Comparative Experimental Investigation Of Performance And Combustion Characteristics In A Single Cylinder Thermal Barrier Coated Diesel Engine Using Diesel And Castor Biodiesel

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Abstract

Rapid depletion of conventional energy sources along with increasing demand for energy is a matter of serious concern. The fact that petroleum based fuels will neither be available in sufficient quantities nor at reasonable price in future has revived interest in exploring alternate fuels for diesel engines. Only non-edible vegetable oils can be seriously considered as fuels for engines as the edible oils are in great demand and are far too expensive as fuels. Gum formation, filter clogging, carbon deposits at the nozzle tips, higher exhaust emissions due to high exhaust temperatures are some of the problems associated with these oils. Using of vegetable oils in low heat rejection engines is the only solution to overcome problems of these oils. The high in cylinder temperature of these engines reduces the ignition delay and aids combustion. The use of LHR (partially stabilised yatria zirconium coating) engine to increase the performance parameters of the test engine Viz. Brake thermal efficiency, Volumetric efficiency are decreased, Brake specific fuel consumption and Exhaust gas temperature are increased for all neat oils compared to diesel. the present work has focused on the performance of castor oil and its blend with Thermal barrier coating on piston, cylinder valve, and cylinder head on a single cylinder, 4 stroke, naturally aspirated, direct injection, water cooled, eddy current dynamometer Kirloskar Diesel Engine at 1500 rpm for variable loads. Initially, castor neat oil and their blends were chosen. From the experimentation, it is observed that 20% of neat oil mixed with 80% of diesel with LHR is best suitable for good result.

Key words: LHR Engine, normal engine Biodiesel, castor oil, COME, combustion Characteristics, Thermal barrier coating, non edible oil alternative fuel.

1. Introduction

According to the present scenario, diesel engines are used for power generation, Automobiles, Ships and Irrigation pumps. The continuous rise in global prices of crude oil, increasing threat to environment due to exhaust emissions, the problem of global warming and the threat of supply fuel oil instabilities have adversely impacted the developing countries, more so to the petroleum importing countries like India. Major portion of today's energy demand in India is being met with fossil fuels. Hence it is high time that alternate fuels for engines should be derived from indigenous sources. As India is an agricultural country, there is a wide scope for the production of vegetable oils from different oil seeds. The present work focused only on non-edible oils as fuel for engines, as the edible oils are in great demand and far too expensive. Vegetable oils are one such alternative source. Diesel engines have the advantages of better fuel economy, lower emissions of HC and CO. However, diesel engines suffered from high emissions of PM/smoke density and NOx, and there is inherent tradeoff between them from the point of view of long term energy security, it is necessary to develop alternative fuels with properties comparable to petroleum based fuels. The main commodity source for Bio-diesel in India can be non-edible oils obtained from plant species such as Jatropha curcus (Ratanjyot), Pongamia pinnata (Karanja), Calophyllum inophyllum (Nagchampa), Hevcca brasiliensis (Rubber), etc. The use of biodiesel in conventional diesel engines results in substantial reduction of un-burnt hydrocarbons, carbon monoxide and particular matters [1].

4. The properties of diesel and COME:

The different properties of diesel fuel and Castor oil methyl ester (COME) are determined and given in below table 4.1. After transisterification process the fuel properties like kinematic viscosity, calorific value, of methyl ester is lower than that of diesel because of oxygen content. The flash and fire point temperature of biodiesel is higher than the pure diesel fuel this is beneficial by safety considerations which can be stored and transported without any risk

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Table 4.1 The properties of diesel and fuel and COME

Properties	Unit	Diesel	Castor oil
Density(15°C)	kg/m^3	875	940
Flash point	°C	45	215
Kinematic Viscosity(40°C)	Mm^2/s	2.4	250
Cetane No.	-------	46	40
Net calorific Value	(MJ/Kg)	43.5	38
Iodine Value	-------	-----	95

3. Experimentation

3.1 Engine components:

The various components of experimental set up are described below. Fig.3.1 shows line diagram of the experimental set up.

