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Experimental Studies of Emissions in a CI Engine Blended with Refined Sunflower Oil

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Abstract

The present study analyzes emissions, by using different blends of diesel and Refined Sunflower oil (RSF) on Kirloskar Direct Injection 4-stroke Diesel engine, single cylinder air-cooled, 4.4 kW, constant speed at 1500 rpm, compression ratio 17.5:1, Methyl Esters of refined sunflower oil (BRS) was transesterified with sodium meth oxide before blending with diesel. The main objective of this study is to measure the NO_x, CO, HC, and Exhaust temperature by varying the Injection pressure and the load. The experiments were conducted with various blends of diesel (BRS10, BRS30, and BRS40) at different pressures (180 bar, 210 bar, & 240 bar) and at different loads (0%, 25%, 50%, 75%, 100%). A 3–hole nozzle was used to inject the fuel. The Emission results were studied using AVL gas analyzer. The results show that there is an increase in CO, marginal increase in NO_x and decrease in HC.

Keywords: Kirloskar Di–Diesel Engine, Injection Pressure, BRS–Biodiesel Refined Sunflower Oil, 3–hole Nozzle, Combustion Emission Characteristics.

1. Introduction

In the Present scenario, the depleting fossil petroleum fuel, with ever increase in fuel price and increase in pollution level hazards to the environment that results due to engine exhaust, forces the usage of alternate fuels. Biodiesel or vegetable oil is eco-friendly and greatly reduce the greenhouse emissions and it is the available choice in comparison with diesel fuel.

The vegetable oils cannot be used directly along with diesel, since it is highly viscous. Transesterification process is done in the presence of methanol, and Sodium methoxide as catalyst. This improves the performance of the engine and reduces the emissions.

1.1 Background

Similar experiments on biodiesel were conducted by many researchers. Literature on biodiesel experiments by Yin et al. [1] shows that methanol with catalyst produces high yield in shorter time which results in UIMS & PUI than MS & FPUI containing lesser quantity catalyst and less energy consumption. In hydro conversion of SF oil Raney Nickel catalyst was investigated by Onyestyak et al. [2] and also tested with some of the octanoic acid as model and compounded at 21 bar in the temperature of 280°C to 340°C, in addition of ln_2O_2 significantly resulted in high alcohol yields. The combustion and emission results in base line fuel and the emission of smoke and nitrogen oxide measured at the engine exhaust while using cottonseed or sunflower oil in different proportions with two speeds and 3 loads tested by Rakopoulos et al. [3] the blends of sunflower, cotton seed, corn and olive used in six cylinders turbo charged heavy duty DI, Mercedes benz mini bus engine with the amount of two speed and three load conditions with neat diesel resulted in no changes in the thermal efficiency,

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reduction of smoke and insignificant increase in NO_x. Shehata [4] conducted experiments on Sunflower oil and Jajoba oil with 80% Pd by varying different engine speed resulted in lower brake thermal efficiency, smoke, CO and HC.

The experiments on the DI diesel Perkinson engine were conducted by Dorado et al. [5] by using reused olive oil methyl ester to study the effect on combustion efficiency. As a result, oxygen concentration was increased and accelerated the combustion. It was also found that the rate of combustion efficiency in the use of reused olive oil, methyl esters, and the rate of combustion efficiency remains almost constant as in the use of diesel oil. A lower energy rate was showed in the palm oil combustion, done by Tashtoush et al. [6] It was more efficient and higher rate of combustion (66%) seen in burning biodiesel, and the same for diesel combustion is 56%. This is because of the properties like high viscosity, less volatility with density. Sudhir et al. [7] conducted test on Diesel Engine, and the rate of combustion temperature and pressure was low in the operation of biodiesel, and the NO_x emissions was also almost to that of diesel. The sulphate emission was very low due to the lesser level of sulphur. The pilot combustion caused the pre-combustion. The observation was that the blending ratio of 15% resulted in reduced smoke opacity. The test conducted in DI stationary engine by Yusuf et al. [8] showed that as the blend increases, the brake power and CO increases in variable speed which was lesser than 1800 rpm. A review was done by Shereena et al. [9] using catalyst along with methanol in the transesterification process, which results in varying fatty acid content of the biodiesel. This could be a good alternative fuel for diesel.

