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*International Journal Of Modern Engineering Research (IJMER)*

# Experimental Investigation on Performance, Emission and Combustion Characteristics of A LHR Single Cylinder Diesel Engine Operating On Mahua Biodiesel and Diesel Fuel

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***Abstract:*** *Diesel is a fossil fuel that is getting depleted at a fast rate. So an alternative fuel is necessary and a need of the hour. Rice bran oil, which is cultivated in India at large scales, has a high potential to become an alternative fuel to replace diesel fuel. Direct use of mahua oil cannot be done, as its viscosity is more than the diesel fuel, and hence affects the combustion characteristics. The mahua oil is esterified to reduce the viscosity and it is blended with diesel on volume basis in different proportions. The use of thermal barrier coatings (TBCs) to increase the combustion temperature in diesel engines has been pursued for over 20 years. Increased combustion temperature can increase the efficiency of the engine. However, TBCs have not yet met with wide success in diesel engine applications because of various problems associated with the thermo-mechanical properties of the coating materials. Although, the in-cylinder temperatures that can be achieved by the application of ceramic coatings can be as high as 850-9000C compared to current temperatures of 650-7000C. The increase in the in-cylinder temperatures helped in better release of energy in the case of biodiesel fuels thereby reducing emissions at, almost the same performance as the diesel fuel. Here the effort has been made to determine the performance, emission and combustion characteristics of MOME blend with diesel in conventional engine and LHR engine.*

***Keywords:*** *LHR Engine, normal engine Biodiesel, mahua oil, MOME, Performance, Emission and combustion Characteristics, Thermal barrier coating.*

## I. Introduction

India is one of the fastest developing countries with a stable economic growth, which multiplies the demand for transportation in many folds. Fuel consumption is directly proportionate to this demand. India depends mainly on imported fuels due to lack of fossil fuel reserves and it has a great impact on economy. India has to look for an alternative to sustain the growth rate. Bio-diesel is a promising alternative for our Diesel needs. With vast vegetation and land availability, certainly bio-diesel is a viable source of fuel for Indian conditions. Recent studies and research have made it possible to extract bio-diesel at economical costs and quantities. The blend of Bio-diesel with fossil diesel has many benefits like reduction in emissions, increase in efficiency of engine, higher Cetane rating, lower engine wear, low fuel consumption, reduction in oil consumption etc. It can be seen that the efficiency of the engine increases by the utilization of Bio-diesel. This will have a great impact on Indian economy.Diesel fuels have deep impact on the industrial economy of a country. These are used in heavy trucks, city transport buses, locomotives, electrical generators, farm equipments, underground mine equipments etc. The consumption of diesel fuels in India for the period 2007-08 was 28.30 million tons, which was 43.2% of the consumption of petroleum products. This requirement was met by importing crude petroleum as well as petroleum products. The import bill on these items was 17,838 crores. With the expected growth rate for diesel consumption more than 14% per annum, shrinking crude oil reserves and limited refining capacity, India is likely to depend more on imports of crude petroleum and petroleum products.[1]

## II. Materials And Methods

The extraction of biodiesel is carried out by base catalyzed transesterification method.

**2.1 Extraction of biodiesel from crude mahua oil:**

To a one liter of crude mahua oil is heated up to 70°C. 300 ml of methanol & 5-7gms sodium methoxide of (catalyst) is added and the mixture is maintained at 65-70$^0$C is about 1½ hours and stirred continuously. The mixture is allowed to settle for 20-30 min until the formation of biodiesel and glycerin layers. The glycerin is removed from the bio-diesel in a separating funnel. The bio diesel produced from mahua biodiesel is ready to use.

**2.2. Transesterificatio**:

It is most commonly used and important method to reduce the viscosity of vegetable oils. In this process triglyceride reacts with three molecules of alcohol in the presence of a catalyst producing a mixture of fatty acids, alkyl ester and glycerol. The process of removal of all the glycerol and the fatty acids from the vegetable oil in the presence of a catalyst is called esterification.

C $CH_2$-OCOR′ | | $CH_2$-OH | $R'COOCH_3$
|  Catalyst |
C CH-OCOR″+ $3CH_3OH$ ⟺ CHOH | + $R''COOCH_3$
| |
C $CH_2$-OCOR‴+ $3CH_3OH$ | $CH_2OH$ | + $R'''COOCH_3$

**Triglycerides** **Methanol** **Glycerol** **Methyl Esters**

Physical and chemical properties are more improved in esterified vegetable oil because esterified vegetable oil contains more Cetane number than diesel fuel. These parameters induce good combustion characteristics in vegetable oil esters. So unburnt hydrocarbon level is decreased in the exhaust. It results in lower generation of hydrocarbon and carbon monoxide in the exhaust than diesel fuel. The vegetable oil esters contain more oxygen and lower calorific value than diesel. So, it enhances the combustion process and generates lower nitric oxide formation in the exhaust than diesel fuel

**3. The Properties of Diesel and Mahua Biodiesel:**

The different properties of diesel fuel and mahua biodiesel are determined and shown in table.3.2 After transesterification process the fuel properties like kinematic viscosity, cv, density, flash and fire point get improved in case of biodiesel. The calorific value of mahua 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.

**Table 3.2 Fuel properties**

| properties | D100 | B10 | B20 | B30 | B100 | Apparatus used |
|---|---|---|---|---|---|---|
| Kinematic viscosity at 40$^0$C (cSt) | 4.6 | 4.8 | 4.95 | 5.05 | 5.2 | Redwood viscometer |
| Calorific value(kJ/kg) | 42600 | 42408.39 | 42212.64 | 41500.54 | 38848.08 | Bomb calorimeter |
| Density (kg/m$^3$) | 828 | 830 | 835 | 840 | 880 | Hydrometer |
| Flash point ($^0$C) | 51 | 62 | 70 | 80 | 155 | Pensky-martien's apparatus |
| Fire point($^0$C) | 57 | 75 | 83 | 94 | 165 | Pensky-martien's apparatus |

## III. Experimental Setup

The experimental setup enables study performance, combustion and emission characteristics. The experiments have been carried out on a DI compression ignition engine for various blends of mahua biodiesel with diesel (MB10%, MB20%, MB30%, and MB100) with varying brake power. The experiment is carried out at constant compression ratio of 17.5:1 and constant injection pressure of 200 bars by varying brake power.

