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EFFECT OF EXHAUST GAS RECIRCULATION ON PERFORMANCE OF A DIESEL ENGINE FUELED WITH WASTE PLASTIC OIL / DIESEL BLENDS

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Abstract: NO_x emission is one of the major sources for health issues, acid rain and global warming. Diesel engine vehicles are the major sources for NO_x emissions. Hence there is a need to reduce the emissions from the engines by identifying suitable techniques or by means of alternate fuels. The present investigation deals with the effect of Exhaust Gas Recirculation (EGR) on 4S, single cylinder, DI diesel engine using plastic oil/Diesel blends P10 (10% plastic oil & 90% diesel in volume), P20 and P30 at various EGR rates. Plastic oil blends were able to operate in diesel engines without any modifications and the results showed that P20 blend had the least NO_xemission quantity.

KEYWORDS: NO_x emissions, Exhaust Gas recirculation, Diesel Engine, Plastic oil.

1 Introduction

The world's total fossil fuels is expected to deplete far sooner than anticipated due to increase in the total population, increase in per capita income and increase in the number of automobile manufacturers. For a fast developing country like India, the standards for emissions are too low. This has led to large outburst of health hazards and environmental degradation due to air pollution. But India as well as all other countries are trying to bring down the emission rates by imposing stringent actions on the standards. So there is a need to bring down the emission rates [1]. New innovative techniques to reduce the emission and some renewable type fuels are under research to achieve it. The major engine emissions which cause all these problems are NO_X, CO, CO_2 and HC. Among these the major emissions are NO_x and CO. NO_x is caused at high combustion temperatures. So it is important to bring down the peak combustion temperature of the engine without compensating in its efficiency. Different methods that are widely used to reduce NO_x from diesel engines are exhaust gas recirculation, retarded injection timing, fuel de-nitrogenation, staged injection of fuel, water injection, the exhaust catalysts and reduction of pre-mixed burn fraction by reducing ignition delay [3]. It is in this context a diesel engine was fueled with waste plastic oil. Exhaust gas recirculation is one of the most effective techniques currently being used for reducing NO_x emission from I.C. engines. In general, introduction of EGR influences diesel engine combustion in three different ways: thermal, chemical and dilution. The thermal effect is related to the increase in inlet charge temperature that increases in charge specific heat capacity due to the presence of CO_2 and H_2O. The chemical effect is related to the dissociation of species during combustion, while dilution is related to the reduction in oxygen availability. EGR involves diverting a fraction of the exhaust gas into the intake manifold

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where the recirculated exhaust gas mixes with the incoming air before being inducted into the combustion chamber. The recirculation of exhaust gases increases the total heat capacity of the working gases in the engine cylinder and thus lowers the peak gas temperature [2].

1.1. Plastic oil

Plastic oil properties are shown in Table 1, they emit high levels of NO_x and smoke which will have an effect on human health. Most of the research work has been done by mixing oil developed from waste plastic disposal with heavy oil for marine application. The results showed that waste plastic pyrolysis oil when mixed with heavy oils reduces the viscosity comparatively and improves the engine performance [1, 6, 9].

Table 1: Comparison of properties

PROPERTY	PLASTIC OIL	DIESEL
Density at 30°C in kg/m^3	835.5	840
Ash content %	0.00023	0.045
Gross calorific value (kJ/kg)	44,340	45,350
Flash point °C	63	50
Fire point °C	68	56
Sulphur content %	0.030	0.045

1.2. Conversion process

Waste plastic material in various sizes and shapes were sorted into categories suitable for crushing, cutting and shredding. The sorted materials were graded into uniform size for ease of handling and melting process. This process of sizing and grading the waste was semiautomatic. The graded feed was stored in a hopper before feeding to the process. The sorted feedstock of known composition was stored separately for proportionate feeding for processing nonstandard feed design or processing special feed designs. The dust and other fine wastes collected from the cyclone filter were disposed through a vent with particle size monitoring system [6]. The assorted waste plastics were fed into a reactor chamber along with 1% of (by weight) catalyst and 10% of (by weight) coal and maintained at a temperature of 300–400^{o}C at atmospheric pressure for about 3–4 h. The outlet gas was condensed and the liquid obtained was taken as fuel. This process gives on weight basis 75% of liquid hydrocarbon, which is a mixture of petrol, diesel and kerosene, 5–10% residual coke and the rest is LPG [2, 6].

