International Engineering Research Journal

Performance and Emission Analysis of Variable Compression Ratio Single Cylinder Diesel Engine for Jatropha and Soybean Oil Biodiesel Blends with diesel

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Abstract
Now days as non-renewable energy sources are depleting there is need to find renewable sources which do not extinguish and also they are eco-friendly. In our effort to find such a solution extensive research is going on the use of biodiesel as a substitute to diesel which is also less polluting. Use of ethanol is promising in diesel but as its properties show ethanol can benefit in reducing viscosity of bio- diesel. So we go for in diesel addition of Soybean and Jatropha oil biodiesel with and without use of ethanol. Experimentation was carried out on variable compression ratio.

Keywords: *Biodiesel, Diesel engine, Jatropha oil, soybean oil.*

1. Introduction

Biodiesel is vegetable oil or animal fat-based diesel fuel having of long-chain alkyl (methyl, ethyl and propyl) esters. Biodiesel is made of chemically reacting lipids (e.g., vegetable oil, soybean oil and animal fat) with alcohol producing fatty acid esters. The current project work is concerned with performance testing as well as emission analysis of a variable compression ratio (VCR) single cylinder diesel engine using alternative fuels. Alternative fuels used are soybean & jatropha and oil. Blends of biodiesels used with diesel are 20, 40, 60, 80, and 100% by volume. The readings are taken at variable compression ratio.

2. Literature review

Many of research work are focused in this field, A. Murugesan, [1] studied various alternatives to diesel. In that use of corn, cottonseed, crambe, linseed, peanut, rapeseed, soybean, palm oils and compared their properties with Diesel. The paper reports that direct use of vegetable oil in internal combustion engine is not possible. So tried biodiesel produced from these vegetable oils. The work concluded that methyl ester of biodiesel can be directly used in internal combustion engine without any modification.

Another researcher group worked on use of soybean biodiesel for checking feasibility in as alternate to Diesel. Report suggests that crank angle differs in very less range. so effect on crank angle need not to study. But at the same time there is large difference between BSFC although power output delivered is same. This is due to engine delivers fuel at volumetric basis. Density of soybean biodiesel is more than diesel so fuel injected is more. Thus soybean biodiesel have 10 % less heating value power output is same [2].

L.M. Das [3] studied Jatropha biodiesel for are combustion analysis. By testing Jatropha blend with diesel containing 20% Jatropha has almost similar properties that of biodiesel. Blend has almost same density and calorific value. But other properties such as cloud point, pour point, flash point and viscosity are somewhat greater than that of pure diesel. So work concluded that 20% Jatropha with diesel can be used in internal combustion engine without any modification.

A. K. Agrawal,[4] emphasized on use of ethanol in biodiesel. Report shows that there is significant reduction in exhaust gases temperature and lubricating oil temperature. Also carbon deposit is 40 % less than in case of biodiesel compared diesel on piston. Also in case of wear of vital moving part is 30% less of 20% biodiesel compared to pure biodiesel. Finally in that report concluded that use of ethanol as additive in gasoline engine causes increase in performance and improvement in exhaust emissions. Also significant reduction observed in CO and NO emission in ethanol diesel blend.

Considerable work has been carried out for use of biodiesel as substitute or partial substitute to diesel. Effect of use of biodiesel in variable compression ratio engine has not been investigated. Also in above paragraph use of ethanol in biodiesel can significantly reduce exhaust emissions. So work is done to light these two parameters which are not efficiently studied until now. So we used Jatropha and Soybean biodiesel various mixtures in addition to ethanol as additive in diesel. The reason for only choosing Jatropha and Soybean as biodiesel is their ample availability, cost economy.

