Effect of EGR on a diesel engine fueled with waste plastic oil blend

G. Balaji*, I. Anvar Saheel, M. Hariharan, P. L. Palaniappan

Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu – 603203

*Corresponding Author: gbalajimech79@gmail.com

Abstract

With the increasing global demand for fuels, there is a need to reduce vehicular emissions which are one of the major causes of air pollution around the globe. NOx emissions leads to health issues, acid rain, global warming, etc. Diesel engines are the major sources for NOx emissions. Hence there is a need to reduce the emissions from the engines by means of alternate fuels and emission control technologies. This investigation deals with the effect of exhaust gas recirculation (EGR) on single cylinder, direct injection diesel engine using plastic oil and diesel blend (10% plastic oil + 90% diesel) at EGR rates of 5%, 10% and 15%. Plastic oil blends were able to operate in diesel engines without any modifications and based on the results, EGR decreases the NOx emissions with a minimum increase in specific fuel consumption. The engine with the EGR rate of 15% and at the full load condition, the emission level of NOx has been decreased from 1327 to 661 ppm. Hence it was concluded that the low emission level of NOx can be obtained using EGR for the plastic oil blend. The results showed that DPB+EGR15 blend had the least NOx emission.

Keywords: Engine, Plastic Oil, EGR, Emissions, Performance

1. Introduction

The total amount of fossil fuel in the world is yet decrease sooner than the predicted level due to the increasing level of the world population. There is a drastic growth in the increase of automobile worldwide. For the developing countries like India, standards of emission are very low compared...
to the other world’s leading countries [1]. This has led to largest health issue and many other problem and causing the air pollution. India and many world top countries are trying to decrease the emission rate and reduce the emission standards of their country. This is the most important part to decrease the emission rate to prevent the environment. There are many innovative technique to bring down the emission rate like use of biofuels, additives, after treatments, etc. Diesel engine are the largest producer of nitrogen oxide compared to the other sources.

In the increasing population the demand for the fuel and the emission produced from the diesel engine is also increasing [2]. The combustion happened at high temperature should be decreased without compensating the efficiency of the engine. There are different method used to minimize the amount of NOx produce in the diesel engine like using EGR, water injection, using catalysts at the exhaust, retarding the ignition timing, fuel di-nitration, staged injection of fuel, etc. EGR is the one of the widely used technique to minimize NOx from C.I engines [3].

The EGR is associated with diverting of the brunt gas in to the cooler and to the engine inlet and further to combustion chamber. Thus recirculation gasses decreases the temperature of the combustion. There are two molecule of nitrogen oxides, nitrogen dioxide- NO$_2$ and nitric oxide – NO but they are formed in very lower amount. But other molecule which is known as nitrous oxide –N$_2$O is the major producer of greenhouse gas as they play important role in the global climate change [4]. NOx plays in the important role in the formation of brown haze over the sky, smog and particulate matter during the summer time. When the NOx molecular are expose to the UV rays in sunlight and they can broke apart from the ozone layer in this the added VOC in the atmosphere. This gas interact with NOx and the other gas to form dangerous molecule. The protective film of the ozone is most important thing to prevent from the UV rays entering in to the earth atmosphere. The acid rain are the major cause of this type of this pollution and these are environment concerns cause by NOx. Ozone, nitrogen oxide, nitric acid can easily entered the body of the person and effect of lungs even the limited time exposure to the gas can be irretentive the lungs and effect lungs of the people [5]. This may also lead to other medical condition like asthma even the less time spent in breathing this pollutant can lead to increase the risk of emergency and need for first aid when there is emergency reach out to the nearest hospital.

Neem biodiesel is used to power diesel engine to reduce the NOx by antioxidant additives and with SCR. The tail pipe emission are decreased with the help of biodiesel in diesel engine. Neem biodiesel produce more amount of NO emission compared to which is caused by diesel engine. In this study, the NOx is reduced by blending neem diesel with diesel as fuel and using SCR at exhaust. This is also one of the most effective way to reduce the emissions [6]. Disposing plastic waste is complex and tough task. These wastes can be converted into plastic oil by the pyrolysis method. The plastic oil thus produced can be blended with diesel and used in engines. Plastic oil and diesel blend is used in the single cylinder engine for the emission analysis with EGR. NOx reduced by 18% with the EGR and 15% with the antioxidant additive. The combined EGR and antioxidant additive reduce 28% NO emissions compared with diesel [7].