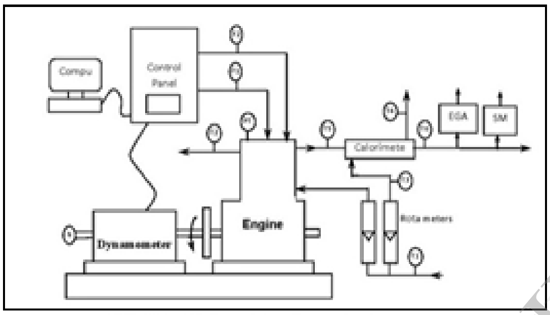

Fig-3.1 Experimental Setup

Table 3.1 Notation

PT	Pressure transducer
N	Rotary encoder
Wt	Weight
F1	Fuel flow
F2	Air flow
F3	Jacket water flow
F4	Calorimeter water flow
T1	Jacket water inlet temperature
T2	Jacket water outlet temperature
T3	Calorimeter water inlet temperature = T1
T4	Calorimeter water outlet temperature
T5	Exhaust gas to calorimeter temperature
T6	Exhaust gas from calorimeter temperature

Table 3.2 Engine specifications

Manufacturer	Kirloskar oil engines Ltd, India
Model	TV-SR, naturally aspirated
Engine	Single cylinder, DI
Bore/stroke	87.5mm/110mm
C.R.	16.5:1
speed	1500r/min, constant
Rated power	5.2kw
Working cycle	four stroke
Injection pressure	200bar/23 def TDC
Type of sensor	Piezo electric
Response time	4 micro seconds

5. Thermal barrier coating:

The surface is coated with an adhesive elastic bond coat by physical vapor deposition. Usually MCrAlY material is used as the bond coat. In the metallic MCrAlY bond coat M is selected from Ni, Co, Fe or a combination thereof. The thickness of this bond coat is maintained between 0.075mm to 0.125mm for effective adhesion. The bond coat is then grit blasted for effective adhesion with top coat.

6. Results and disscusions

6.1 Castor bio-diesel and its blends with normal engine performance characterstics

6.1.1 Air-Fuel ratio:

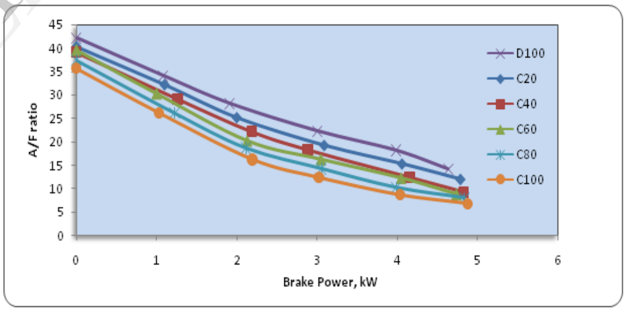

Figure 6.1.1

Figure 6.1.1 shows the comparison between air fuel ratio and break power and it can be observed that air fuel ratio of pure diesel is higher than the C60 and C100 castor blends and is slightly equal to C20 and C80 castor blends.

6.1.2 Brake thermal efficiency:

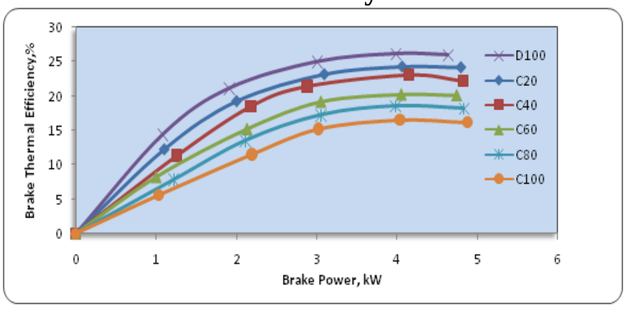

Figure 6.1.2

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The variation of Brake thermal efficiency with Brake power for diesel, and castor biodiesel and its blend are shown in figure 6.1.2. The Increase in thermal efficiency due to high percentage of oxygen presence in the biodiesel, the extra oxygen leads to causes better combustion inside the combustion chamber. The thermal efficiency of the engine is improved by increasing the concentration of the biodiesel in the blends and also the additional lubricant provided by biodiesel. The main reason for increasing the thermal efficiency with increase in injection pressure may be due to atomization.

