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Effect of Exhaust Gas Recirculation on Performance and Emission of Direct Ignition Diesel Engine Fuelled with Diesel-Biodiesel-Ethanol Blend

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ABSTRACT: The present study focused on effective utilization of ternary fuel blend in DI diesel engine operating at different exhaust gas recirculation. In this work an effort was made to compare the performance, emission characteristics of the diesel engine fuelled with pure diesel, pure Mahuva biodiesel and the blend of diesel-biodiesel-ethanol (ternary fuel blends). It was observed that the performance of the diesel engine with ternary fuel blends is as par with pure diesel. The experiments were conducted on single cylinder direct injection diesel engine at constant speed 1500 rpm with rated power 5.2 kW. The engine was run without EGR, and 5% EGR. The results obtained were compared with that of pure diesel fuel. The results show 5% EGR was suitable for ternary fuel blends, which can be used as an effective alternative fuel for diesel engines.

Key words: Ternary fuel, performance, EGR, biodiesel

I. INTRODUCTION

The increase on energy demand, environmental concern of the global warming and increasing in the petroleum price in the worldwide has greatly increased the interest of using alternative fuels in internal combustion engines. For the past few decades, a lot of effort has been made to reduce the dependency on petroleum fuels for power generation and transportation all over the world. Among the proposed alternative fuels, biodiesel and alcohols have received much attention in recent years for diesel engines and could be one remedy in many countries to reduce their oil imports [S.A. Sahir 2014]. Biodiesel and alcohol have many advantages over diesel as renewable and domestically produced energy resources. Moreover, they are recognised as environmentally friendly alternative fuels [Istvan Barbas 2010]. The production of biodiesel from the microalgae as the third generation biodiesel feed stock, the systematic characterisation of algae biomass, algae oil and algae biodiesel to establish the potential of microalgae for biodiesel production [[M.G. Dastidar, *et al* 2001].

Among the alcohols ethanol is used as an effective alternative fuel, a fuel extender, an oxygenate for diesel engines. Ethanol is regards as a renewable fuel because it can be made from many types of raw materials such as corn, sugar cane, sugar beets, molasses, cassava, waste biomass materials, sorghum, barley, maize, etc. Generally, ethanol can be blended with diesel and can be used as an alternative fuel for diesel engine with no engine modifications [Alan C. Hansen 2005]. Ethanol is slightly immiscible with diesel which leads to phase separation and instability of the blend. The phase separation can be prevented in two ways: by adding an emulsifier that acts to suspend small droplets of ethanol within the diesel fuel, or by adding a co-solvent that acts as a bridging agent through molecular compatibility and bonding to produce a homogeneous blend [M. Lapuerta, et al 2007]. Biodiesel is known to act as an additive or emulsifier due to its potential to improve the solubility of ethanol in diesel fuel and could improve lubricity of ethanol over a wide range of temperatures.

The blends of diesel-biodiesel-ethanol (Ternary blend) are stable well below sub-zero temperatures and have shown equal or superior fuel properties to diesel fuel and can be effectively used as an alternative fuel for diesel engines [Fernando, *et al* 2004].

II. EXPERIMENTAL WORK

The experiment was conducted on direct injection diesel engine fuelled with ternary fuel blend at constant engine speed 1500 rpm. The rated power of the engine is 5.2 kW. The engine specifications are given in table 1.. Ternary fuel blends were prepared with various proportions of three fuels, diesel, pure Mahuva biodiesel and ethanol.

The proportions are:

- 70% diesel-20% biodiesel-10% ethanol (B20)
- 60% diesel-30% biodiesel-10%ethanol (B30)
- 50% diesel-40% biodiesel-10% ethanol (B40

Figure 1 shows the arrangement of value and manometer to regulate exhaust gas recirculation to the diesel engine.

Fig. 1. Pictorial view of EGR arrangement to diesel engine.

Table. 1: Engine specifications.

