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Experimental Analysis of Emissions in a 4S Diesel Engine Blended with Refined Vegetable Oil

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ABSTRACT: In the scenario of fossil fuels and in ever depleting, there is always a scope for alternative fuels and this paper aims to study blends of diesel with Refined corn oil (BRC) on a stationery engine. The experiment is done on krisloskar Direct injection 4 stroke diesel engine, single cylinder, air cooled 4.4 kW constant speed at 1500 rpm with an compression ratio 17.5:1. Methyl esters of BRC were transesterified with sodim meth oxide before blending with diesel. For different blends at diesel (10%, 30%, 40%) in volume at specific injection pressures (180bar, 210 bar and 240bar) against different loads (0%, 25%, 50%, 75%, and 100%) have been tried in the experiment to study NOx, CO, HC, Smoke emissions with exhaust temperature. A 3- hole nozzle has been used and the emission are analyzed with AVL gas analyzer. Even though marginal increase in NOx with exhaust temperature at higher temperature are noticed the decrease in engine temperature by 3 deg in addition to HC and CO an significant.

KEYWORDS: Kirloskar Di – Direct Injection Diesel Engine, Fuel Injection pressure, BRC – Biodiesel Refined Corn oil, 3 – hole Nozzle, Combustion and Emission characteristics.

I. INTRODUCTION

In Indian scenario, increase in price of diesel and decrease in fossil fuels, to look for alternative fuels. To reduce the emissions and smoke, one of the way by blending the vegetable oil with diesel at different percentages. The biodegradation of biodiesel is higher than diesel and saves the environment. This result in reducing global warming effect and it reduces the cost of the fuel.

The transesterification process carried out in the presence of methanol and sodium meth oxide as catalyst, since the refined vegetable oil is highly viscous. The transesterified oil then blended with diesel in terms of percentages. Hence, decrease in emissions whereas performance increases.

1.1 Background: The numbers of similar experiments were conducted on biodiesel as follows. Mahin pey.N et al., [1] explains, for transportation and safe handling, low sulphur content with neutral CO_2 is essential. Jewel A. Capunitan et al., [2] one of the valuable energy of fuels is the chemical stock produced from pyrolysis processed of corn stover, conducted the experiments**.** The various studies made by, Ilknur Demiral et al., [3] on chromatographic and spectroscopic on bio-oil reveals that corncob stock can be classified as a renewable fuel. Significant reduction of about 52.1% in green house gas emissions is evident [Nathan Kauffman] [4]. The literature on production of raw material for biodiesel revealed by Xiao Huang et al., [5] that a corn stove hydrolysate as fermentation feedstock for preparing microbial liquid reduces Nitrogen content. N.N.A.N. Yusuf et al., [6] showed that compared with petroleum diesel, reduction in emissions of biodiesel, on CO_2, SO_2, particulate, CO and the HC and increase of about 10% NO_x is noticed. However, blending biodiesel with petroleum diesel reduces NO_x emission with slight increase in other values but are of acceptable criteria. Sources of producing biodiesel include edible oil of corn and canola [Prafulla D. Patil et al.,] [7] by using reused olive oil methyl ester to study the effect on combustion efficiency. As a result, oxygen concentration increases and it accelerates 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

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diesel oil. A lower energy rate was noticed in the palm oil combustion, done by Tashtoush G et, al,.[8]. It was more efficient and higher rate of combustion (66%) seen in burning biodiesel, when compared with the diesel combustion that is (56%). This is because of the properties like high viscosity, less volatility and density. Sudhir C.V. et, al, [9] conducted test on Diesel Engine, The rate of combustion temperature and pressure were low in the operation of biodiesel, and the NOx emissions was also equal 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 .T. F. et, al, [10] 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, [11] using catalyst along with methanol in the transesterification process, which results in varying fatty acid content of the biodiesel.

