Experimental Investigation of Performance, Combustion and Emission Characteristics in Single Cylinder Low Heat Rejection Diesel Engine Using Diesel and Neem Kernel Biodiesel

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Abstract— The use of methyl esters of vegetable oil known as biodiesel are increasingly popular because of their low impact on environment, green alternate fuel and most interestingly it's use in engines does not require major modification in the engine hardware. Use of biodiesel as sole fuel in conventional direct injection diesel engine results in combustion problems, hence it is proposed to use the biodiesel in low heat rejection (LHR) diesel engines with its significance characteristics of higher operating temperature, maximum heat release, higher brake thermal efficiency (BTE) and ability to handle the lower calorific value (CV) fuel. In this work biodiesel from Neem kernel oil was used as sole fuel in LHR direct injection (DI) diesel engine. The low heat rejection engine was developed with uniform metal matrix composites (MMC) coating of cylinder head. The experimental investigation was carried out in a single cylinder water-cooled LHR direct injection diesel engine. In this investigation, the combustion, performance and emission analysis were carried out in a diesel and biodiesel fueled LHR engine under identical operating conditions. The brake thermal efficiency (BTE) of LHR engine with biodiesel is decreased marginally than LHR engine operated with diesel. Carbon monoxide (CO) and Hydrocarbon (HC) emission levels are decreased but in contrast the Oxide of Nitrogen (NO_x) emission level was increased due to the higher peak temperature. In the final analysis, it was found that, the results are quite satisfactory.

Key words: LHR Engine, Biodiesel, Neem kernel oil, Combustion Characteristics, Performance Characteristics, Emission Characteristics, Thermal coating

I. INTRODUCTION

In recent times, the world is confronted with the twin crisis of fossil fuel depletion and environmental degradations. The situations have led to the search for an alternative fuel which should be not only sustainable but also environment friendly without sacrificing the performance. Thedifferent sources for alternative fuels are edible and non-edible vegetable oils, animal fats and waste oil (triglycerides). Vegetable oils, being renewable, are widely available from variety of sources have low sulfur contents close to zero and hence cause less environmental damage (lower greenhouse effect) than diesel. In the context of India, non-edible vegetable oil can be the most viable alternative for petroleum fuels since there is shortage of edible oils to meet the domestic requirements [1]. At present Government have a tough challenge on their hands to overcome the import of crude petroleum from the other petroleum oil producing countries. On the other hand the environmental pollutions from the transportation vehicles have a big problem of climate change and acid rain. Hence governments in the world have been focusing on the utilization of renewable energy sources [2].

There are different kinds of vegetable oils and biodiesel have been tested in diesel engines its reducing characteristic for greenhouse gas emissions. Its help on reducing a country's reliance on crude oil imports its supportive characteristic on agriculture by providing a new market for domestic crops, its effective lubricating property that eliminates the need of any lubricate additive and its wide acceptance by vehicle manufacturers can be listed as the most important advantages of biodiesel fuel. There are more than 350 oil bearing crops identified, among which only jatropha, pongamia, sunflower, soyabean, cottonseed, rapeseed, palm oil and peanut oil are considered as potential alternative fuels for diesel engines. [3].

The concept of LHR engine is to reduce heat loss to coolant by providing thermal insulation in the path of heat flow to the coolant. LHR enginesare classified depending on degree of insulation such as low grade, medium grade and high grade insulated engines. Several methods adopted for achieving low grade LHR engines are using ceramic coatings on piston, liner and cylinder head, while medium grade LHR engines provide an air gap in the piston and other components with low-thermal conductivity materials like superni, cast iron and mild steel etc. High grade LHR engine is the combination of low grade and medium grade engines.

Neem (Azadirachtaindica) is a tree in the mahogany family Meliaceae which is abundantly grown in varied parts of India. The neem grows on almost all types of soils including clayey, saline and alkaline conditions. Indian neem trees have a potentials to provide one million tons of fruits per year and 0.1 million tons of kernels per years (assuming 10% kernel yield). Neem seeds yield 40-60% oil. [4]. In this present investigation neem kernel oil is selected for the test and it's suitability as an alternate fuel is examined. This is accomplished by blending of neem kernel bio diesel with diesel in N10 (10:90), N20 (20:80), N30 (30:70) and 100% on volume basis. Then the performance, combustion and emission characteristics of low heat rejection diesel engine using various blends are studied and result are compared with normal engine.

