HIGHER INJECTION PRESSURES COUPLED WITH EGR IN IMPROVING EMISSION/PERFORMANCE OF DIESEL ENGINE USING SIMAROUBA BIODIESEL

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Abstract: Although Biodiesel provides better results at higher injection opening pressures, it is limited by higher NOx emission. This can be mitigated adding by Exhaust gas recirculation. In this paper, the combined effect of the injection opening pressure viz. 220 bars, 240 bars and Exhaust gas recirculation (EGR) viz.5% and 10% on engine performance and emission parameters of CI engine fueled with Simarouba biodiesel and Diesel blends are presented. The increase of EGR rates from 5% to 10% resulted in 10% and 14% reduction of NOx at 220 bars and 240 bars respectively. The Higher injection pressure of 240 bars enhances BTHE by 6.12% for B25 blend while B50 offers only 4.3% increment in BTHE. The experimental results show that increased EGR rates result in considerable reduction in NOx formation simultaneously worsens engine performance and later found to be better with an application of higher injection pressures.

Key Words: **Engine performance, injection opening pressure, exhaust gas recirculation, simarouba biodiesel, NOx**

1. INTRODUCTION

Alcoholic esters are explored as a substitute of conventional fossil Diesel which can be derived from natural oil resources comprising fair amount oxygen content. Biodiesels are considered as a alternate fuel to Diesel engine which can be used without any major engine modification. Also these Alcoholic esters constitute low levels of sulphur; hence the toxicity of fuel is under control [4]. Ministry of New and Renewable Energy, Govt. of India, is policing use of Bio-fuels and targeting to employ at least 20% bio-fuel blends as fuel for conventional power sectors and transportation needs [1,35]. Continuous research on biodiesel fueled diesel engines by many researchers points to a highlighting facts like improved performance, lesser CO, UBHC and higher NO_x emissions. In order to limit NO_X the engine parameters like, static injection timing (SIT) [3, 35], Injector opening pressure (IoP) [2, 15, 17, 18 and 19] and CR [3, 9] are varied regularly but desirous results are to be sought till date. Glaude P A et. al. [21] concluded by stating that alcoholic esters are bounded with Oxygen molecularly and helps in dipping soot levels and other harmful emissions, as oxygen molecules in biodiesel encourages the oxidation of unsaturated hydrocarbon species. Additionally the inculcation of oxygen molecules in fuel highly affects the in-cylinder temperature [22, 23]. Gumus M. et. al. [8] analyzed the effect of fuel injection pressure on performance and emission parameters of DI diesel engine fueled with biodiesel-diesel blends. Diesel engine was operated at four preset injectors which could inject fuel at 180, 200, 220 and 240 bars. Results revealed that at higher pressures, Specific Fuel Consumption to load reduced for higher concentration of biodiesel in blend and increase in NO_x and CO_2 emission. Jindal S. Nandwana et.al. [9, 10] deduced that higher compression ratio and injection pressure resulted in increased thermal efficiency and reduced BSFC. Also higher compression ratio and injection pressure resulted in lower levels of smoke, UBHC and oxides of Carbon [14]. Mahesh P. Joshi et. al. [15, 16] investigated the effect of different injection pressures (210, 220, 230 and 240 bar), injection timings (19^0, 23^0, 27^0 bTDC), varying nozzle holes (3 and 4 each of 0.3 mm diameter) and compression ratio on diesel engine fueled with blends of cotton seed oil methyl ester and diesel. The optimized engine operating parameters were found to be 19^0 SIT bTDC, 230 bar IP, 4-hole nozzle of 0.3 mm dia. and 17.5 CR. The combined effect of injection timing and injection pressure on diesel engine fueled with waste cooking oil biodiesel blends [17] were investigated and found that advancement of static injection timing and elevated injection opening pressure for biodiesel blends in CI engine provides increased NOx and reduced smoke. So the contribution of Biodiesel as alternate fuel is limited unless and until levels of NOx are not controlled. EGR is one of popular methods which assist in lowering oxides of nitrogen emission [3, 25, 33 and 34]. Rajesh kumar et.al. [25] Stated that NOx formation can be challenged by employing an EGR up to 30%. T. Jacobs [28] found external EGR more effective compared to internal EGR system since, internal EGR provides very short time of response and also the gases cannot be cooled effectively. A part of exhaust gas is diverted to intake manifold where it gets mixed with the incoming air before combustion in combustion chamber [29]. It is quite a known fact that Biodiesel being heavier fuel than diesel, engine requires higher Compression ratio, Higher Injection opening Pressure and more time for atomization. But by doing so the fuel combustion efficiency can be enhanced and collaterally levels of NOx comingout of the engine emissions also increases. So to quench the above research gap, the control of NOx levels with combined effect of higher levels of injection opening pressure and EGR is employed in the present research.