1.2 Methodology

The Density, Kinematic viscosity of the BRS is within the limits of the Biodiesel Standards. It is estimated that the calorific value of the BRS is lesser when compared with diesel. The Engine requires a modification to improve emission reduction. The flash point of the BRS is high about 254°C compared with pure diesel and is safe to store and transport. The properties of the Diesel, Biodiesel standards & BRS as shown in Table 3.

The aim of the work is to analyze emissions and to study the performance of the Diesel engine by using biodiesel. This has been done by changing the injection pressure, fuelled with transesterified refined sunflower oil combined with pure diesel at different blends (BRS10, BRS30, and BRS40).

1.3 Nomenclature

BRS	–	Biodiesel Refined Sunflower oil
PD	–	Pure Diesel
ρ	–	Density, kg/m3
L	–	Length, mm
BP	–	Brake power, kW
N	–	Engine running speed, rpm
T	–	Torque, N-m
CV	–	Calorific Value of the fuel, kJ
R	–	Radius of the drum, mm
A	–	Area of the piston, mm^2
K	–	No. of cylinders
BIS	–	Bureau of Indian standards
ASTM	–	American standards of Testing and Materials

2. Methodology

2.1 Transesterification Process

The Methyl esters are formed by transesterification process. One litre of refined sunflower oil is treated with 400g of methanol and 30g of Sodium methoxide as catalyst. During the first phase oil is heated to raise of 20°C to 30°C from the room temperature and is allowed to cool naturally. For production of pure methyl ester, without any soap content, methanol is added to the preheated oil with catalyst at cold temperature and the mixture is heated to the order of 70°C to 80°C during the transesterification process of oil to reduce viscosity.

CH_2OCOR				CH_2OH	RCOOR
I				I	
CH_2OCOR	+	3ROH	$\xrightarrow{\text{catalyst}}$	CH_2OH	+ RCOOR
I				I	
CH_2OCOR				CH_2OH	RCOOR
Transesterification		Alcohol	Catalyst	Glycerin	Methyl Esters

2.2 Table 1. Specification of Test Engine

Type	:	Kirloskar Vertical, 4S, Single acting, High speed, C.I. Diesel Engine
Combustion	:	Direct Injection
Rated Power	:	4.3 kW
Rated Speed	:	1500 rpm
Compression Ratio	:	17.5:1
Injector type	:	Single, 3-hole jet injector
Fuel injection pressure	:	210 bar
Dynamometer	:	Eddy current

Dynamometer arm length	:	200 mm
Bore	:	87.5 mm
Stroke	:	110 mm
Connecting Rod	:	200 mm
Cubic Capacity	:	661.5 cm^3
Maximum Torque	:	0.030 kN – m (full load @ 1500 rpm)
Fuel tank Capacity	:	6.5 liters
Injection pump type	:	Single cylinder flange mounted without camshaft
Governor type	:	Mechanical centrifugal type

2.3 Table 2. Details of Measuring Systems

1.	AVL Pressure Transducer GH 12 D		
2.	Software Version V 2.0	–	AVL 617 Indi meter
3.	Data Analyzer from Engine	–	AVL PIEZO CHARGE AMPLIFIER
4.	To measure pressure	–	AVL 364 Angle Encoder
5.	Smoke meter	–	AVL 437 C Smoke
6.	5 Gas Analyzer (NO_x, HC, CO, CO_2, O_2)	–	AVL DIGAS 444 Analyzer

2.4 Experimental Setup

A stationary kirloskar 4S, DI Diesel Engine was used for conducting experiments. The specification of the engine is given in Table 1. The load on the engine was applied using Electrical loading (Dynamometer). The Eddy current dynamometer for loading is coupled to the engine for different loading (0%, 25%, 50%, 75%, 100%) conditions. The exhaust gas emissions from the engine was measured using AVL DIGAS 444 Analyser (NO_x, HC, CO, CO_2, O_2) and the smoke opacity was measured using AVL 437C smoke meter. AVL 364 Angle Encoder was used to measure the pressure and crank angle as given in Table 2.