II. THE PROPERTIES OF DIESEL AND NEEM KERNEL BIODIESEL

The different properties of diesel fuel and neem kernel biodiesel are determined and given in Table.1. After transesterification process the fuel properties like kinematic viscosity, calorific value, and density, flash and fire point get improved in case of biodiesel. The calorific value of neem kernel biodiesel 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.

Properties	Diesel fuel	Neem kernel biodiesel	Apparatus used
Kinematic viscosity at 40^0C (cSt)	4.1	5.2	Redwood viscometer
Calorific value(kJ/kg)	42600	41543	Bomb calorimeter
Density (kg/m^3)	828	900	Hydrometer
Flash point (^{0}C)	51	160	Pensky-martien's apparatus
Fire point(^{0}C)	57	175	Pensky-martien's apparatus

Table 1: Fuel properties

III. EXPERIMENTATION

A. *Engine components:*

The various components of experimental, photograph of the experimental set up is shown in Fig.1. Fig.2 shows line diagram. The important components of the system are

- The engine
- Dynamometer
- Smoke meter
- Exhaust gas analyzer

Fig. 1: Photograph of experimental setup

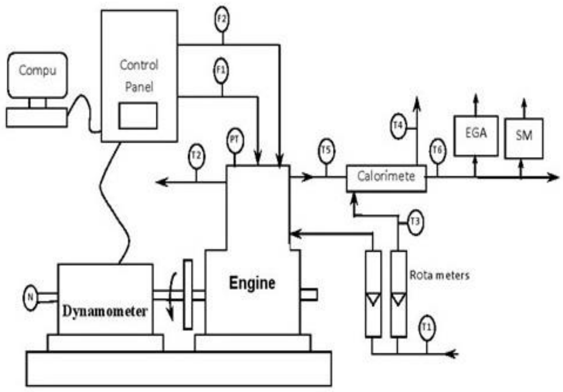

Fig. 2: Experimental set up

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

Table 2: notations

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 before TDC
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 degree encoder with resolution of 1 degree

Table 3: Technical specifications of the Kirloskar diesel engine

IV. RESULT AND DISCUSSIONS

A. *Introduction*

The experimental results obtained from the tests carried out on engine performance combustion and emission characteristics are presented in this section. These include results at constant speeds with different loads for the different fuels i.e. standard diesel fuel and the three multi-blend biodiesel products. The results are discussed from the viewpoint of using multi-blend biodiesel as an alternative fuel for compression ignition LHR engines.

B. *Performance analysis on low heat rejection engine*

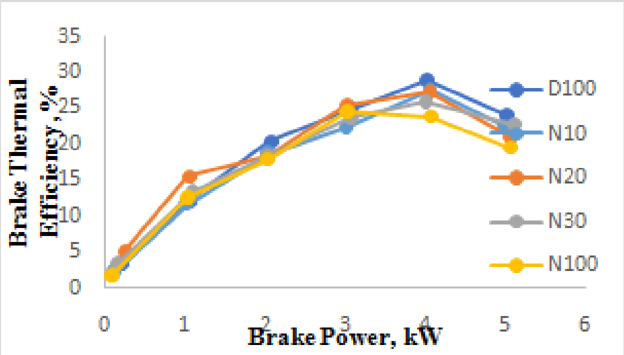

Fig. 3: Variation of the brake thermal efficiency with load for diesel and neem kernel biodiesel.

Change in brake thermal efficiency of blends N10, N20, N30 and diesel with respect to change in brake power is shown in the Fig.3. At no load condition, brake thermal efficiency of N20 and diesel is same. As the load on the engine increases, brake thermal efficiency increases because brake thermal efficiency is the function of brake power and brake power increases as the load on the engine increases. At part load conditions, the brake thermal efficiency of N20 is more than diesel because mass of N20 supplied is 19.35% less than that of diesel and calorific value of N20 is also less than that of diesel. Brake thermal efficiency of N15 and N20 is almost same.

