Experimental Investigation on Low Heat Rejection Engine Fueled with Cotton Seed Oil and Its Biodiesel

Basavaraj M Shrigiri[1], Omprakash D Hebbal[2], K Hema Chandra Reddy[3]

[1]*Research Scholar, JNT University, Anantapur, shrigiri2007@gmail.com*

[2] *Professor, P D A College of Engineering, Gulbarga.*

[3]*Registrar, JNT University, Anantapur*

***Abstract*—In the recent years, depletion of resources and increased environmental awareness are driving the researchers to develop viable alternative fuels from non conventional resources. The biodiesel has emerged as a most potential alternative substitute for diesel engine on account of its lesser emission. Crude oil derived from cotton seed has high viscosity, low volatility and low cetane number. The biodiesel is produced by transesterification process. Transesterification is a process commonly used to reduce the viscosity of edible and non edible vegetable oils. In the present study, cotton seed oil (CSO) a non edible vegetable oil is converted into cotton seed methyl esters (CSME) by transesterification process. The tests are conducted on a 5.2 kW, single cylinder, four stroke, direct injection, water cooled diesel engine for different loads viz 0%, 10%, 25%, 50%, 75% and maximum load. The properties of cotton seed oil and its methyl esters are determined using standard equipments. The tests are conducted on the engine and combustion, emission and performance characteristics are determined. It is observed that Low Heat Rejection (LHR) fueled CSME performed better compared with LHR engine fueled with CSO and normal diesel engine(NDE).**

Keywords:-Cottonseed, Biodiesel, Transesterification, Properties,

I. INTRODUCTION

In the recent years, the world is confronted with twin crisis of fossil fuel depletion and environmental dilapidations. These situations have forced the researchers to search for alternative fuels. Vegetable oils have the greatest potential to be used as alternative fuels for the diesel engines due to a very significant fact that they are renewable energy sources and could produce less exhaust emissions [1]. The high viscosity and poor volatility are the major limitations of vegetable oils for their utilization as a fuel in diesel engine [2].

In normal diesel engine, about one third of the total energy is rejected to the cooling water. The basic concept of the low heat rejection engine is to reduce this heat loss to the cooling water and converting the energy in the form of useful work [3]. Various important advantages of the LHR concept are reduced hydrocarbons, fuel economy, carbon monoxide emissions and smoke, reduced noise due to a lower rate of pressure rise and higher energy in the exhaust gases [4-7]. Low cetane fuel can be used in LHR engines [8]. Within the LHR engine concept, the combustion chamber of a diesel engine is insulated by using high temperature resistsnt materials on engine components, such as cylinder head, valves, cylinder liners and exhaust ports. By eliminating the need for a conventional cooling system and reducing lost energy, the overall performance of this engine system will drastically improves. And could potentially result in 50% volume and 30% weight reductions in the entire propulsion system [9].

II. EXPERIMENTATION

The engine used in this study is computerized Kirloskar make, single cylinder, four stroke, vertical, water cooled, direct injection diesel engine. The important engine specifications are given in Table 1. An eddy current dynamometer is used to load the test engine. Exhaust emission from the engine is measured with help of AVL DiTEST 1000 (Five gas analyzer) and smoke emission is measured with the help of AVL DiSMOKE 480 (Smoke meter).

Crude cotton seed oil is selected for the preparation of biodiesel. Thirty five grams of sodium hydroxide (NaoH) and 2 liters of methyl alcohol (CH_3OH) are used for esterification of 10 liters of cotton seed oil. The catalyst is dissolved in the alcohol then the alcohol-catalyst mixture is poured into the cotton seed oil which is heated and mixed thoroughly. The temperature of the cotton seed oil, alcohol and catalyst mixture is maintained at 60^oC for an hour. When the transesterificationis finished the mixture is taken into a separating funnel to settle. After the settlement of the biodiesel and the glycerin, the glycerin is drained. The biodiesel is washed thoroughly with pure water to remove alcohol and catalyst residue. After washing, the biodiesel is heated to a temperature of 110^oC in order to remove the traces of water in the form of vapors. The properties of the diesel, cotton seed oil and its methyl ester are determined according to the ASTM standards. As can be seen from Table 2, the calorific value of CSME is lower than that of diesel and other properties are higher than the diesel.

