 | Volume 3 | Issue 8| Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Experimental Investigation of a CRDI Engine Performance Operating With High FIP at Various Injection Timings under LTC Mode

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ABSTRACT

Present experimental work is carried out for the study of effect of biodiesel blends, fuel Injection timing (FIT), Fuel injection pressure (FIP) along with exhaust gas recirculation (EGR) ratio in CRDI diesel engine for performance (BTE) and NOx emissions. The parameters of the engine were measured and analyzed at JB10,JB20 biodiesel blends, 10°,14°,18° CA BTDC Injection timings with 400,500 and 600 bar FIP for EGR rates of 10% and 20% at constant speed. The results revealed about improvement of performance in terms of brake thermal efficiency for blends JB10, JB20 blends with advancement of injection timing, higher FIP also a slight increase NOx emissions were observed when working with biodiesel. Usage of EGR reduced the NOx emissions without affecting its efficiency, hence it can be optimized that engine operating with the combination of biodiesel blends and along with EGR rate culminates into NOx reductions without compromising its performance.
Keywords: CRDI Engine, Injection timing, Injection pressure, Biodiesel, EGR

I. INTRODUCTION

As per ASTM standard biodiesel is defined as "a fuel comprised of monoalkyl esters of long-chain fatty acids derived from vegetable oils or animal fats, designated B100"[1], it could become an alternative renewable fuel for C I engines in the context to depletion of fossil fuels. In general diesel-powered engines are extensively used in power generating and transportation sectors because of their performance, robustness [2,3], regrettably, exhaust emissions churned out from these C I engines like particulate matter (PM) and nitrogen oxides (NO_x) are major contributors to environment degradation, especially in metro cities. Hence either any one or combination of many from the list of alcohols, biodiesel or vegetable oil may perhaps offer feasible solutions of environmental preservation and blended with mineral diesel which hardly affects the its performance [4]. The concern of higher NO_x level in the engine exhaust could be countered by using Low temperature combustion (LTC) strategy, a promising solution that limits the NO_x and soot formation simultaneously without compromising its performance.

1.1 Low Temperature Combustion (LTC)

Is a one of the in-cylinder technic that mainly focuses to lower the temperatures inside cylinder during combustion such a strategy is called as low temperature combustion (LTC), this can be achieved by External exhaust gas recirculation (EGR) method. This strategy effectively used for total controlling the emissions and improving efficiency [5].

II. EXPERIMENTAL SETUP AND METHODOLOGY

Properties of mineral diesel and biodiesel blends used for experimental analysis are determined as per standards (ASTM) and listed in Table 1. A CRDI engine experimental setup (Figure 1) consists of appropriate instrumentation like dynamometer (eddy current type) for loading, fuel measuring unit and AVL DI Gas 444 five gas analyser for oxides of notrigen (NO_x in ppm) measurement. The engine performance and NO_x were recorded at constant engine speed of 2200 rpm by varying load from zero to 100% with step up of 25% each time. Initially experiments conducted with diesel fuel, considering it as a reference one remaining set of experimentation continued with biodiesel blends. Here Jatropha curcas biodiesel has been blended by volume basis, JB10 consists of 10% of biodiesel, similarly JB20 and JB30. Along with blends, 10% and 20% exhaust gas recirculation ratio are applied for various FIP and FIT. During experimentation reading of three sets were noted after achieving steady state condition and experimental outcome are compared and presented here.

Table 1. Properties of fuels.