3. Fuel Properties

Table.1. Different fuel properties for various soybean biodiesel bends

Sr. No.	Test Parameter	Units	Results (%)							
			DIESEL 100	SB 100	SB 20 DIESEL 80	SB 20 e5 DIESEL 75	SB 40 DIESEL 60	SB 40 e5 DIESEL 55	SB 60 DIESEL 40	SB 80 DIESEL 20
1	Gross Calorific Value	KJ/kg	39561	38060	43500	40298	40851	39791	42044	40299
2	Kinematic Viscosity @40^{0}C	cSt	2.7	4.96	2.95	2.5	3.28	2.8	3.82	4.36
3	Cloud Point	^{0}C	-1	-3	-3	_	-2	_	-2	-1
4	Pour Point	^{0}C	-4	-5	-6	_	-5	_	-4	-3
5	Density @15^{0}c	Kg/m^3	822	873	823	842.3	831	850.4	855	857

From Table.1 and 2 we found that GCV of pure soybean doesn‘t defer to much from diesel & its mixture of Diesel gives higher value of GCV & we get maximum value of GCV @20% blend of Soybean to Diesel. It is clear that viscosity of biodiesel is varies in between 2.95 to 4.36 cSt is higher than that of diesel fuel. So, viscosity of pure soybean is more than diesel. And their percentages in Diesel also increase the viscosity of mixture so this is adverse impact on Diesel engine.

It is concluded that GCV of blend decreases with addition of ethanol in biodiesel. The kinematic viscosity also decreases in case of ethanol addition in biodiesel and only the density of Jatropha increases with addition of ethanol.

Table.2. Different fuel properties for various jatropha biodiesel bends

Sr. No.	Test Parameter	Units	Results (%)							
			DIESEL 100	JB 100	JB 20 DIESEL 80	JB 20 e5 DIESEL 75	JB 40 DIESEL 60	JB 40 e5 DIESEL 55	JB 60 DIESEL 40	JB 80 DIESEL 20
1	Gross Calorific Value	KJ/kg	39561	39930	46196	41891	38370	39135	40444	41128
2	Kinematic Viscosity @40^{0}C	cSt	2.7	5.00	3.17	2.5	3.10	2.9	3.65	4.5
3	Cloud Point	^{0}C	-1	-1	-4	_	-3	_	-1	-2
4	Pour Point	^{0}C	-4	-4	-7	_	-5	_	-3	-5
5	Density @15^{0}c	Kg/m^3	822	863	811	841.7	847	852.5	848	859

The GCV of Jatropha & diesel are nearly same. 20%Jatropha with Diesel gives maximum value of GCV so this mixture is preferable.

We can see minor increment in Kinematic viscosity and Gross Calorific value, without addition of ethanol. Minor decrease in kinematic viscosity and gross calorific value when added with ethanol.20% & 40% mixture of jatropha & soybean can be efficiently used in diesel as its properties are very similar to diesel without any modification in diesel engine.

4. Experimental Setup

Fig.1. Schematic representation of engine test setup

Table.3. Variable Compression Ratio Engine Set-Up Specifications

Product	VCR Engine test setup 1 cylinder, 4 stroke, Diesel (Computerized)
Engine	Make Kirloskar, Type 1 cylinder, 4 stroke Diesel, water cooled, power 3.5 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm, 661 cc, CR 17.5, Modified to VCR engine, CR range 12 to 18
Dynamometer	Type eddy current, water cooled, with loading unit
Propeller Shafts	With universal joints
Fuel Tank	Capacity 15 lit with glass fuel metering column
Calorimeter & Pump	Pipe in pipe, Mono-block Pump
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K
Load indicator	Digital, Range 0-50 Kg, Supply 230VAC
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Rota meter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Overall dimensions	W 2000 x D 2500 x H 1500 mm

A high compression ratio is desirable because it allows an engine to extract more mechanical energy from a given mass of air-fuel mixture due to its higher thermal efficiency. This occurs because internal combustion engines are heat engines, and higher efficiency is created because higher compression ratios permits the same combustion temperature to reach with less fuel, while giving a longer expansion cycle, creating more mechanical power output and lowering the exhaust temperature. It may be more helpful to think of it as an expansion ratio. Since more expansion

reduces temperature of exhaust gases and therefore energy wasted to atmosphere. Diesel engines actually have a higher peak combustion temperature than petrol engines, but the greater expansion means they reject less heat in their cooler exhaust.
Higher compression ratio will however make gasoline engines subjected to engine knocking if lower octane rated fuel is used, also known as detonation. This can be reduced efficiency or damage the engine if knock sensors are not present to retard the timing.
There are some advantages of variable compression ratio engine over constant compression ratio engine
i. High compression ratio is used for good stability and low load operations.
ii. Low compression ratio is used at full load to boost turbocharger intake pressure.
iii. At full load turbocharger boost capacity is high so reduction in compression ratio is necessary for more efficiency and to reduce thermal stress