| | |
|---|---|
| Manufacture : | Kirlosker oil engines Ltd, India |
| Model : | TV-SR, naturally aspirated |
| Engine | Single cylinder, DI |
| Bore/stroke | 87.5mm/110mm |
| Compression Ratio | 17.5:1 |
| speed | 1500r/min, constant |
| Rated power | 5.2kw |
| Working cycle | 4 stroke |
| Injection pressure | 200bar/23 def TDC |
| Type of sensor | Piezo electric |
| Response time | 4 micro seconds |

Fig 4.1: Photograph of engine setup

Table 4.1: Engine specification

## IV. Results And Discussions

### 4.2 Performance, emission and combustion characterstics of mahua bio-diesel and its blends on diesel engine:

#### 4.2.1 Variation of brake thermal efficiency with brake power

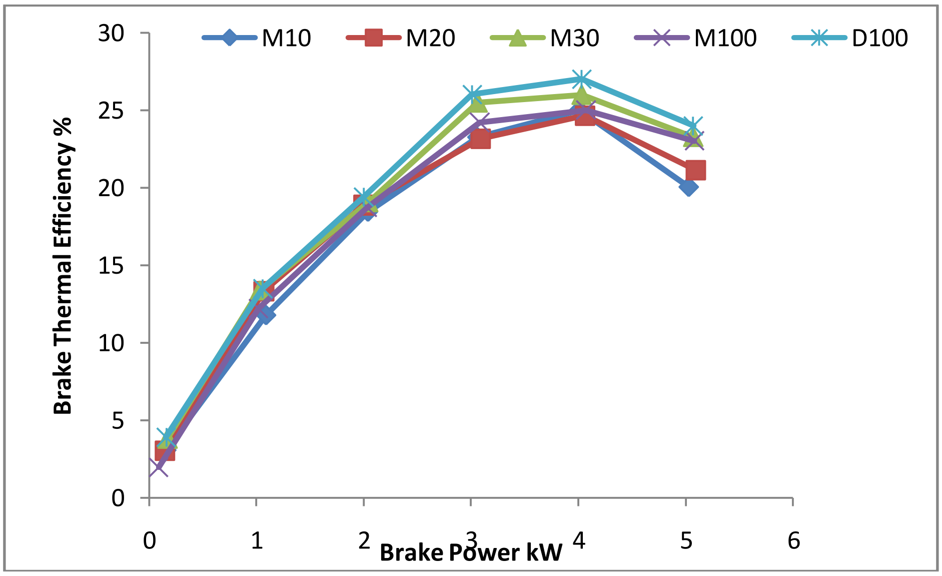


Fig- 4.1 Variation of brake thermal efficiency with brake power

The variation of brake thermal efficiency with brake power for diesel, mahua biodiesel and their blends are shown in fig.4.1. Brake thermal efficiency of 30% blend is very close to diesel for entire range of operation. Maximum brake thermal efficiency diesel oil is 27% against 26% of 30% blend which is lower by 1% we can say that of brake thermal efficiency of 30% blend is well comparable with diesel oil. Brake thermal efficiency of other blends follows in order of 10%, 20%, blend and mahua biodiesel. The maximum brake thermal efficiency of 20% and mahua biodiesel are 24.65% and 25% against 25.62% of diesel oil. And minimum brake thermal efficiency is 1.95% of mahua biodiesel at 0.09kw brake power.

**4.2.2 Variation of specific fuel consumption with brake power**

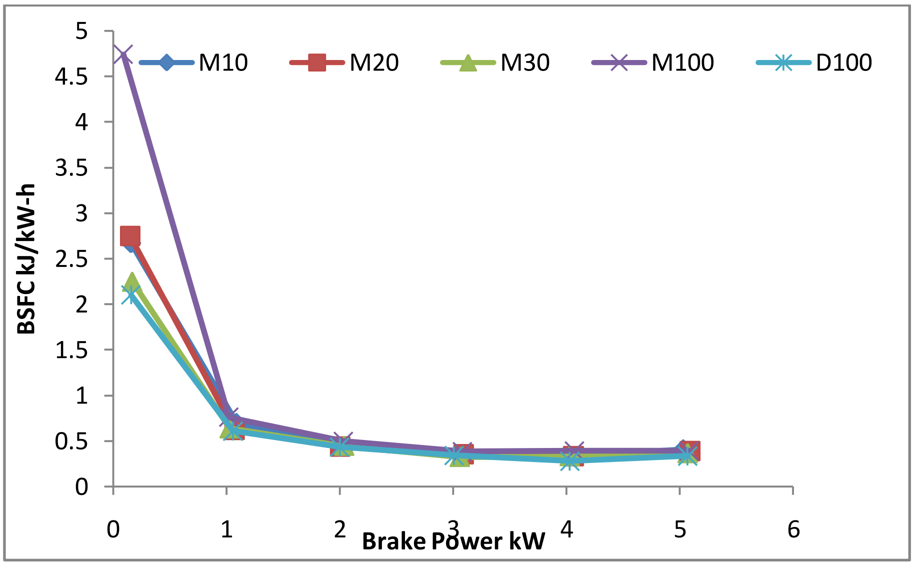


Fig- 4.2 Variation of specific fuel consumption with brake power

The variation of specific fuel consumption with brake power for diesel, mahua biodiesel and their blends are shown in fig.4.2.As the power developed increases the specific fuel consumption decreases for all the tested fuels. This may be due to fuel density, viscosity and heating value of the fuels. BSFC of 30% blend closely matches with diesel oil. Minimum BSFC of 10% blend 20% blend and 100% blend are 0.33 kg/kW-h, 0.336 kg/kW-h, and 0.388 kg/kW-h against 0.28 kg/kW-h of diesel oil. The specific fuel consumption of all blends is more than that of diesel oil.