Table 1
Specification of the test engine

Manufacturer	Kirloskar Oil Engines Ltd., India
Model	TV-SR II, naturally aspirated

Engine	Single cylinder, direct injection diesel engine
Bore/stroke/compression Ratio	87.5 mm/110 mm/ 17.5:1
Rated power	5.2 kW
Speed	1500 rpm, constant
Injection pressure/advance	200bar/23 degree beforeTDC
Dynamometer	Eddy current
Type of starting	Manually
Air flow measurement	Air box with 'U' tube
Exhaust gas temperature	RTD thermocouple
Fuel flow measurement	Burette with digital stopwatch
Governor	Mechanical governing (Centrifugal type)
Sensor response	Piezo electric
Time sampling	4 micro seconds
Resolution crank	1 degree crank angle
Angle sensor	360° encoder with resolution of 1 degree

Table 2
Properties of the test fuels

Properties	Diesel	CSO	CSME
Calorific value(kJ/kg)	42600	34590	39029
Density (kg/m^3)	0.831	0.922	0.878
Flash point (^{o}C)	51	260	165
Fire point(^{o}C)	57	280	175
Carbon residue (%)	00	0.8330	0.199

The tests are conducted for variable brake power of 0%, 10% 25%, 50%, 75% and 100% at rated speed. First, diesel fuel is used as fuel. After completion of the test of normal engine, the piston is coated with plasma sprayed 100% zirconium oxide (ZrO_2) with a thickness of 0.1 mm over a 0.1 mm thickness of 50% ZrO_2+50% Al_2O_3 then which is coated over a 0.1 mm thickness of 25% ZrO_2+75% Al_2O_3 and finally thisis coated over a 0.15 thickness of bond coat of nickel chromium (Ni-Cr), as the test engine is converted to a LHR condition. Then, the CSO and CSME which have the properties given in Table 2,are used as fuel. After completion of the test on LHR engine, the results are compared.

III. RESULTS AND DISCUSSIONS

The main objective of this work is to investigate the performance, emission and combustion characteristics of LHR engine fueled with CSME and CSO compared to that of normal diesel.

3.1. Performance analysis

Important engine performance parameters, such as brake thermal efficiency and specific fuel consumption for LHR engine fueled with CSME, CSO with standard diesel, are calculated, analyzed and graphically represented. The effect of brake power on brake thermal efficiency is shown in Fig. 1. There is a steady increase in brake thermal efficiency as brake power increases. It is seen that, the brake thermal efficiency is lower for the entire brake power range for LHR engine fueled with CSME and CSO compared to normal diesel. This may be due to poor formation of mixture as a result of high viscosity and low volatility. However, there is not much variation at lower brake power.

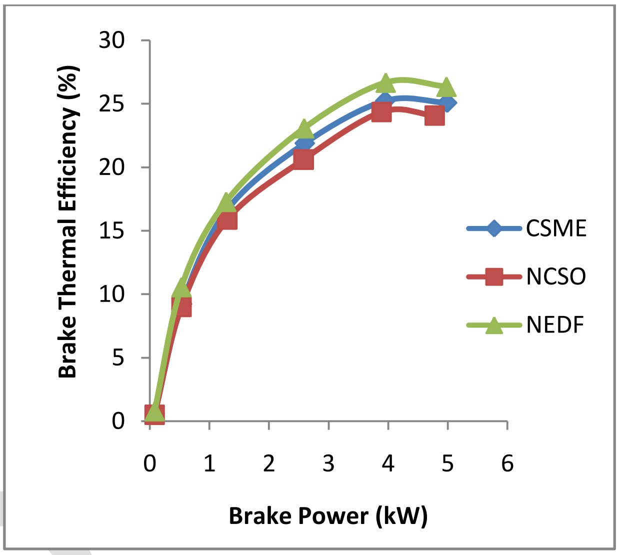

Fig. 1. Variation of brake thermal efficiency with brake power

From Fig 2, it is observed that LHR engine fueled with CSME and CSO have higher SFC as compared to normal diesel engine due to lower heating value. The SFC of LHR engine fueled with CSME at maximum load is greater than that of normal diesel engine at all brake power. The reason may be the differences in heating value and density between LHR engines fueled CSME and standard diesel.