Specifications	Details
Number of strokes	4
Power output	5.2 kW/ 7BHP
Bore x Stroke	87.5 mm x 110 mm
Number of cylinders	One
Constant speed	1500 RPM
Orifice diameter	20 mm
Injection pressure	180-220
Swept volume	0.662 liter
Nozzle hole diameter	0.223 mm

III. RESULTS AND DISCUSSIONS

Performance characteristics:

Fig. 2 and fig. 3 shows the variation of brake thermal efficiency (BTE) with brake power (BP) for without EGR and 5% EGR respectively. The BTE increases with increase in load. For different fuel blends, BTE is more for 5% EGR than without EGR; it may be due to recirculation of unburned hydrocarbon. Figure 2and 3 shows BTE of diesel fuel is 28% and 29% without EGR and with 5% EGR respectively. BTE of B20 is more than all other ternary fuel blends. BTE for B20 is 27% and 28% without and with 5% EGR respectively. The BTE of B20 is 1% less than that of pure diesel fuel it is because of lower heating value.

Fig. 4 and fig. 5 shows variation of brake specific fuel consumption (BSFC) with BP without and with 5% EGR respectively. It is observed from the graph that the BSFC is fairly independent of EGR at lower rates. The BSFC reduces with load for all the fuel modes. It is almost same at medium and higher load. The BSFC of pure biodiesel and other blends is higher than that of pure diesel fuel; it is due to lower calorific value, higher viscosity, density and boiling point. BSFC with 5% EGR is more than without EGR for all fuel blends, it is due to the formation of rich mixture because of less oxygen availability.

Fig. 6 and fig. 7 shows the variation of exhaust gas temperature (EGT) with BP without and with 5% EGR respectively. It is observed from the graph that exhaust gas temperature increases with increase in load. Without EGR, EGT of biodiesel & other blends are almost same as of diesel fuel at all load conditions. EGT decreases with increase in EGR rate. The reason may be lower availability of oxygen for combustion and higher specific heat of intake air temperature. Addition of ethanol reduces the EGT; it is due to high evaporative heat and low heating values, which takes off the heat from the combustion space.

Emission characteristics:

Figure 8 and figure 9 shows the variation of carbon monoxide (CO) with BP without and with 5% EGR respectively. The CO emissions are almost same at low and medium loads and increased significantly at higher loads with all the fuel modes. The CO emissions of the ternary blends were not much different from that of conventional diesel at low and medium loads. However the CO emission of these blends decreased significantly, when compared with those of conventional diesel at full load.

This is due to enrichment of oxygen owing to the ethanol and biodiesel addition, in which an increase in the proportion of oxygen will promote the further oxidation of CO. The CO increases with 5% EGR rates this is due to lower availability of oxygen, which leads to incomplete combustion.

Figure 10 and figure 11 shows the variation of carbon dioxide (CO_2) with BP without and 5% EGR respectively. The CO_2 emissions increased with load for all the fuel modes. The CO_2 emissions increase with increasing biodiesel content in the blend; this is due to the high carbon-to-hydrogen ratio and the presence of oxygen in the biodiesel molecule. On the other hand, a substantial reduction of CO_2 emission occurs when ethanol is added. This is due to low carbon-to-hydrogen ratio in ethanol molecule. Carbon dioxide decreases with 5% EGR it is due to reduction in the availability of oxygen for complete combustion.

Figure 12 and figure 13 shows the variation of unburned hydrocarbon (UBHC) with BP without and 5% EGR respectively. The HC emissions were minimum at medium load and maximum at low and full load of the engine for all the fuel modes. HC emissions reduce with increasing biodiesel content in the blend. This is due to higher cetane number of biodiesel, causes shorter ignition delay and improves combustion efficiency, thus reducing the unburned hydrocarbons; in addition, the presence of oxygen in the biodiesel molecule intensifies the post-flame oxidation of UBHC in the combustion chamber.

Brake thermal efficiency:

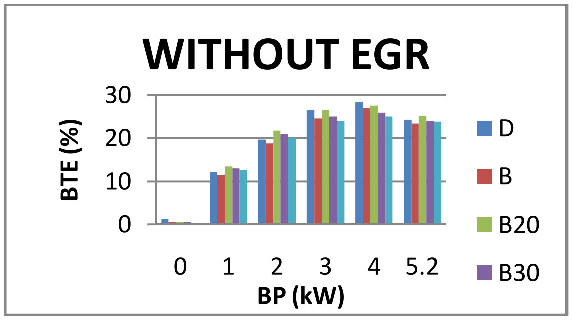

Fig. 2. Variation of brake thermal efficiency with BP, without EGR.