**4.2.3Variation of exhaust gas temperature with brake power**

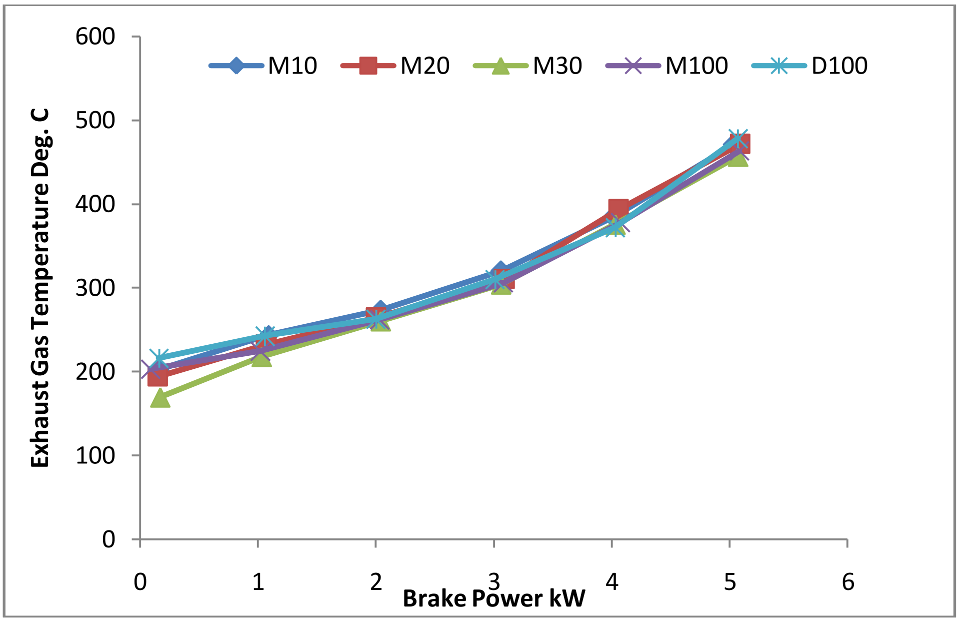


Fig- 4.3 Variation of exhaust gas temperature with brake power

The variation of exhaust gas temperature with brake power for diesel, mahua biodiesel and their blends are shown in fig.4.2. The exhaust gas temperature of 30% blend has lower values compared with all other blends and is well comparable with diesel oil. The exhaust gas temperature of all blends with diesel increases with increases in operating loads. The 30% blend has higher performance than other blends due to reduction in exhaust loss.

#### 4.2.4 Variation of carbon monoxide emission with brake power

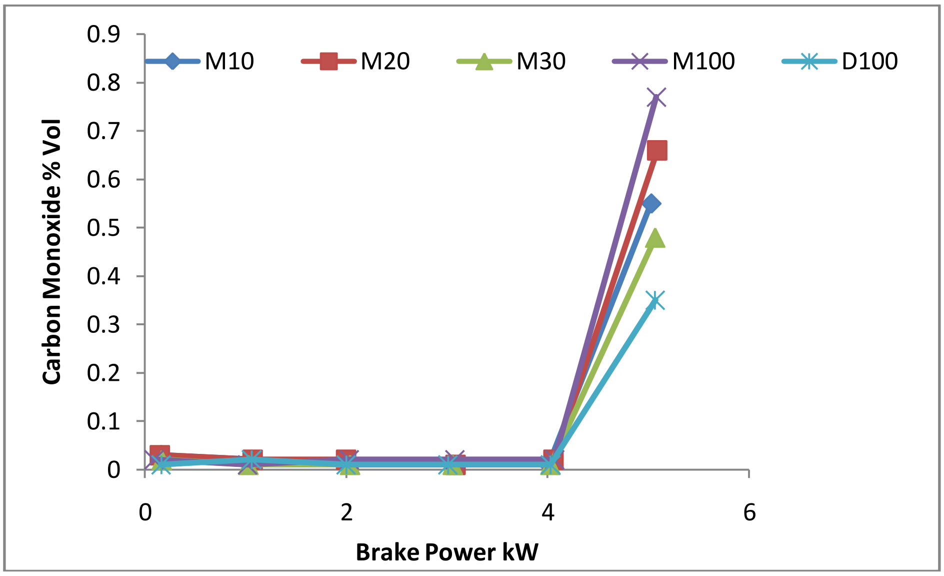


Fig-4.4 Variation of CO emission with brake power

The variation of carbon monoxide emission with brake power for diesel, mahua biodiesel and their blends are shown in fig.4.4.CO emission of all blends is higher than that of diesel. Among the blends, 30 % blend has a lower CO emission followed by 10%, 20% blend. CO emission of 10%, 20% and 30% blends at maximum load is 0.55, 0.66 and 0.48 % volume against 0.35 % volume of diesel oil. CO emission of neat mahua biodiesel is higher than all other blends for entire operating range and the maximum value is 0.77 % volume occurs at rated load.

#### 4.2.5 Variation of hydrocarbon emission with brake power

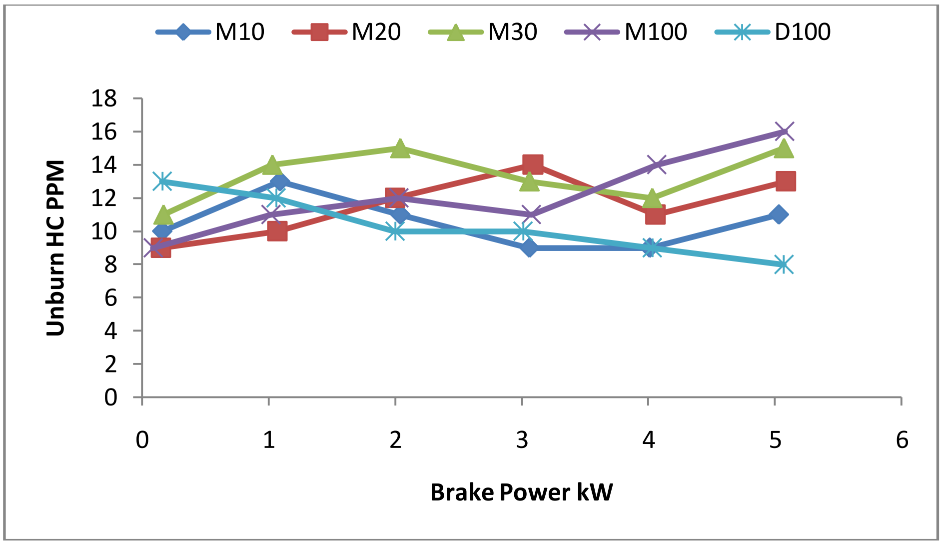


Fig-4.5 Variation of hydrocarbon emission with brake power

The variation of carbon monoxide emission with brake power for diesel, mahua biodiesel and their blends are shown in fig.4.5.Unburnt HC emission of all blends is lower than that of diesel for low and part load operation. However at maximum load unburnt HC is more for 30 % blend and 20% blend. Maximum unburnt HC of neat mahua biodiesel is 16 ppm compared with 8 ppm of diesel at 5.07kW brake power.

