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Investigation of emission & performance characteristics of waste cooking oil from diesel engine using exhaust gas recirculation

Mahesh Kumbhare, M.J. Sable

Abstract

It has shown that biodiesel-fueled engines produce less CO, unburned HC and smoke emissions compared to diesel fuel, but higher NO_x emissions. Exhaust Gas Recirculation (EGR) is an efficient technique to reduce NO_x emission as it lowers the flame temperature in the combustion chamber. The objective of this work is to reduce NO_x emission from Waste cooking oil biodiesel fueled CI engine. A Single cylinder, water cooled, constant speed direct injection diesel engine was used for this experiment. The content of HC, NO_x, CO and smoke in the exhaust gas were measured to estimate the emissions. Application of EGR with biodiesel resulted in reductions in NO_x emissions without any significant upsurge in smoke emissions. The graphs were plotted comparing the emissions from diesel fuel and Waste cooking oil biodiesel fuel without EGR and with 5%, 10%, 15% EGR.

Keywords: EGR, NO_x, Diesel Engine, Emissions.

Introduction

In India diesel engines are widely used for transport and agricultural machinery due to its superior fuel efficiency. The increasing cost of petrol has made people to depend largely on diesel based engines. Due to depletion and higher cost of petroleum based fuels researchers around the world look for alternate fuels. Biodiesel which is mainly mono alkyl esters of long chain fatty acids has been accepted as a suitable alternate to diesel fuel. Moreover, the emission is very much reduced by utilizing biodiesel. Biodiesel blended with diesel fuel showed better performance. Vegetable oils because of their higher viscosity and huge carbon deposits can be used only as a short term fuel in diesel engines. Viscosity of vegetable oils can be reduced and made equivalent to diesel fuel by transesterification. Large number of feedstocks including nonedible oils and wastes from hotels, beef tallow and chicken feather meals are utilized for biodiesel production. In developed countries, used cooking oils are available in plenty and are used as cheap feedstock for biodiesel production.

In India because of huge population and availability of large number of restaurants a huge amount of edible oil is consumed for food preparation. The used oil thus produced is dumped outside resulting in environmental degradation. This could be avoided if these used oils are collected and converted into biodiesel. In this study used palm oil was collected from different restaurants in Tirunelveli region of south India and was converted into biodiesel. The biodiesel thus produced is blended with diesel at different volume proportions and tested in a DI diesel engine to evaluate its performance, emission and combustion profile.

One simple way of reducing the NO_x emission of a diesel engine is by late injection of fuel into the combustion chamber. This technique is effective but increases fuel consumption by 10–15%, which necessitates the use of more effective NO_x reduction techniques like exhaust gas recirculation (EGR). Re-circulating part of the exhaust gas helps in reducing NO_x, but appreciable particulate emissions are observed at high loads, hence there is a trade-off between NO_x and smoke emission. To get maximum benefit from this trade-off, a particulate trap may be used to reduce the amount of unburnt particulates in EGR, which in turn reduce the particulate emission also.

2. Materials and methods

Waste cooking oil collected from the restaurants is considered as feedstock for the biodiesel production. Transesterification is a chemical process of transforming large, branched,

triglyceride molecules of Waste cooking oils and fats into smaller, straight chain molecules, almost similar in size to the molecules of the species present in diesel fuel. The process takes place by reacting the vegetable oil with an alcohol in the presence of catalyst. In general, due to high value of free fatty acids (FFA) of waste vegetable oils, acid catalyzed transesterification is adopted. However, FFA of the feedstock used in this work is less and hence alkali catalyzed transesterification process is employed for the conversion of Waste cooking oil into ester. The Waste cooking oil is preheated in a reactor to remove the moisture. Potassium methoxide is prepared by dissolving potassium hydroxide in methanol. Various concentration of KOH in the methoxide was prepared and the process is optimized for the maximum yield. For the optimized KOH concentration, alcohol proportion also optimized to obtain the maximum yield. Methoxide is mixed with preheated oil and the reaction carried out under nominal speed stirring by a mechanized stirrer and at a constant reaction temperature of 55°C for 2 hours. During that time period the chemical reaction takes place between raw WCO oil and the methanol. At the end of completion of reaction, the mixture was drained and transferred to the separating funnel. The phase separation was taken place in the funnel in two layers. Upper layer was the biodiesel and lower phase was Glycerine. Finally, washing was made with water.

Table 1: Properties of Oil

Sr. No.	Property	Diesel	WCO
1	Density (kg/m ³)	850	885
2	Kinematic Viscosity (cSt)	2.44	4.76
3	Heating Value (kJ/kg)	41000	40200
4	Cloud Point (°C)	3	16
5	Pour Point (°C)	-6	19
6	Flash Point (°C)	70	145

3. Experimental Setup

A naturally aspirated single cylinder diesel engine is selected for experimentation. Modifications are made to the original engine set up to work with option EGR. A heat exchanger is used to cool the exhaust gas while entering the inlet. The control valve is provided to recirculate exhaust gas into the inlet pipe. Fig .No.1 gives the details of the experimental setup. Smoke meter is used to measure emissions. The emission concentrations are measured after engine has attained steady state for each set of readings. A schematic of experimental set up is shown in figure 1.



