Effect of Variable Compression Ratio on Performance of a Diesel Engine Fueled with Karanja Biodiesel and its Blends

Rahul Kumar Mishra, Dr. Tarun soota, Ranjeet singh
1.3. P.G Scholar (Thermal Engg.) at BIET Jhansi(U.P), 2. Associate Professor, Department of mechanical engineering BIET Jhansi (U.P),INDIA, 284128

Abstract: Rapid exploration and lavish consumption of underground petroleum resources have led to the scarcity of underground fossil fuels moreover the toxic emissions from such fuels are pernicious which have increased the health hazards around the world. So the aim was to find an alternative fuel which would meet the requirements of petroleum or fossil fuels. Biodiesel is a clean, renewable and bio-degradable fuel having several advantages, one of the most important of which is being its eco-friendly and better knocking characteristics than diesel fuel. In this work the performance of Karanja oil was analyzed on a four stroke, single cylinder, water cooled, variable compression ratio diesel engine. The fuel used was 5% - 25% karanja oil methyl ester by volume in diesel. The results such obtained are compared with standard diesel fuel. Several properties i.e. Brake Thermal Efficiency, Brake Specific Fuel Consumptions, Exhaust Gas Temperature are determined at all operating conditions & at variable compression ratio 17 and 17.5.

Keywords: Karanja biodiesel, Performance, Variable compression ratio CI engine.

1. INTRODUCTION
Entire world is confronting with the problems of environmental degradation, fossil fuel depletion and pollution. Extreme extraction and consumption on large scale have caused the deficiency in carbon based resources underground. The use of various biofuels i.e. Karanja, Jatropha, Cotton seed etc. might overcome these problem up to some extent and also provide a solution to the worldwide energy crossroads [1]. Kolhe et al. conducted the experiments on variable compression ratio engine at a fixed engine speed of 1500 rpm, with variable load and at a compression ratios of 17.5 and 18.5 and found an increases in specific fuel consumption with increase in concentration of karanja methyl ester (KME)in blends. The brake thermal efficiency (BTE) of karanja oil blend (B20) was slightly higher than diesel. He also reported the higher exhaust gas temperature for diesel at higher compression ratio due to higher calorific value of diesel than KME blends [2]. Dhar & Agarwal, performed experiments on direct injection diesel engine with varying speed and load and investigated that at lower load the BTE of KME blends were lower when compared to diesel but with increase in loads the BTE of KME blends and diesel were almost equal, maximum torque attained by KME 10 and KME 20 was slightly higher as compared to diesel but with increase in percentage of KME in blends the torque was slightly lower than that of diesel fuel, they further reported lower cylinder pressure for rich blends at lower engine speed [3]. Anand et al. conducted experiments with direct injection, multi cylinder truck diesel engine and reported that the ignition delay for biodiesel and
methanol blends was slightly higher as compared to pure biodiesel as maximum increase in crank angle was limited to 1 deg [4]. Kadu & Sarda, performed experiments on four stroke, CI engine with karanja biodiesel for a engine speed between 1500 rpm to 4000 rpm and investigated that BTE was slightly lower for the KME blends as compared to diesel at higher fuel inlet temperature and higher engine speed, he further reported that for neat Karanja oil, brake specific fuel consumption (BSFC) was higher at low speed and decreases with increase in speed and then it reaches a value almost equal to that of diesel fuel and at maximum speed the BSFC of both the diesel and neat karanja fuel become equal [5]. Peterson et al. performed test, on a direct injected, four-cylinder John Deere 4329t-turbocharged diesel engine and investigated that the specific gravity of biodiesel was higher compared to diesel and viscosity of biodiesel was 1.9 times to that of diesel fuel at 40°C, heat of combustion for biodiesel was 12% lower than that of diesel fuel, the smoke opacity and engine power with use of biodiesel were lowered by 71% and 4.8% respectively when compared with diesel fuel, maximum engine torque was lowered by 6% and 3.2% at variable speeds of 1700rpm and 1300 rpm, respectively. However, no marginal differences between thermal efficiencies were recorded [6]. P.V Rao, performed experiments on a 3.72 kW, water cooled, direction injection engine having compression ratio of 16.5 and 1600 rpm engine speed and found that the ignition lag of KME blends was shorter and hence combust earlier in combustion chamber due to having higher cetane number than that of diesel fuel, the heat release rate (HRR) of KME blends was lower compared to diesel fuel due to having lower calorific value of KME oil [7]. Yadav et. al conducted experiments with Karanja biodiesel on Vertical, four stroke, single cylinder, DI diesel engine at a speed of 1600 rpm and investigated that the brake thermal efficiency of B20 blends was higher than that of higher blends because the calorific value of higher blends decreases with increase in KME percentage in blends. BSFC for B20 was higher compared to that of diesel and BSFC for B10 was lower when compared to other blends and diesel. Maximum Exhaust gas temperature (EGT) was associated with B10, EGT for diesel was 187°C at no load and 402°C at full load, while EGT for B20 rises from 139°C at no load to 420°C at full load [8]. Raheman & Phadatare, performed experiments with karanja biodiesel on diesel engine with 20% to 80% blends by volume in diesel and investigated that brake specific fuel consumption for all tested fuels decreases when the load on engine increases. At a test speed of 2525 rpm (± 2%), the BSFC for B20 & B40 was observed to be 0.8 to 7.4% lower that of diesel fuel, but in case of B60 & B100 the BSFC was observed 11% to 48% higher than that of diesel fuel. BTE was observed to increase with increase in load at all condition, BTE for B20 was highest i.e. 26.79% and BTE for B40 was 26.16% which was which was higher than diesel (24.62%) [9]. Many researchers have conducted experiments with karanja biodiesel and found that this can be a substitute for diesel fuel as its properties are very close to diesel. Some properties like cetane number, high viscosity etc. of karanja biodiesel affect the combustion and hence the engine performance because of having different chemical and physical characteristics. The objective of this work is to find the usage of karanja biodiesel and use it as a substitute of diesel fuel in CI engine for calculation of various performance parameters.