#### 4.2.6 Variation of $NO_x$ emission with brake power

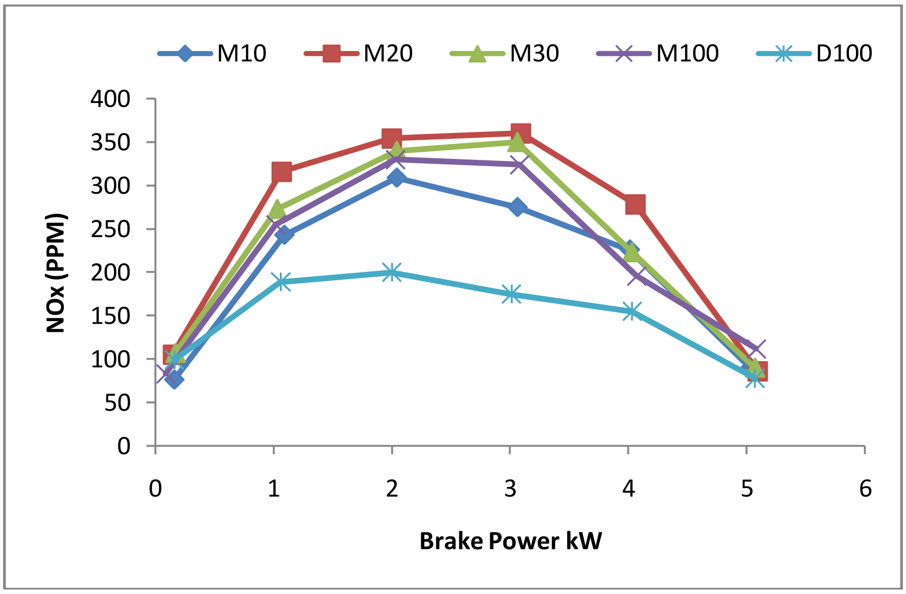


Fig-4.6 Variation of $NO_x$ emission with brake power

The variation of $NO_x$ emission with brake power for diesel, mahua biodiesel and their blends are shown in fig.4.6. $NO_x$ Emission of 30 % blend is lower compared with other blends followed by 20% blend. However smoke emission of 30 % blend is higher than that of diesel. Smoke emission at maximum load for 10%, 20%, 30% and 100% blends are 309,360,350, and 330 ppm against, 200 ppm of diesel oil. For 20% of blend smoke emission is on higher side for entire range of operation and maximum emission of 112 ppm occurs at maximum load.

#### 4.2.7 Variation of carbon dioxide emission with brake power

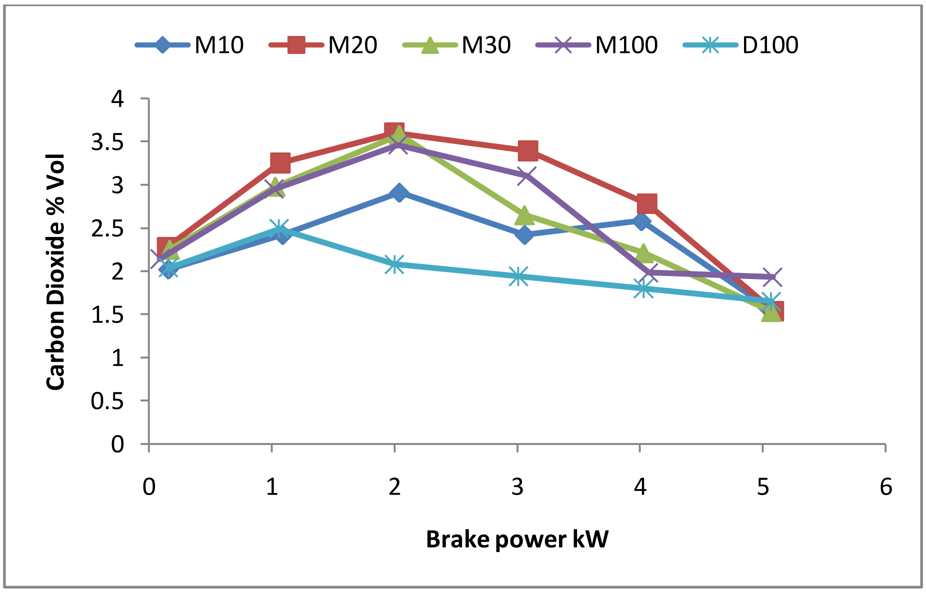


Fig-4.7 Variation of carbon dioxide emission with brake power

The Variation of carbon dioxide emission with brake power for diesel, mahua biodiesel and their blends are shown in fig.4.7. The carbon dioxide emission blend 20% and 30% are up to 3.09 and 3.06kW is same. The 20% blend is increases at 3.09 and 4.07kW and finally at maximum load both are same. Compared to all blends carbon dioxide emission is decreases in diesel oil.