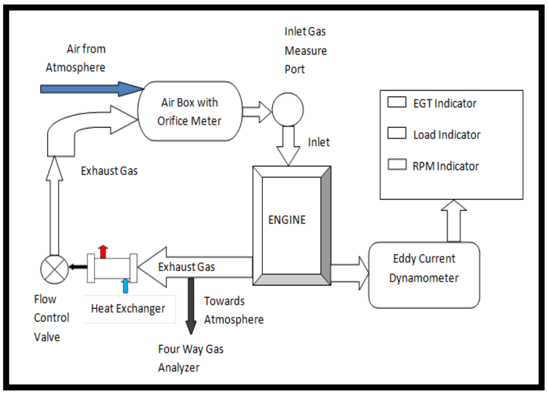

Fig. 1. Schematic Diagram of Engine Setup

Table 1. Specifications of Engine

Manufacture	Rocket engg. Corpn. Ltd.
SFC	251 g/kWhr.
Rated power	4.8 kW @ 1500 RPM
Standard CR	17.5:1
Bore	87.5 mm
Stroke	110 mm
Injection Timing	23^0 before TDC
Inlet valve open bTDC	4.5 bTDC
Exhaust valve open	35.5 bBDC
Inlet valve close	35.5 aBDC
Exhaust valve close	4.5 aTDC

Table 2. Device Specifications and Terminology

Device specification	Range	Accuracy	Uncertainties
Carbon monoxides (CO)	0-10.00%	±0.01%	±0.1
Carbon Dioxides (CO_2)	0-20.00%	±0.01%	±0.15
Oxides of Nitrogen (NOx)	0-5000 ppm	±1 ppm	±0.2
Oxygen (O2)	0-25.00%	±0.01%	±0.1
Hydrocarbons (HC)	1-1500 ppm	±1 ppm	±0.2
Exhaust gas temp. (EGT)	0-500^{0}C	±1^{0}C	±0.1
Tachometer	0-10000 rpm	±10 rpm	±0.2
Fuel flow meter	1-30 cc	±0.1 cc	±0.5
Pressure transducer	0-500 bar	±1 bar	±0.1

Table 3. Uncertainties in results

Calculated results	Uncertainties
Brake Power	±2.0
Specific fuel consumption	±1.8

2.EXPERIMENTAL SETUP AND PROCEDURE

The experimentation was performed on a single cylinder diesel engine provided with EGR setup. The specifications of the engine are tabulated in table 1. The exhaust emissions were measured using a Naman make analyser where the gases like CO was measured using non-dispersive infrared (NDIR) detectors where as oxides of nitrogen was measured using excited chemiluminescence, and the HC with heated FID. Experimentation were formed using two blends of simarouba biodiesel viz B25 and B50 for varying engine parameters like Injection opening pressure(IoP), percentage of exhaust Gas in inlet air mixture (%EGR) and load. Amount of EGR was varied on evaluation of amount of Carbon di-oxide at inlet to outlet.