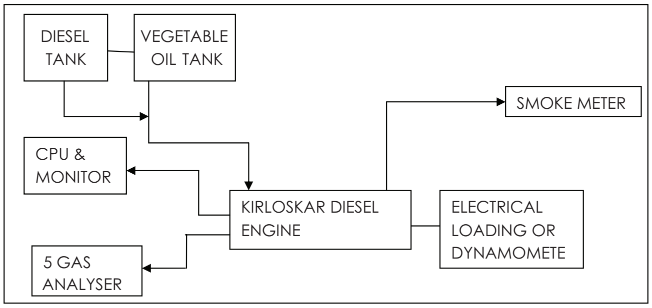

Figure 1. Schematic Diagram of Experimental set-up.

1 – Kirloskar Vertical C.I. Diesel Engine, 2 – Fuel Tank, 3 – AVL 437 C Smoke meter, 4 – Electrical loading device, 5 – Engine temperature monitor.

2.5 Test Procedure

The experiments were conducted at different load conditions, with different pressures at different blends viz (10% BRS + 90% PD), (30% BRS + 70% PD), (40% BRS + 60% PD) as fuel. The test was conducted at a constant speed of 1500 rpm. The engine was allowed to run at no load cndition for 10 minutes, using each proportion of the blend before applying the load. The loads were increased gradually for each blend in steps of 25% at constant speed of 1500 rpm at different pressures. The objective is to analyze the emissions based on the above conditions. The schematic diagram of Experimental setup as shown in Figure 1.

2.6 Table 3. Comparison of Properties of Diesel, Biodiesel Standards & BRS

S.No.	Properties	Diesel	BIS Standard Bio Diesel	ASTM D – 6751 (IS 15607:2005)	Refined Sunflower oil
1.	Cetane Index (min)	46	51	–	38
2.	Density at 15°C kg/m3	820–845	860–900	(860–900 Kg/m3)	923
3.	Kinematic Viscosity at 40 ° C cst	2–4.5	2.5–6	1.9–6 mm2/s	28.3
4.	Flash point °C min	35°C	262°C	130°C min	254
5.	Calroific Value kJ/kg	44,000	–	–	39,284
6.	Water Content mg / kg	200	500	0.050% by mass, max	0.05%
7.	Copper strip Corrosion 3 hr @ 100°C (max)	1	1@50°C	No. 3 (Max)	No. 1

3. Results & Discussions

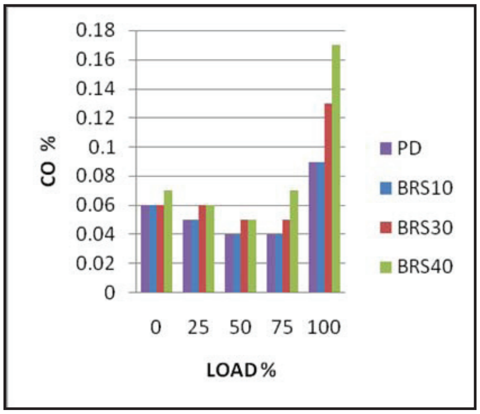

Figure 2. Variation of CO with respect to various blends of biodiesel at 180 bar.