**4.2.8 Variation of crank angle with cylinder pressure**

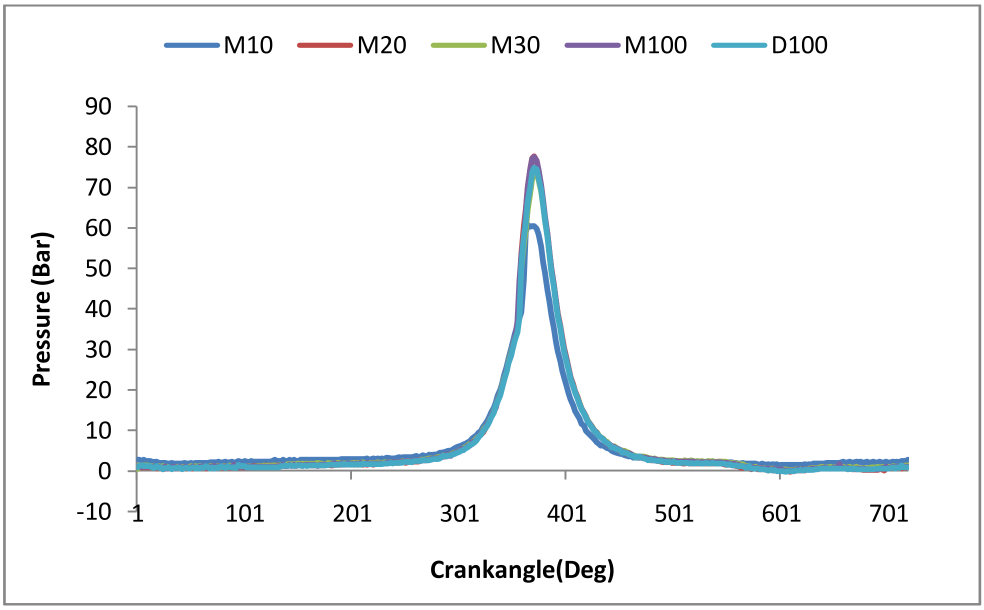


Fig-4.8.Variation of crank angle with cylinder pressure

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 mahua biodiesel are presented in fig-4.8. Peak pressures and crank angle is 77.43 bars and 371.Deg at100% pure biodiesel and diesel oil is 73.55 bars and 369.Deg. respectively. The blend 30% is same for all the pressures and crank angle.

**4.2.9 Variation of crank angle with net heat release rate**

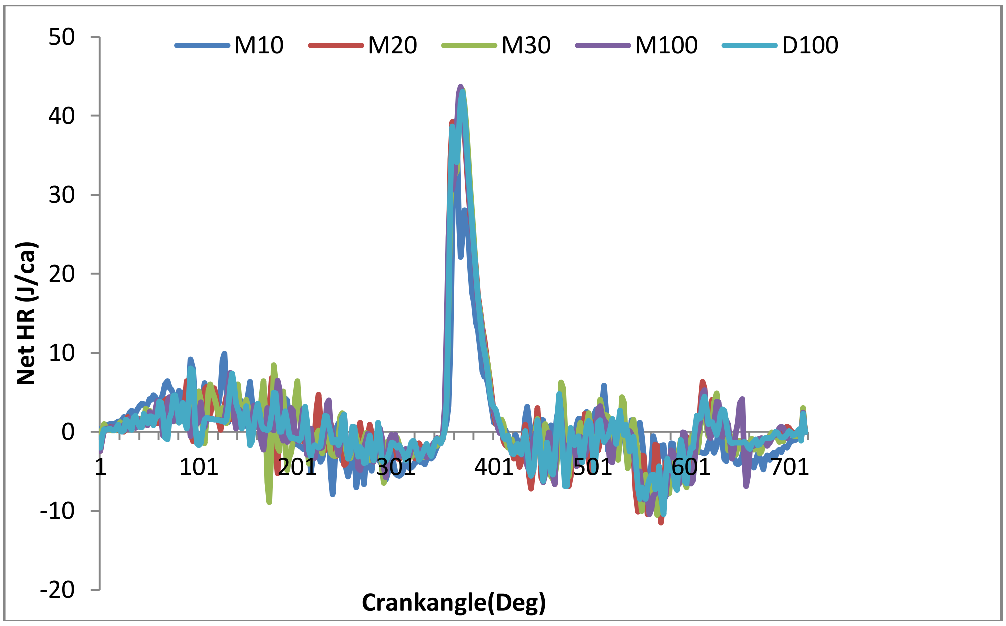


Fig-4.9.Variation of heat release rate with crank angle

The variation of cylinder net heat release rate with respect to crank angle for diesel and different blends of mahua biodiesel are shown in fig.4.9.The peak point of heat release rate with crank angle is diesel oil is 41.38(J/ca) and 367.Deg.

**4.2.10 Variation of crank angle versus cumulative heat release rate**

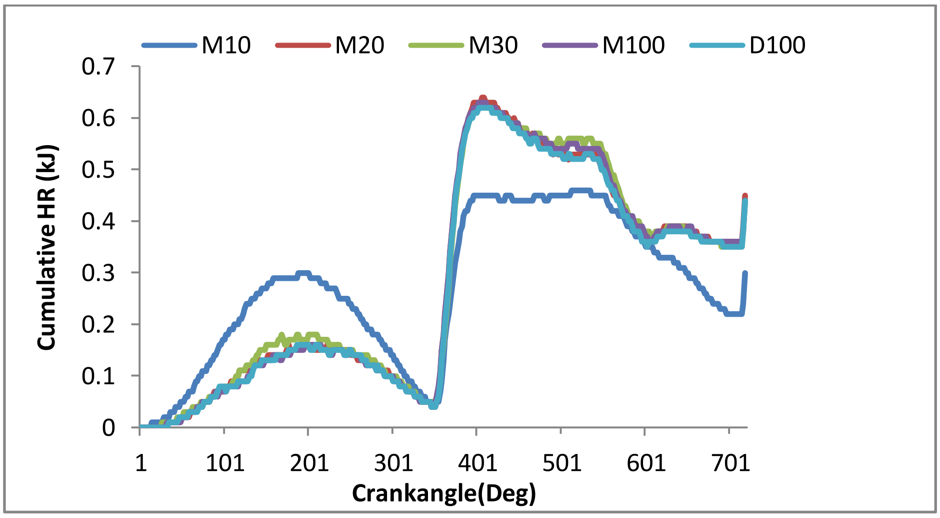


Fig-4.10. Variation of cumulative heat release rate with crank angle

The variation of cumulative heat release rate with crank angle is shown in figure (4.10). The diesel and blend values are same in all loads expect 10% 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.

**4.3. Comparison of mahua biodiesel performance and emission with normal engine and LHR engine.**

To ascertain the validity of results obtained, mahua biodiesel LHR engine performance and emission is compared with normal engine results obtained by similar experimental work of Haiter Lenin [16] This person also used the similar engine specification, 5.2kW, 1500rpm, injection pressure 200 bars, and kirlosker make diesel engine.