3. ANALYSIS OF EXPERIMENTAL ERRORS AND UNCERTAINTIES

Accuracy and uncertainties of devices and calculated results are given in table 2, 3. Total uncertainties (TUC) were found using the equation.

$$TUC = \sqrt[2]{1^2 + 2^2 + 0.1^2 + 0.1^2 + 0.15^2 + 0.2^2 + 0.2^2 + 0.1^2 + 0.1^2 + 0.5^2} = 2.32\%$$

4. RESULTS AND DISCUSSION

The Observation recorded in two parts i.e. performance evaluation and emissions coming out from engine. The performance parameters considered were Brake thermal efficiency (BTE), Brake specific fuel consumption and Exhaust gas temperature (EGT) rise in 30 sec. The emission contents considered were carbon di-oxide (CO2), Carbon monoxide (CO),Oxides of nitrogen (NOX) and Unburnt hydrocarbons (UBHC).

Performance Parameters:

BRAKE THERMAL EFFICIENCY (BTHE)

Brake thermal efficiency of the engine was studied at different engine torque, for various blends and EGR rates at 220bars and 240 bars injection opening pressures as shown in Fig 2. The Thermal efficiency tends to increase with concentration of biodiesel but tradeoffs were observed when EGR rate was increased. The above observation was also significant for both blends. Also it was found that the higher injection pressure improves the thermal performance of the engine providing better combustion for blends B25 and B50.

The highest BTHE recorded was 30.90% for IoP of 240 Bar with 5% EGR for B25 blend. But for same IoP and Blend, increase of EGR rate to 10% drops down the BTHE to 29.9%. This might be due to of displacement of a few amount of oxygen in the incoming air by the re-circulated exhaust gas. Also, this leads to unavailability of oxygen content in the air, which tends to show incomplete combustion phenomenon. Similar phenomenon of the varying IoP was observed by Channapattana et.al.[2] who determined experimentally effect of injection opening pressure on DI engine fuelled with Honne Biodiesel and found that higher IoP causes better atomization guaranteeing enhanced combustion of blends.