5. Results & Discussion

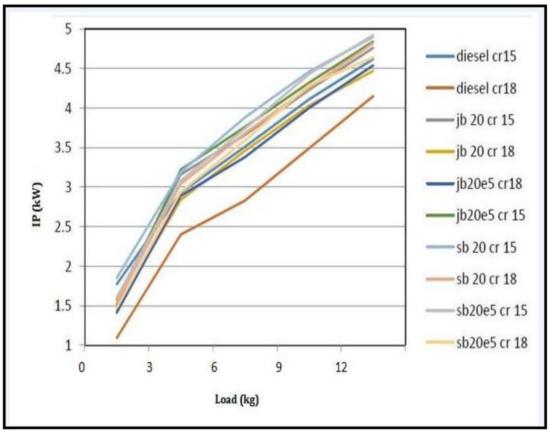
[A] Performance analysis:-

Engine tests have been carried out with the aim of comparing performance parameters like power, brake thermal efficiency, specific fuel consumption and emissions such as CO, NOx, etc.

1. Indicated power

- From Fig 2, that power produced in diesel 18 Compression Ratio is lowest. So less CR is preferable. And soybean has higher calorific value. So soybean blend without ethanol is more preferable.

Fig.2. Indicated power for various blends of biodiesel



2. Brake power

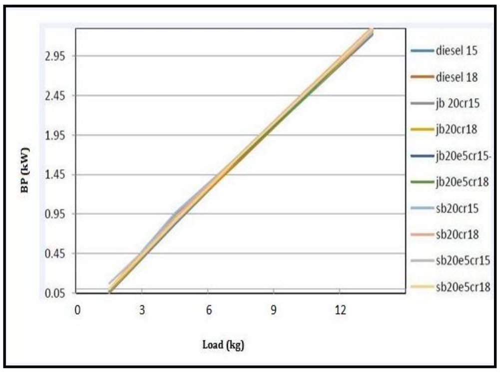


Fig.3. Brake powers for various blends of biodiesel.

- Fig 3 shows that there is almost no difference in power produced.

3. Friction power

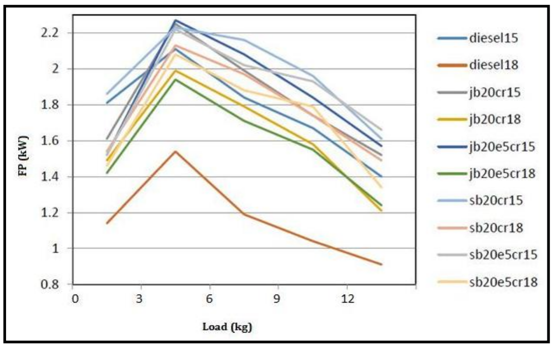


Fig.4. Friction power for various blends of biodiesel

- From Fig 4, friction power loss is less in case of diesel 18 CR. So more CR is preferable. And it is also less in ethanol added fuel than blend without ethanol.

4. Specific fuel consumption

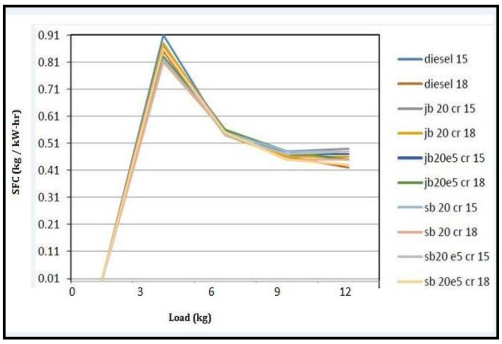


Fig.5. Specific fuel consumption for blends

- From Fig 5, we get Specific fuel consumption is more in case of diesel fuel. And is less in case of soybean with ethanol for Compression Ratio 18.