**4.3.1 Variation of brake thermal efficiency with brake power**

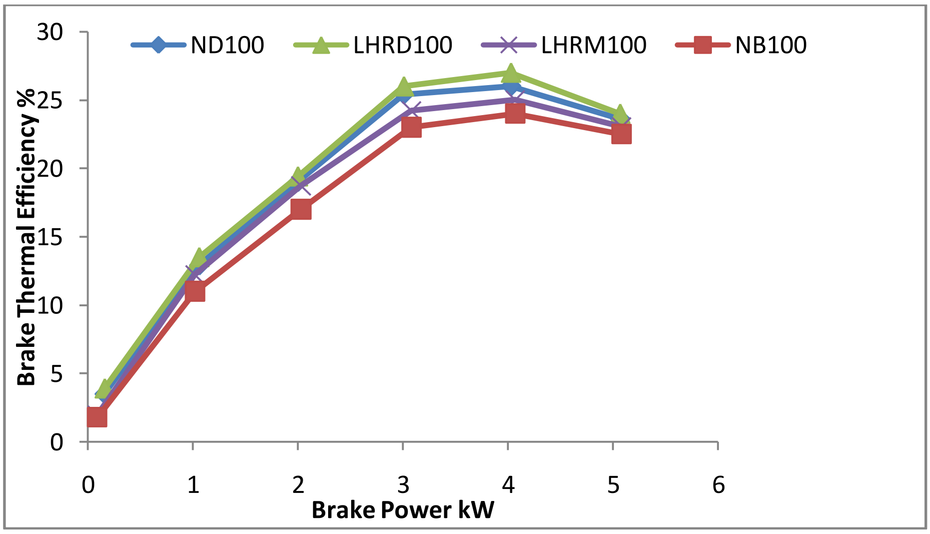


Fig- 4.11 Variation of brake thermal efficiency with brake power

The variation of brake thermal efficiency with brake power for normal engine and LHR engine of diesel, and mahua biodiesel are shown in fig.4.11.The maximum brake thermal efficiency is 27%, 26%, 25%, and 24% for LHRD100, ND100, LHRM100, and NB100. Entire operating loads the LHR engine having maximum brake thermal efficiency compared with normal engine.

**4.3.2 Variation of specific fuel consumption with brake power**

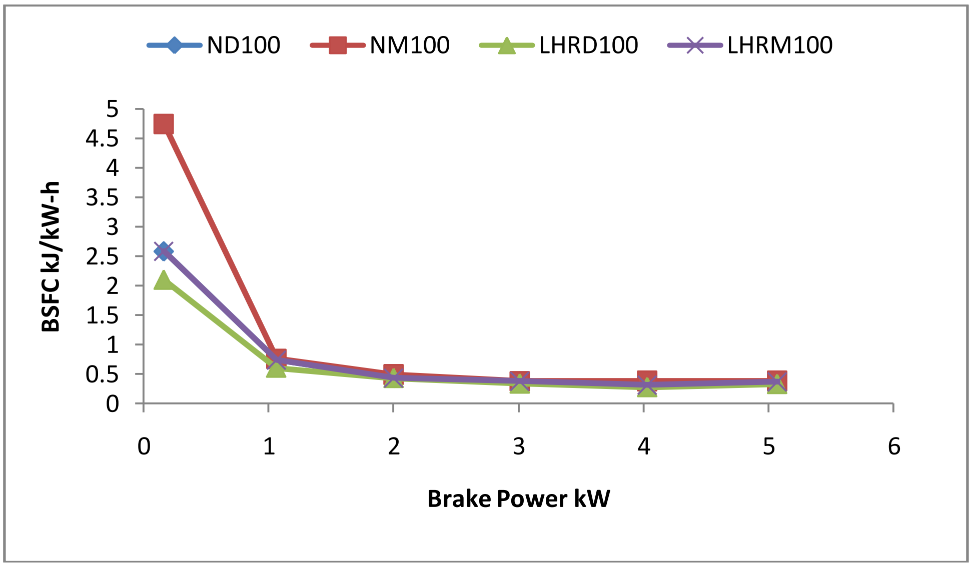


Fig- 4.12 Variation of specific fuel consumption with brake power

The variation of specific fuel consumption with brake power for normal engine and LHR engine of diesel and mahua biodiesel are shown in fig.4.12.The LHRD100 is having minimum specific fuel consumption at maximum load 0.333 kJ/kW-h at 5.07kW. The NM100 and LHRM100 having same specific fuel consumption at entire operating load. The NM100 is having maximum specific fuel consumption of 4.8 kJ/kW-h, at 5.08kW load.

**4.3.3Variation of exhaust gas temperature with brake power**

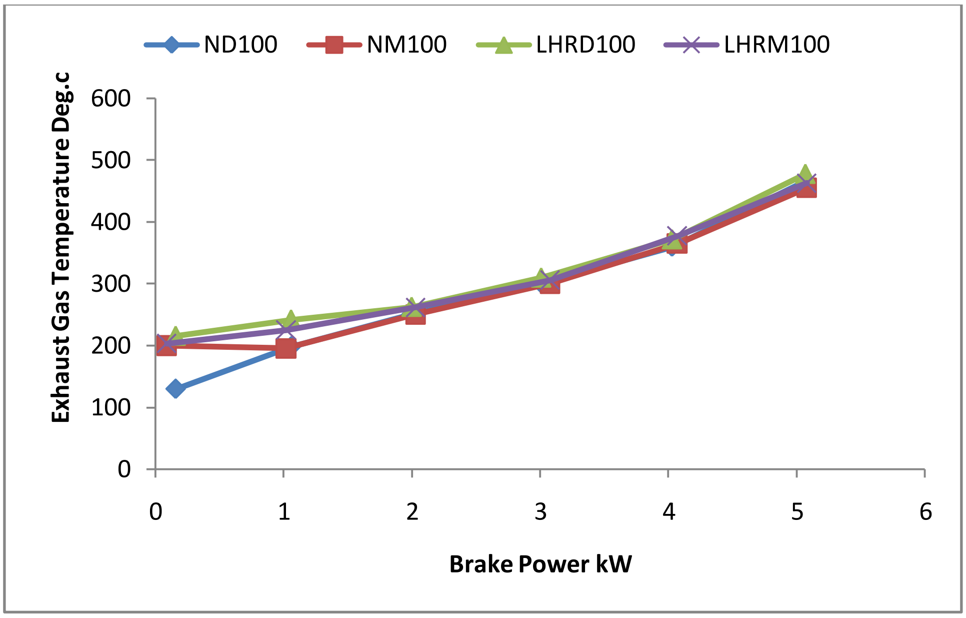


Fig- 4.13. Variation of exhaust gas temperature with brake power

The variation of exhaust gas temperature with brake power for normal engine and LHR engine of diesel and mahua biodiesel are shown in fig.4.13. The exhaust gas temperature is initial two loads are LHRD100 is maximum 215 $^{o}$, and 242.47 $^{o}$ at 0.16kW, 1.06kW after that four loads LHRD100 and LHRM100 both are same. The minimum exhaust gas temperature is NM100.

