Experimental Investigation the Performance, Combustion and Emission of CI Engine using B20 Cotton Seed Oil Methyl Ester with Exhaust Gas Recirculation

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Abstract: **Demand for fuel and the use of petroleum products are increasing day by day which causes serious problems such as petroleum depletion, environment degradation etc. So biodiesel is a good alternative for conventional diesel fuel. By using biodiesel there are also some disadvantages such as high oxides of nitrogen, high fuel consumption and higher density. To overcome this problems from and reducing exhaust emission EGR playing a important role.**

Biodiesel is obtained from cotton seed oil by transesterification process. The experiment work is done by a CI engine using cotton seed oil biodiesel with Exhaust Gas Recirculation. The present investigation was to study the combustion and performance characteristics of all the blends by compare them with diesel. Experimental results show that performance and combustion characteristics improved with B20 biodiesel blend and reduction in NOX emission by using Exhaust Gas Recirculation. The thermal efficiency will increase and SFC(Specific fuel consumption) is better in case of Biodiesel blend. Considerable reductions parameters like carbon monoxide, unburned hydrocarbon and increases in nitrogen oxide emissions are attained while using B20 biodiesel blend compared with diesel. However there is a significant reduction in CO, UBHC and NO_x emission parameters for B20 biodiesel blend with Exhaust Gas Recirculation.

Keywords: CI Engine, emission, B20 Cotton seed oil methyl ester, Exhaust Gas Recirculation.

1. INTRODUCTION

Over the last two decades in world, there has been a tremendous increase in the number of industries and automobiles. Present Scenario the motor vehicle population in India is about one hundred million. Even though the transport sector plays a essential role in the economic development of any country, it brings an unavoidable specter of environmental deterioration along with it. This is specially a big problem for developing country like India. Development of new energy resources has become important agenda in relation to national energy policy (1). According to estimates of the oil and gas journal, crude oil production is expected to reach a peak in another one decade, and from then on, it is eventually going to decrease. With this, the crude oil, will be expensive progressively until it becomes unaffordable while putting pressure on the import bill and increasing the import bill deficit (3). Thus, there is a need to look at other options as far as energy needs are concerned. Based on the recent research, biodiesel has more attractive because of its performance and environmental benefits and the facts that it is eco-friendly, non-toxic and can be made from the renewable resources. Biodiesel is also having a small number of drawbacks, such as superior viscosity, superior molecular weight, higher poor point and lower volatility compared with diesel. These drawbacks cause poor atomization and lead to incomplete combustion. So, to reduce above mentioned drawbacks additives are used (2).

1.1 Cotton Plant

Cotton is a natural fibre of vegetable origin, like linen, jute or hemp. Mostly composed of cellulose (carbohydrate plant substance) and formed by twisted, ribbon like shaped fibres, cotton is the fruit of a shrubby plant commonly referred to as the "cotton plant". The cotton plant, a variety of plants of the genus gossypium, belongs to the malvacae family, which comprises approximately 1,500 species, also including the baobab tree, the bombax or the mallow. The plant, growing up to 10 meters height in the wild, has been domesticated to range between 1 to 2 meters under commercial cultivation in order to facilitate picking. Either herbaceous or ligneous, it thrives in dry tropical and subtropical areas. Whereas by nature the plant is a perennial tree (lasting about 10 years), under extensive cultivation it is mostly grown as an annual shrub. The cotton flower has five large petals (showy, white, white creamy, or even rose in colour), which soon fall off leaving capsules or "cotton bolls" having a thick and rigid external layer. The capsule bursts open upon maturity, revealing the seeds and masses of white/creamy and downy fibres. Cotton fibres of the gossypium hirsutum species range from about 2 to 3 centimeters in length, whereas gossypium barbadense cotton produces long staple fibres up to 5 centimeters in length. Their surface is finely indented and they become kinked together and interlocked. The cotton plant is almost exclusively cultivated for its oleaginous seeds and for the seminal fibres growing from them (i.e. cotton, strictly speaking). In ordinary usage, the term "cotton" also makes reference to fibres that are made into fabric wires suitable for use in the textile industry (4).

Cotton plants can grow into shrubs 6 m to 10 m height, although they are usually much smaller in cultivation. Cotton leaves are broad and have three to five (or even seven) lobes and fruits are creamy white flowers are produced that later turn deep pink and fall off, leaving seed pods called 'cotton bolls'. Inside the bolls are seeds surrounded by fibres which are spun into thread for cloth. These cotton fibres are used to make 40% of the world's textiles.