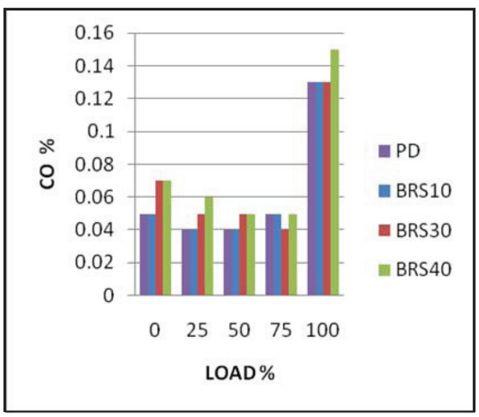

Figure 3. Variation of CO with respect to various blends of biodiesel at 210 bar.

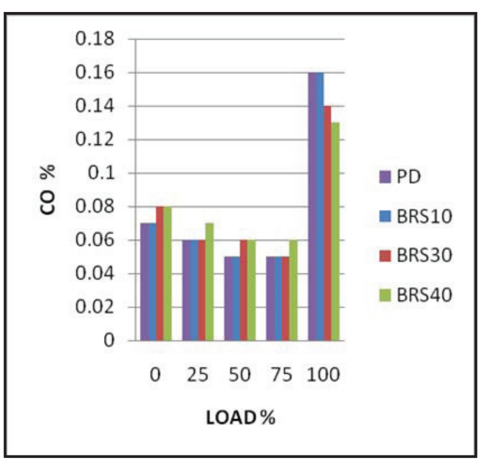

Figure 4. Variation of CO with respect to various blends of biodiesel at 240 bar.

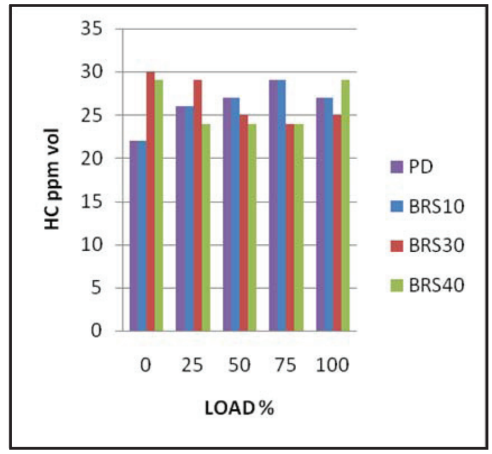

Figure 5. Variation of HC with respect to various blends of biodiesel at 180 bar.

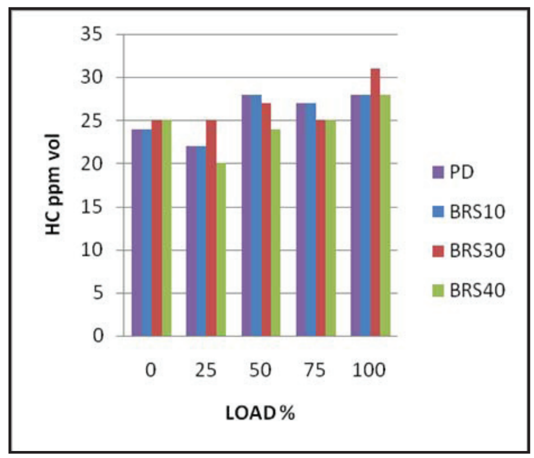

Figure 6. Variation of HC with respect to various blends of biodiesel at 210 bar.

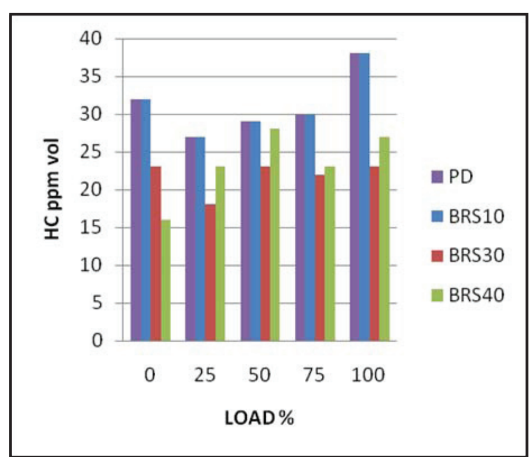

Figure 7. Variation of HC with respect to various blends of biodiesel at 240 bar.