6.1.3 Exhaust Gas temperature:

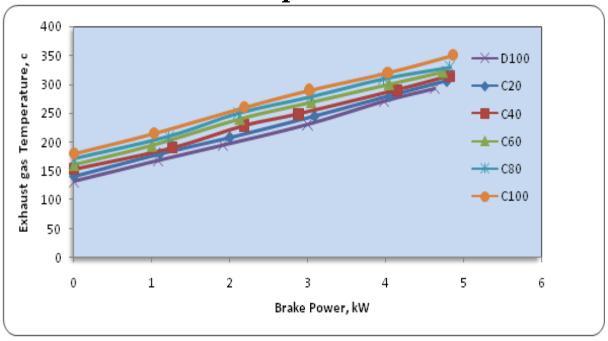

Figure 6.1.3

The variation of exhaust emission temperature with brake power for diesel, and other blends of castor biodiesel are shown in figure 6.1.3 the exhaust emission temperature of all the biodiesel are higher than the diesel as it is evident from the graph.

6.1.4 Indicated mean effective pressure:

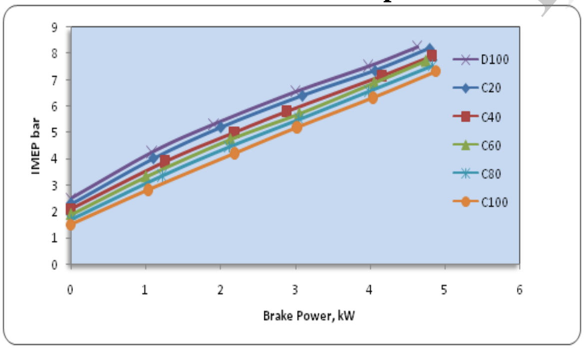

Figure 6.1.4

The variations of indicated mean effective pressure with brake power for diesel and castor biodiesel blends are shown in figure 6.1.4.The indicated mean effective pressure increases with increase in concentration of castor in diesel increases the indicated mean effective pressure.

6.1.5 Mechanical efficiency:

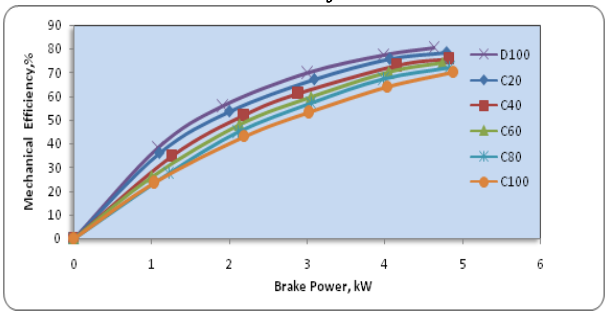

Figure 6.1.5

The variation of mechanical efficiency with brake power, for diesel and castor biodiesel blends are as shown in figure 6.1.5. The mechanical efficiency of diesel is slightly higher than the castor biodiesel. From the graph it is evident that with increase in the concentration of castor biodiesel in neat diesel decreases the mechanical efficiency.

6.1.6. Specific fuel consumption:

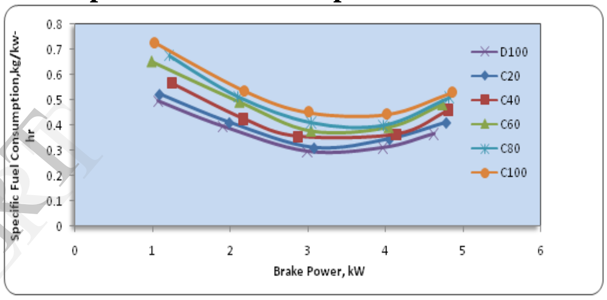

Figure 6.1.6

The variation of specific fuel consumption with Brake power for diesel, and castor biodiesel oil and it's blends are shown in figure 6.1.6. Specific fuel consumption for castor biodiesel blends are higher than diesel for certain lower loads, but for higher loads, consumptio rate remains almost constant as evident from the graph.