Cotton comes from cultivated plants from the genus gossypium. They have been cultivated since ancient times for their fibres which are used as textiles. Cotton has other more surprising uses too from medicines and mattresses to seed oil and even sausage skins. The majority is produced by China, America, India, the Central Asian Republics, Pakistan, Brazil and Egypt. It is found exhaustively in India especially Maharashtra, Gujarat, Punjab, western Uttar Pradesh, Assam, Andhra Pradesh, Karnataka and Tamilnadu where it is commercially cultivated. Figure 3.3 shows the stages of cotton plant.

Figure 3.3: Stages of Cotton Plant

(A: Cotton plant B: Cotton flower C: Cotton fibre D: Cotton seed)

1.2 Composition

Fatty acid profile generally consists of 70% unsaturated fatty acids (18% monounsaturated and 52% polyunsaturated) and 26% saturated fat. When it is fully hydrogenated, its profile is 94% saturated fat and 2% unsaturated fatty (1.5% monounsaturated and 0.5% polyunsaturated). The cotton seed oil industry claims that cotton seed oil does not need to be hydrogenated as much as other polyunsaturated oils to achieve similar results (5).

Table 1.1: Analysis of Cotton Seed Oil.		**Table 1.2 :** Fatty Acid Composition of cotton Seed Oil	
Particulars	**Cotton seed oil (%)**	**Oil/fatty acid**	**Cotton seed oil (%)**
Hydrogen	11.28	Palmitic $C_{16:0}$	28
Carbon	81.42	Linoleic $C_{18:2}$	58

Nitrogen	0.028	Stearic $C_{18:0}$	1
Oxygen	7.22	Oleic $C_{18:1}$	13

Table 1.3: Physical Properties Cotton Seed Oil (5)

Properties	Straight Diesel	COME	ASTM standard
Chemical formula	$C_{14.09}H_{24.78}$	$C_{54}H_{101}O_6$	-
Kinematic viscosity (mm^2/s) at 40^0C	3.8	6.1	D445
Density (kg/m^3) at15^0C	836	848	D 1298
Higher calorific value (KJ/Kg)	43,850	40,610	D 5865
Cetane number	49	53	D613
Flash point (^0C)	55	200	-
Cloud point (^0C)	-20	-2	D2500
Pour point (^0C)	-24	-5	D97

2. EXPERIMENTAL SETUP FOR ENGINE TESTING

The experimental set up of the present work with various components is shown in Figure.1 and Figure.2 and the experimental work carried out for the objectives, requires an engine test set up adequately instrumented for necessary performance and emission characteristics. Cotton seed oil blend and pure diesel were used to test a TV2, Kirloskar, Sinle acting, 4-stroke, water cooled diesel engine having a rated output of 16HP at 1800 rpm and a compression ratio of 17.5:1. The engine was coupled with an eddy current dynamometer to apply different engine loads. The emissions from the engine were studied at different engine loads. After the engine reach stabilized working condition, emissions like carbon monoxide, hydrocarbon, Nitrous oxide and exhaust gas temperature (EGT) were measured using a smoke meter and an exhaust gas analyzer.

Figure 1: Diesel Engine Test Rig

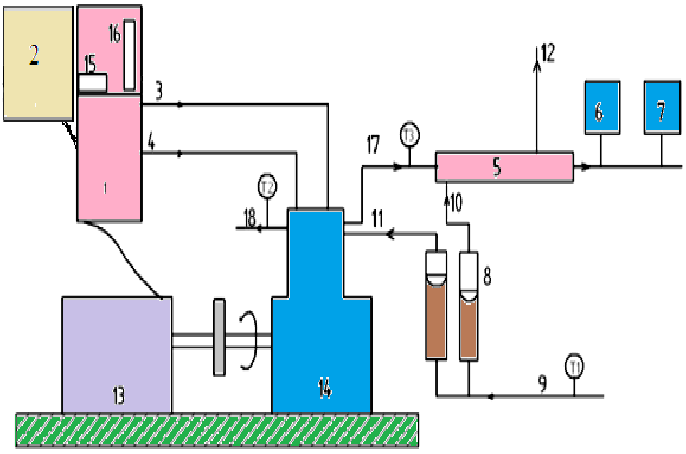

Figure.2: Schematic Diagram of the Experimental Set Up

1 = Control Panel
2 = Computer system
3 = Diesel flow line
4 = Air flow line
5 = Calorimeter
6 = Exhaust gas analyzer
7 = Smoke meter
8 = Rota meter
9= Inlet water temperature
10= Calorimeter inlet water temperature
11= Inlet water temperature
12 = Calorimeter outlet water temperature
13 = Dynamometer
14 = CI Engine
15 = Speed measurement
16 = Burette for fuel measurement
17 = Exhaust gas outlet
18 = Outlet water temperature
T1= Inlet water temperature
T2 = Outlet water temperature
T3 = Exhaust gas temperature