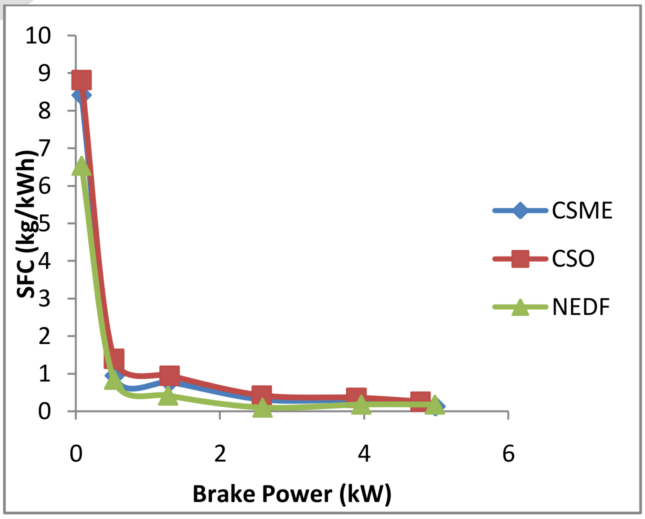

Fig. 2. Variation of SFC with brake power

The effect of brake power on exhaust gas temperature (EGT) is shown in Fig. 3. It shows increasing exhaust temperature with increase in brake power for LHR engine fueled with CSME and CSO. The reason may be poor volatility and higher viscosity of these biofuels and higher boiling points in CSME and CSO than diesel. Those constituent having higher boiling points are not adequately evaporated during the main combustion phase and continued to burn in the late combustion phase. This resulted in a slightly higher EGT.

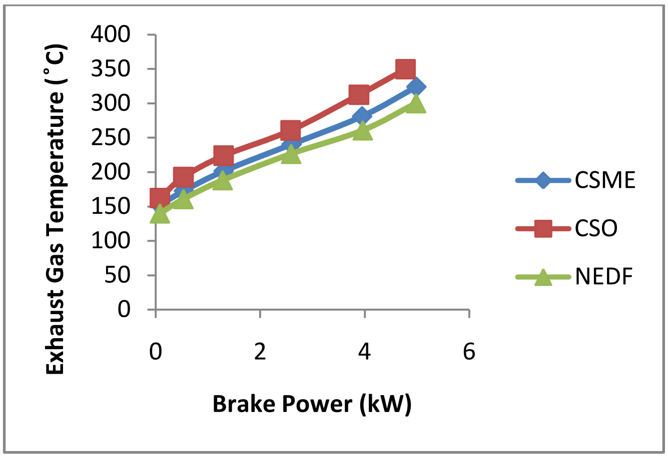

Fig. 3. Variation of EGT with brake power

3.2 Emission analysis

3.2.1 Carbon monoxide emission

The effect of brake power on carbon monoxide is shown in Fig. 4. The carbon monoxide for LHR engine fueled with CSME and CSO is slightly higher than the normal diesel at all loads. It is seen that, the CO decreases with increasing brake power for all test oils. It is also observed that CSME results in slight increment in a CO level when compared to the normal engine fueled with diesel.

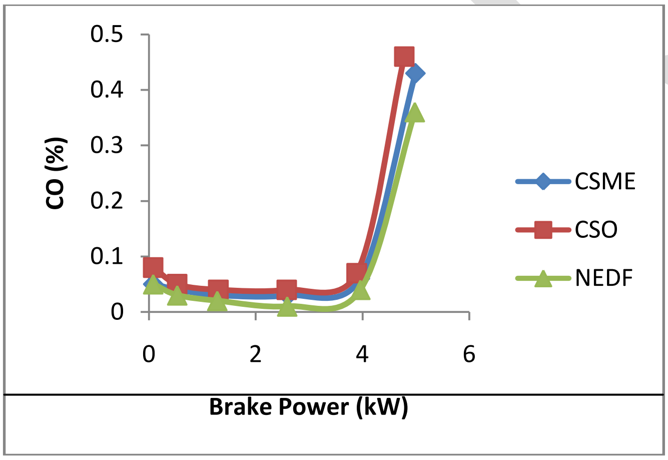

Fig. 4. Variation of CO with brake power

3.2.2 Hydrocarbon emission

The effect of brake power on hydrocarbon is shown in Fig. 5. It is seen that, unburned hydrocarbon (HC) emission for LHR engine fueled CSME is slightly lower and LHR engine fueled CSO is slightly higher than normal diesel engine fueled with diesel. The effect of fuel viscosity on fuel spray quality would be expected to produce some HC increases with vegetable oils.