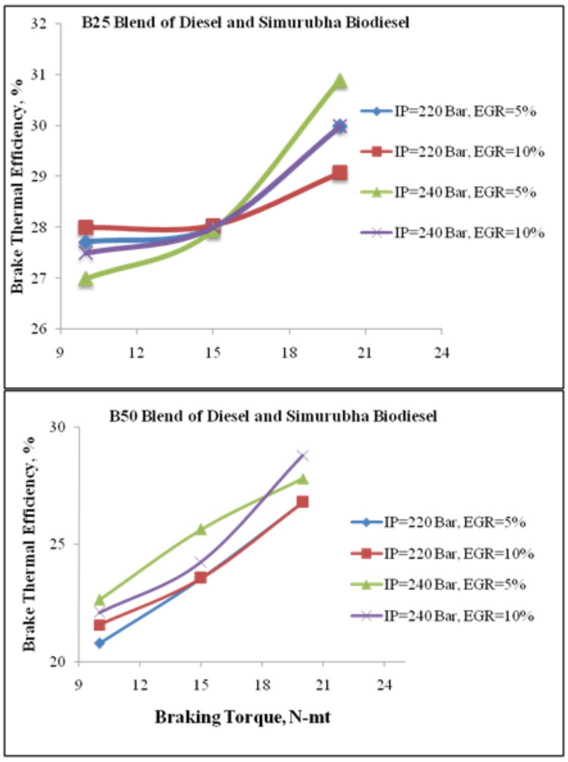

Fig 2: Effect of BTHE with load at different injection pressures and EGR rates

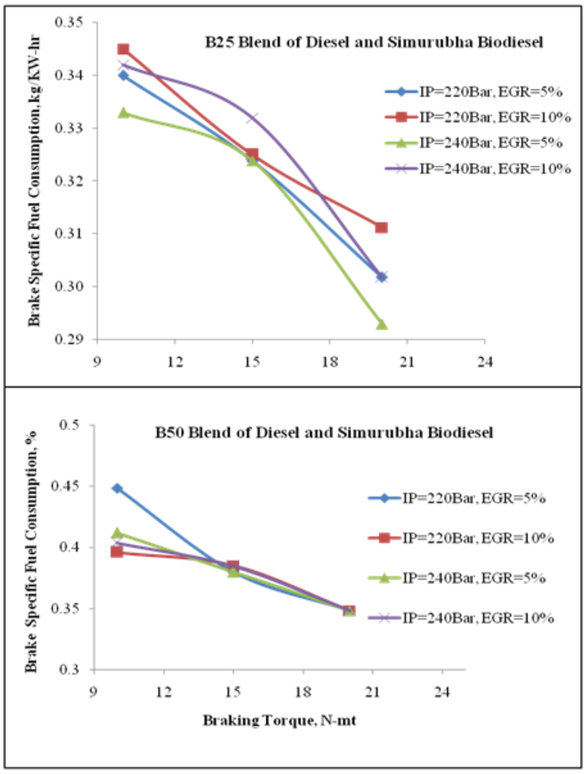

Fig. 3: Effect of BSFC with load at different injection pressures and EGR rates

BRAKE SPECIFIC FUEL CONSUMPTION (BSFC)

It is quite desirous for an alternate fuel to show similar bsfc values of that of conventional diesel but as the net heating value of Biodiesel and its blends is lower in comparison to diesel the BSFC value tend to shoot up. As said the Brake Specific Fuel Consumption of simarouba biodiesel blends B 25 and B50 are illustrated graphically in fig 3, where it could be observed that the BSFC values tend to diminish for all incrementing loads for all blends or IoP or EGR%. Even Harish Venu et. al. [32] recorded the same phenomenon where the BSFC recordings reduced with increase in engine load and at reduced injection timing. Also, the combined effect of increase of EGR and IoP brings rise BSFC values. This is mainly because of opposing effects of increase in BSFC with rise in EGR rate [36] and decrease in BSFC with rise in IoP.

Emission Parameters:

CARBON DI-OXIDE (CO_2) EMISSION

The indication of Carbon Di-oxide emission signifies complete combustion and its variation is observed in fig. 4. It was found that CO_2 emission rises with increase in torque for all injection pressure, blends and EGR rate. The lowest carbon di-oxide emission 3.39% observed for blend B25 at injection pressure 220 bar and 10% EGR while, the highest CO_2 emission 9.06% observed for blend B50 at 240 bar injection pressure and 5% EGR. Higher injection pressure ensures significant injection delay period, it results in better atomization of fuel which further improves the combustion process and discharges higher carbon dioxide as a byproduct. Increase in IoP increases CO_2 emission and increase in EGR rate reduces CO_2. [34] S V Channapattana et. al.[2] too found substantial increase in CO_2 emission with increase in IoP and it further found to be slightly increased with increase in biodiesel blend proportion.

CARBON MONOXIDE (CO) EMISSION

The carbon monoxide coming out of combustion chamber signifies incomplete combustion. The increase of IoP was found to reduce CO in the emittents [2] and is shown in figure 5. It was observed that the CO increases with increase in EGR rate for same injection pressure and Blend, but further increase in injection pressure results in reduced CO for same blend and EGR rate due to increase in ignition delay that improves the rate of combustion. Higher rates of EGR were found to reduce the cylinder temperature. It is well known that the CO emission at lower cylinder temperature can't be completely converted into carbon di-oxide since the conversion from CO to CO_2 is endothermic in nature. This higher cylinder temperature can be achieved by increasing the IoP. Higher blend proportion compromises with more oxygen molecules which tend to increase CO_2 formation. N. K. Miller Jothi et. al. [34] found lower CO emission without EGR while, CO emission found significant at 5% EGR rate and 40% load, it further increases with EGR up to 20%.