Table : Technical specification of Engine

Manufacturer	Kirloskar oil Engines Ltd
Model	TV-2
No of Cylinder	Two
Type of Engine	Vertical, 4-Stroke cycle, Single acting
Cooling	Water
Fuel	Diesel
HP	16HP
Starting	Hand Cranking
Bore	87.5mm
Stroke	110mm
Cubic Capacity	1322cc
Nominal Compression Ratio	17.5:1

Fuel Timing by Spill(BTDC)	26 Deg
Inlet valve opens BTDC	4.5 Deg
Inlet valve closes ATDC	35.5 Deg
Exhaust valve opens BBDC	35.5 Deg
Exhaust valve closes ATDC	4.5 Deg
Valve Clearance Inlet	0.18mm
Valve Clearance Exhaust	0.20mm

3. RESULTS AND DISCUSSION

With the above described experimental setup, the CI engine is tested for combustion, performance and emission characteristics with test fuels. The CI engine is tested under constant speed of 1800rpm with varying load from zero percentage load to 100% load.

3.1 Performance characteristics

In this section various performance characteristics like Specific fuel consumption and Brake thermal efficiency were discussed.

3.1.1 Brake Thermal Efficiency

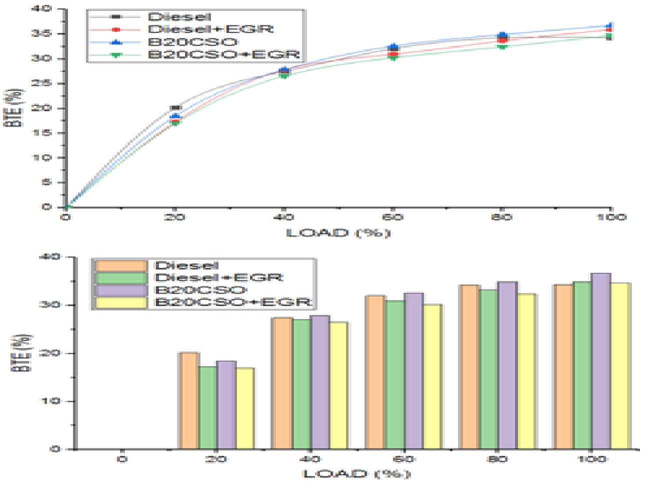

Figure 2-Variations of brake thermal efficiency

Figure shows the BTE variations with load for all test fuels. It is clear from the graph that BTE increases with increase in load. It has been observed that for all test fuels, the BTE is higher than the neat diesel except 20% load. The maximum BTE is accounted for B20CSOME and minimum is observed for diesel full load. This shows that there is increase in BTE compared to diesel and B20N respectively. This is because of better air fuel mixing, improved combustion. The increase in BTE is also accounted for oxygen present in biodiesel which provide oxygen for combustion.

3.1.2 Specific Fuel Consumption

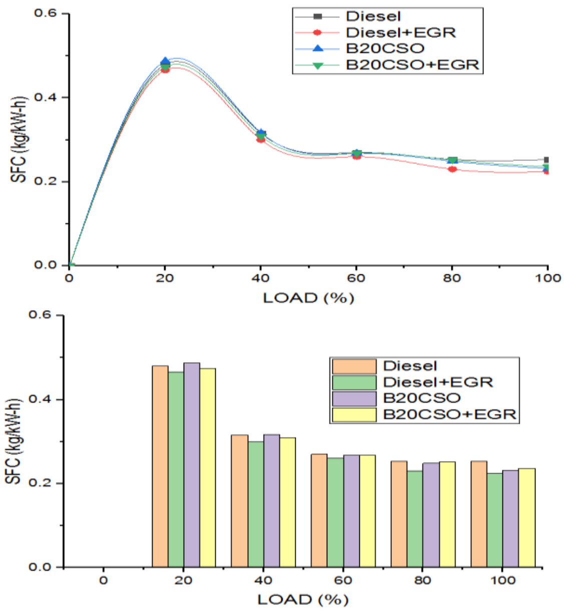

Figure 3-Variation of SFC

Fig shows the SFC variations with respect to load applied for all tested fuels. It is clear from the graph that SFC decreases with increase in load. At full load the maximum SFC is observed for diesel and minimum for B20CSOME. So there is decrease in SFC of B20CSOME than diesel. This is because of lower calorific values of blended oils and also because of better combustion, due to good atomization.