Details	**Diesel**	**JB10**	**JB20**	**JB30**
Density (kg/m3)	831	842	846	852
Lower calorific value (MJ/kg)	42.50	40.65	40.20	40.03
Viscosity (cSt)	3.40	3.70	3.85	4.05

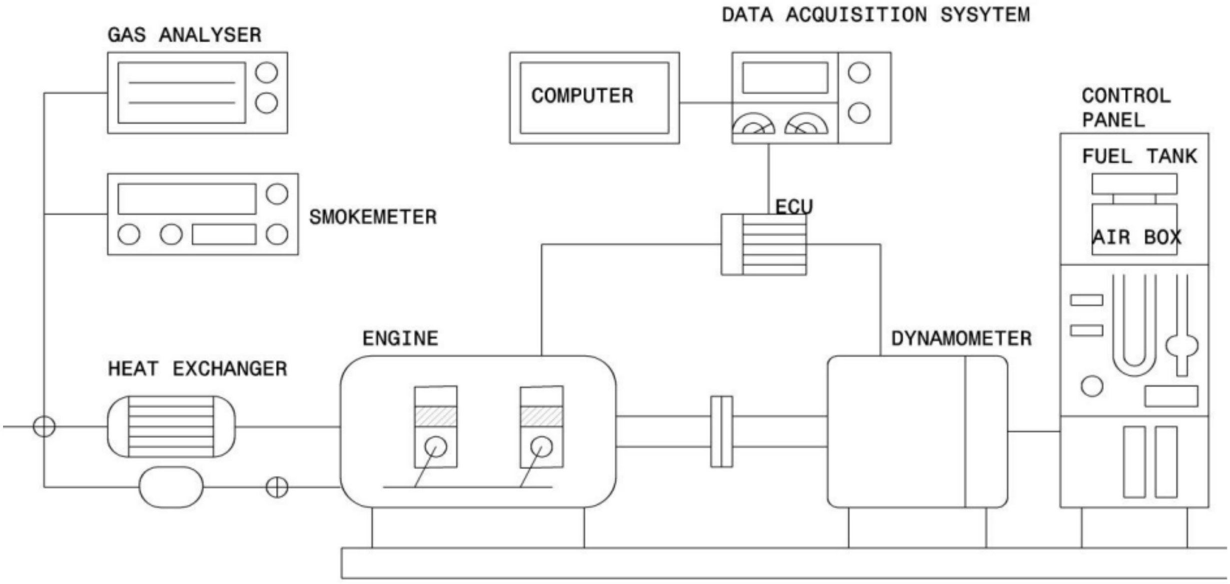

Figure 1. Experimental setup

III. RESULTS AND DISCUSSION

3.1 Brake thermal efficiency (BTE)

Performance of an engine by applying biodiesel blends, EGR rate at various fuel injection timing and injection pressure is indicated in Figure 2. Initially engine operated with 14° CA injection timing and FIP of 400 bar for diesel, then continued with JB10, JB20 and JB30 blends for EGR rates of 10% and 20%. It is to be noted that brake thermal efficiency increases as increase in load, this trend is because of decrease in heat losses during engine operation [6,7].

Further, increase in BTE around 0.4% and 1% at 400 bar FIP, 14°CA with usage of JB10 and JB20 blends is indicated in Figure 2 (a). This is because of molecules of oxygen present in the blends which leads to better combustion [8,9]. Further lower value of 1.4% is noticed at JB30 is due to higher viscosity and lower heating of the blend.

Figure 2 (b-d) shows 10% and 20% EGR rate application with blends. Enhancement in performance of about 1.2 % for 600 bar FIP with JB20 blend and 10% EGR rate is observed compared with diesel fuel operation, here unburnt hydrocarbons in the exhausts re-enter combustion chamber by mixing with fresh air and burn hence improvement in performance is noticed [10-14].

Further, the performance at various injection pressure and Injection timings were analyzed. Of the two injection timing chosen, one is advanced (18°CA) and another is retarded (10°CA), each by 4°CA BTDC. At Retarded FIT of 10 °CA BTDC, reduction in efficiency is observed whereas at advanced FIT of 18°CA BTDC, the improvement in performance is noticed, these results were noticed for all fuels (Figure 2 b & c). Decline in BTE at retarded FIT is mainly due to reason that fuel has less time available for combustion as it is injected nearer to TDC leading to incomplete combustion of fuel and the reduction is around 0.4% by compared to 14°CA BTDC for 600 bar FIP. Advanced FIT allows better mixing because of longer ignition delay hence advanced injection timing results in improved combustion leading to higher BTE. For same FIP of 600 bar, the enhancement of 0.3% in BTE is seen with blend JB20 for EGR 10% rate compared with standard condition at 75% load condition.