1.2 Methodology:

The flash point of BRC is high (about 254 °C) and the density, kinematic viscosity is within the limits of biodiesel standards. Since the calorific value of the BRC is less at about 16%, the engine requires a modification to reduce emissions. In addition, the BRC is safe, store and transport.

Emission study was analyzed to know the effectiveness of diesel engine by using biodiesel. This is done by varying the injection pressures fuelled with transesterified refined corn oil combine with pure diesel with blends 10%, 30%, and 40% in volume

1.3 Nomenclature:

BRC	-	Biodiesel refined Corn oil	PD	-	Pure Diesel
ρ	-	Density, kg/m^3	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			

II. METHODOLOGY

2.1 Transesterification process:

The methyl esters are derived by transesterification process. Using 30 g of sodium meth oxide as catalyst, one liter of refined corn –oil is treated with 250 ml of methanol. The total mixture is poured into a flask, containing refined corn oil which being stirred well in the room temperature, stirring continues up to 65°C to 70°C, to make the reaction completed bringing the content with orange brown color and is further cooled back to room temperature. The BRC oil separated in a beaker, which is with no soap content

CH_2OCOR					CH_2OH	RCOOR
I					I	
CH_2OCOR	+	3ROH	catalyst →	CH_2OH +	RCOOR	
I					I	
CH_2OCOR					CH_2OH RCOOR	
Transesterification		Alcohol	Catalyst		Glycerine	Methyl Esters

2.2 Table 1 - Specifications 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

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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:

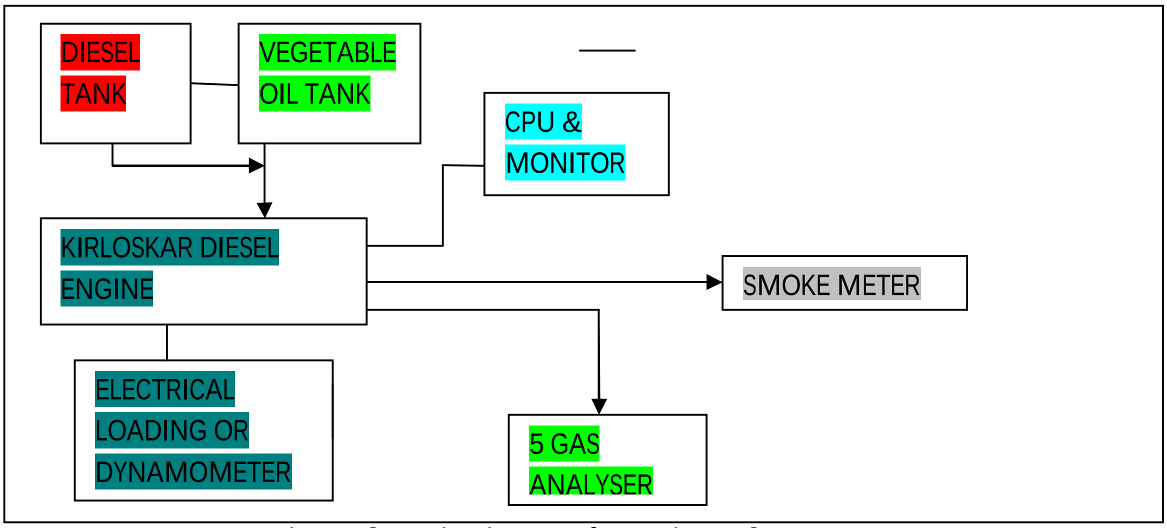

Fig. 1 Schematic Diagram of Experimental setp

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

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The detailed specification of a stationary kirlosker 4S, DI, Diesel engine is listed in Table – 1, which is used for conducting experiments. An Eddy current dynomometer (Electrical loading) is used to couple the load at different loading set conditons like 0%, 25%, 50%, 75%, and 100% with AVL DIGAS 444 analyzer. The exhasut gas emissons like NOx, HC, CO, CO_2 and O_2 are studied.The smoke opacity was measured using AVL 437C smoke meter and the pressure and crank angle were measured using 364 Angle encoder. The details of Measuring systems as given in Table – 2.