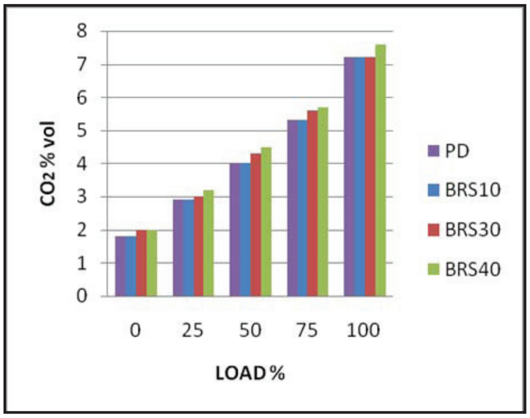

Figure 8. Variation of CO2 with respect to various blends of biodiesel at 180 bar.

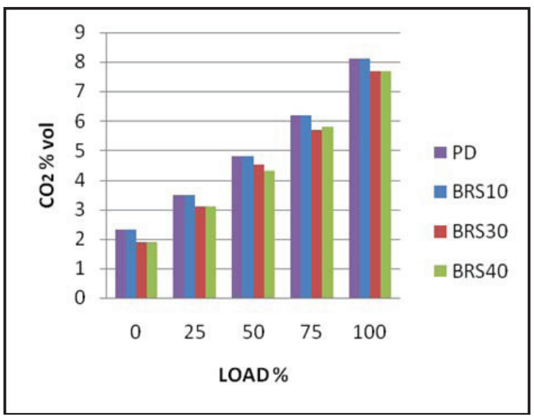

Figure 9. Variation of CO2 with respect to various blends of biodiesel at 210 bar.

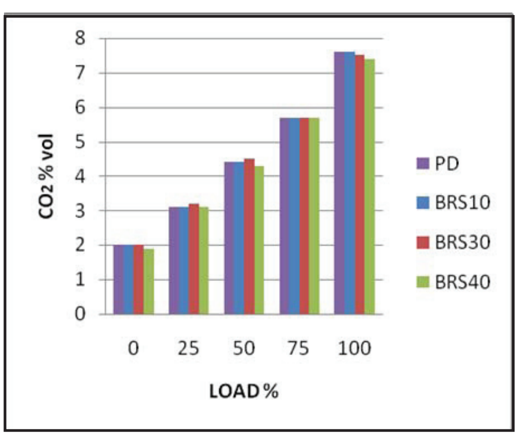

Figure 10. Variation of CO2 with respect to various blends of biodiesel at 240 bar.

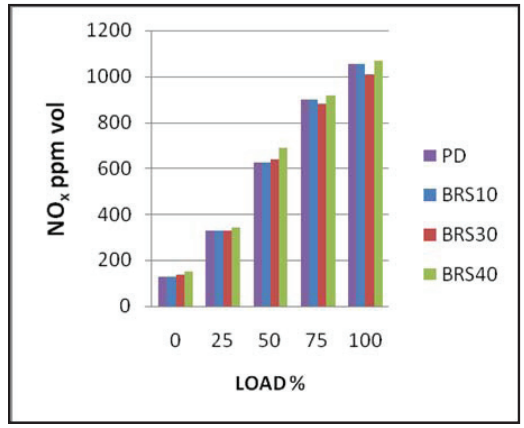

Figure 11. Variation of NOx with respect to various blends of biodiesel at 180 bar.

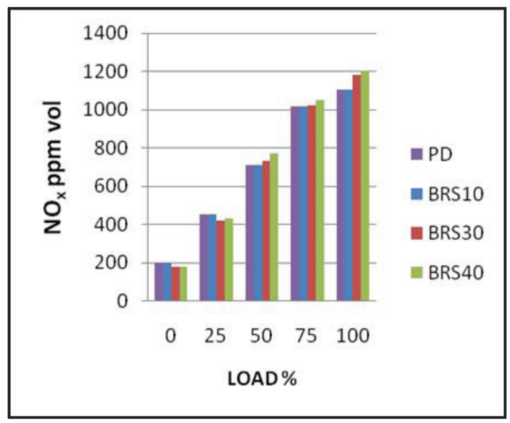

Figure 12. Variation of NOx with respect to various blends of biodiesel at 210 bar.

