Reduction in NOx Emission of Soap-Nut Oil Biodiesel in VCR Diesel Engine Using EGR

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Abstract

Researchers from all over the world are looking for the best alternative fuel for a variety of uses due to the significant increase in demand for energy with the fewest emissions feasible. Additionally, a number of emission standards for automobiles have been developed globally to minimize the quantity of pollutants produced by the engine. Biodiesel is one of the best suitable fuels and is generated form waste vegetable oil by means of transesterification process. However, increased NO_x emission is one of the main disadvantages of using biodiesel as a fuel. In order to reduce the emissions to a greater extent, Exhaust gas re-circulation (EGR) process can be employed that can control the NO_x emissions from the engine. By regulating the flame temperature and oxygen concentration in the chamber, a certain portion of exhaust is recirculated back into the combustion chamber with a new charge, which contributes to a reduction in NOx emissions. Effect of three different EGR ratios on the performance and emission parameter is studied. The blend of Soap-nut oil biodiesel with BHT as an additive will be used for the current experiment. The experiment showed that reduction in NO_x emissions leads to increase in percentage of EGR gas which also tends to increase brake thermal efficiency. However, increase in hydro-carbons, carbon monoxide emission and smoke opacity are recorded with the use of EGR.

Keywords: Soap-nut oil biodiesel, VCR Diesel engine, BHT*, EGR, Emissions*

Introduction

Fuel is one of the most important resources available today [1]. It is urgently needed to sustain and enrich human civilization. The non-renewable hydrocarbon fuels will soon run out of supply [2][3]. Due to the toxic chemicals they generate, such as NOx, CO2, and CO monoxide, traditional fuels are hazardous to the atmosphere [4]. Additionally, burning diesel releases a limited amount of CO2 into the atmosphere, which raises the earth's temperature and contributes to global warming [5]. To function in a full-fledged application, the majority of these alternative sources need to go through a specific maturation stage [6]. The majority of biofuels is environmentally favorable, with low levels of greenhouse gas emissions (which cause the earth's temperature to rise) and pollution such CO, HC unburned and smoke opacity [7]. Biodiesel is a fuel that burns cleaner than regular fuel; biodiesel is made from animal and plant fats, both fresh and used, as well as many types of renewable vegetable oils [8]. Over the years, experts have worked hard to find solutions to the problems associated with using biofuels to cut air pollution.

Nomenclature	
B20	80% Diesel + 20% Soap-nut oil biodiesel (SNB)
Without EGR	B20 + 0% EGR
5% EGR	B20 + 5% EGR
10% EGR	B20 + 10%EGR

Under ideal circumstances, the combustion of the mixture of hydrocarbons that is known as diesel fuel would produce solely carbon dioxide (CO2) and water vapor as byproducts. The bulk of the components that are found in diesel exhaust gases are carbon dioxide (CO2), water, and unused engine charge air [9]. The generation of nitrogen oxides in diesel engines is a phenomenon that is particularly sensitive to temperature. The reduction of NOX is assisted by the recirculation of some of the exhaust gas [10]. It is essential to understand how the recirculation of exhaust gas affects the engine's performance characteristics whenever this process is carried out [11]. Multiple components of availability were singled out and computed independently in conjunction with crank position. After that, the various scenarios of EGR, including chemical, radical, and thermal situations, were included into an availability study for dual-fuel engines operating at part loads [12]. They discovered that the chemical case of EGR had a detrimental impact, and in this scenario, the availability of unburned chemicals was raised, while the availability of work was lowered in comparison with the baseline engine. The thermal and radical examples both had beneficial impacts on the availability parameters, particularly with regard to the availability of unburned chemicals and work.