5. Torque

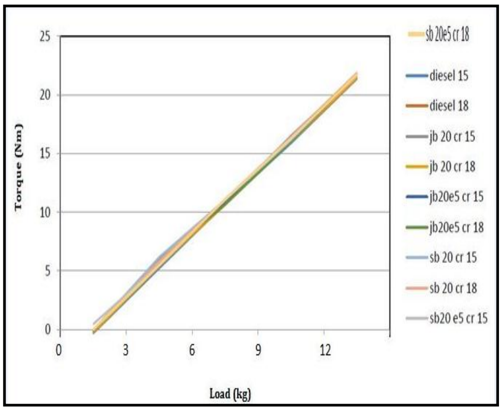


Fig.6. Torque for various blends of biodiesel

- Fig 6 shows that in all cases torque produced is almost same so there is not much difference in power produced.

6. Indicated thermal efficiency

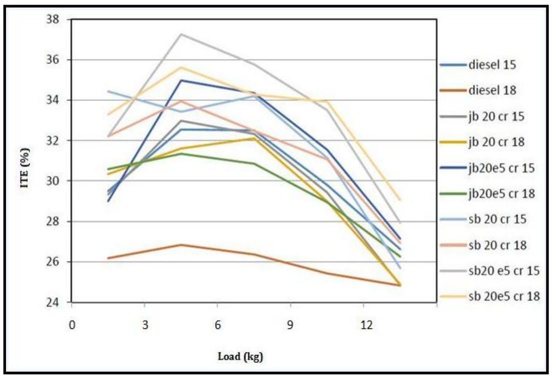


Fig.7. Indicated thermal efficiency for various blends

- From Fig 7, we get Input power is maximum in case of soybean with ethanol blend.

7. Brake thermal efficiency

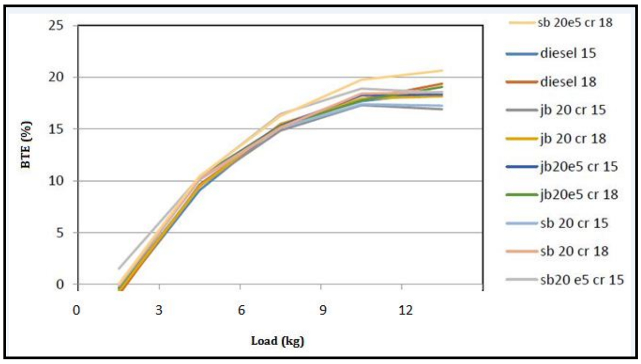


Fig.8. BTE for various blends of biodiesel

- Fig 8, gives Brake thermal efficiency is higher in case of soybean than any other.

8. Mechanical efficiency

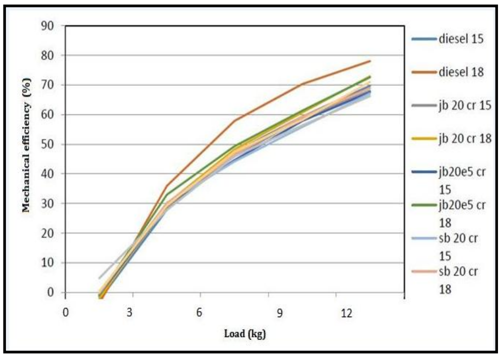


Fig.9. Mechanical efficiency for various blends

- Mechanical efficiency is higher in case of diesel 18 and lowest in case of soybean with ethanol.

9. Volumetric efficiency

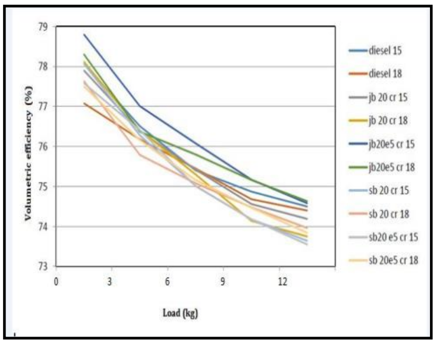


Fig.10.Volumetric efficiency for various blends

- From Fig 10, we get volumetric efficiency is highest at zero load conditions is goes on decreasing with increasing load. Also it is highest in case of jatropha with ethanol mixture.