2. EXPERIMENTAL SET-UP
A Kirloskar TV1 having power 3.50 kW @ 1500 rpm which is 1 Cylinder, Four stroke, Constant Speed, Water Cooled, Variable compression ratio(VCR) Diesel Engine is used for the experiments.
Engine was equipped with different measurement units i.e. flow measuring unit, exhaust gas analyzer etc. and these were arranged at appropriate place on engine. The engine was having two different fuel tanks for diesel and biodiesel separately. The detailed specifications of the test engine is given in the table below.

Table 1. The detail technical specifications of the engine

| Parameters              | Specifications          |
|-------------------------|-------------------------|
| Manufacturer            | Kirloskar               |
| Model                   | TV1                     |
| No. of cylinders        | 1                       |
| No. of stroke           | 4                       |
| Bore X Stroke           | 87.5 mm X 110 mm        |
| Compression Ratio       | 12:1 to 18:1            |
| Speed (rpm)             | 1500                    |
| Power output            | 3.5 kW                  |
| Dynamometer             | Eddy current dynamometer|

3. METHODOLOGY AND PROCEDURE

Different blends i.e. B5 (5% KME and 95% diesel), B10 (10% KME and 90% diesel), B15 (15% KME and 85% diesel), B20 (20% KME and 80% diesel) and B25 (25% KME and 75% diesel) were prepared on volume basis with the help of a measuring flask to perform the required operations on engine.