From ASTM standards, the thermal and physical properties were examined and listed below

S.No	Property	Values
1.	Density	0.930g/cc
2.	Kinematic Viscosity	9.99 cSt
3.	Flash point	238°C

4.	Fire point	254°C
5.	Calorific Value	38212 kJ/kg

A diesel engine's performance, combustion, and emission characteristics are intimately correlated with how well the fuel it is injected with burns [13]. The author and we came to the same conclusion: B20 blends are more compatible with the majority of distribution and storage equipment and may be used directly in all types of diesel engines without any modifications. According to the author, diesel engine emissions of PM, HC, and CO have reduced, but NOx emission has slightly increased [14]. Senthur Prabu and colleagues looked at the combustion, operational, and emission characteristics of diesel engines (DI) running on mixes of WCO biodiesel and diesel with butylated hydroxytoluene (BHT) and n-butanol as supplements [15].The researchers concluded that there is a significant observations for EGR % v/s load for brake thermal efficiency and brake specific fuel consumption.

The initial idea for this study was to study the emissions and performance characteristics of a single-cylinder, 4-stroke, constant-rpm, 1500 rpm DI engine with soap-nut biodiesel at different loads and graphs have been plotted. The Nox emissions are highest with 5% EGR value.

Experimental Setup

A single cylinder, 4-stroke, direct injection diesel engine running at a constant speed of 1500 rpm was used to study the performance, combustion, and emission characteristics of various soap-nut biodiesel (SNB)/diesel blends. An eddy current dynamometer and a diesel engine are linked, and the load ranges from 0% to 100% with a 25% load increment. Fig. 2 displays a schematic representation of the engine configuration. The table 2 provides a list of engine specifications.

Table 1 ENGINE SPECIFICATION

Manufacturer	**Kirloskar Oil Engines Ltd., India**
Model	TV1- Water cooled
Engine Type	Single cylinder, 4 stroke, direct injection diesel engine
Bore and stroke	87.5 mm and 110 mm
Compression ratio	17.5:1 [Standard]
VCR	12:1 – 18:1
Injection timing	23o before TDC (rated)
Injection pressure	220 bar
Speed	1500 rpm, Constant

Rated power	7.5 kW
Engine capacity	554 CC

Table 2 EMISSION ANALYSER AND SMOKE METER SPECIFICATION:

Particulars		**Details**
Exhaust Gas Analyzer	Model	AVL Di Gas 444
HC (ppm)		Range- 0-2000 ppm Accuracy- ±5 ppm
CO (%)		Range- 0-10% Accuracy- ±0.03%
NOx (ppm)		Range- 0-5000 ppm Accuracy- ±10 ppm
Smoke Meter	Model	AVL 437C
Range- 0-100% Accuracy- ±1%		
Light source		Halgen lamp, 12 V

1. Results and Discussions

The test was carried out utilizing soap nut oil biodiesel diesel with B20 , without EGR, 5% EGR and 10% EGR in a direct injection, four-stroke diesel engine. Analysis is done of the performance, emission, and combustion properties**.**