2.5 TEST PROCEDURE:

The BRC blends with pure diesel as 10:90, 30:70, and 40:60, were used to conduct experiments at different pressures at a constant speed of 1500 rpm. No load conditon was observed for 10 minutes, using each proportion of blend before applying load. Gradual increase of load for every blend in step of 25% at constant speed for varied pressure. The objective is to analyze emissions based on above conditions and the schematic diagram of the experimental setup is shown in fig - .1

2.7 Table 3 - Comparison of properties of Diesel, Biodiesel Standards & BRC

S.No.	Properties	Diesel	BIS Standard Bio Diesel	ASTM D – 6751 (IS 15607:2005)	BRC
1.	Cetane Index (min)	46	51	-	35
2.	Density at 15 ° C kg / m^3	820 – 845	860 – 900	(860-900 Kg/m^3)	923
3.	Kinematic Viscosity at 40 ° C cst	2 – 4.5	2.5 – 6	1.9 – 6 mm^2/s	29.3
4.	Flash point ° C min	35 ° C	262 ° C	130 ° C min	282 °C
5.	Calroific Value kJ/kg	44,000	-	-	36,824
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
8.	Ash % by mass	0.01	-	-	0.004

III. RESULTS & DISCUSSIONS

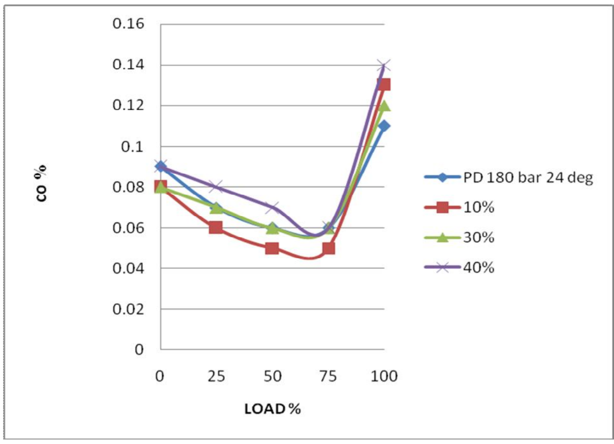

Fig – 2 Variation of CO with respect to various blends of biodiesel at 180 bar

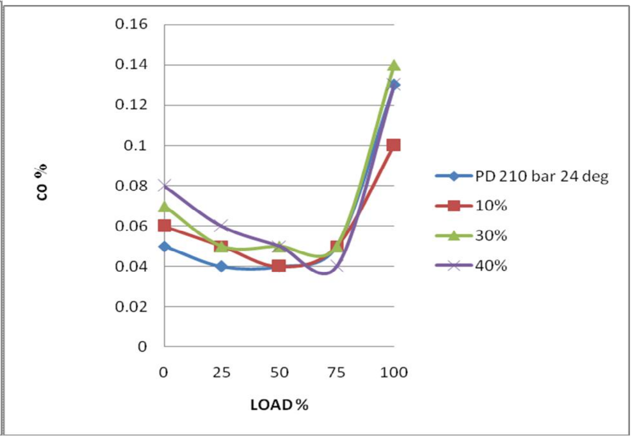

Fig – 3 Variation of CO with respect to various blends of biodiesel at 210 bar

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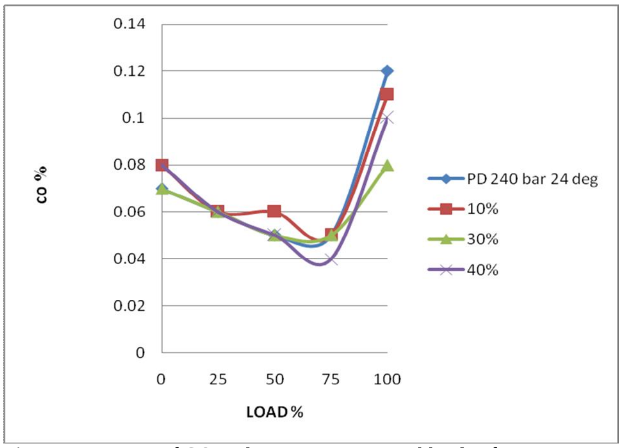