The addition of ethanol increases the HC emission. It is due to lower cetane number of ethanol, ignition delay increases which causes incomplete combustion. With increase in EGR levels, HC emission also increases. This is due to oxygen deficiency for complete combustion.

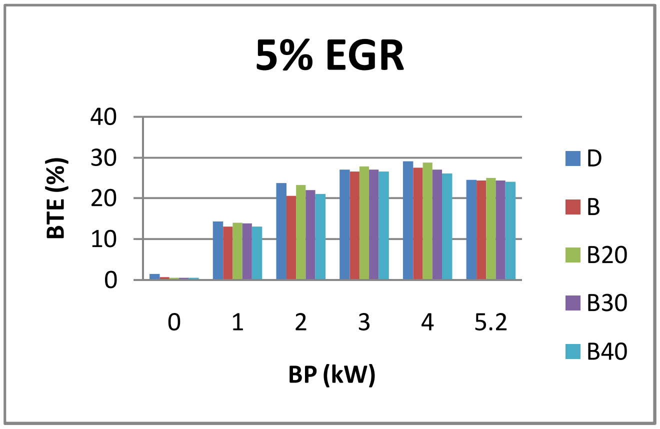

Fig. 3. Variation of brake thermal efficiency with BP at 5% EGR.

Brake specific fuel consumption:

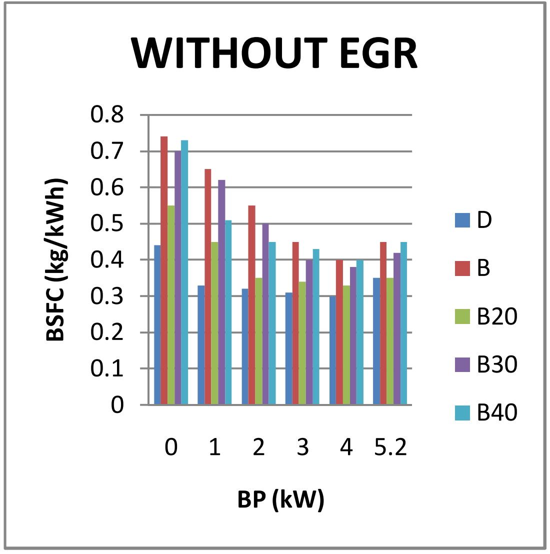

Fig. 4. Variation brake specific fuel consumption with BP without EGR.

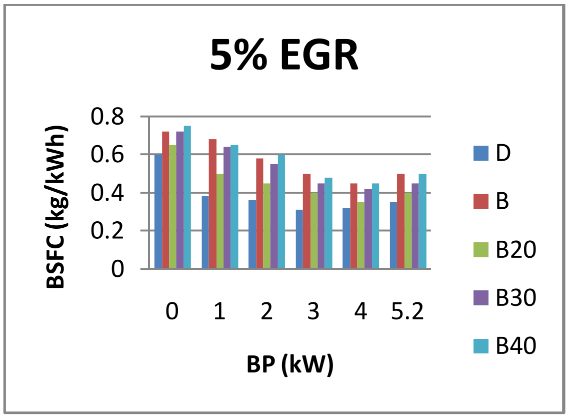

Fig. 5. Variation of brake specific fuel consumption with BP with 5% EGR.

Figure 14 and figure 15 shows variation of oxides of nitrogen with BP without and with 5% EGR, recirculation of 5% of EGR will decrease of oxides of nitrogen it is because of EGR reduces the gas temperature inside the cylinder.