6.1.7 Cylinder pressure v/s crank angle:

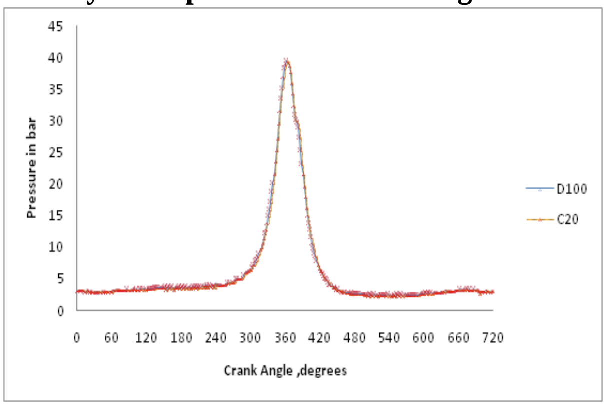

Figure 6.1.7

Figure 6.1.7. Shows the comparison of pressure with crank angle for different Castor methyl ester biodiesel blends and diesel at full load. It was found that the

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cylinder pressure CME20 (76.87 bar) Diesel (79.375 bar) at 18:1. From the figure it is shown that the pressure increases with increase in injection pressure 240 bar and advanced injection timing 27°BTDC.

6.2 Performance and combustion characteristics of castor bio-diesel and its blends on LHR engine:

6.2.1 Air-Fuel ratio:

The variation of the air fuel ratio with load for diesel and castor blends is shown in figure 6.2.1 Fuel consumption is high for castor blends compared to diesel hence air ratio decreases with increase in load because fuel mixing process is affected by the difficulty in atomization of biodiesel due to its higher viscosity. By providing a hot combustion chamber will result incomplete vaporization of the rich mixtures. This hot combustion chamber can be obtained by providing Moderate thermal insulation in the combustion chamber, to retain the heat generated from combustion. With the thin-partially stabilised yatria zirconium – coated combustion chamber, higher brake thermal efficiencies were obtained.

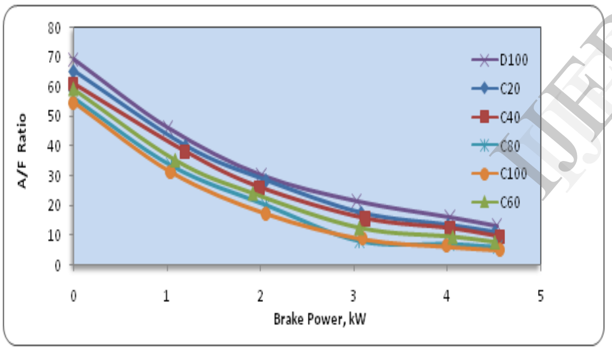

Figure 6.2.1

6.2.2 Brake thermal efficiency

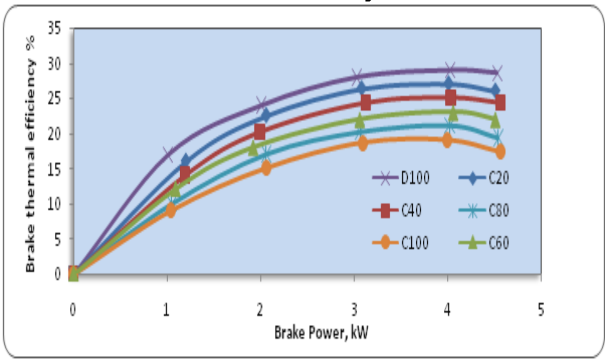

Figure 6.2.2

The variation of the brake thermal efficiency with load for diesel and castor blends is shown in figure 6.2.2. shows the variation of brake thermal efficiency (BTE) with brake power output for Castor oil and its blends with diesel. In the test engine. BTE of 20% blend of castor oil compared well with diesel and exhibited the highest value at 76.92% of total load. The maximum BTE at 20% blend of castor oil is 33.20% obtained at 4 Kw against the 34.1%, for diesel. The thermal efficiency is lower for COME than diesel. It may be due to larger differences in viscosity, specific gravity and volatility between diesel and *COME*. The graph of Brake Thermal Efficiency Vs Brake power. It has been observed that at all loads Brake thermal efficiency is improved in case of PME at 180 bar pressure with coating. Increase in pressure increases the fuel consumed and thus reduction in Brake Thermal Efficiency.