Fig – 4 Variation of CO with respect to various blends of biodiesel at 240 bar

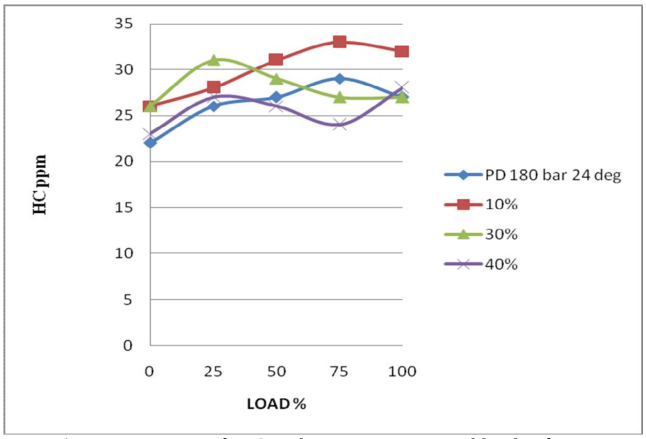

Fig – 5 Variation of HC with respect to various blends of biodiesel at 180 bar

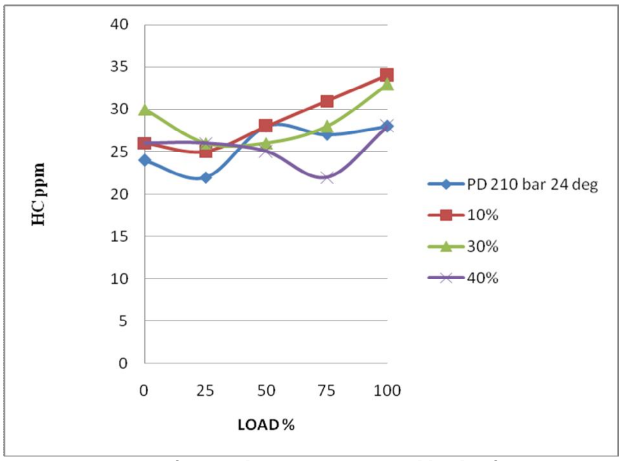

Fig – 6 Variation of HC with respect to various blends of biodiesel at 210 bar

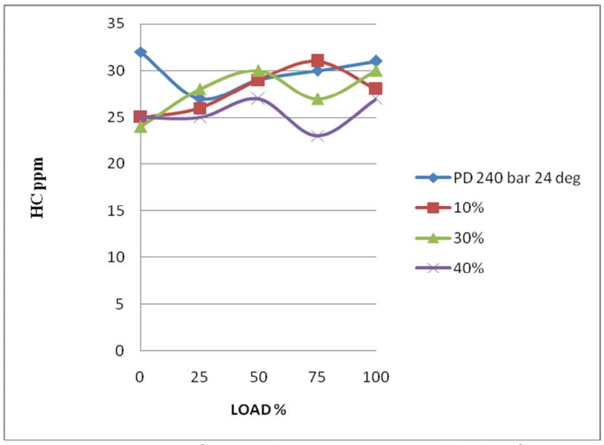

Fig – 7 Variation of HC with respect to various blends of biodiesel at 240 bar