**4.3.4 Variation of carbon monoxide emission with brake power**

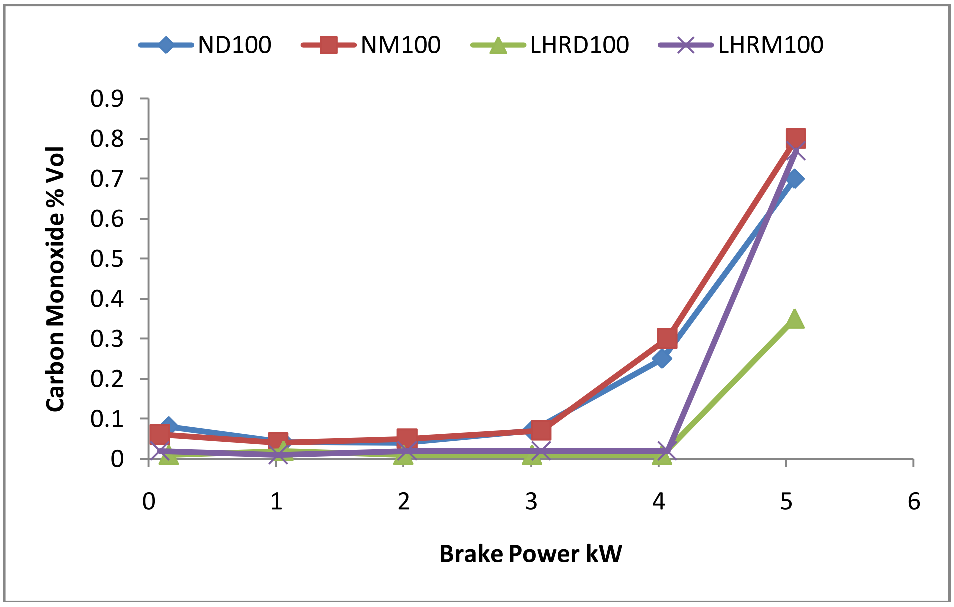


Fig-4.14. Variation of CO emission with brake power

The variation of carbon monoxide emission with brake power for normal engine and LHR engine of diesel and mahua biodiesel are shown in fig.4.14. The carbon monoxide emission gradually increases with increase in load. The carbon monoxide emission of LHRD100, LHRM100 is lower than ND100, NM100.This is because of the availability of oxygen content which makes the combustion better.

**4.3.5 Variation of hydrocarbon emission with brake power**

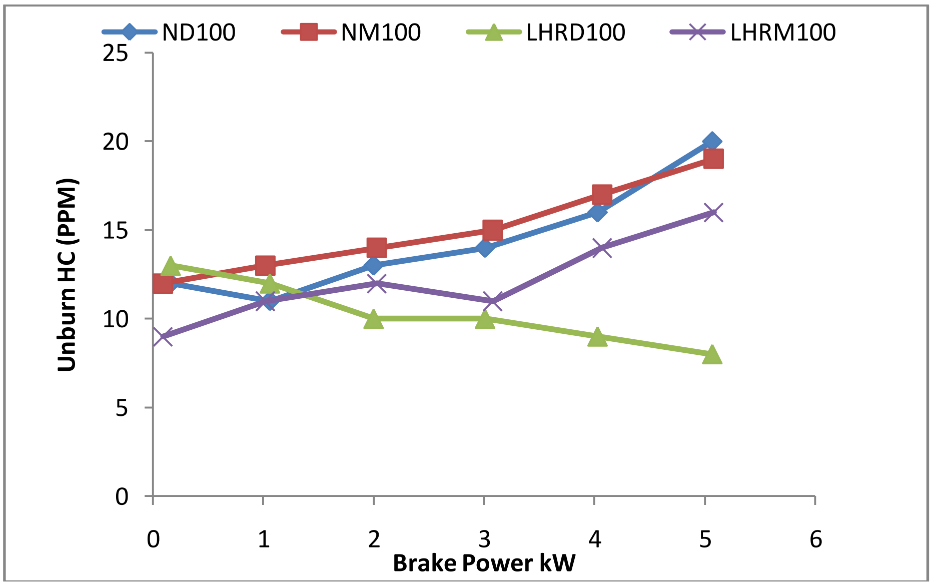


Fig-4.15 Variation of hydrocarbon emission with brake power

The variation of hydrocarbon emission with brake power for normal engine and LHR engine of diesel and mahua biodiesel are shown in fig.4.15. The hydrocarbon emission is low in LHRD100 and LHRM100 when compared with the ND100, and NM100. The decrease in the hydrocarbon in the LHR engine may be due to the increase in after combustion temperature due to decrease in heat rejected to cooling and heat loss to atmosphere due to the MMC coating.