Emission of the CI engine can be controlled by using modification in fuel, modification in engine, and the exhaust treatment. In this mentioned technique the treatment at the exhaust is the most easy
and efficient way to decrease the emission. In this no engine modification is required and in this type of selective catalytic reduction. The result shows that the plastic oil obtained using degrade plastic is a good alternative of the diesel fuel, and with antioxidant adding and incorporating SCR is very effective in reduction of the nitrogen oxide emission by 66% without any decrease of the brake thermal efficiency [8]. Plastic oil blend with diesel in the ratio PO25, PO50, PO75 were used for the analysis. The result obtained indicate that the BTE of all the blends of plastic oil is decreased than it is caused in diesel at the different load. At peak load, the cylinder pressure and combustion timing and heat release and the ignition delay of the plastic oil and the blend of the diesel are higher than the diesel. During the engine running with the high pressure of the plastic oil were increase by 7% but this shows the low brake thermal efficiency based on test result obtained is shows the combustion characteristics which are mostly determined by the properties of the diesel [9]. There is big scope of the using plastic oil as alternative fuel. The plastic oil was studied with petrol and found that it can also be used in the CI engine. In this study, the injection timing was varied and the performance, combustion, emission characteristics are done. Results shows, there is decrease in the oxides of the nitrogen, unburnt hydrocarbons, carbon monoxide while the BTE and the smoke increased under all the test condition [10].

2. Experimentation

![Figure 1. Photographic view of EGR Setup.](image-url)
This study was done on a Kirloskar engine of 5.2 kW which runs at a rpm of 1500, single cylinder, water cooled diesel engine and they are connected with the eddy current dynamometer, figure 1. The AVL gas and smoke analyzers were used in the tail pipe at the exhaust to find the amount of the exhaust gases and smoke, figure 2. The smoke quantity in 1% opacity can be found using this
type of the smoke meter. The uncertainty percentage of this instrument is 1.4 and the altered fuel ignition and timing at the engine is 200 bar and 20 deg. The efficiency and the power produced was measured by changing in the load of 0%, 25%, 50%, 75%, and 100%. At the start of the engine with new test fuel the engine is allowed to run for 10 min prior applying the load for each test fuel. The EGR valve is opened using the manual valve produced in the engine. The test fuel properties were shown in table 1

3. Result and Discussion

The result of the combustion ignition power train obtained from the diesel, DPB with different ratios of EGR are studied for emission, combustion and performance characteristics.

3.1 Emission characteristics

Figure 3 represent the variation of NO emission for diesel, diesel plastic oil blend (DPB) diesel plastic blend and EGR at 5%, diesel plastic oil blend and EGR at 10%, diesel plastic oil blend and EGR at 15%. The engine is reached the greater amount of NOx rate when the EGR valve is not used. When the engine speed increases the NOx also increases. This happens due to the higher oxygen content is mixing with the diesel fuel. So that the oxidation take place in the combustion chamber so the combustion chamber temperature is increased, due to the raise of temperature NOx emission also generated and increased [11]. NOx emission decreases when there is increase in the EGR flow rate. It is found that NOx emission for diesel was 1492 ppm, for DPB it was found to be 1327 ppm, for DPB+EGR5 it is found to be 1027 ppm, for DPB+EGR10 it is found to 832 ppm, DPB+EGR15 it is found to be 661 ppm. And as the EGR rate increases DPB+EGR15 it was found that the NOx emission lowers as the EGR rate is high.