6.2.3 Specific fuel consumption:

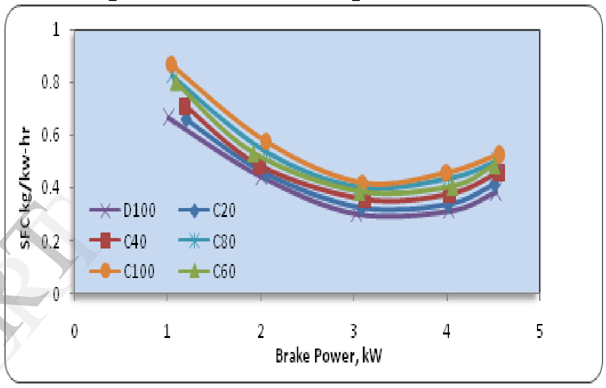

Figure 6.2.3

Figure 6.2.3. Shows the specific fuel consumption of castor biodiesel and its blends with respect to brake power. The variation of brake specific fuel consumption with brake power output for castor oil and its blends with diesel in the test engine. Diesel has lower SFC value compared with all other blends, whereas 20% blend of castor oil has lower SFC values. The lowest SFC of neat castor oil is 0.305 Kg/Kw- hr, whereas it is 0.210 Kg/Kw-hr for diesel. At the maximum thermal efficiency load of 20% blend, the SFC of castor oil is 0.320 Kg/Kw- hr, corresponding to the 0.251 value for diesel. 20% blend of castor has the lower SFC compared to its other blends. It is observed that there is steady increase of Fuel consumption from No load to 60% load at 250 bar and without Coating. There is almost no change FC at 180 bars with/without coating. However SFC has reduced at 180 bar injection pressure.

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6.2.4 Mechanical efficiency:

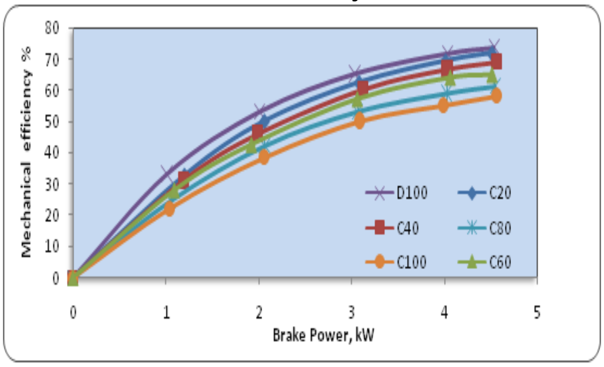

Figure 6.2.4

The variation of the mechanical efficiency with load for diesel and COME blends are shows in figure 6.2.4. It is observed that mechanical efficiency increases the brake pressure. COME 20 showed better results than blends. The mechanical efficiency of diesel is slightly higher than the castor biodiesel. From the graph it shows that increase in the concentration of castor biodiesel in neat diesel decreases the mechanical efficiency. In this graph C20 and D100 have almost same mechanical efficiency and C20 is little smaller than D100 due to thermal barrier coating gives us better higher brake power and indicated power. We can conclude that 20% of castor can use with LHR coating in the engine.

6.2.5 Indicated mean effective pressure:

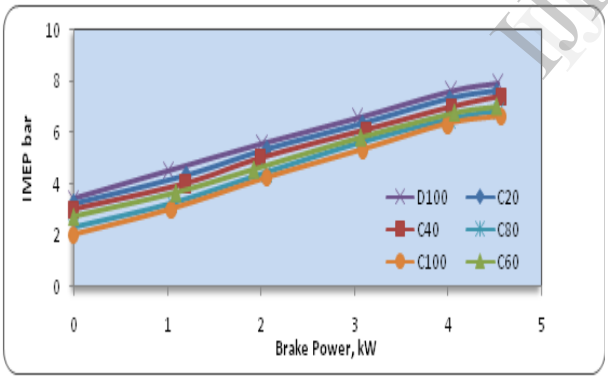

Figure 6.2.5

The figure 6.2.5. Shows the indicated mean effective pressure with brake power for diesel and castor biodiesel blends. The indicated mean effective pressure for C20 is 7.67 bars and for diesel 7.66 bar. From the graph it is evident that with increase in concentration of castor biodiesel in diesel increase the indicated mean effective pressure.