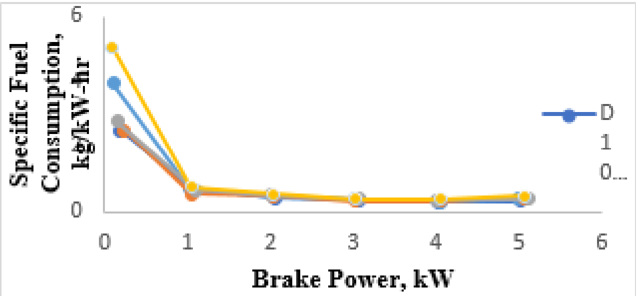

Fig. 4: Variation of specific fuel consumption with brake power.

The variation of BSFC and BSEC with load for different blends and diesel are presented in Figures 4 and 5. It is observed from Figures 4.2 and 4.3 that the BSFC and BSEC for all the fuel blends and diesel tested decrease with increase in load. This is due to higher percentage increase in brake power with load as compared to increase in the fuel consumption. For the blends N20, the BSFC is lower than and equal to that of diesel, respectively, and this enables complete combustion and the negative effect of BSEC is less than that of diesel at all loads. This could be due to the presence of dissolved oxygen in the neem kernel biodiesel that enables complete combustion and the negative effect of the increased viscosity could not have been initiated.

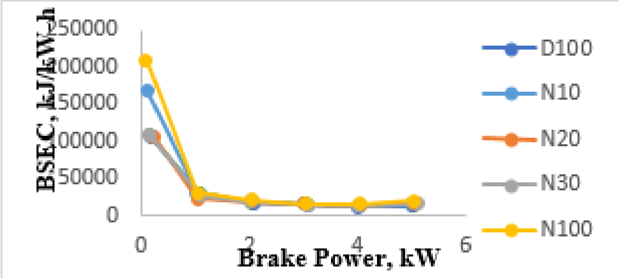

Fig. 5: Variation of break specific energy consumption with break power

However, as the neem kernel biodiesel concentration in the blend increases further, the BSFC increases at all loads and the percentage increase is higher at low loads. Whereas the BSEC for all the fuels tested increases initially at low loads and at higher load conditions, its value is less than that of diesel for all the blends and more than that of diesel for neem kernel biodiesel. This could be due to the lower calorific value of the neem kernel biodiesel and the high mass flow of fuel entering into the engine. Also, the engine has been designed only for diesel fuel and has been used for neem kernel biodiesel in an unmodified condition. In addition, the high viscosity of the blends may also inhibit the proper atomization of the fuel, which in turn affects the combustion process.

The variation of exhaust gas temperature for different blends with respect to the brake power is indicated in Fig.6. The exhaust gas temperature for all the fuels tested increases with increase in the brake power. Exhaust gas temperature is an indicative of the quality of combustion in the combustion chamber. At all loads, diesel was found to have the highest temperature and the temperatures for the different blends showed a downward trend with increasing concentration of neem kernel biodiesel in the blends.

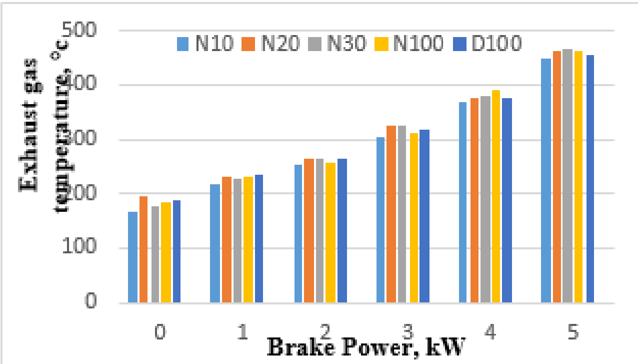

Fig. 6: Variation of exhaust gas temperature with brake power

C. Emission characteristics

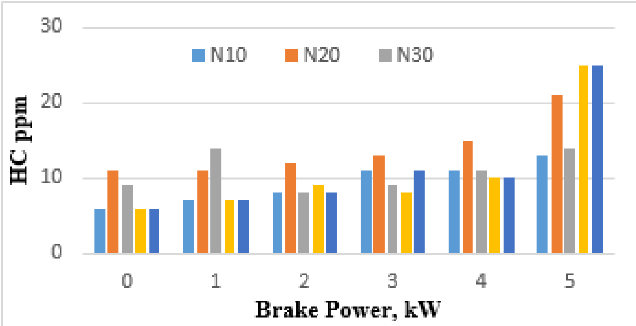

Fig. 7: Variation of hydrocarbon with brake power.