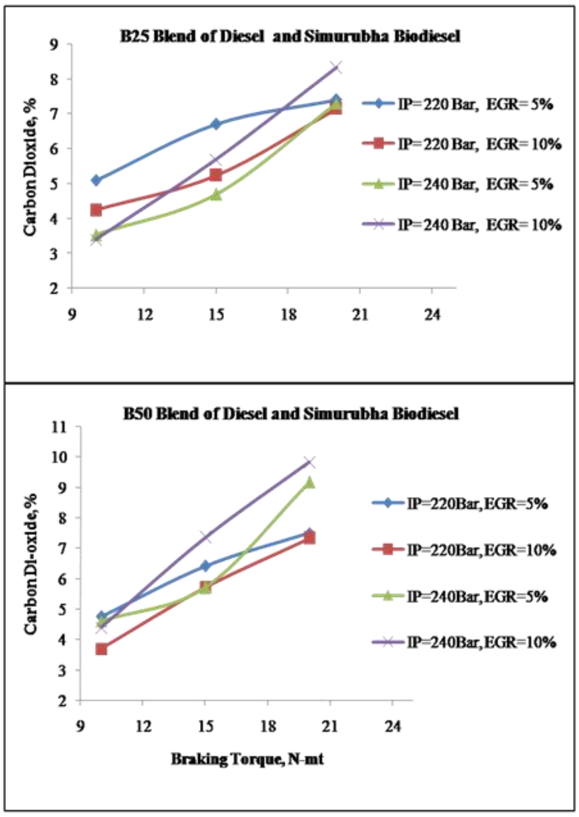

Fig.4: Effect of CO_2 with load at different injection pressures and EGR rates

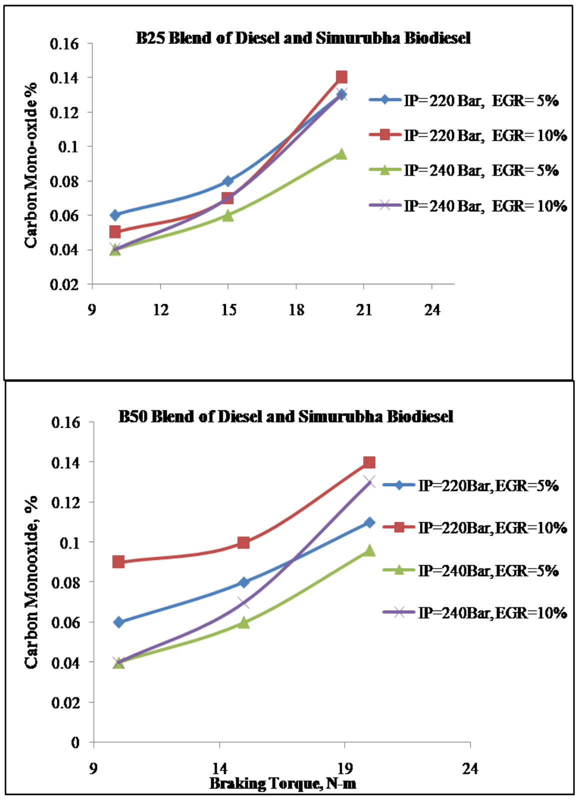

Fig 5: Effect of CO with load at different injection pressures and EGR rates

UNBURNT HYDROCARBONS (UBHC) EMISSION

UBHC emission is factor of incomplete combustion, so the introduction EGR was found to be promoting UBHC. At higher IoP's tends to balance this effect of Incremented UBHC and which can point shoot the fact that Combustion was found to better at higher IoP's in spite of EGR. Fig 6 explains that UBHC emission was found to be increased consistently with % EGR for same IoP but, considerable reduction in amount of UBHC emission was observed when IP increases from 220 bars to 240 bars. The lowest value of UBHC was recorded at IoP of 240 Bar and 5% EGR rate for both blends of B25 and B50. It can be concluded that HC emission to be increasing with increase in% EGR. It was observed that with increase in the injection pressure the HC emission increases. **B. Rajesh kumar et. al. [33]** detected considerable increment in HC emission with increasing EGR rates. This is mainly due to the higher EGR rates results in lower flame temperature and it further deteriorates the combustion process.