Figure 3. Variation of NOx emission
Figure 4 represents the different levels of CO emission for diesel, diesel plastic oil blend (DPB), diesel plastic blend and EGR at 5%, diesel plastic oil blend and EGR at 10%, diesel plastic oil blend and EGR at 15%. The proportion of CO production for diesel fuel blend increased above 60% load, and when the engine runs with the EGR, the CO emission increased to that without EGR. The CO was at the highest whenever the engine runs at a maximum rate of 15% EGR at all engine speeds. When the engine used more than 5% EGR, the CO emission was quickly increased. It is observed that CO emission for diesel was 0.163%, for DPB it was found to be 0.111%, for DPB+EGR5 it is found to be 0.158%, for DPB+EGR10 it is found to be 0.286, for DPB+EGR15 it is found to be 0.455%. CO2 has the opposite collation with CO, so its require sufficient time for covert from CO2 to CO [12]. Lack of time may leads to produce more CO which is harmful gas for environment.

Figure 5 represents the different levels of CO2 emission for diesel, diesel plastic oil blend (DPB), diesel plastic blend and EGR at 5%, diesel plastic oil blend and EGR at 10%, diesel plastic oil blend and EGR at 15% When the EGR is used. CO which not converted it will combine with O2 which is from fresh air so that it is converted to CO2. When the engine works with EGR, CO2 is increased when compared to EGR is not used. CO2 is the main composition of EGR gas which indicates the quality of combustion and temperature [13]. The CO2 was at the highest whenever the engine operated at a maximum rate of 15% EGR at all engine speeds. It is found that CO2 emission level for diesel was 9.52%, for DPB it was found to be 9.77%, for DPB+EGR5 it is found to be 10.3%, for DPB+EGR10 it is found to be 10.5%, for DPB+EGR15 it is found to be 11.1%. When the load increases CO2 increase with all EGR rate.
Figure 5 shows the variation of CO₂ emission for Diesel, Diesel plastic oil blend (DPB) Diesel plastic blend and EGR at 5%, Diesel plastic oil blend and EGR at 10%, Diesel plastic oil blend and EGR at 15%. The CO₂ level decreases when the EGR is in use. Normally, the diesel engine gives a less CO₂ emission when diesel is used as a fuel. It is found that CO₂ release for diesel was 7.12%, for
DPB it was draft to be 8.07%, for DPB+EGR5 it is found to be 7.51%, for DPB+EGR10 it is found to be 6.83%, for DPB+EGR15 it is found to be 5.95%. $O_2$ acts in combustion area due to its higher heat capacity, and making it possible to reduce high temperature of the cylinder [14]. And as the EGR rate increases DPB+EGR15 it was identified that the $O_2$ emission decreases as the EGR rate increases. At high load DPB+EGR15 has minimum $O_2$ emission as compared to other blends. Figure 7 represent the different level of HC emission for diesel, diesel plastic oil blend (DPB), diesel plastic blend and EGR at 5%, diesel plastic oil blend and EGR at 10%, diesel plastic oil blend and EGR at 15%. The variation of HC is a ppm under full load of the engine with the applying of various EGR flow rate. HC Emission is low in diesel engine when diesel is used as fuel. While increasing the percentage of EGR, HC rate is also increases when compared to the engine without EGR. It is Found that HC pollution for diesel was 70ppm, for DPB it was drafted to be 69ppm, for DPB+EGR5 it is found to be 68ppm, for DPB+EGR10 it is found to be 67ppm, for DPB+EGR15 it is found to be 72ppm. When the engine runs without EGR the HC produced is low compared to HC produce with different rates with EGR. The HC emission were significantly higher across all the blended diesel.

Figure 8 represent the different level of smoke intensity for diesel, diesel plastic oil blend (DPB), diesel plastic blend and EGR at 5%, diesel plastic oil blend and EGR at 10%, diesel plastic oil blend and EGR at 15%. The smoke emission formation is due to the diffusion of the burning rage is low. The increase in smoke for DPB+EGR15 may be because of higher carbon to hydrogen ratio and the presence of aromatic elements in the DPB. It is found that smoke opacity emission for diesel was 67.2%, for DPB it was found to be 68.7%, for DPB+EGR5 it is found to be 75.7%, for DPB+EGR10 it is found to be 82.1%, for DPB+EGR15 it is found to be 87.3%.