Fig 1: Experimental Test rig.

Table 2: Engine Specifications

Sr. No.	Specification	Value
1	Maximum Engine Output	3.7 kw
2	Maximum Engine Speed	1500 rpm
3	Bore x Stroke	87 x 110 mm
4	Compression Ratio	16:1

4. Results and Discussion

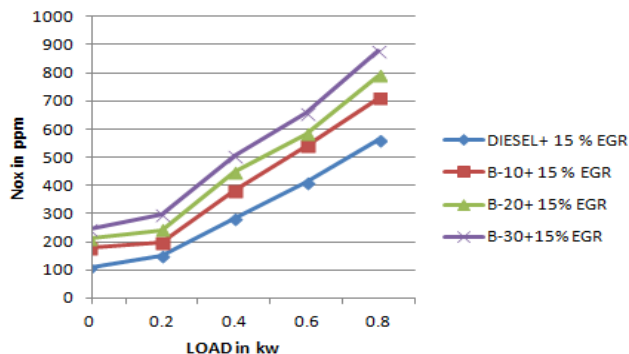


Fig 2: Variation of NOx with Load in kw

Nitrous oxide formation is a temperature dependant phenomenon along with residence time of fuel and air. Biodiesel combustion emits more NOx in comparison to diesel. The reason can be due to quantity of nitrogen present in the fuel. Figure no 2 gives the variation of NO with load. It is evident that as the load increases NO emissions increased, due to rise in temperature leads to more NO formation. NOx emissions versus EGR rate at full load is shown in figure 3. NOx is found highest for B-30 and decreased with increase in EGR %

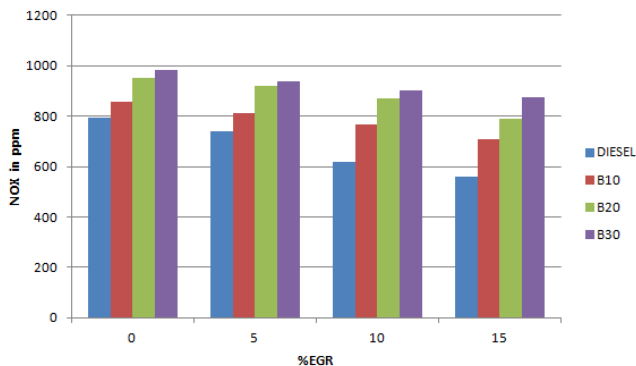


Fig 3: Variation of NOx Vs %EGR

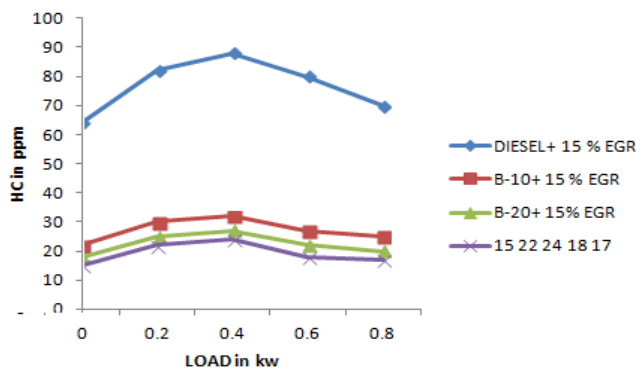


Fig 4: Variation of HC Vs Load in kw

It is observed that as EGR rate increases a rise Unburnt HC emission occurred in the exhaust. UHC emissions are lower for biodiesel diesel blends and with pure biodiesel the quantities are much reduced in comparison to diesel for all the loads of engine operation. Effect of EGR is to increase the HC emissions in the exhaust. Pure diesel observed to be giving higher UHC emissions with EGR rate in comparison to biodiesel. Variation in HC for Diesel and Blends with change in EGR rate is as shown in fig.5

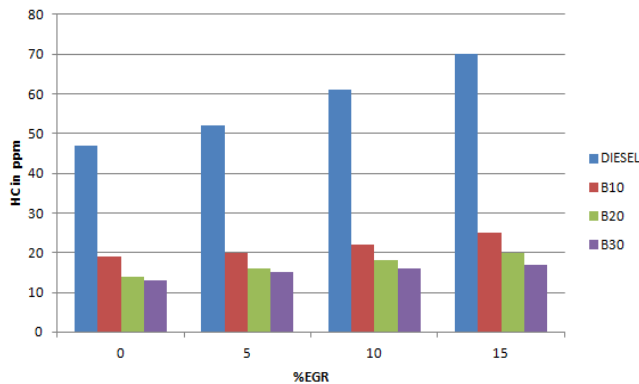


Fig 5: Variation of HC Vs %EGR

The nature of variation of Carbon monoxide with load is shown in figure 6. At part loads the engine is operated at higher air fuel ratios, these lean mixtures left unburnt leads to higher CO emissions. At higher loads rich mixtures leads to increase in CO formation.