1.3. Exhaust gas recirculation

EGR is a useful technique for reducing NO_x formation. Exhaust consists of CO_2, N_2 and water vapour mainly. When a part of this exhaust gas is re-circulated to the combustion cylinder, it acts as a diluent. This also reduces the O_2 concentration in the combustion chamber [3]. The specific heat of EGR is much higher than fresh air hence EGR increases the heat capacity of the intake charge, thus decreasing the temperature rise for the same heat release.

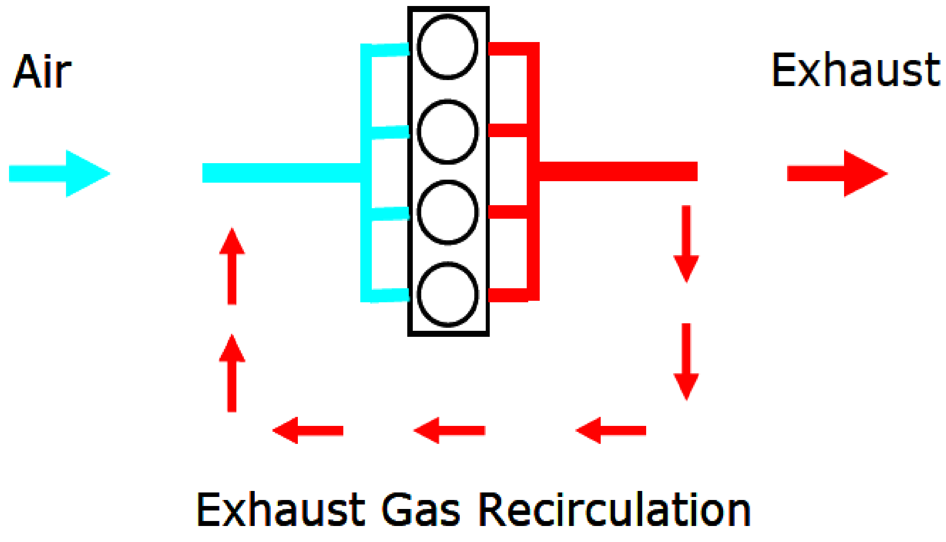

Fig. 1 Exhaust gas recirculation

$$EGR\ (\%) = \frac{\dot{m}_{\text{exhaust intake}}}{\dot{m}_{\text{exhaust intake}} + \dot{m}_{\text{air intake}}}\ [4] \tag{1}$$

The combustion temperature, with different EGR rates, depends on oxygen concentration and heat capacity of the intake charge of the engine. At high loads, it is difficult to employ EGR due to deterioration in diffusion combustion and this result in an excessive increase in smoke and particulate emissions. At low loads, unburned hydrocarbons contained in the EGR would possibly re-burn in the mixture, leading to lower unburned fuel in exhaust and improved brake thermal efficiency. Apart from this, hot EGR would raise the intake charge temperature, thereby, influencing combustion and exhaust emissions [3]. A decrease in intake oxygen concentration decreases NO emission. The EGR decreases local atomic oxygen concentration and local temperature, which in turn reduces the NO formation rate. The Temperature in the combustion chamber is major factor for NO formation than oxygen concentration. The increased intake charge heat capacity also influence the temperature inside and hence the NO_x formation.

1.3.1. Types of EGR system

EGR is briefly classified as

i. Hot EGR
ii. Cooled EGR
iii. High pressure EGR
iv. Low pressure EGR

(i) Hot EGR

Exhaust gas is re-circulated without being cooled, resulting in the increased charge temperature. The exhaust gas directly recirculated to the engine inlet with the help of control valve which decides the EGR rate which is to be recirculated back to the engine [7].

(ii) Cooled EGR

Exhaust gas is cooled before recirculation with heat exchanger, resulting in the decreased combustion temperature in the cylinder.