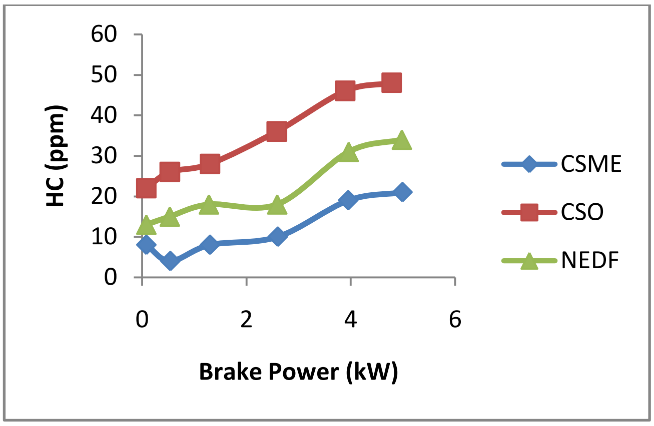

Fig.5. Variation of Hydrocarbon with brake power

3.2.3 Oxides of nitrogen emission (NO_x)

The effect of brake power on oxides of nitrogen is shown in Fig. 6. The NO_x for LHR engine fueled with CSME and CSO is higher than that of diesel. The NO_x of LHR engine fueled with CSO is close to diesel engine for the entire range of operation and LHR fueled with CSME has higher NO_x emission compared to normal diesel engine fueled with diesel. The maximum NO_x emission for LHR engine fueled with CSME and CSO is 741 ppm and 635 ppm against 610 ppm of normal diesel engine at 75% loading.

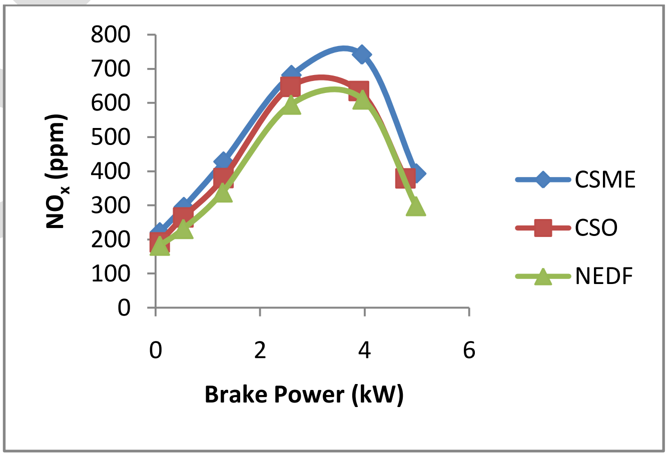

Fig. 6. Variation of NOx with brake power

3.3 Combustion analysis

Fig. 7 shows the variation of cylinder pressure with crank angle for all brake power at rater speed for LHR engine fueled CSME, CSO and normal engine fueled with diesel. It is observed that, the peak pressure for the LHR engine fueled CSME and CSO are 64.8 bar and 60.12 bar respectively and the peak pressure for the normal diesel engine fueled with diesel is 64.9 bar. The cylinder peak pressure for LHR engine fueled CSME and CSO are slightly lower than that of normal engine fueled with diesel. It is observed that, the crank angle at which peak pressure occurs slightly shifts away from TDC i.e. for the peak pressure for LHR engine fueled with CSME occurred at 12^{o} CA aTDC, for LHR engine fueled CSO it is

11^{o} CA aTDC and for standard engine fueled with diesel is 13^{o} aTDC.