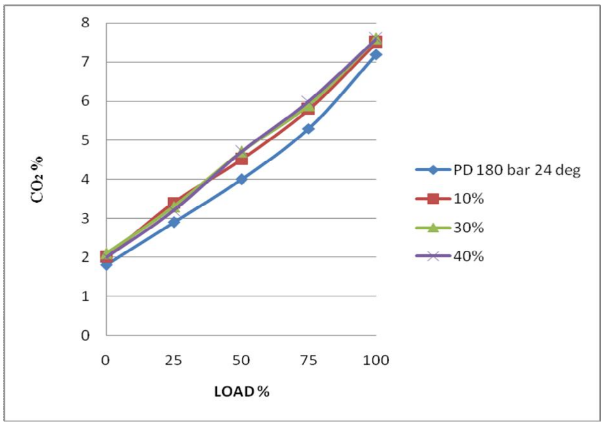

Fig – 8 Variation of CO_2 with respect to various blends of biodiesel at 180 bar

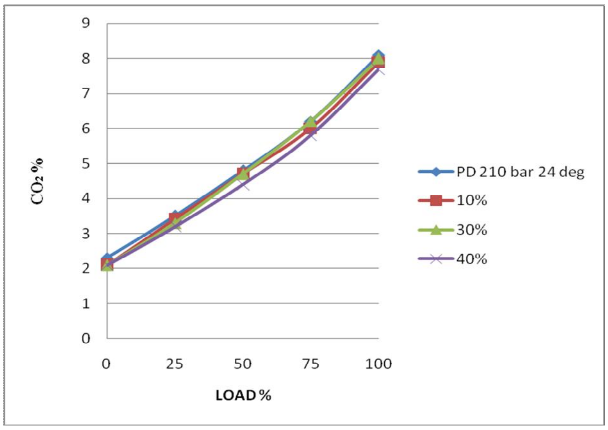

Fig – 9 Variation of CO_2 with respect to various blends of biodiesel at 210 bar

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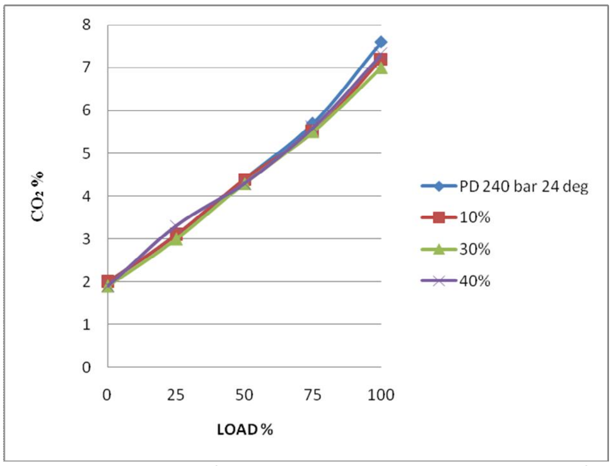

Fig – 10 Variation of CO_2 with respect to various blends of of biodiesel at 240 bar