(iii) High pressure EGR

The EGR is passed from upstream of the turbine to the downstream of the compressor. The basic advantages of this system are: Since EGR is not passed through compressor or intercooler, the problems of durability and reliability are not there. The particulate trap is optional [7].

(iv) Low pressure EGR

The passage for EGR was provided from downstream of the turbine to upstream side of the compressor. A suitable pressure difference was obtained. The advantagesassociated with this system are: Reduced control complexity, Fuel economy.

2 Experimental setup

The experimental setup used for this investigation consists of a direct injection diesel engine, EGR valve, EGR cooler, carbon filter, Thermocouple, gas analyser. The engine employed for the experimental work was a four stroke, single cylinder, water cooled DI diesel engine developing 3.728 kW at 1500 rpm. The schematic diagram of the experimental set up is shown in Fig. 2.

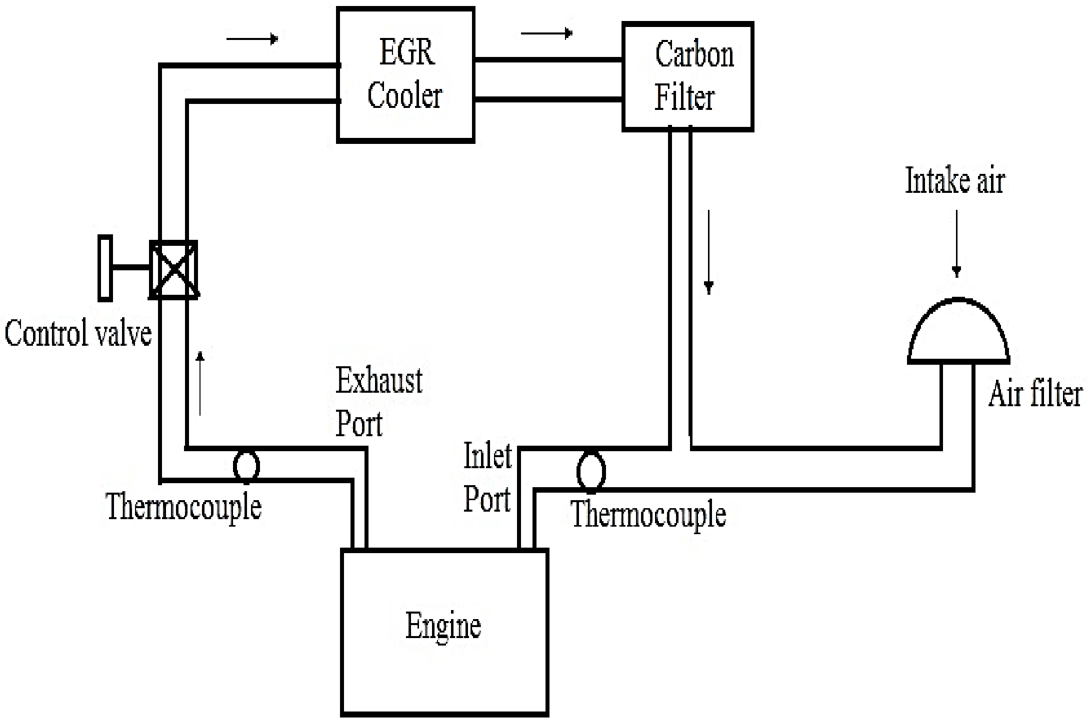

Fig. 2 Schematic representation of EGR

In fabrication, the exhaust gas recirculation through CPVC pipe having the diameter of 3.2 cm and the length of 100 cm throughout the recirculation. Control valves installed between intercooler and exhaust port of an engine to regulate the percentage of EGR rate that has to be recirculated back into the engine. The control valve is made of brass material to withstand high temperature. Intercooler was installed in between the carbon filter and the exhaust port through control valve. The intercooler which was widely used to cool the gases mainly in automobiles for the purpose of exhaust gas cooling. Catalytic converter was used as carbon filter were placed after the intercooler and before the intake port of an engine, this will filter the carbon particles from the exhaust gas which is to be recirculated back into the intake manifold of the engine. Then finally the exhaust gas is allowed to mix up with the atmospheric air and fed to the intake port of an engine. Thermocouples were placed at exhaust port, after intercooler and at the intake port of an engine to measure the various temperature. Hence the overall fabrication was shown in the fig 3.