6.2.6 Exhaust Gas temperature:

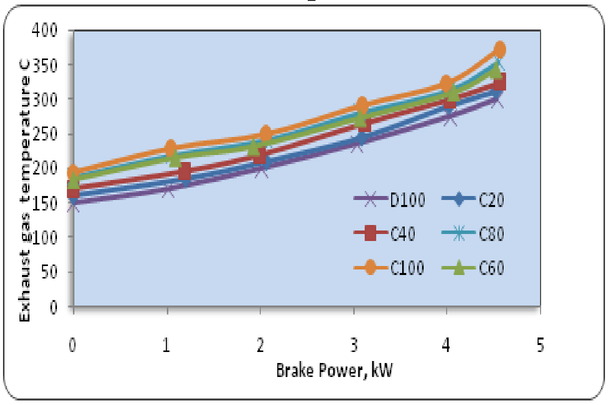

Figure 6.2.6

The variation of exhaust gas temperature with brake power for diesel, and other blends of castor biodiesel are shown in figure 6.2.6. Shows the variation of Exhaust Gas Temperature (E.G.T) with brake power output for castor oil and its blends with diesel in the test engine. The E.G.T of 20% blend of castor oil has lower values compared with all other blends and is well comparable with diesel. The E.G.T of all blends and diesel increases with increase of operating loads. The 20% blend of castor oil has higher performance than other blends due to reduction in exhaust loss. At all loads improvement in exhaust gas temperature is observed at 250 bar and with coating. It is obvious that Exhaust gas temperature increases when heat rejection to the coolant reduced or fuel consumption is increased when all the parameters are same.

6.2.7 Cylinder pressure v/s crank angle:

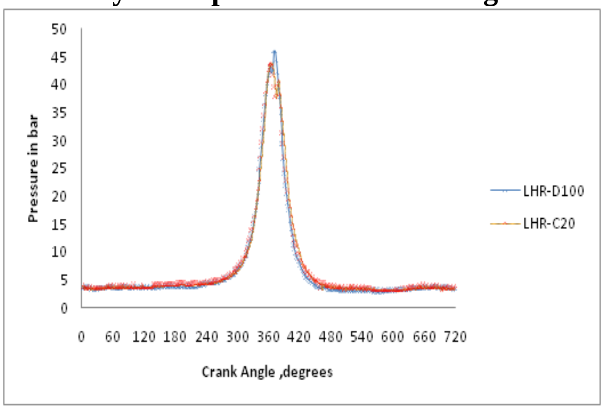

Figure 6.2.7

In a CI engine the cylinder pressure depends on the fuel burning rate during the premixed burning phase, which in turn leads better combustion. Figure 6.2.7. Shows the typical variation of cylinder pressure with respect to crank angle. Peak pressure of 46.52 bar and 46.21 are found for pure diesel and C20 respectively. From the test result it is observed that the peak pressure variation are less since the properties such as calorific value, viscosity and density are brought closer to diesel after transesterification of vegetable oil, no major variation

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are found. Peak pressure as compared to normal engine is higher due to complete combustion of fuel in LHR engine.

6.3 Comparative analysis of performance and combustion characteristics of castor biodiesel blends and diesel on normal engine and low heat rejection engine:

6.3.1 Air-Fuel ratio:

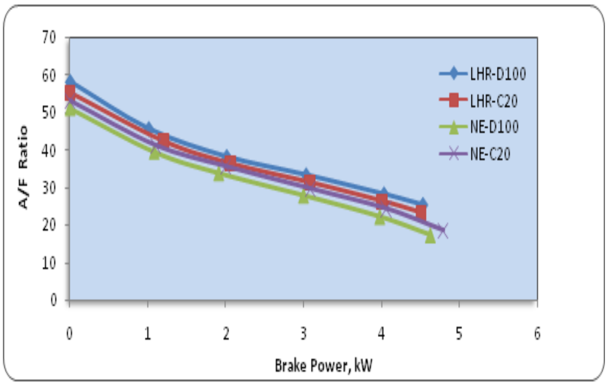

Figure 6.3.1

The variation of the air fuel ratio with load for diesel and COME blends are shown in figure 6.3.1. Fuel consumption is for COME blends compared to diesel hence air fuel ratio decreases with increase in load because air fuel mixing process is affected by the difficulty in atomisation of the biodiesel due to its higher viscosity.