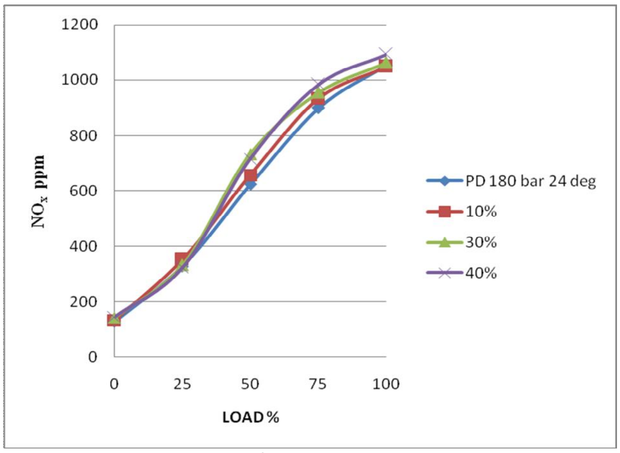

Fig – 11 Variation of NO_x with respect to various blends biodiesel at 180 bar

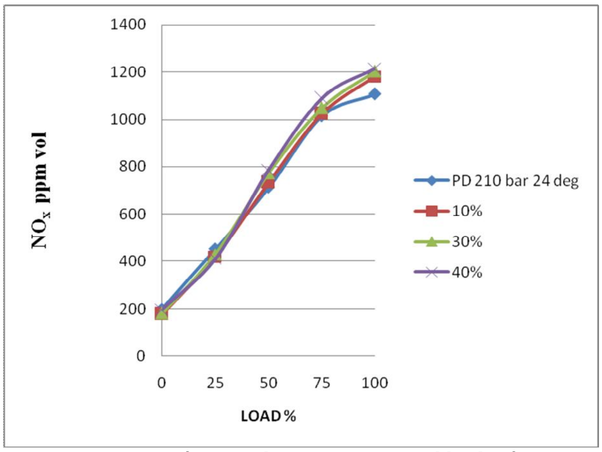

Fig – 12 Variation of NO_x with respect to various blends of biodiesel at 210 bar

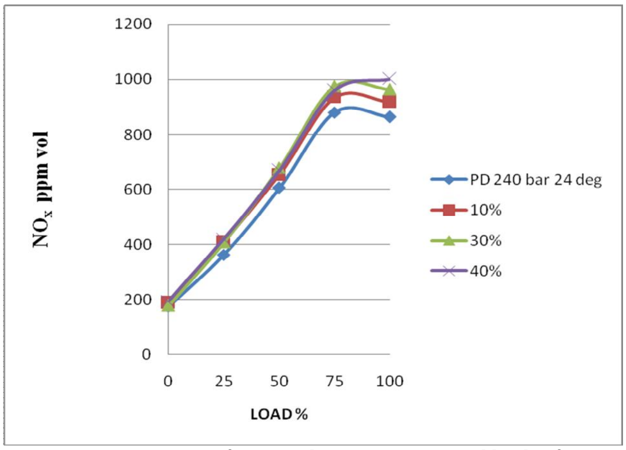

Fig – 13 Variation of NO_x with respect to various blends of biodiesel at 240 bar

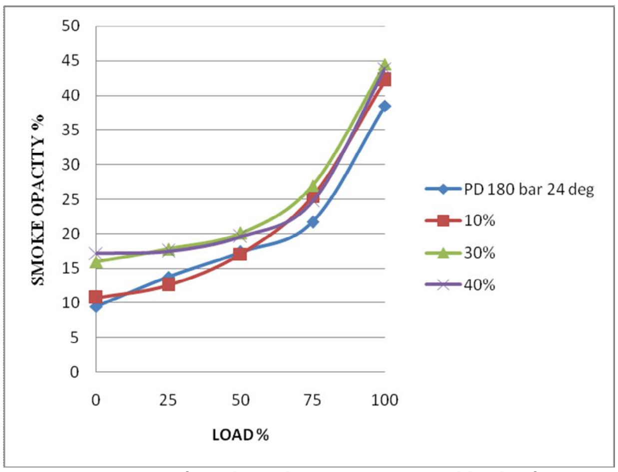

Fig – 14 Variation of Smoke with respect to various blends of biodiesel at 180 bar

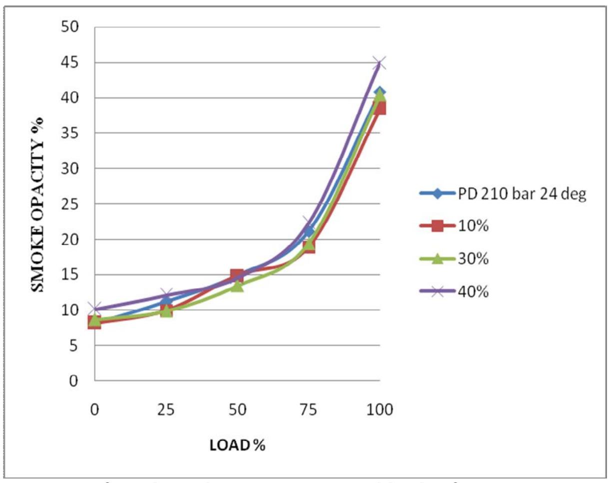

Fig – 15 Variation of Smoke with respect to various blends of biodiesel at 210 bar