**4.3.6 Variation of $NO_x$ emission with brake power**

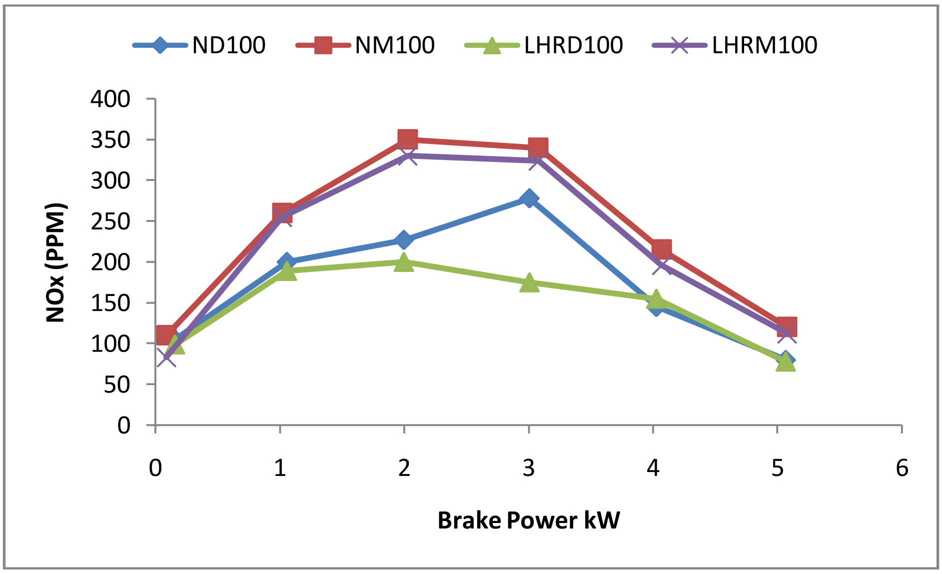


Fig-4.16 Variation of $NO_x$ emission with brake power

The variation of oxides of nitrogen emission with brake power for normal engine and LHR engine of diesel and mahua biodiesel are shown in fig.4.16.The oxides of nitrogen emission gradually increases and decreases with increase in load. And Compared to the normal engine. The Oxides of nitrogen emission in the LHR engine are more because of an increase in after combustion temperature due to the MMC coating.

**4.3.7 Variation of carbon dioxide emission with brake power**

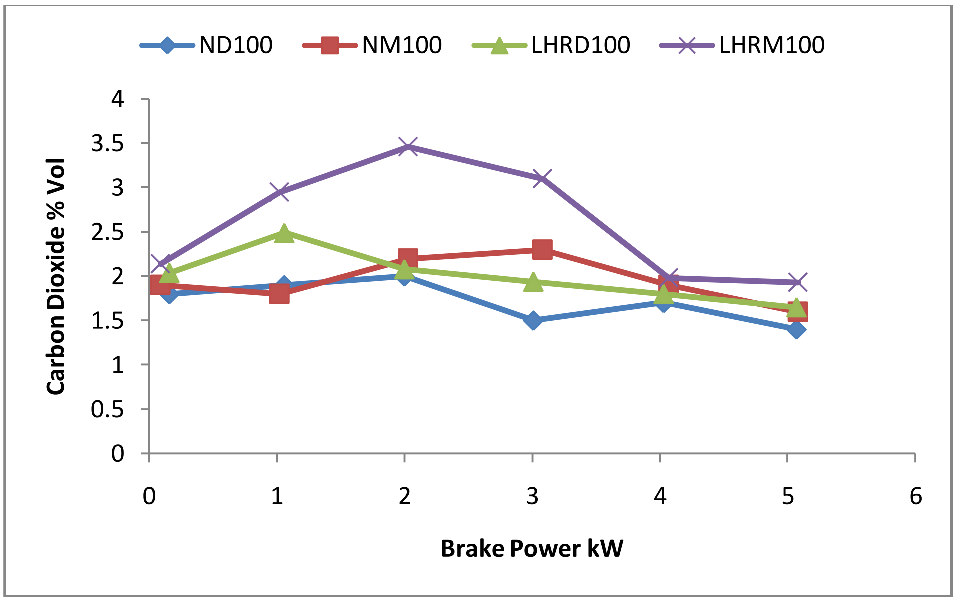


Fig-4.17. Variation of carbon dioxide emission with brake poweer

The variation of carbon dioxide emission with brake power for normal engine and LHR engine of diesel and mahua biodiesel are shown in fig.4.16.The carbon dioxide emission maximum in NM100, and LHRM100. The LHRD100 is having minimum carbon dioxide emission compared with ND100, NM100, and LHRM100. The experimental study was carried out with diesel and mahua oil biodiesel blend. The MMC coating was done on the cylinder head and engine to convert the normal engine into low heat rejection engine. It was observed that the heat transferred to the coolant and surrounding was reduced well due to the thermal barrier coating. The specific energy consumption of LHR engine with biodiesel was higher than diesel oil, but lower than the normal engine operations. The high operating temperature during combustion in low heat rejection engine makes the combustion process to nearly a complete combustion. At maximum load the carbon monoxide and unburned hydrocarbon emission level decreases for LHR engine with mahua biodiesel blend. The reduction in carbon monoxide and unburned hydrocarbon emission level is due to the high combustion temperature and availability of oxygen in biodiesel blend.

## V. Conclusions

Experimental conducted on a single cylinder DI- LHR diesel engine to compare the suitability of mahua biodiesel as an alternate fuel. Then the performance and emission characteristics of blends are evaluated and compared with diesel and optimum blend is determined. For conformation its available results are compared with the results of normal engine mohua biodiesel available in literature for similar work. From the above discussion, the following conclusions are follows.

- The mahua biodiesel is satisfies the important properties like; density, viscosity, flash point, fire point and calorific value as per ASTM standards.
- Mahua biodiesel can be directly used in diesel engines without any engine modifications.
- Engine works smoothly on mahua biodiesel with Performance comparable to diesel operation.
- Brake thermal efficiency of 30% blend is equal to diesel compared to other blends
- Specific fuel consumption is neared to diesel oil at minimum loads and increases at maximum loads. Minimum BSFC of 10% blend 20% blend and 100% blend are 0.33 kg/kW-h, 0.336 kg/kW-h, and 0.388 kg/kW-h against 0.28 kg/kW-h of diesel oil.
- The exhaust gas temperature of all blends and diesel increases with increases of operating loads.
- Combustion characteristics are all blends of mahua biodiesel is almost same as that of diesel.
- The emission characteristics like CO, HC are increases and $CO_2$, $NO_x$ levels are decrease against diesel oil.
- Performance of LHR mahua biodiesel is validated as results are in well comparison with results normal engine mahua biodiesel.
- Form the above conclusions mahua biodiesel is suitable for normal engine and as well as LHR engine also.

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