B] Exhaust analysis

1. **CO**

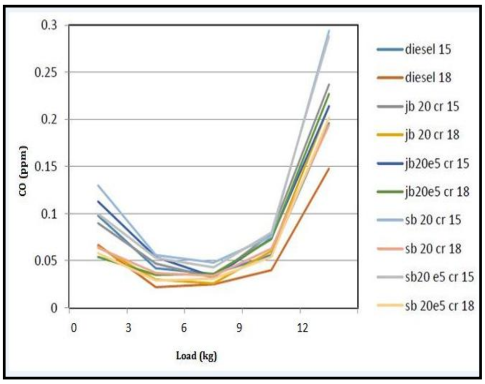


Fig.11. CO for various blends

- Fig 11 shows CO emissions in case of diesel is lowest for 18 compression ratio and that of soybean is highest for 15 CR.

2. CO_2

- From Fig 12, JB 20 with ethanol has highest emissions compared to other blends.

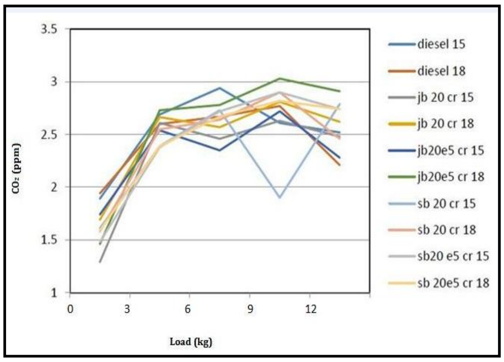


Fig.12. CO_2 for various blends

3. NO_x

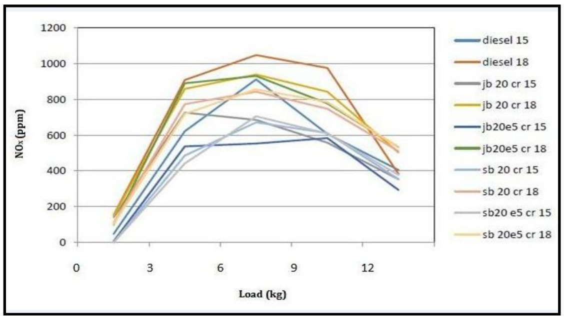


Fig.13. NO_x for various blends

- Fig 13, shows diesel compression ratio CR 18 has highest emission and jatropha with ethanol has lowest emissions means temperature produced is highest in case of diesel and it is lowest in case of ethanol with jatropha.

4. HC

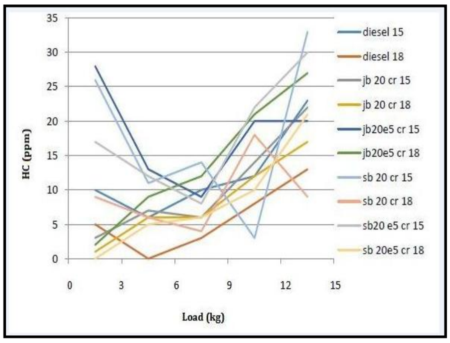


Fig.14. HC for various blends of biodiesel

- From Fig 14 is observed that there is no definite pattern on HC emissions.

6. Conclusion

- Minor increase in kinematic viscosity and gross calorific value, without addition of ethanol.
- Minor decrease in kinematic viscosity and gross calorific value when added with ethanol.
- 20% & 40% mixture of jatropha & soybean can be efficiently used in diesel as its properties are very similar to diesel without any modification in diesel engine.
- On engine trials on variable compression ratio from performance perspective soybean 20% blend in diesel with 5% ethanol as additive for CR 15 compression ratio is emerges as best substitute in diesel fuel.
- Use of soybean decreases NO_x emission is observed.

7. Future scope

- Biodiesel: Future Fuel for India? The biodiesel industry in India is still in its infancy despite the fact that the demand for diesel is five times higher than that for petrol. Currently, biofuel production is minimal, accounting for only 1% of global production. Future bioenergy sector will likely require policy support such as stimulus packages, community and local interest, technological breakthroughs, and cost effective feed stock production.

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