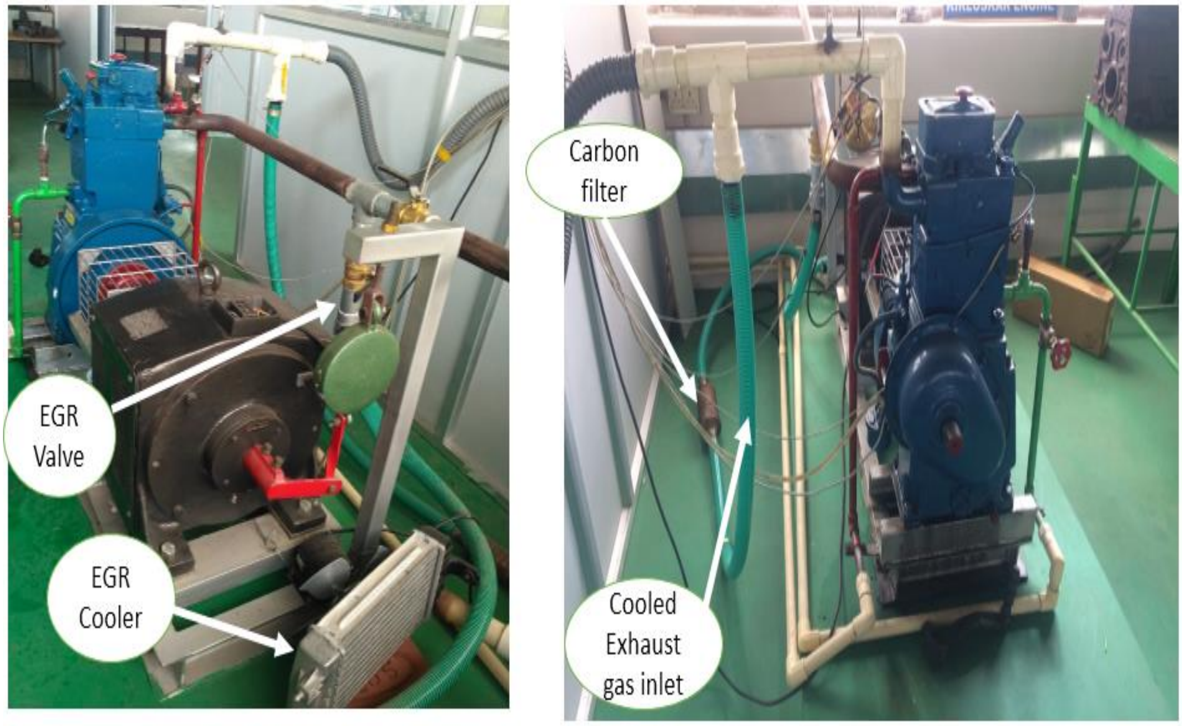

Fig. 3 Exhaust gas recirculation setup

An electrical dynamometer was used to provide the engine load. An air box was fixed to the engine for airflow measurement which consists of orifice tube arrangement for the intake air flow measurement. The fuel flow rate was measured on volumetric basis using a burette and a stopwatch. Thermocouple was connected with a digital temperature indicator was used to measure the exhaust gas temperature. An exhaust gas analyser was used to measure NO_x, HC, CO and CO_2 emissions from the exhaust gas of the engine. All the experiments were conducted at the rated engine speed of 1500 rpm. All the tests were conducted by starting the engine with diesel only. Then the engine was run with waste plastic oil blends (P10, P20, P30). At the end of the test, the engine was run for some time with diesel to flush out the waste plastic oil from the fuel line and the injection system.

3 Performance analysis of diesel engine

The performance of the diesel engine is analyzed at various EGR rates (10, 20 and 30%) and blends (P10, P20, P30).