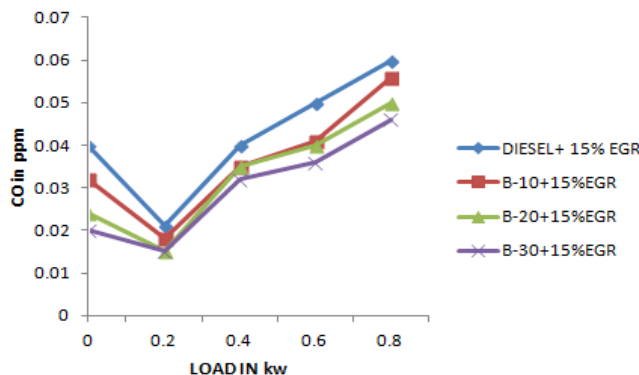


Fig 6: Variation of CO Vs Load in kw

The effect of exhaust gas recirculation on CO emissions is shown in figure 7. CO emissions increases with EGR rate at a given load of engine operation.

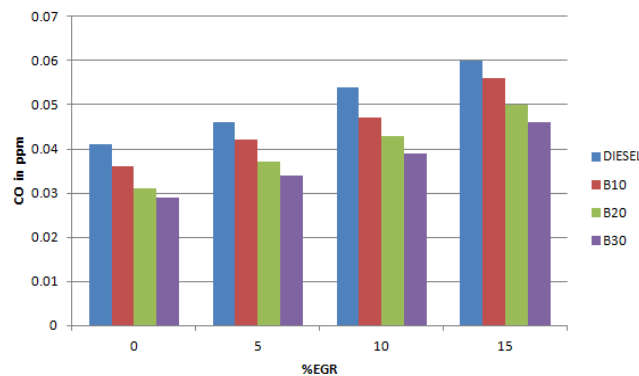


Fig 7: Variation of CO Vs % EGR

The variation of brake specific fuel consumption (BSFC) with load is shown in figure 8. Little amounts of biodiesel in diesel resulted in reduction of BSFC values, as B10, B20 showed fewer values of BSFC in comparison to diesel, the reason for more fuel consumption for pure biodiesel can be because of its lower heating value and higher viscosity

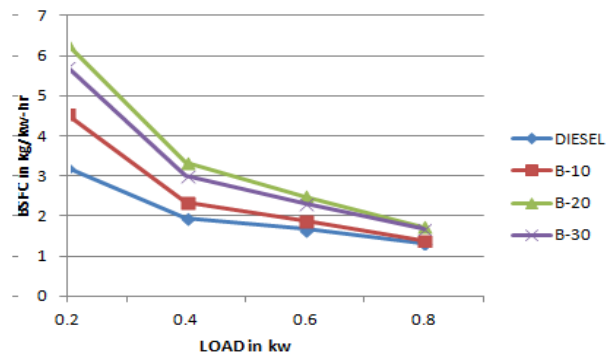


Fig 8: Variation of BSFC in kg/kw-hr Vs Load in kw

BSFC variation with EGR rate at full load is shown in figure 9. With the rise in EGR rate there is, rise specific fuel consumption this is severe for higher EGR rates i.e. more than 20%. The engine was run with EGR at the cost of little fuel loss.

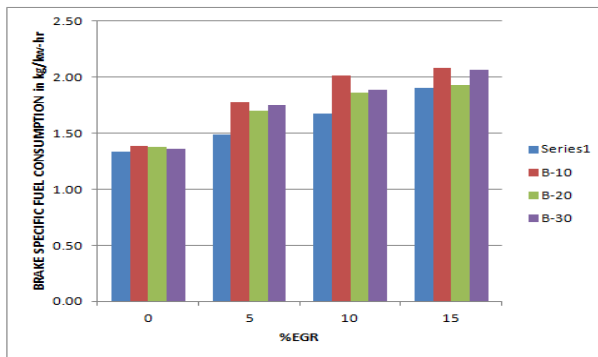


Fig 9: Variation of BSFC Vs % EGR

5. Conclusions

1. Brake Specific fuel consumption increases for pure biodiesel, and decreased for B10, B20 in comparison to diesel. The main cause of the increase in BSFC values for pure biodiesel its high value of viscosity when compared with diesel.
2. Effect of EGR is to increase the fuel consumption of the engine. Unburnt hydrocarbon emissions seem to reduce with biodiesel-diesel blends and with pure biodiesel, however with EGR the hydrocarbon emissions increased. With increase in EGR rate the carbon monoxide emissions also increased.
3. Nitrous oxide emissions are considerably reduced with the rise in EGR rate. When the engine is operated with biodiesel EGR would be best pretreatment method to reduce the NOx emissions at the cost of little fuel penalty.

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