Table 2. Physico-chemical properties of diesel & karanja methyl ester blends

| S.N | Blends | Density(g/ml)@40°C | K.Viscosity(cst)@15°C | Calorific value(cal/gm) |
|-----|--------|---------------------|------------------------|-------------------------|
| 1   | Pure diesel | 0.838 | 3.35 | 10476 |
| 2   | B05 | 0.840 | 3.42 | 10432 |
| 3   | B10 | 0.842 | 3.56 | 10394 |
| 4   | B15 | 0.844 | 3.68 | 10350 |
| 5   | B20 | 0.847 | 3.74 | 10307 |
| 6   | B25 | 0.851 | 3.86 | 10273 |
| 7   | B100 | 0.882 | 5.82 | 9697 |
|     | Test methods | IS 1448 P-32 | IS 1448 P-25 | IS 1448 P-6 |
Both the tanks were filled with different fuels, one with diesel and another with the prepared karanja blend, the engine was started at no load condition with diesel at compression ratio 17.5 to obtain a base line data and engine was allowed to run for nearly 20-30 minute and the inlet valve allowing the diesel to enter the cylinder is closed and the inlet valve of karanja oil to cylinder inlet is opened. The performance of karanja biodiesel blend is calculated from no load to full load conditions by varying the load on engine gradually and then the compression ratio was changed to 17 and readings are taken in same manner, then the next prepared blend is poured into the tank and readings are taken likewise. During switching off the engine the karanja oil valve is closed and diesel inlet valve is reopened and engine is allowed to run for 10-15 minute in order to facilitate the ease in starting during next start. At each interval the readings are taken either manually or by logging into an I.C Engine software.

4. RESULTS AND DISCUSSIONS

Brake Thermal Efficiency

The variation of Brake Thermal Efficiency of engine with karanja biodiesel is shown in Fig. it is found that with increase in load the BTE of all blends increases. The BTE of karanja biodiesel and its blends was found to be lower than that of diesel fuel because of the lower calorific value, higher viscosity as well as higher density of karanja biodiesel as compared to diesel. The lower calorific value & higher viscosity leads to a poor atomization inside the combustion chamber leading a reduction in the efficiency of the fuel. At full load conditions, the BTE for the karanja blends at CR 17 are 27.01%, 25.61%, 25.01%, 24.32% and 23.79% for B5, B10, B15, B20 and B25 respectively whereas the BTE is slightly higher i.e. 27.65% for diesel fuel at same load and CR.

When the CR is increased from 17 to 17.5, slight increase in BTE was observed for all the blends, the reason being better combustion at higher CR due to surplus amount of fuel intake inside the combustion chamber.
Further as the CR increases from 17 to 17.5 a slight decrease in BSFC was observed because at increased CR the engine produces comparatively more brake power than an engine running at low CR, hence the BSFC decreases at higher CR.

**Brake Specific Fuel Consumption (BSFC)**

BSFC is defined as the mass of fuel consumed per hour for per kg of brake power produced. KME has lower calorific value than that of diesel and hence the BSFC is slightly higher than that of diesel for KME and its blends when compared to that of diesel. At low load conditions the BSFC is higher for the fuels but as the load increases, BSFC starts decreasing because at higher loads there is an increase in temperature inside the engine cylinder and at such a high temperature the viscosity of the fuel decreases which causes proper atomization of fuel, also at higher load the brake power produced by engine increases and hence BSFC decreases [3].
Exhaust Gas Temperature

Temperature of exhaust gases, exhausted from the engine cylinder, shows the extent of temperature reached inside the cylinder during combustion, with increase in load on engine the cylinder pressure increases and more of the fuel is burnt leading to an increase in temperature. The temperature of exhaust gas is higher for diesel as compared to KME at all load because the calorific value of diesel is more than that of KME and therefore ample amount of heat is released in the combustion chamber leading to higher temperature. As the percentage of karanja in the blends increases, the volume of diesel fuel decreases accordingly, which causes a reduction in calorific value of the fuel hence lesser amount of heat is released in the combustion chamber for higher blends which reduces the temperature of exhaust gases.

Fig. 5 Variation of BSFC with CR (At full load)

Exhaust Gas Temperature

Temperature of exhaust gases, exhausted from the engine cylinder, shows the extent of temperature reached inside the cylinder during combustion, with increase in load on engine the cylinder pressure increases and more of the fuel is burnt leading to an increase in temperature. The temperature of exhaust gas is higher for diesel as compared to KME at all load because the calorific value of diesel is more than that of KME and therefore ample amount of heat is released in the combustion chamber leading to higher temperature. As the percentage of karanja in the blends increases, the volume of diesel fuel decreases accordingly, which causes a reduction in calorific value of the fuel hence lesser amount of heat is released in the combustion chamber for higher blends which reduces the temperature of exhaust gases.