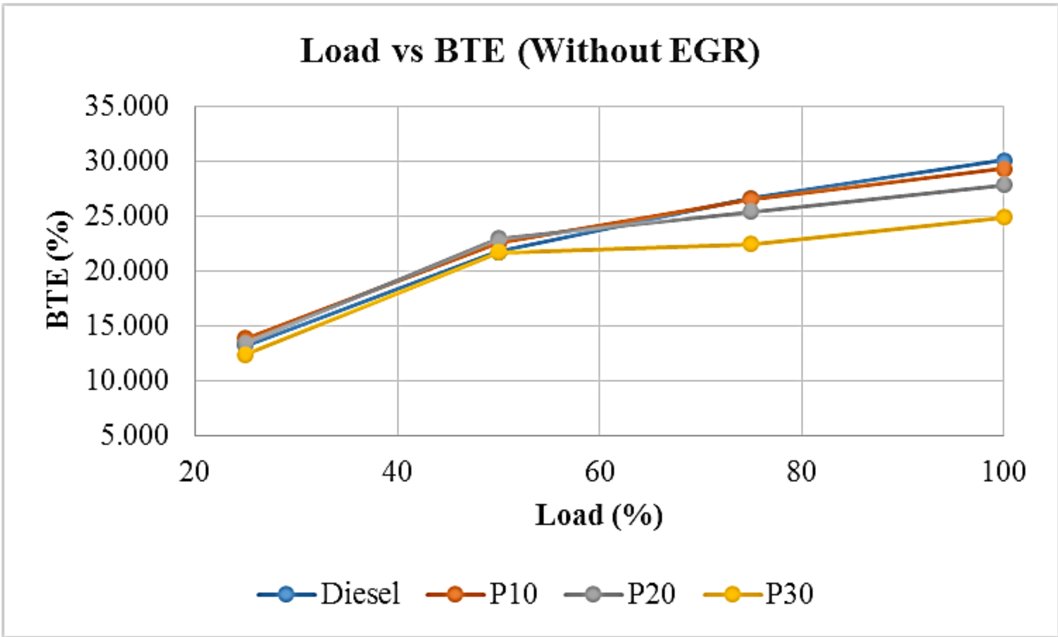

Fig. 4 Brake Thermal Efficiency for various blends without EGR

From the experimental values, as the blend ratio increases Brake Thermal Efficiency and the gross calorific value of fuel decreases thereby reducing the engine speed. P10 blend gives higher BTE as compared to other blends without considering EGR. The Brake thermal efficiency of P10 blend was found to be 29.27% and for diesel it was 30.43% comparatively closer for the same condition.