1.1 *Performance Studies*

1.1.1. *Brake Thermal Efficiency (BTE)*

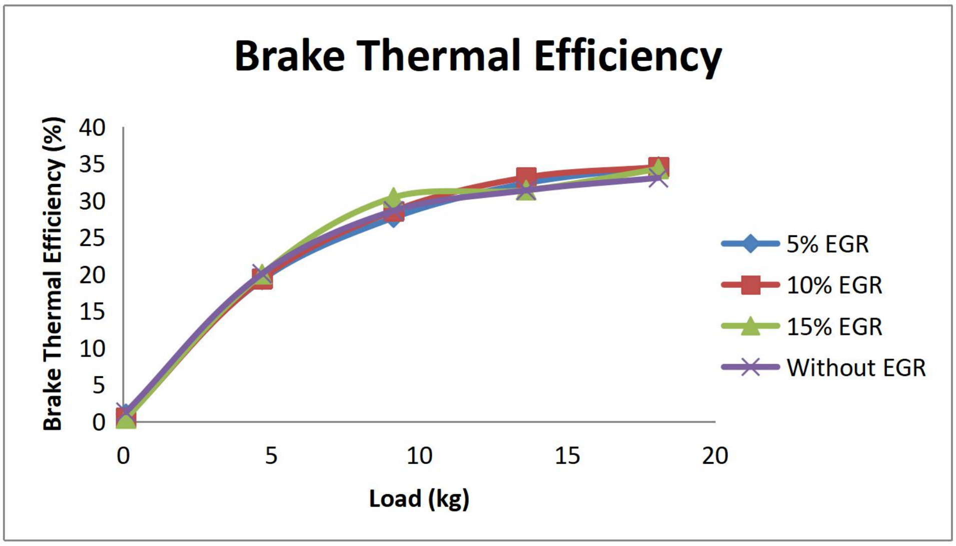

Fig.1 Brake Thermal Efficiency vs Load at different EGR%

The Figure 1 depicts variation of brake thermal efficiency with increasing load, while EGR of 5%, 10% and 15% is applied. The brake thermal efficiency changes dramatically with increase in load. At higher loads, the BTE of 0% EGR, 5% EGR, 10% EGR and 15% EGR are 33.06%, 34.27% ,34.58% 34.52%, and respectively. It can be observed that the BTE is least in case of 0% EGR and follows proportional trend to be highest in the case of 10% EGR. The BTE increases also with EGR up to about 10% EGR and then starts to fall. The recirculation of exhaust gases causes the hydrocarbon that enters the combustion chamber to be burned again, increasing BTE. EGR also raises the temperature of the intake charge, speeding up combustion. However, excessive exhaust gas recirculation displaces a significant amount of the air required for burning, decreasing thermal efficiency.

The following observations are subject to the hydrocarbon re-combustion of recirculated exhaust gas in the combustion chamber, the EGR also acts as a preheater for the intake air-fuel mixture [21, 22].

1.1.2. *Brake specific fuel Consumption (BSFC)*

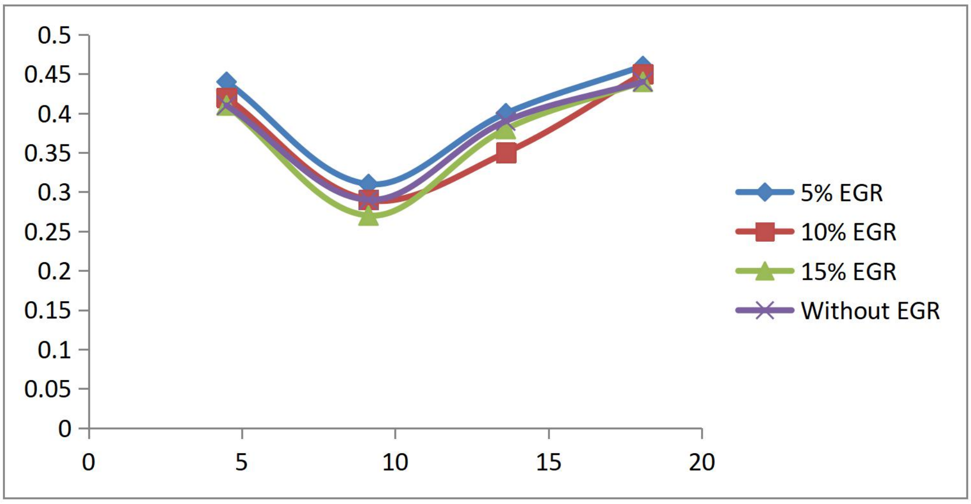

Fig.2 Specific Fuel Consumption vs Load at different EGR%

Specific fuel consumption vs load curve is demonstrated in the above figure.2, it shows the variation of BSFC with engine load for various percentages of EGR; by varying the percentage of exhaust gas which is recirculated under 0%, 5%, 10%, and 15% load. It can be seen that at lower loads the BSFC is highest for no EGR and lowest for 15%, while at higher loads the trend changes, such that the BSFC is highest for 15% EGR. As the intake charge temperature rises, the rate at which the fuel is burned increases, resulting in a decrease in BSFC with EGR.