Exhaust gas temperature:

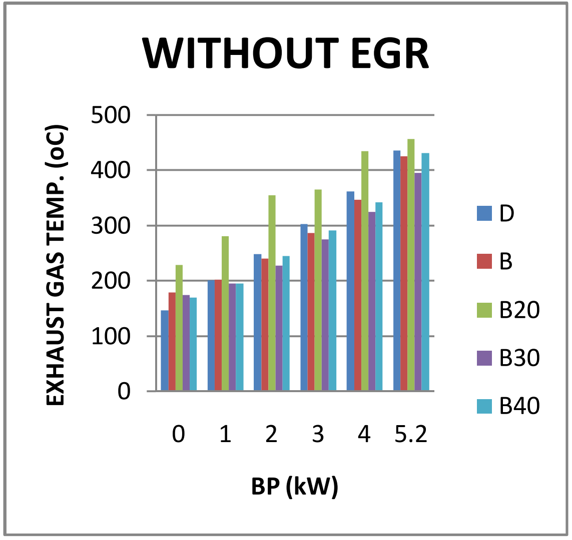

Fig. 6. Variation of exhaust gas temperature with BP.

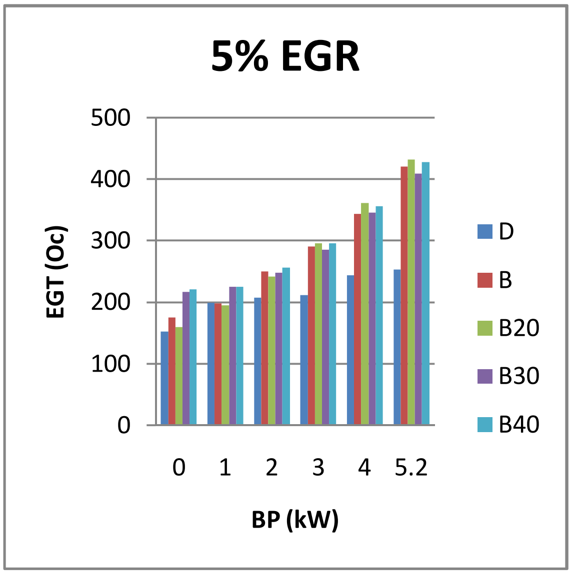

Fig. 7. Variation of exhaust gas temperature with BP.

EMISSION CHARACTERISTICS

Carbon monoxide:

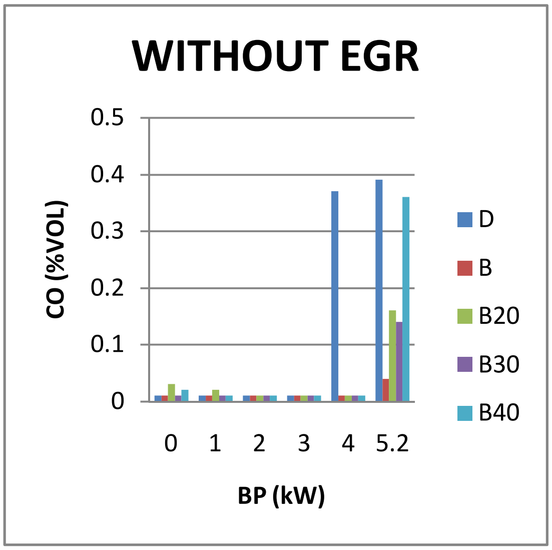

Fig. 8. Variation of CO emission with BP.

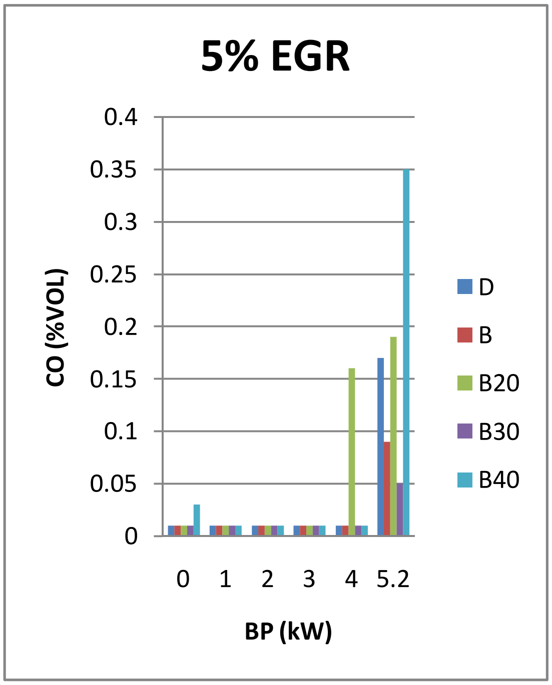

Fig. 9. Variation of CO with BP.