Fig.7 shows the variation in the quantity of unburnt hydrocarbons with change in brake power. At no load conditions, diesel and N10 emits same amount of unburnt hydrocarbons whereas, maximum unburnt hydrocarbons are emitted by N20. At part and full loads, N20, N100 resulted in maximum unburnt hydrocarbons followed by N30 whereas diesel resulted in least unburnt hydrocarbons.

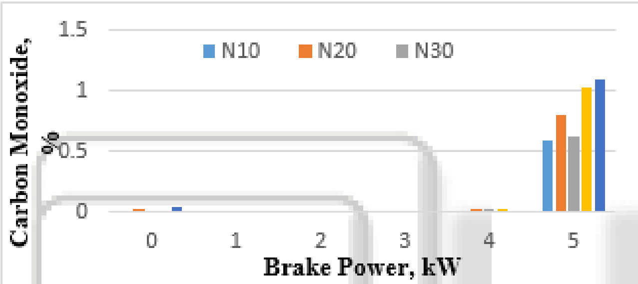

Fig. 8: Variation of carbon monoxide with brake power

Fig.8 shows the variation of carbon monoxide emission with brake power for neem kernel biodiesel oil and its blends in the test engine. The CO emission depends upon the strength of the mixture, availability of oxygen and viscosity of fuel. CO emission of all blends is higher than that of diesel. Among the blends 10% blend has a lower CO emission followed by 20% blend. CO emission of 10% and 20% blends at maximum load is 0.03% and 0.042% volume against 0.028% volume of diesel. CO emission of neat neem kernel biodiesel is higher than all other blends for entire operating range and maximum of 0.05% occurs at the rated load. This due to incomplete combustion at higher loads which results in higher CO emissions.

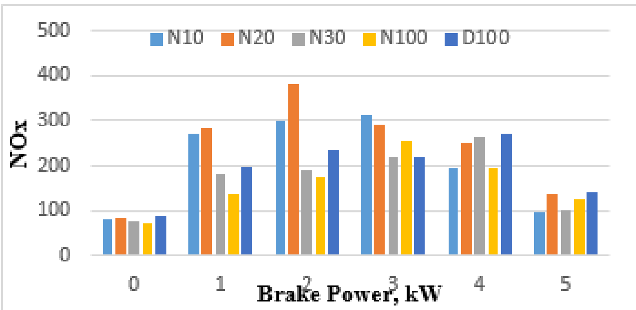

Fig. 9 : Variation of NOx with brake power

Fig.9 shows the variation of nitrogen oxides emission with brake power output for neem kernel biodiesel oil and its blends with diesel in the test engine. The NO_x emission for biodiesel and its blends is higher than that of diesel. The $NO_x$of 10% blend is very close to diesel for entire range of operation and the neat neem kernel biodiesel has less NO_x emission compared to diesel. The maximum NO_xemission of 10% and neat biodiesel is 311ppm and 255ppm against 271ppm of diesel. The maximum NO_x emission for the 20% blend is 295ppm.

D. Combustion characteristics

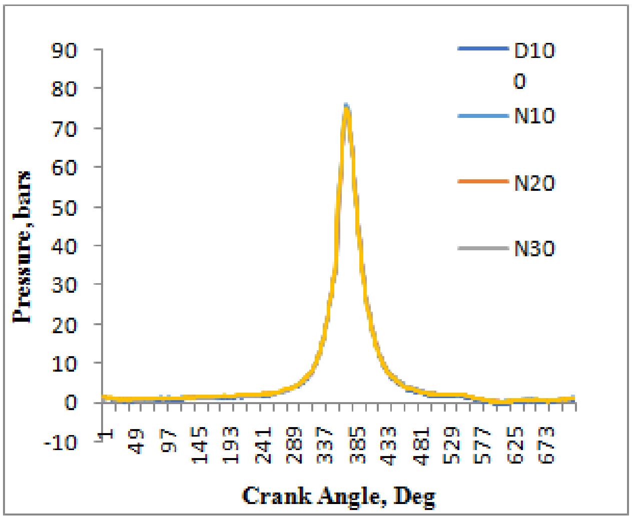

Fig.10: Variation of cylinder pressure with crank angle.