3.2 Combustion Characteristics

The combustion process can affect the emission and performance characteristics of CI engine. In this section the combustion Characteristics such as HRR and Peak cylinder pressure are discussed.

3.2.1 Peak Cylinder Pressure

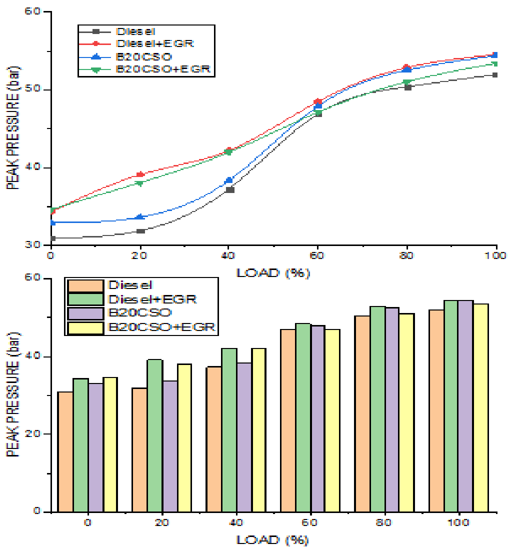

Figure 4- Variation of BMEP

Figure shows the variations of peak cylinder pressure with respect to load. The peak cylinder pressure increases with increase in load. It is comparatively high for blended fuels than neat diesel. It is maximum for B20CSOME than diesel. This higher peak cylinder pressure is because of the high catalytic activity of biodiesel and reduced ignition delay, which promotes complete combustion there by increasing the cylinder pressure.

3.3 Emission Characteristics

This section is deals with the emission characteristics such as CO, UBHC and NOx emissions for all test fuels with varying load.

3.3.1 CO Emissions

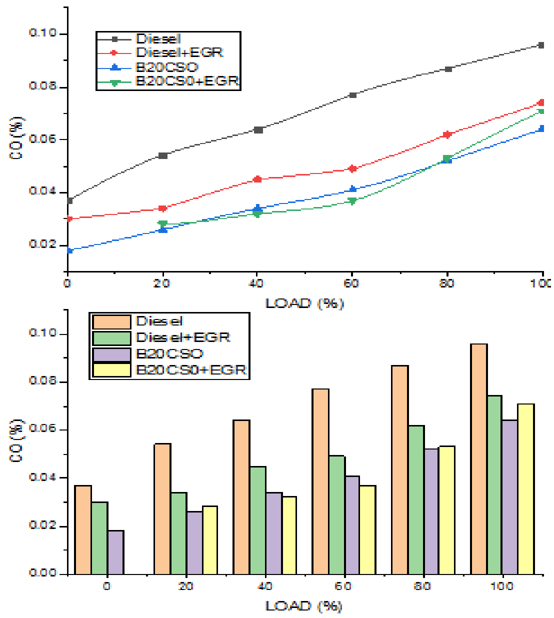

Figure 5- variations of CO

Fig shows the variation of emission of CO with respect to load. The CO increases with increase in load. The graph clearly shows the decrease CO of biodiesel blends compared to neat diesel. The CO emission is maximum for diesel and minimum for B20CSOME. From the graph it is clear that, the emission of CO in B20CSOME is lower compared to diesel. This is because of the fine atomization and oxygen content in the fuel which results in complete combustion. If comparing the emission of diesel and diesel+EGR the percentage of CO reduces by using for both diesel and B20CSOME.