OXIDES OF NITROGEN EMISSION

Fig 7 indicates the variation of Oxides of nitrogen with load for B25 and B50 blends respectively. From many investigators who have varied IoP in Diesel engine have found that engine conveys greater NOx at the amplified fuel IoP's due to reduced ignition delay and higher in-cylinder temperature. NOx control can be policed through exhaust gas recirculation method.NO_X emittents are higher at higher IoP's. This was due to better atomization leading to peak combustion temperatures inside the cylinder. As the EGR rate increases at same IoP, NOx values get reduced. The lower values of Oxides of Nitrogen observed for higher Blend concentration and (B50 blend) at IoP 240bars and EGR rate of 10%. **N. K. Miller Jothi et. al. [34]** observed that without EGR and with higher portion of biodiesel the NOx emission was more. Also NOx emission increases with blend proportion because of presence of higher oxygen content [2].

5. CONCLUSION

The thermal efficiency of engine found to be less with incrementation of % EGR. Also trade off's observed in the case of oxides of Nitrogen emission. Variation of higher IoP's lead in enhancement of BTHE by 6.12% for B25 blend while, B50 offers only 4.3%. Increase of % EGR from 5% to 10% results in 10% and 14% NO_x reduction at 220 bars and 240 bars respectively. For combustion it is desirous to use higher IoP with EgR as performance and emission standards are in order with respect to conventional fuel. EGR technique in spite of being controller for oxides of nitrogen coming out of engine yet is limited in usage as it contaminates oxygen content reduces the combustion efficiency and provides recycled un-burnt hydrocarbons.

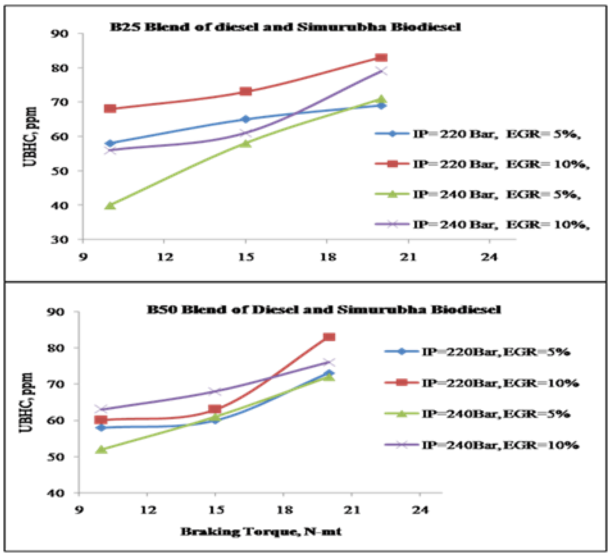

Fig 6: Effect of HC/UBHC with load at different injection pressures and EGR rates

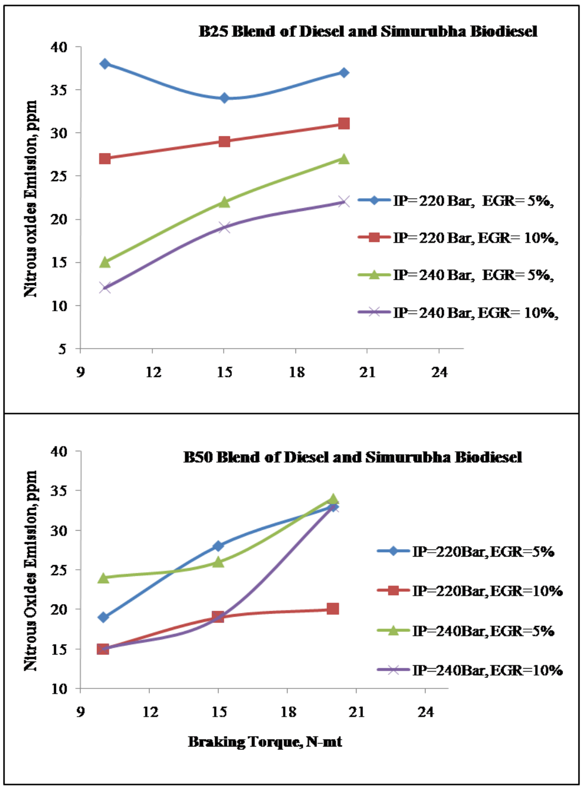

Fig 7: Effect of NO_x with load at different injection pressures and EGR rates

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