6.3.2. Indicated mean effective pressure:

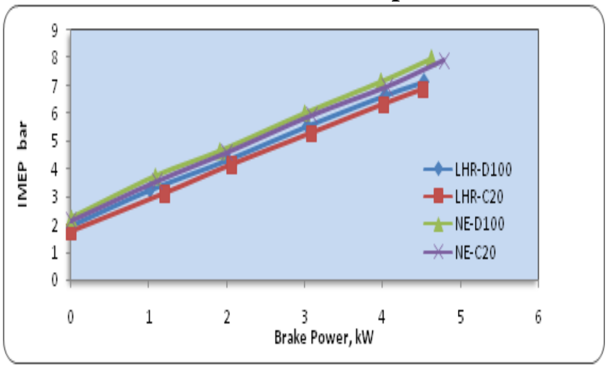

Figure 6.3.2

The variation of the mean indicated pressure with load for diesel and COME blends are shown in figure 6.3.2. Indicated mean effective pressure is low for COME compared to diesel this is because of volatility and caloric value of COME. By using thermal barrier coating there is slight increase in indicated mean effective pressure as compared to normal engine. Here we can observe that as the load increases the mean pressure of an engine increases.

6.3.3 Exhaust Gas temperature:

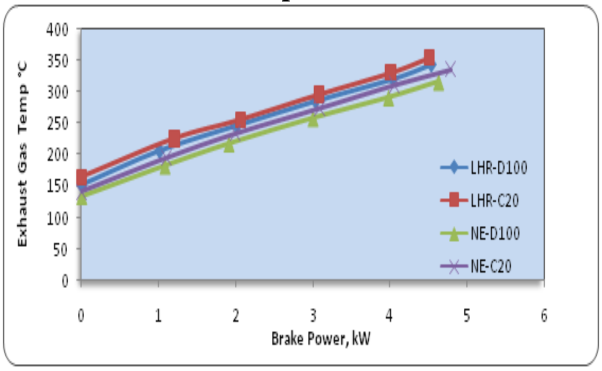

Figure 3.3.3

The variation of the exhaust gas temperature with load for diesel and COME blends are shown in figure 6.3.3. When Bio fuel concentration increases the exhaust temperature increase. The same also when load increases the exhaust temperature increases.

6.3.4 Brake thermal efficiency:

The variation of the brake thermal efficiency with load for diesel and come blends are shown in figure 6.3.4 .we can observe that C20 with LHR has higher brake thermal efficiency than normal engine D100 this is because of increased combustion rate which provides complete burning of fuel and due to low heat rejection. The thermal efficiency of C20 is lower than diesel due to large difference in viscosity specific gravity and volatility.

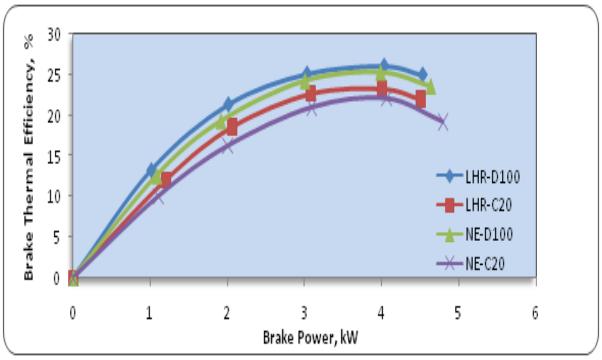

Figure 6.3.4

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6.3.5 Mechanical efficiency:

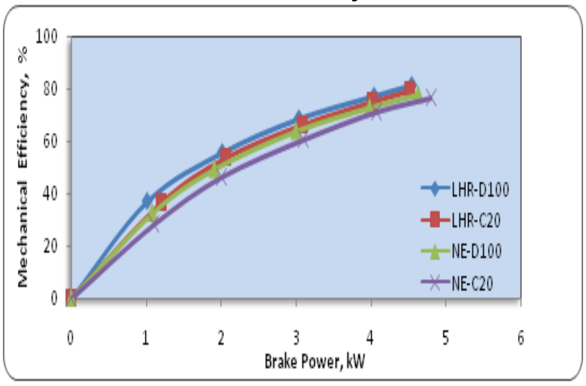

Figure 6.3.5

The variation of the mechanical efficiency with load for diesel and COME blends are shown in fig 6.3.5. It is observed that mechanical efficiency increases the load. C20 and D100 are almost same so C20 shows better result as compared to other blends.

