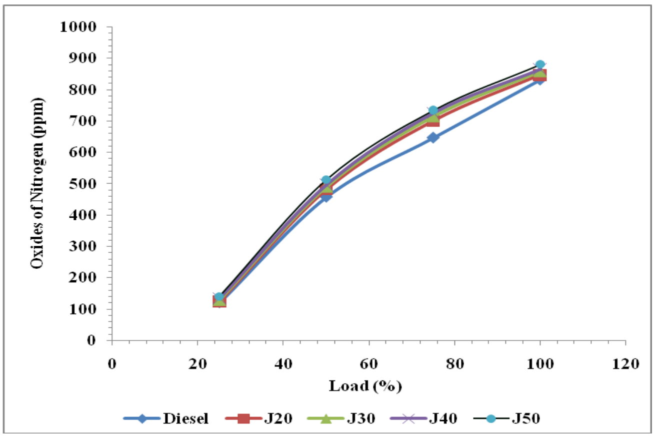

Figure 6 Variation of NOx with Engine Load at Constant Speed 1500rpm at CR 18

It can be observed that as the engine load increases, more fuel is injected and the heat transfer per cycle decreases, resulting in higher temperatures of the burning gas. This led to an increase in the formation of NOx emissions. The biodiesel and its blends were found to emit a larger amount of NOx, while diesel fuel produced the lowest amount of NOx emission. The NOx increase in the emissions may be associated with the oxygen content of the biodiesel, since the fuel oxygen may provide additional oxygen for the formation NOx. One potential drawback to the use of biodiesel is evidently the increase in NOx emissions. Although the increase is small in comparison to the reductions in other regulated pollutants, such NOx increases may be problematic for ozone non-attainment areas.

IV. CONCLUSIONS

Based on the results of this study, it can be concluded that the BSFC, BThE and ExGT of the engine are function of the biodiesel blend and load. For the same operating conditions, performance of the engine reduced with increase in biodiesel percentage in the blend. However, with increase in load this difference was reduced and the engine performance became similar to that of diesel. Biodiesel could be safely blended with pure diesel. B20 shows similar performance at any of the load as that of the diesel. Biodiesel blends have shown reduced emissions of CO and HC than that of the diesel. The NOx emission is more for biodiesel blends than the diesel fuel.

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