3.3.2 NOx emissions

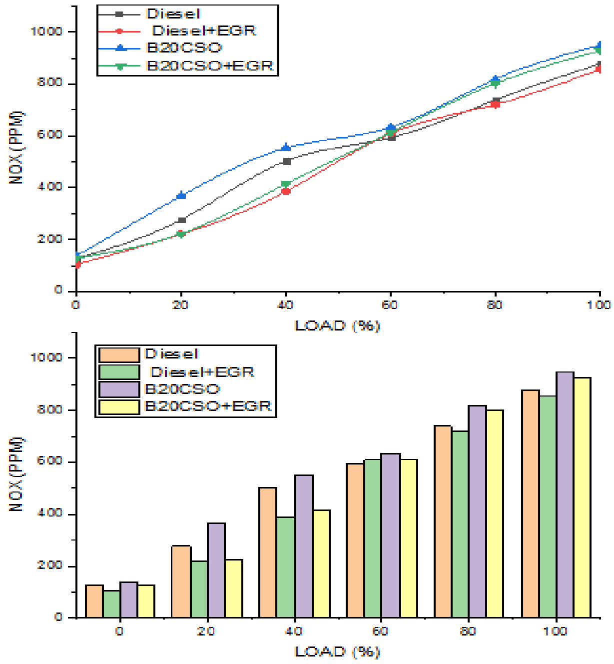

Figure 6- variation of NOx

Figure shows the variations of NOx emission with respect to load. The NOx increases with increase in load. Nitrogen reacts with oxygen only at high temperature and pressure, the high temperature in cylinder results in reaction of nitrogen with oxygen and produce NOx. The NOx emission increases with the temperature raise. From the graph the maximum and minimum NOx emissions were showed for B20CSOME and diesel respectively. To reducing of NOx is essential so we used EGR to reduce the NOx. In graph it clearly shows EGR considerable reducing the NOx emission for both diesel and B20CSOME. This is due to oxygen present in biodiesel which improves the combustion there by increasing the cylinder temperature, which results in higher NOx emission.

3.3.3 UBHC Emission

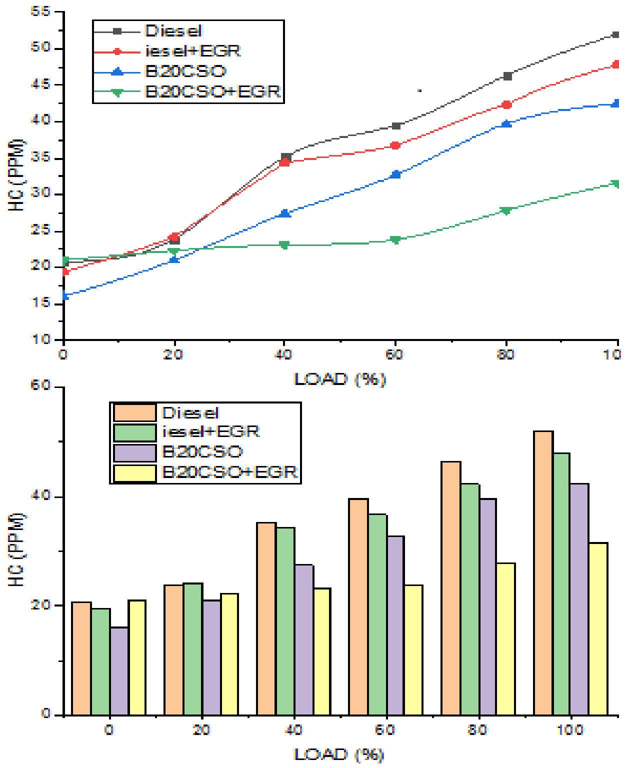

Figure 7-variation of UBHC

Fig shows the variation of UBHC with respect to load. The UBHC increases with increase in load. At all loads the UBHC emission is low for all the test fuels compared to neat diesel. The maximum and minimum UBHC emissions are observed for diesel and B20CSOME+EGR respectively. UBHC emissions are reducing by using EGR. In graph it clearly shows UBHC emission of diesel+EGR and B20CSOME+EGR is lower compare with diesel and B20CSOME. Biodiesel gives lower UBHC than diesel due to oxygen supplied for biodiesel for complete combustion there by reducing UBHC.

4. CONCLUSIONS

Based on the investigated various characteristics like Combustion, Performance and emission of CI diesel engine with test fuels, the following conclusions were made.

- The maximum BTE is accounted for B20CSOME and minimum is observed for diesel. This shows that there is increase in BTE for B20CSOME compared to diesel. We can observe using EGR reduces the thermal efficiency.
- The biodiesel which provide oxygen for complete combustion reduces the emission of CO and UBHC, However we can see NOx is increased for B20CSO due to high oxygen content, increased cylinder pressure and complete combustion.
- Using EGR reduces the NOx and UBHC emission.
- Due to the reduced ignition delay and advancement of premixed combustion zone, we can see that the HRR and cylinder peak pressure are reduced.

Finally we can conclude that the biodiesel and EGR plays an important role in controlling emissions and improving performance and combustion.

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