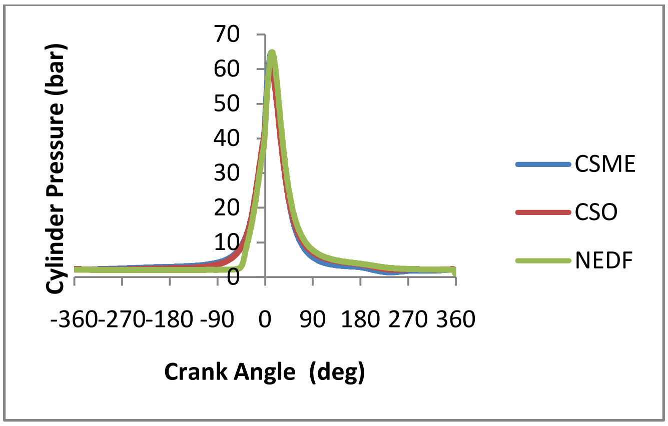

Fig.7. Variation of cylinder pressure with crank angle

Fig. 8 shows comparison of heat release rate for LHR engine fueled CSME, CSO and normal engine fueled with diesel. The premixed burning phase associated with a high release rate is important for normal engine fueled with diesel and is responsible for the higher peak pressure and higher rates of pressure rise. This may be the reason for higher thermal efficiency with normal engine fueled with diesel. In LHR engine fueled with CSME and CSO, there is significant increase in combustion rates during the later stage that has resulted to higher exhaust temperatures and lower thermal efficiency. The LHR engine fueled with CSME and CSO has reduced heat release rate compared to normal engine fueled with diesel.

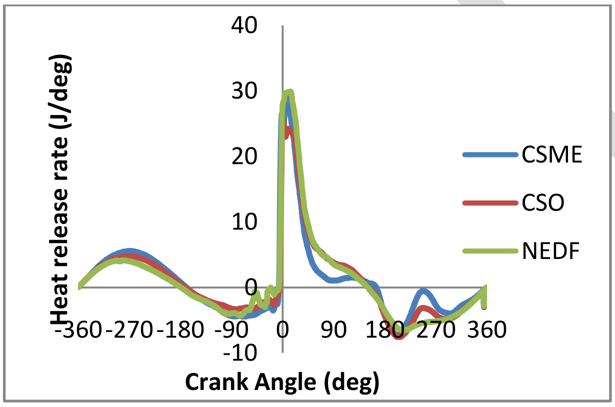

Fig.8. Variation of heat release rate with crank angle

IV CONCLUSIONS

In this work, the piston face is coated with metal matrix composite materials. Cotton seed methyl ester and cotton seed oil are used in coated engine and diesel used for uncoated normal engine. The combustion, emission and performance characteristics of LHR engine fueled with CSME and CSO are analyzed and compared with that of normal engine fueled with diesel. The summarized conclusions are as follows:

- The cylinder pressure in LHR engine fueled with CSME is almost same as that of normal engine fueled with diesel and LHR engine fueled with CSO is 7.34 % less than that of normal engine fueled with diesel at 9 degree crank angle after TDC.
- The heat release rate in LHR engine fueled with CSME is slightly less than normal engine fueled with diesel and LHR engine fueled with CSO is 16.66% lesser than normal engine fueled with diesel.
- The carbon monoxide emission for LHR engine fueled with CSME and CSO is almost same up to 3.9 kW of brake power and slight increase in CO after 3.9 kW of brake power than that of normal engine fueled with diesel.
- The unburned hydrocarbon emission for LHR engine fueled with CSME is 35-45 % lower and LHR engine fueled with CSO is 45-50% higher than that of normal engine fueled with diesel.
- The oxides of nitrogen emission of LHR engine fueled with CSME and CSO are almost same than that of normal engine fueled with diesel up to 50% of brake power and emissions are increased slightly for LHR engine fueled with CSO up to75 % of brake power.
- The brake thermal efficiency of LHR engine fueled with CSME is almost same of that of normal diesel engine and LHR engine fueled with CSO is 2-3 % lesser than that of normal diesel engine fueled with diesel.
- The specific fuel consumption of LHR engine fueled with CSME and CSO is almost same than that of normal engine fueled with diesel except for the range of 20 – 40 % of brake power.

The above comparative study clearly reveals the possibility of using the biodiesel in LHR direct injection diesel engine. The combustion, performance and emission characteristics show the suitability of cotton seed oil biodiesel in LHR engine.

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