6.3.6 Specific fuel consumption:

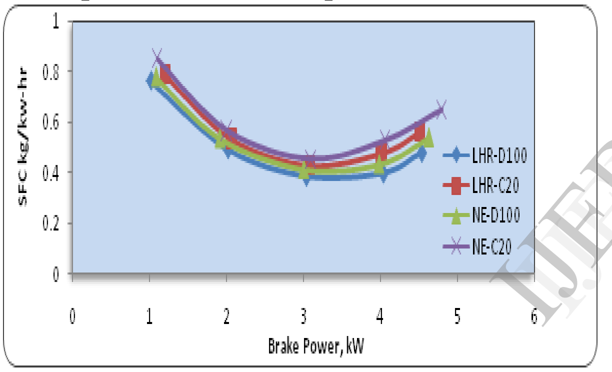

Figure 6.3.6

The variation of the specific fuel consumption with load for diesel and COME blends are shown in figure 6.3.6. A decrease in SFC with increase in load was observed. The SFC of diesel engine depends on the relationship among volumetric efficiency fuel injection, fuel density viscosity and lower heating value. More biodiesel and its blends are needed to produce the same amount of energy due to its lower heating value its comparison with diesel fuel. The SFC increased with the increasing proportion of biodiesel in the blend.

6.3.6 Cylinder pressure v/s crank angle

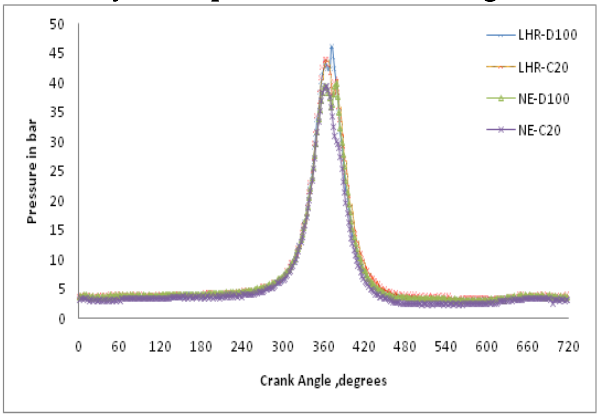

Fig 6.3.7

In a CI engine the cylinder pressure is depends on the fuel-burning rate during the premixed burning phase, which in turn leads better combustion and heat release. Figure 6.3.7. Shows the typical variation of cylinder pressure with respect to crank angle. The cylinder pressure in the case of biodiesel fueled LHR engine is about 4.7 % lesser than the diesel fueled LHR engine and higher by about 1.64 % and 12.22% than conventional engine fueled with diesel and biodiesel. This reduction in the in cylinder pressure may be due to lower calorific value and slower combustion rates associated with biodiesel fueled LHR engine. However the cylinder pressure is relatively higher than the diesel engine fueled with diesel and biodiesel. It is noted that the maximum pressure obtained for LHR engine fueled with biodiesel was closer with TDC around 2 degree crank angle than LHR engine fueled with diesel. The fuel-burning rate in the early stage of combustion is higher in the case of biodiesel than the diesel fuel, which bring the peak pressure more closely to TDC.

Conclusion:

The following conclusions were drawn from these investigations carried out on normal engine and LHR engine for different loads:

- Using insulation to reduce the heat loss to the cooling system of the engine causes the cylinder walls to become hotter and increases exhaust gas energy.
- Thermal efficiency is not improved to the same extent that heat rejection is reduced by combustion chamber insulation.
- High temperatures on the combustion chamber wall surface due to insulation cause a drop in volumetric efficiency although increased boost pressure from the turbocharger can be used to overcome this problem.

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- The detail study of performance and combustion characteristics of castor biodiesel and its blends on normal engine we can observe that 20% blend of castor biodiesel in diesel fuel has almost same mechanical efficiency, same specific fuel consumption and same indicated thermal efficiency .we can also see that there is slight increase in brake thermal efficiency which is a positive sign with this blend. In case of peak pressure we can see that there is almost same pressure as that of diesel fuel. So we can conclude that without any modification in engine we can save diesel fuel for certain extent without any compromise with standard performance and combustion characteristics and in future castor biodiesel can be a best alternative fuel which can replace the diesel.. There is increase in parameters like brake thermal efficiency, mechanical efficiency and brake mean effective pressure and there is decrease in specific fuel consumption, volumetric efficiency and fuel consumption which can be observed in comparative graph. There is also increase in peak pressure which higher than that of biodiesel with normal engine. We can conclude that the C20 with LHR shows same graphs as compared to D100 this blend is best suitable for an engine.

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