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. The variation of cylinder pressure with respect to crank angle for diesel and different blends of neem kernel biodiesel are presented in Fig.10. Peak pressures and crank angle is 75.41 bars and 371.Deg at 100% pure biodiesel and diesel oil is 75 bars and 371.Deg. respectively.

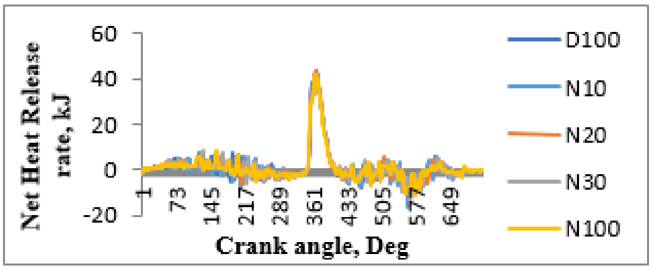

Fig. 11: Variation of heat release rate with crank angle

The variation of cylindernet heat release ratewith respect to crank angle for diesel and different blends of neem kernel biodiesel are shown in Fig.11.The peak point of heat release rate with crank angle in N30 is 42.42 (kJ) and 367 Deg.

The variation of cumulative heat release rate with crank angle is shown in Fig.12. The diesel and blend values are same in all loads expect 30% blend. The two main phases of the combustion process, premixed and diffusion, are clearly seen in the rate of heat release curve. If all heat losses (due to heat transfer from the gases to the cylinder walls, dissociation, incomplete combustion, gas leakage) are added to the apparent heat release characteristics, the fuel burn characteristics are obtained.

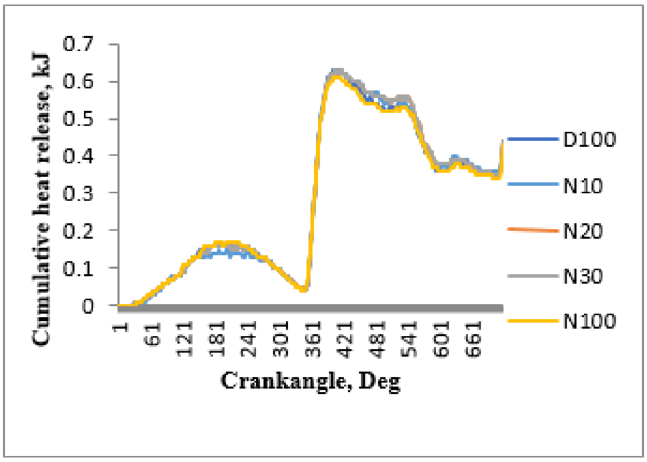

Fig. 12: Variation of cumulative heat release rate with crank angle

E. Comparison of neem kernel biodiesel performance and emission with normal engine and LHR engine.

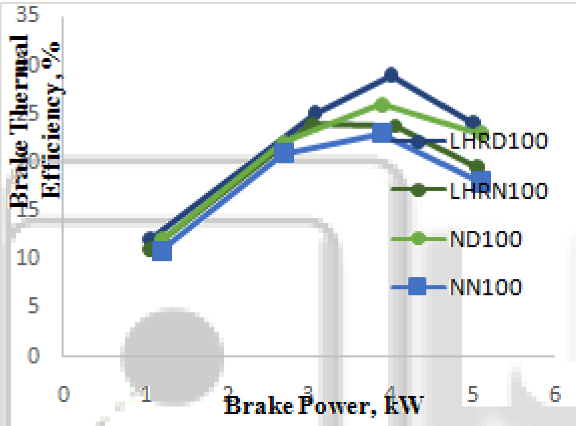

Fig. 13: Variation of brake thermal efficiency with brake power

The plot representing the relation between the Brake Power and the Brake Thermal Efficiency is shown in the Fig.13. It reveals that the thermal efficiency is more for LHR engine than that of conventional engine. The amount of heat transfer to the engine components is reduced and further the heat retained in the combustion chamber increases the combustion. Thus some part of the saved energy is converted into useful work. This increases the thermal efficiency of LHR engine than conventional engine.