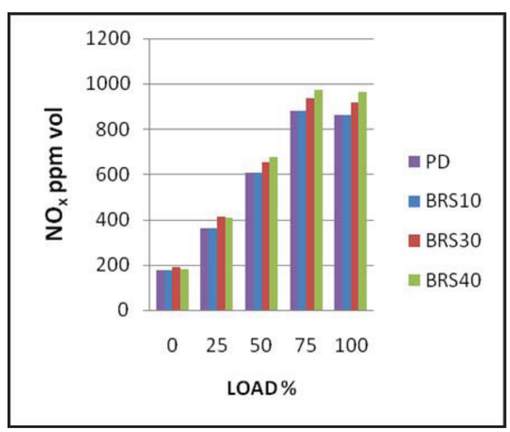

Figure 13. Variation of NOx with respect to various blends of biodiesel at 240 bar.

In the test conditions, by varying the pressure for variable loads, the emissions studied are discussed below.

3.1 Carbon mono oxide (CO)

As seen in the result of three blends shown in Figure 2, 3, 4, the BRS10 is almost equal to diesel, and for BRS20 and BRS30, the emission of CO increases for different loading at different injection pressures. The efficiency of combustion decreases because of the higher carbon content in rich fuel.

3.2 Hydrocarbon (HC)

Figure 5, 6 and 7 shows that there is a better reduction with BRS30 at 180 bar, 210 bar and 240 bar with respect to the various loadings. Tamilvedhan [10] explains, the engine fueled with methyl esters where the mixtures is either too rich to ignite and oxidized fuel in the exhaust this is due to complete combustion. The three hole nozzle is used in the injector which has the reduced size of droplets leading to the better combustion in the cylinder temperature, with increased amount of fuel even at higher loads.

3.3 Carbon-di-oxide (CO_2)

Figure 8, 9, 10, depicts that there is a marginal increase of CO at 180 bar and better reduction in 210 and 240 bar with 40% blend. Rakopoulas [3] explains that the required fuel rate is to be higher since the calorific value of vegetable oil is lesser, compared to neat diesel and the subtle distribution of the fuel air packets at different locations are necessary for effective combustion. Three hole nozzle spray at lower pressure from the smaller orifice diameter increases CO and at the higher injection pressure decreases CO due to the conversion of carbon atoms to CO_2 with enough oxygen which results in better combustion.

3.4 Nitrous Oxide (NO_x)

NO_x emission marginally increases with 30% and 40% blend at different injection pressures and various loads whereas at the 10% of biodiesel blend remains as like diesel. NO_x is formed due to lower cetane number and higher ignition delay leading to premixed combustion [11]. It could be due to the injection pressure and 3 – hole nozzle splits the fuel particles leading to higher flame temperature which increases NO_x.

4. Conclusion

The experiments conducted revealed, that the refined sunflower biodiesel, when blended with diesel by varying the pressure and loading, resulted in desired pattern of emissions. The conclusion are

a. The CO is same at 10% blend at all loads whereas there is an increase in CO with 210 bar and 240 bar in all blends.
b. The HC emission decreases significantly for 30% and 40% blend at different injection pressure, loading as compared with diesel.
c. There is a marginal increase in NO_x, when compared to pure diesel.
d. The reduction in engine temperature of the order of 2°C, supports the usage of the biodiesel for different engines.

5. Future Scope of work

The above analysis can be performed by changing the nozzle angle and nozzle orifice with various profiles and sizes like Elliptical, semi elliptical, etc., in addition to varying the number of nozzles against different blend ratio which may yield higher efficiency with lower emissions.

6. References

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