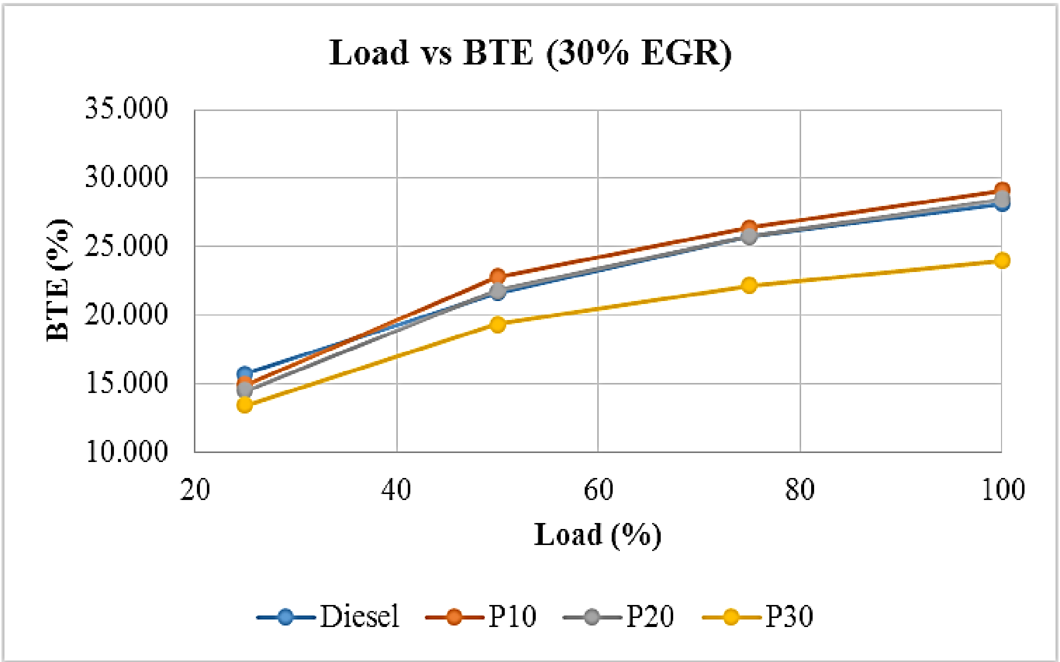

Fig. 5 Brake Thermal Efficiency for various blends at 30% EGR

From Fig. 5, for 30% EGR rate it was found that the BTE of the blend P10 is higher than the diesel at 30% EGR rate. At peak load the BTE of P10 was higher than P20 and the NO_x emission was also higher than P20.