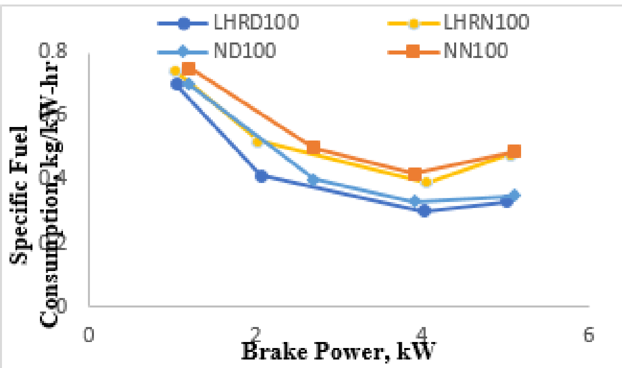

Fig. 14: Variation of specific fuel consumption with brake power

The variation of specific fuel consumption with brake power for LHR engine and normal engine of diesel and neem kernel biodiesel are shown in Fig.14. At maximum load the specific fuel consumption of LHR engine fueled with biodiesel is higher than LHR engine fueled with diesel and lower by conventional engine fueled with diesel and biodiesel. This higher fuel consumption was due to the combined effect of lower calorific value and high density of biodiesel. The test engine consumed additional biodiesel fuel in order to retain the same power output.

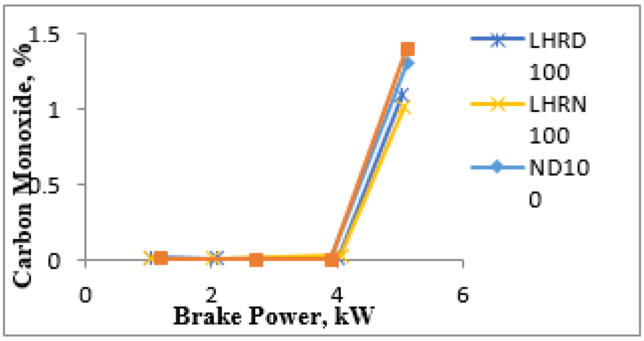

Fig. 15: Variation of carbon monoxide emission with brake power

The variation of carbon monoxide (CO) with brake power for LHR engine and normal engine of diesel and neem kernel biodiesel are shown in Fig.15. The fuels are producing higher amount of carbon monoxide emission at low power outputs and giving lower values at higher power conditions. Carbon monoxide emission decreases with increasing power output. At full load, CO emission for LHR engine with biodiesel fuel is lower than conventional engine fueled with biodiesel and diesel.

V. CONCLUSIONS

The biodiesel produced from neem kernel oil by transesterification process reduces the viscosity of the oil in order to match the suitability of diesel fuel. The diesel engine is modified in to LHR engine by means of metal matrix composites (MMC) coating. The various performance, combustion emission parameters were analyzed and the following conclusions were arrived it.

- The maximum efficiency obtained in the case of LHR engine fueled with biodiesel was lower than the LHR engine operated with diesel fuel. However the efficiency of the LHR engine with biodiesel fuel is well within the expected limits.
- The exhaust gas temperature of LHR engine fueled with biodiesel was lower than LHR engine fueled with diesel throughout the operating condition. The low exhaust gas temperature indicates the heat release rate during the late combustion was comparatively lower than diesel fuel.
- The specific fuel consumption of LHR engine with biodiesel was higher than LHR engine fueled with diesel. The higher consumption of fuel due to low calorific value and high viscosity. Even though it could be expected to the offset by the cost of biodiesel.

- The specific energy consumption of LHR engine with biodiesel was higher than LHR engine fueled with diesel fuel.
- It was found that, CO and HC emissions for LHR engine with biodiesel was considerably lower than LHR engine fueled with diesel. This reduction of emissions due to excess oxygen availability along with higher operating temperature.
- NO emission for LHR engine with biodiesel fuel was higher than LHR engine fueled with diesel. The operating conditions of LHR engine were favorable to NO formation. However this increase in emission level was within the acceptable limits.
- The particulate matter of LHR engine with biodiesel fuel is higher than LHR engine fueled with diesel due to incomplete combustion.
- After comparison of LHR diesel engine running on neat neem kernel biodiesel and diesel with normal engine running on a neem oil and diesel, it is concluded that brake thermal efficiency of diesel and neat biodiesel of LHR engine is higher than that of normal engine.
- The specific fuel consumption for LHR engine is less than that of normal engine

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 neem kernel biodiesel in LHR engine.

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