To meet the power demand at higher loads more fuel needs to be burnt in case of 15% EGR, owing to the lower availability of oxygen in the air-fuel mixture [23].

1.2. *Emission characteristics*

1.2.1. *Hydrocarbon Emissions (HC)*

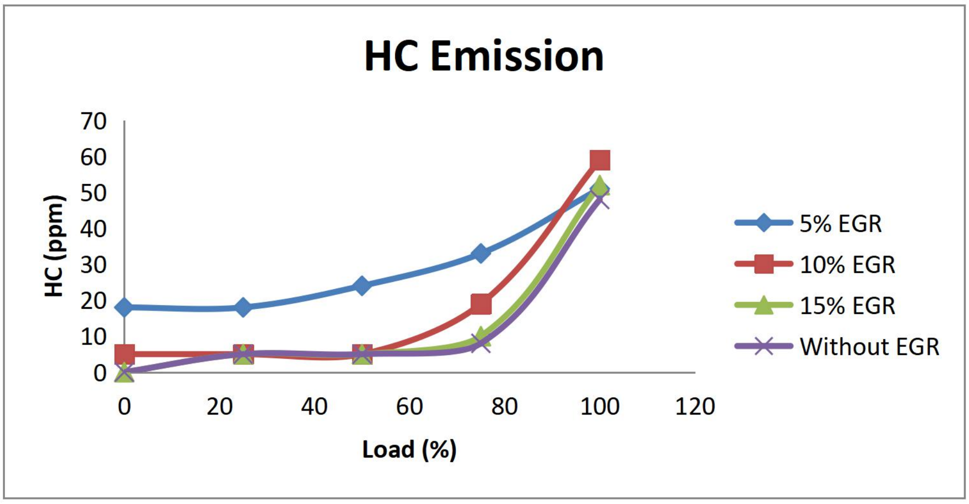

Fig.3 Hydrocarbon Emissions vs Load at different EGR%

The plot in figure.3 shows a relation between variation of Hydrocarbon emission and increasing load. It can be seen that at lower loads, 15% EGR shows corresponds to highest emission while 0% EGR corresponds to least emission. The rise in HC emissions is due to the fact that the injected mixture now has a higher CO2 component than it did before. Fresh air was used before. At higher loads the trend observed is same, but the emission decreases for all EGR values.

The following observation can be attributed to the fact that there's lesser oxygen available for combustion which leads to richer fuel and hence incomplete combustion. Thus, the exhaust gas contains more HCs.