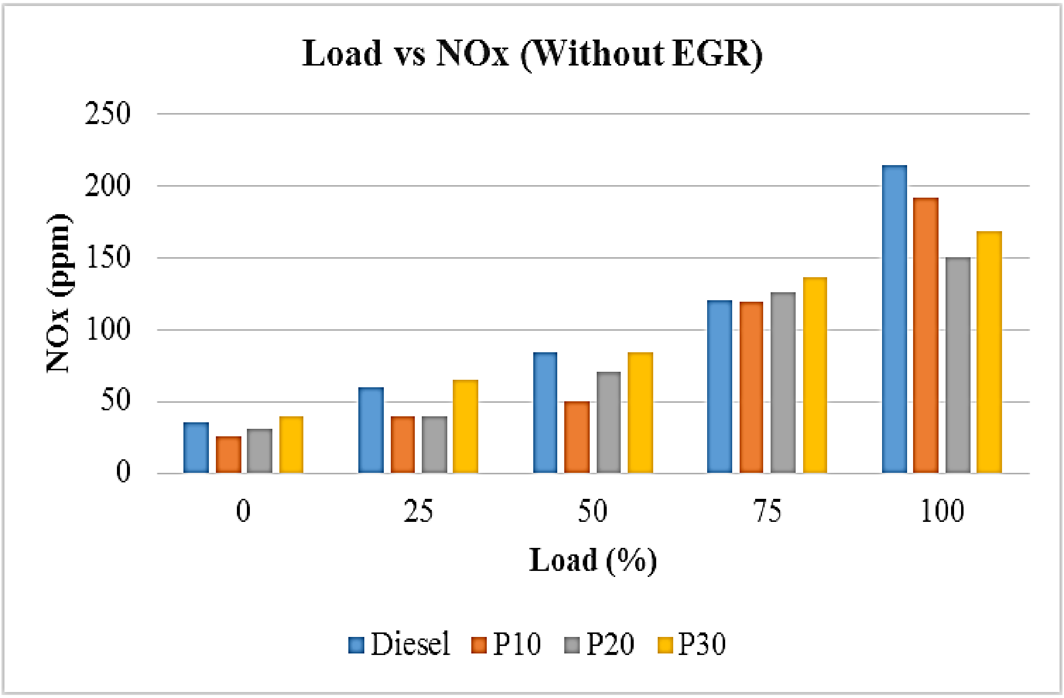

Fig. 6 NO_x emissions for various blends without EGR

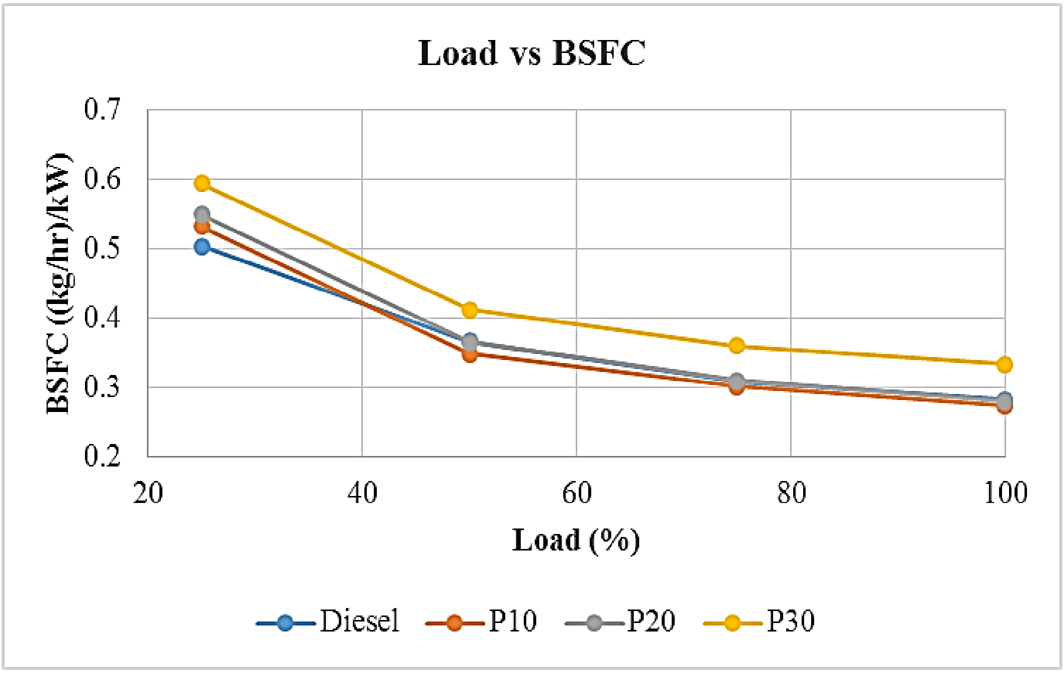

Fig. 7 BSFC for various loads with 30% EGR

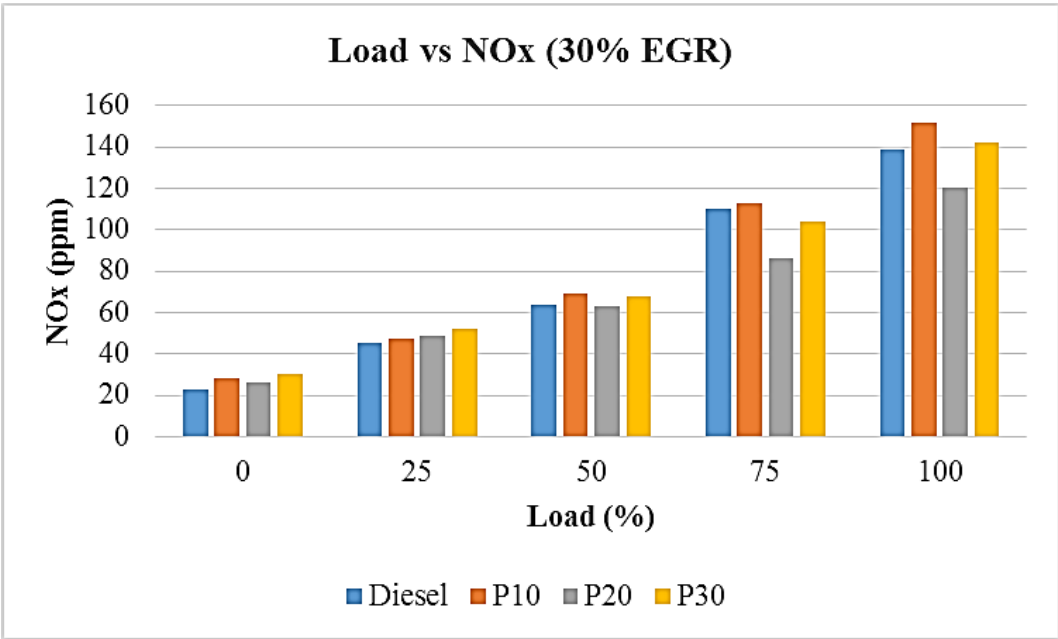

Fig. 8 NO_x emissions for various blends with 30% EGR

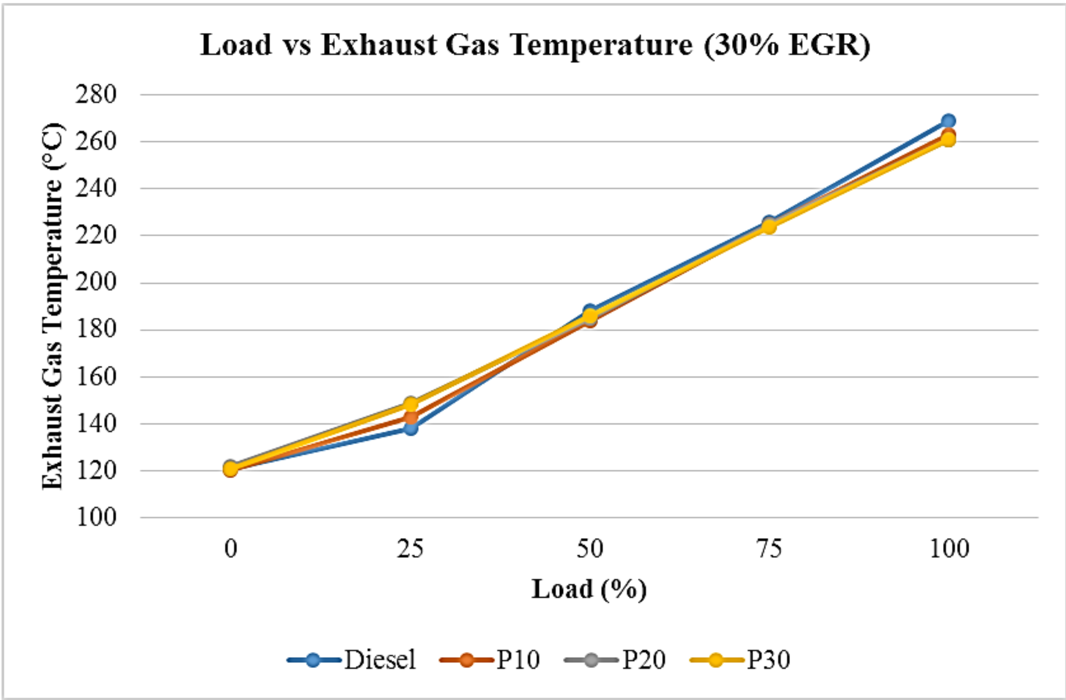

Fig. 9 Exhaust gas temperature for various blends at 30% EGR

The above graph shows that the NO_x emissions of plastic oil blends was higher as compared to diesel fuel without using the Exhaust gas recirculation (EGR) setup. As the load increase the NO_x emissions also increased due to the high temperature in the combustion chamber and high oxygen content in the intake air. And as the blend ratio increase the NO_x emissions also increased. So the EGR is to introduce to reduce the NO_x emissions from the exhaust gas of the engine.

In Fig. 7, Brake Specific Fuel Consumption (BSFC) is compared for 30% EGR for various blends. The BSFC for blends P10, P20 are similar with the diesel values. When comparing BSFC values both P10 and P20 could be an efficient alternate for diesel. So we have to compare the other important factors like NO_x, CO and HC emissions.

From Fig. 8, at 30% EGR rate it was identified that the NO_x emission decreases as the EGR rate increases. At peak load P20 has minimum NO_x emission as compared to other blends.

From the above graph as the EGR rate increases the exhaust gas temperature slightly decreases. For diesel fuel EGT decreases 2°C with 30% EGR rate. For P20 blend, at 30% EGR rate and peak load condition, the EGT decreases from 266 to 261°C.

4 CONCLUSIONS

The Direct Injection CI engine was able to operate with plastic oil blends. From the experimental results and analysis at 30% EGR and at peak load condition, P20 blend had BTE and BSFC almost equal to diesel and higher than the other blend values when compared. However the NO_x emission was found to be 14 % lower than that of diesel. Hence P20 is better alternate fuel for diesel.

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