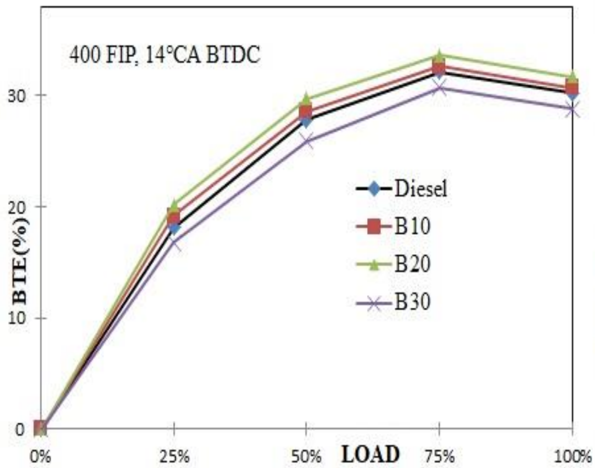

Figure 2 (a)

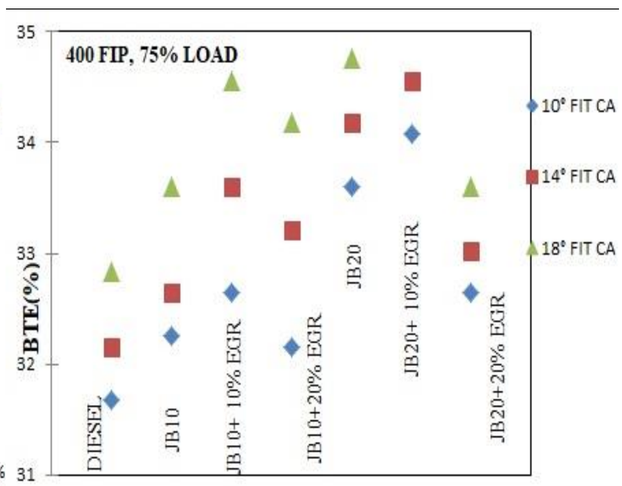

Figure 2 (b)

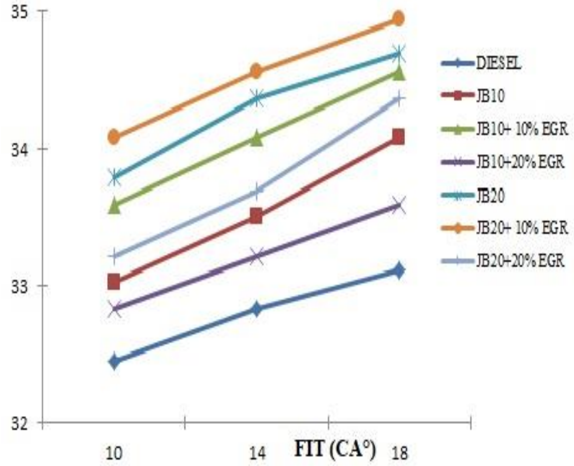

Figure 2 (c)

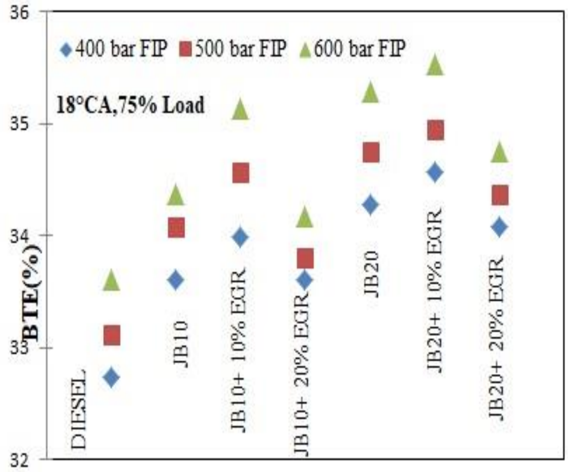

Figure 2 (d)