1.2.2. *Carbon Monoxide emissions (CO)*

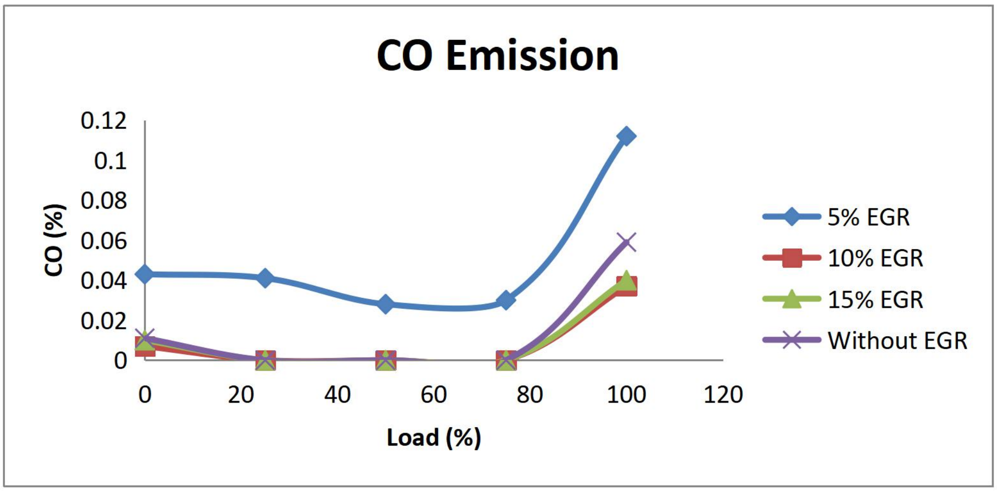

Fig.4 Carbon Monoxide Emissions vs Load at different EGR%

Figure.4 shows the emission of carbon monoxide with the increase in engine load. From the graph it can be seen that at lower loads, the CO emission is lowest for 10% EGR and maximum for 5% EGR; while at larger loads, the tendency is still present, but the emissions rise as previously described. At higher loads i.e. at 100% load highest emission is shown by 15% EGR i.e. 0.04% while 0.112%, 0.037%, 0.059% emissions are shown by 5% EGR, 10%RGR, without EGR respectively. The concentration of carbon monoxide rises proportionately with the amount of EGR used. The main causes of CO emissions from IC engines are low combustion and excessive rich fuel air ratios. Low engine power is caused by higher CO emissions. This phenomenon may be seen because there is not enough oxygen available, which results in incomplete combustion because of the heterogeneous mixture and causes CO emissions to rise. The rise in carbon monoxide emission caused by EGR may be blamed for the decrease in oxygen levels that occur as the proportion of EGR increases.

1.2.3. *NO_x Emissions*

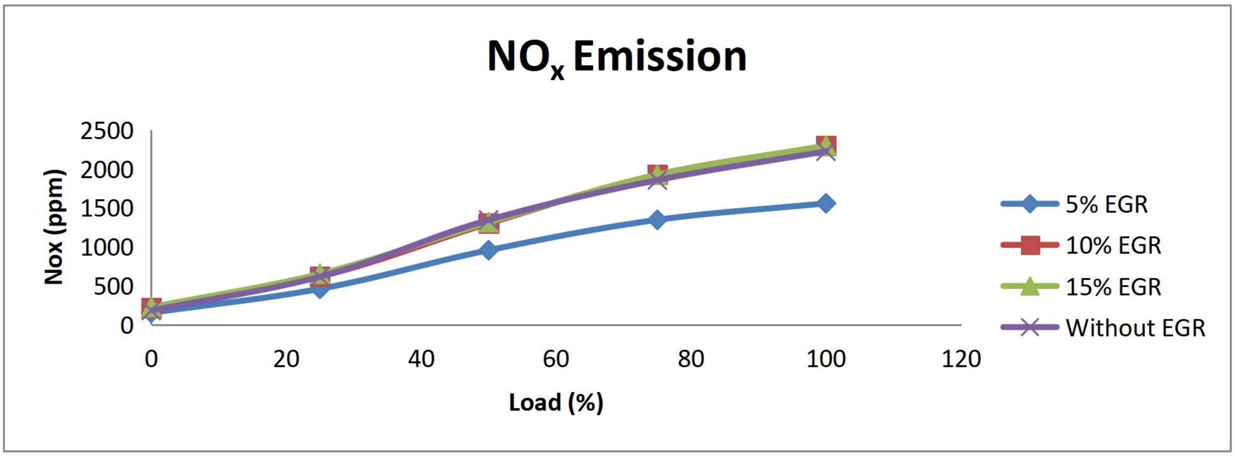

Fig.5 NOx Emissions vs Load at different EGR%

The relationship between NOx and load is shown by the curve shown in figure.5 above. The Nox emissions are increasing with the increase in percentage of EGR When operating at greater loads, the lowest emissions are seen with 5% EGR, while the highest emissions are shown with 10% EGR.At higher loads the NOx emissions for 5% EGR, 10% EGR, 15%EGR, and without EGR are 1559ppm, 2298ppm, 2298ppm, and 2227ppm respectively. As was said earlier, the NOx level rises as the load does. Compared to 5% EGR, the EGR with 10%, 15%, and without EGR produced greater levels of NOx emissions when subjected to higher loads This decrease in nitrogen oxides (NOx) is made possible by the decreased temperature of the exhaust stream. The aforementioned facts may be attributed to the fact that the absence of

EGR is synonymous with leaner fuel; hence, higher levels of oxygen will result in higher temperatures, which in turn will result in increased levels of NOx emission.