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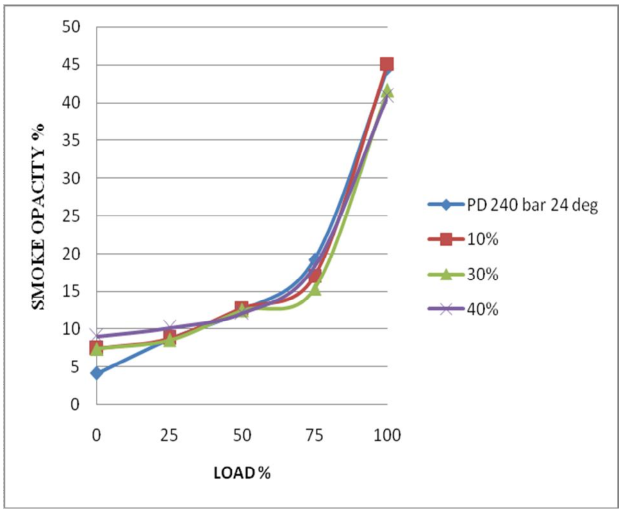

Fig – 16 Variation of Smoke with respect to various blends of biodiesel at 240 bar

In the test conditions, at different pressures (180 bar, 210 bar, & 240 bar) against different loads, the emissions studied are discussed below

3.1 Carbon mono oxide (CO) : Fig 2,3,4 shows that CO decrement is noticed at 180 bar for all blends. However at 210 bar, it increases upto 75% of load and thereafter it decreases for higher loads. Significantly CO reduction happens at about 18% at 240 bar with 40% blend. The emission reduction at high injection pressure happens due to higher heating value of biodiesel with more oxygen molecules effect in stable combustion of the biodiesel blend.

3.2 Hydrocarbon (HC) :. At three different pressures, HC is analyzed against different blend ratio. At 240 bar with 40% blend ratio HC decreases whereas at 180 bar with 10% blend and 210 bar with 30% HC increases. The results shwon in fig. 5,6 & 7.

3.3 Carbon-di-oxide (CO_2): Fig 8, 9 & 10 points out that, Emission of CO_2 increases with 10% and 30% blends against all pressures. But at 210 bar and 240 bar, the reduction in CO_2 is noticed for 40% blend. High O_2 content and different spraying conditions against the different engine loads makes complete combustion for biodiesel which reduces CO_2 emission significantly.

3.4 Nitrous Oxide (NO_x): At all blends, NO_x emission reduces against lower loads and vice versa as shown in fig. 11, 12, 13. This is because of effective spraying of blended diesel by 3 hole nozzle through small orifices result in NO_x reduction and as load increases, the temperature in inside cylinder increases resulting in higher NO_x emission.

3.5 Smoke: From Fig 14, 15, & 16 Smoke results in the reaction during combustion and it increases at 180 bar for 30% and 40% blends. At 210 bar and 240 bar smoke decrease is observed. Always for intial loads smoke is increased and at higher loads it is gradually decreased, with a reduction of smoke temperature of the order of 2˚C. The hetrogeneous mix of molecules of lubricating oil in vapour form with biofuel during combustion results in partial combustion which results smoke.

IV. CONCLUSION

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

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a. The higher pressure plays a crucial reduction of emissions as in 240 bar with 40% diesel.
b. The NO_x emission is generally less for lower percentage of blends with lower pressures and at higher pressure the emission of NO_x increases.
c. Biodiesel smoke opacity is marginally high when compared with diesel.
d. Engine temperature increases during the lower loads and it decreases against higher loads.

V. FUTURE SCOPE OF WORK

By modifying cone angle in the nozzle and various cross sections of fuel injection like elliptical, semielliptical, circular, triangular etc, there is a scope of improvement. Also increase in number of nozzles against different blend ratio may yield higher efficiency with lower emissions.

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