Carbon dioxide:

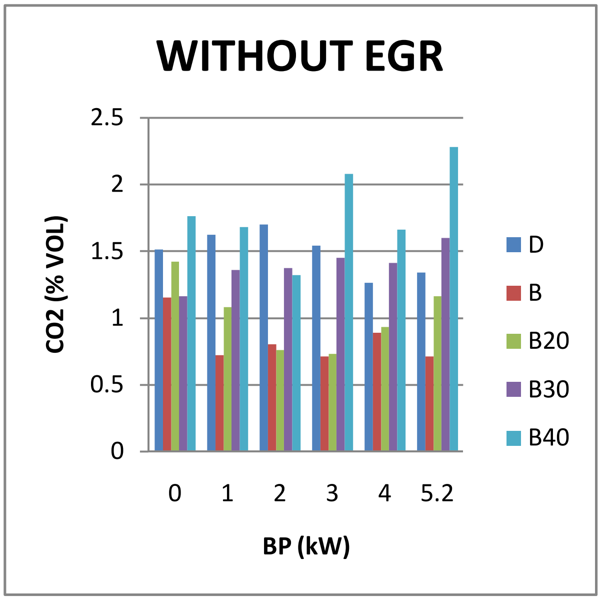

Fig. 10. Variation of CO_2 with BP.

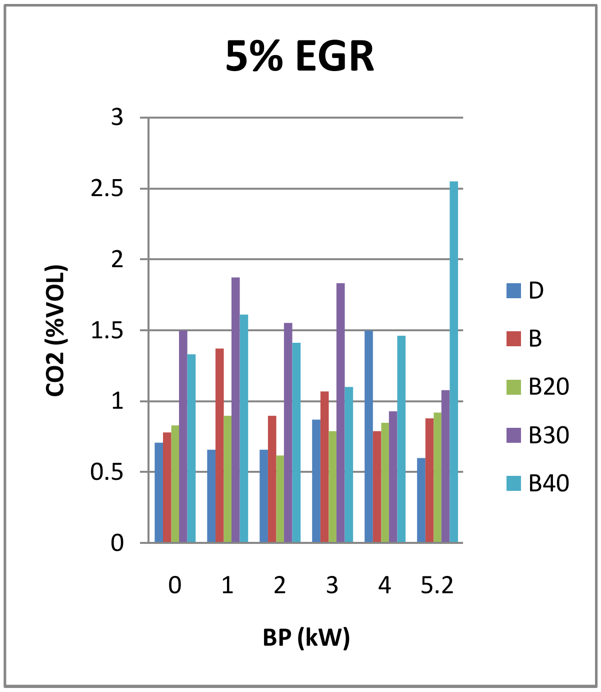

Fig. 11. Variation of CO2 with BP.

Unburnt hydrocarbon:

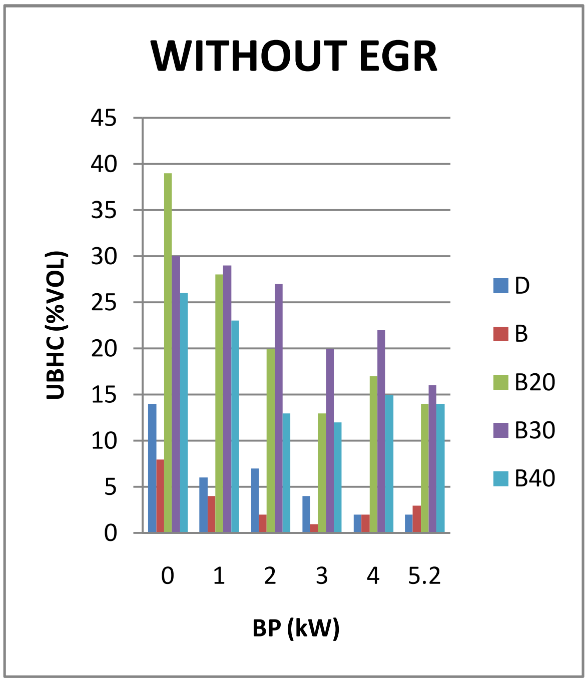

Fig. 12. Variation of UBHC with BP.