1.2.4. *Smoke opacity*

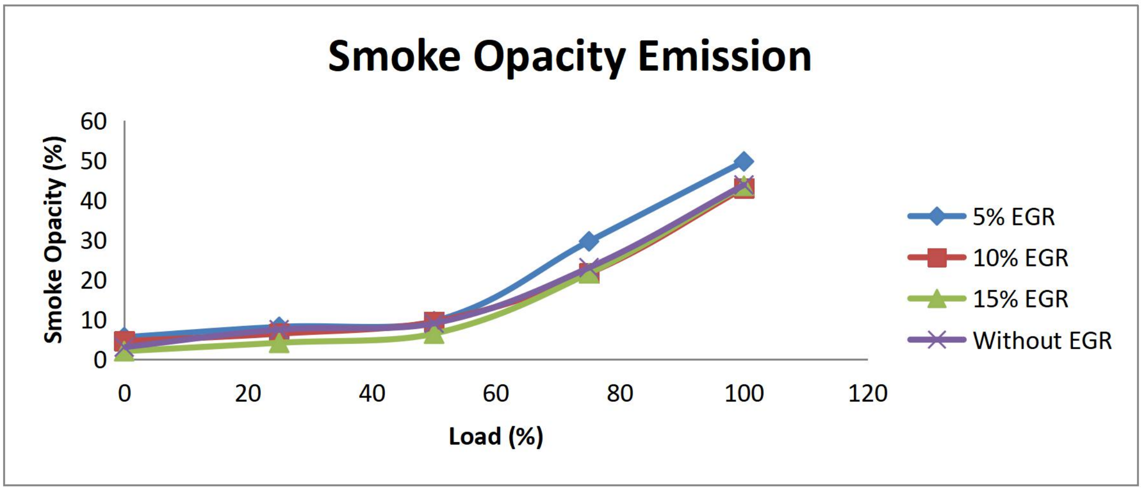

Fig.6 Smoke Opacity vs Load at different EGR%

The fluctuation in smoke opacity that can be seen in Figure.6 is directly related to the load. When operating at lower loads, the smoke opacity is at its lowest and is significantly lower; yet, when operating at 5% EGR, it is at its maximum. The overall trend shows that there is an increase in opacity along with an increase in load. At lower loads the smoke opacity for 5% EGR, 10% EGR, 15%EGR, and without EGR are5.5%, 4.5%, 2%,3% respectively while at higher loads smoke opacity is 49.7%, 43%, 43.6%, 43.8% respectively.To a large extent, smoke is determined by the amount of oxygen that is present in the fuel. Since oxygen content is the most important factor in determining smoke levels, looking at Figure 6 reveals that there is an increase in smoke opacity for all percentage of EGR when they are operated under full load conditions. These findings can be explained, in large part, by the production of particulate matter as a consequence of incomplete combustion, which is, in turn, a consequence of there being an inadequate supply of oxygen.

Conclusion

Through a technique calledTrans-esterification, the researchers in this study were able to manufacture soap nut oil biodiesel with a yield of 80%. The chemical and physical characteristics of soap nut oil biodiesel are measured, and it is found to be in compliance with the specifications for different percentage of EGR. The CO emissions are highest for 5%

EGR compared to other EGR. The NOx emissions are observed highest without EGR and NOx emissions increases as the load increases. The smoke capacity is lowest with higher loads while it is highest in case of 15% EGR. The BSFC is highest for no EGR and lowest for 15% at lower loads, while at higher loads the trend changes, such that the BSFC is highest for 15% EGR. The Brake thermal efficiency is least in case of 0% EGR while it is highest in case of 15% EGR.

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