Fig. 6 Variation of EGT with Load at CR 17 and 17.5 respectively
As the CR increases the combustion becomes better inside the engine cylinder leading to a rise in cylinder pressure which further increases the temperature inside the cylinder, rate of combustion increases and the temperature of gases coming out after expansion, increases.

![Variation of EGT with compression ratio (At full load)](image)

**CONCLUSION**

Performance characteristics of variable compression ratio diesel engine which is fueled with karanja biodiesel is investigated at different load and compression ratios and the results are compared with the standard baseline data obtained from diesel fuel. The results show that the properties hence obtained i.e. BTE, BSFC and EGT are dependent on biodiesel blends, loads and compression ratios. These results when compared with results obtained from diesel fuel, following conclusions are made:

- Brake thermal efficiency for all the fuels increases with increase in load and compression ratio because of better combustion at higher load.
- Brake thermal efficiency of karanja biodiesel and its blends decreases with increase in percentage of KME in blend because of decreasing calorific value and BTE for all blends is lower than diesel.
- BSFC are found to be higher for KME and its blends as compared to diesel fuel because of lower calorific value of biodiesel.
- With increase in load BSFC decreases due to good quality of combustion of fuel and increasing brake power.
- Exhaust gas temperature for all the KME and its blends are found to be lower than diesel fuel because of high calorific value of diesel fuel and lower viscosity than KME.
- EGT is further found to be increased at higher compression ration because of proper atomization of fuel inside the combustion chamber.
REFERENCES

[1] A. Agarwal “Biofuels (alcohol and biodiesel) applications as fuels for internal combustion engines,” Progress in energy and combustion science 33 ,233-271, june 2007
[2] A. Kohle, S. Shelke, S. Khandare “Performance, Emission and Combustion Characteristics of a Variable Compression Ratio Diesel Engine Fueled with Karanj Biodiesel and Its Blends,” International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:8, No:4,2014
[3] A. Dhar, A. Agarwal “Performance, emissions and combustion characteristics of Karanja biodiesel in a transportation engine, Fuel 119, 70–80,2014
[4] K. Anand, R. Sharma, P. Mehta “Experimental investigations on combustion, performance and emissions characteristics of neat karanja biodiesel and its methanol blend in a diesel engine,” biomass and bioenergy, vol.35 ,pp533-541,2011
[5] S. Kadu, R. Sharda “Experimental Investigations on the Use of Preheated Neat Karanja Oil as Fuel in a Compression Ignition Engine,” International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:4, No:12, 2010
[6] C. Peterson and D. Reece, “Emissions characteristics of ethyl and methyl ester of rapeseed oil compared with low sulfur diesel control fuel in a chassis dynamometer test of a pickup truck,” Transactions of ASAE, Vol. 39, (3), pp.805-816, 1995
[7] P.V. Rao “Effect of properties of Karanja methyl ester on combustion and NOx emissions of a diesel engine,” Journal of Petroleum Technology and Alternative Fuels Vol. 2(5), pp. 63-75, May 2011
[8] H. Yadav, P. Vaghela, R. Prajapati “Experimental Investigation of Performance & Emission for the Blend of Diesel & Karanja Bio-Diesel” International Journal Of Engineering Sciences & Research Technology, 3(3): March, 2014
[9] H. Raheman and A. G. Phadate. "Emissions and Performance of Diesel Engine from Blends of Karanja Methyl Ester (Biodiesel) and Diesel." Biomass and Bioenergy,vol. 24,issue no. 4, pp. 393-397,2004

Name: Rahul Kumar Mishra, B.Tech (Mechanical Engg.) from LKCE Ghaziabad(U.P), M.Tech (Thermal Engg.) from BIET Jhansi (U.P)

Name: Ranjeet Singh, B.Tech (Mechanical Engg.) from MJPRU Bareilly (U.P), M.Tech (Thermal Engg.) from BIET Jhansi (U.P)
Dr Tarun Soota, PhD from U.P.T.U. Lucknow, Associate Professor in mechanical engineering department, Bundelkhand Institute of Engineering and technology, Jhansi. He has more than 14 years of experience in teaching and research. He has more than 20 papers in national and International publications. He is actively involved in teaching and research.