Results of variation in performance with increase of FIP is as shown Figure 2 (d), The highest enhancement of BTE is noticed at 600 bar FIP by 0.6% and by 0.3% at 500 bar as compared to 400 bar FIP at a fixed injection timing for blend JB20 at 18°CA without EGR condition. This is because fuel injected at higher pressure results faster and better combustion as a result of reduced injection duration and fine droplets of spray [15].

3.2 Nitrogen Oxides (NO_x) Emissions

Oxides of nitrogen (NO_x) are formed by combination of nitrogen and oxygen at high temperatures generated due combustion [14]. Usage of biodiesel blends in engine leads to higher quantity NO_x formation compared to diesel is due to presence of higher level of oxygen molecule in the biodiesel and higher combustion temperature. For all tested conditions, highest NO_x is observed at JB20 blend. The increase in NO_x emission for JB10, JB20 and JB30 is around 10%, 14%, 7% respectively for 400 bar FIP at 14^0 CA, when compared with diesel at full load condition as shown in Figure 3 (a).

Reduction in NO_x formation is noticed with the application of EGR rate as shown in Figure 3 (c-d). This is due to the reason that exhaust gas recirculation dilutes concentration of oxygen during combustion process which reduces the flame temperature thereby limiting the formation of NO_x. Advantage of NO_x reduction has occurred at full load condition and 20% EGR rate, higher the amount of exhaust gas recirculation rate more the percentage of reduction in NO_x emission level due to lower volumetric efficiency at that particular condition, so reduction rate is depends upon the quantity of EGR rate. The reduction is 11% and 16% for 10% and 20% EGR rate respectively for JB20 blend ratio at 18°CA FIT (Figure 3 b).

At the advanced FIT of 18°CA BTDC, fuel gets much time to mix well and burn leading to peak temperatures and pressures in the cylinder resulting more level NO_x emissions. Reverse trend is seen at retarded timing of 10°CABTDC because of lower peak temperatures resulting in diminishing of NO_x emission in the exhausts. The increasing order is about 5% and 8% respectively for 14°CA and 18°CA compared with fuel injection timing 10°CA BTDC at 75% load condition for JB20 fuel with 600 bar FIP (Figure 3 c).

Further, higher FIP leads to more concentration of nitrogen oxides from engine as shown in Figure 3 (d), because of higher in-cylinder temperature generated due to better atomization of fuel spray. 15% is highest increase is noticed at 600 bar FIP (18°CA FIT) at 75% load condition compared with lower FIP.

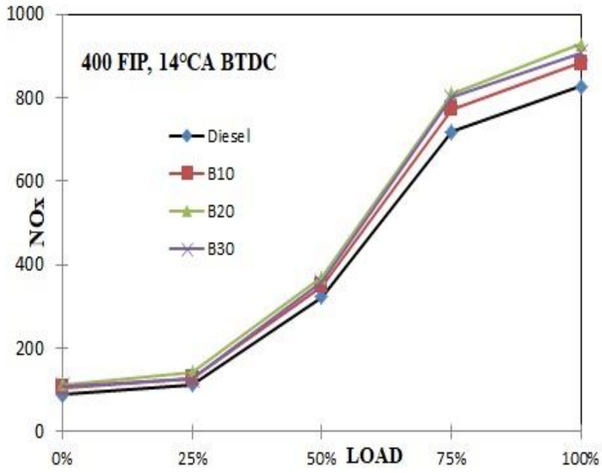

Figure 3 (a)