Figure 7. Variation of HC emission
3.2 Combustion characteristics

Figure 9 represent the different level of crank angle for diesel, diesel plastic oil blend (DPB), diesel plastic blend and EGR at 5%, diesel plastic oil blend and EGR at 10%, diesel plastic oil blend and EGR at 15%. These are the results got in EGR operation as heat absorbing factor which causing a sudden low temperature in combustion chamber [15]. The cylinder pressure was high when the EGR was not in use and it reduce when the exhaust gas recirculation rate was increased. This is due to the temperature changes happens in combustion region when reduce the EGR valve. The result is in agreement with that of using EGR of 5%, 10% and 15% in which the in-cylinder pressure reduced with the use of EGR.
Figure 10 represent the different level of net heat release for diesel, diesel plastic oil blend (DPB), diesel plastic blend and EGR at 5%, diesel plastic oil blend and EGR at 10%, diesel plastic oil blend and EGR at 15% heat release rate is decreased due to the drop in quality of the fuel. When the load increases the neat heat releases decreases due to the quality of fuel. Compared to the diesel the net heat release decrease for DPB+EGR15. When the neat heat release rate the fuel quality of the incoming fuel is low.

Figure 11. Cumulative heat release
Figure 11 represent the different level of cumulative heat release for diesel, diesel plastic oil blend (DPB), diesel plastic blend and EGR at 5%, diesel plastic oil blend and EGR at 10%, diesel plastic oil blend and EGR at 15% When diesel is compared with DPB+EGR10, DPB+EGR10 has the high heat release due to the burnt gas are send through the inlet again so the heat release is high when burnt gas high compared to the fresh charge.

3.3 Performance characteristics

Figure 12 represent the different level of specific fuel consumption for diesel, diesel plastic oil blend (DPB), diesel plastic blend and EGR at 5%, diesel plastic oil blend and EGR at 10%, diesel plastic oil blend and EGR at 15% the low ratio blends shows the minimal reduction SFC this phenomena is due to the dilution of intake of new air which mixes with the exhaust gas which is recirculated into the combustion Engine by EGR system determine the lead to incomplete combustion of the mixer specific fuel consumption is high for diesel in initial load and for DPB+EGR15 the consumption of fuel is less and when the load increases there is only a slight various in the fuel consumption of the plastic oil blends. It is observed that specific fuel consumption for diesel was 4.34, for DPB it was found to be 0.42, for DPB+EGR5 it is found to be 0.31, for DPB+EGR10 it is found to be 0.27, for DPB+EGR15 it is found to be 0.28.

Figure 12. Specific fuel consumption
Figure 13 represent the different level of brake thermal efficiency for diesel, diesel plastic oil blend (DPB), diesel plastic blend and EGR at 5%, diesel plastic oil blend and EGR at 10%, diesel plastic oil blend and EGR at 15% brake thermal efficiency is used to determine the helpfulness of combustion system by accepting the diesel inputs provided and its efficient in converting the fuel to the mechanical output brake thermal efficiency. Brake thermal efficiency increase with increase in load. The greater brake thermal efficiency at 100% of rated load is 31.03% for DPB+EGR15 which is 9% greater than diesel. BSFC of the engine constantly decreases with increasing in load.

4. Conclusion

A combustion ignition engine running with EGR, which are running with a blend of diesel along with plastic oil has been investigated for emission, combustion and performance characteristics. The following conclusions are arrived:

- Diesel and plastic oil blend can be used an alternative for diesel when compared with the diesel but there is decrease in brake thermal efficiency.
- Combining exhaust gas recirculation with the engine reduces NOx emission by 50.18% for DPB+EGR15.
- The increase in HC emission of 2.7% is due to EGR and addition of plastic oil to the diesel.
- Incorporating EGR and adding plastic oil to the diesel lightly decreases the BTE with the direct increase in SFC.
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