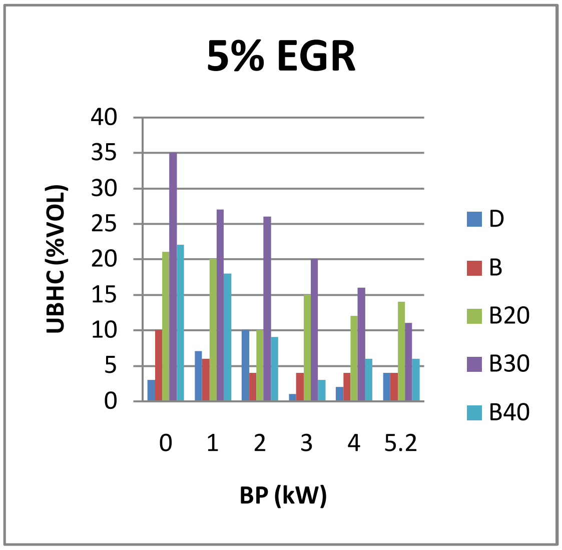

Fig. 13. Variation of UBHC with BP.

Oxides of Nitrogen:

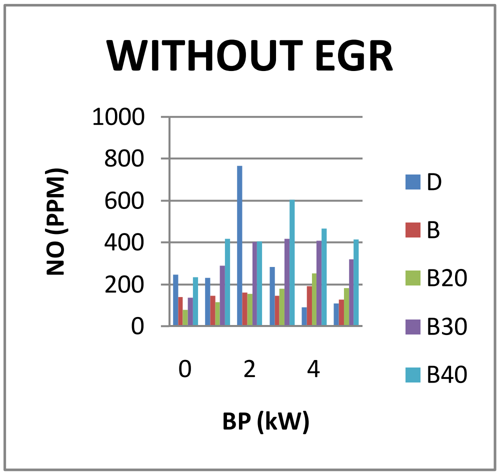

Fig. 14. Variation of oxides of Nitrogen with BP.

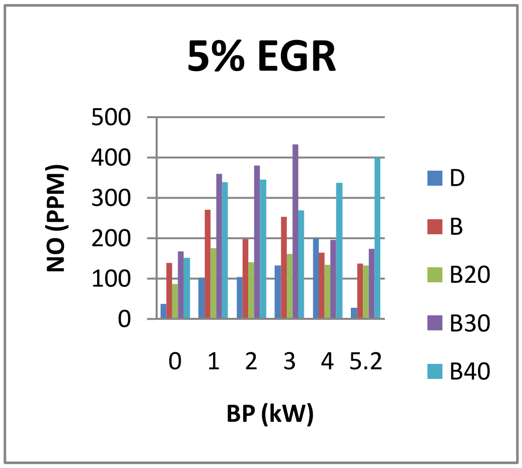

Fig. 15. Variation of oxides of Nitrogen with BP.

CONCLUSIONS

(i) Brake thermal efficiency of ternary fuel blends is same as that of diesel fuel. B20 have better BTE than all other fuel blends and pure biodiesel.

(i) Brake specific fuel consumption of disel fuel is slightly lower than that of mahuva biodiesel and ternary fuel blends

(i) Exhaust gas temperatures for ternary fuel blends are almost same as that of pure diesel fuel

(i) Emissions like CO, CO_2, NO and UBHC are better for ternary fuel blends than that of pure diesel fuel.

(i) Ternary fuel blends can be effectively used as as alternative fuel in diesel engine with 5% EGR.

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