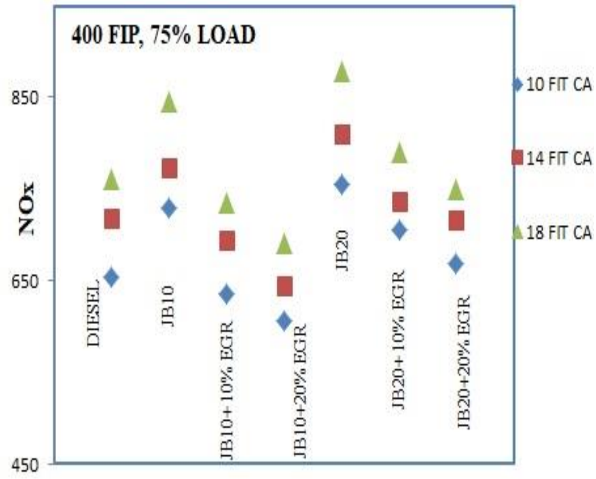

Figure 3 (b)

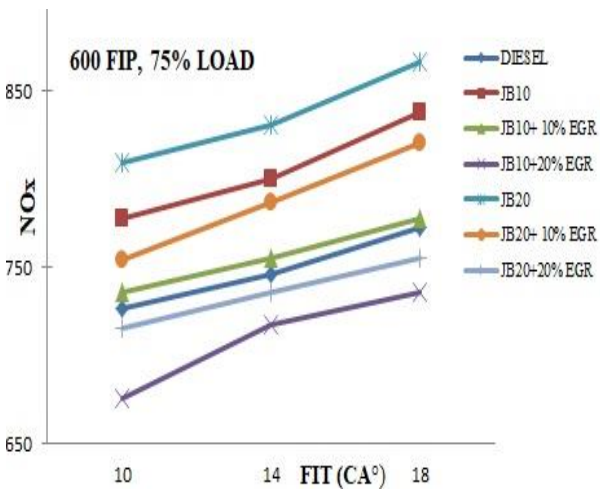

Figure 3 (c)

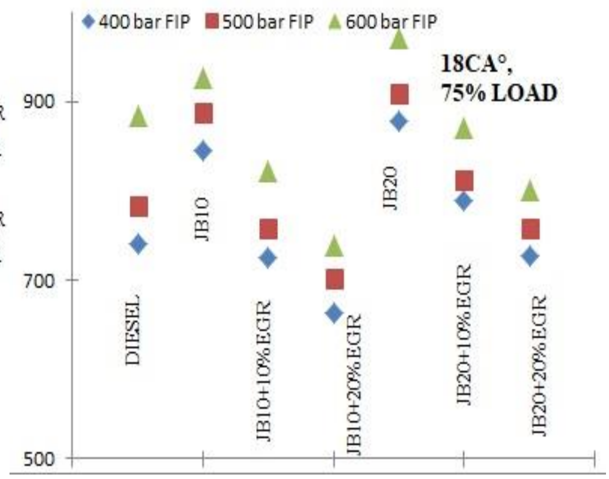

Figure 3 (d)

IV. CONCLUSIONS

Following conclusions were drawn based on the experimental study

- Biodiesel blend up to 20% can be used in CRDI engine and an improvement of around 1% in performance is noticed for JB20 and 10% EGR rate for 18°CA at 600 FIP bar
- An improvement in performance is observed at higher FIP of 600 bar compared to 400 and 500 bar FIP. Similar trend is also noticed at advanced FIT 18° CA BTDC compared to 10° & 18° CA BTDC.
- Increasing fuel injection pressure and advancement of fuel injection timing increases the brake thermal efficiency and as well emissions of nitrogen oxides (NO_x)
- The increase in NO_x emission is noticed with usage of biodiesel blend compared to with diesel fuel. NO_x emission also increased with higher FIP and with advancement of fuel injection timing.
- Decrease in NO_x emissions noticed with application of EGR rates.
- Net effect of combining biodiesel blend (B20), EGR (10%) and higher fuel injection pressure (600bar) results better performance with reduced NO_x emissions compared against reference fuel (diesel) operating conditions.

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