Experimental Investigation of Performance, Emission And Combustion Characteristic of CI Engine Using Ethanol Blended With Mahua Oil And Diesel

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***Abstract**-Import of petroleum products is a major drain on our foreign exchange sources and with growing demand in future years the situation is likely become even worse. Hence it has become imperative to find suitable fuels, which can be produced in our country. Non-edible vegetable oils such as Pongamia, Mahua Jatropha etc can either be fully or partially substitute for diesel oil. Mahua oil is non edible vegetable oil which is available in large quantities in India. In this paper will be discuss the use of diesel with ethanol and mahua oil blends in diesel four-stroke engine. Blending of mahua oil, ethanol with diesel are B5E5D90%, B20E5D75%, B35E5D60% and B50E5D45% maximum possible proportion helps to reduce the specific fuel consumption of diesel fuel. This alternative fuel contains mahua and ethanol so it reduces the emission compared to diesel. Ethanol is a good cooling agent due to blending of ethanol so the NOx will be reduced. For those mixtures the brake thermal efficiency, brake specific fuel consumption and combustion characteristics are calculated. The gas emissions of NOx, carbon monoxide (CO), hydrocarbons (HC), are being measured by the use of AVL smoke meter. The experimental investigation has been done on single cylinder CI Engine coupled with an eddy current dynamometer, data acquisition system (Kirolskar high speed four stroke diesel engine with 5.2 KW, 1500rpm.) and the result has been record.*

Keyword: Biodiesel (Mahua oil), Ethanol, Diesel, performance, emission, combustion.

I. INTRODUCTION

Wind is a form From the stand point of preserving the global environment and to sustain from the large imports of crude petroleum and petroleum products from gulf Countries, alternate diesel fuels is the need of the hour. The recent upward trend in oil prices due to uncertainties in supply of petroleum products scarcity and ultimately depletion has a great impact on Indian economy and the nation has to look for alternatives to sustain the growth rate[1]. In IC engine the addition of diethyl ether and ethanol on engine performance and emissions of a bio-diesel diesel blended fuel engine. It can be used in diesel engine without any modification [2]. Increased environmental concerns and poor international politics have sparked new interests for alternatively fueled vehicles. There are numerous alternative fuel technologies including gasoline-hybrids, diesels, full electrics, as well as hydrogen and ethanol. These technologies are changing rapidly and consumers are having difficulty trying to decipher which type of vehicle is the most worthy investment [3]. Since the dawn of oil age man has burnt about 800 million barrels of petroleum. About 71 barrels are burnt everyday throughout the world. And this consumption rate goes on increasing by 2% every year. The 2% doubles the quantity every 34 years. Somewhere between 1000 to 1600 billion barrels of fuel consumption are assumed to be in formation where economic recovery is possible. By current year the world would have consumed about one-half of the total amounts that is technically and economically feasible to extract. And at the current rate of consumption 1600 billion barrels would be depleted in 60 years. It is high time to think about the alternative fuels [4].

Biodiesel has properties similar to diesel and therefore can be used in diesel engines with less or no engine modifications. Biodiesel is non toxic, biodegradable and contains no aromatics and sulfur. it can be blended with diesel at any proportion. Engine efficiency with biodiesel is proved to be comparable with diesel. (kalligeros et al., 2003) [5]. Biodiesel blends have been reported to produce lower smoke, CO and HC and higher oxides of nitrogen (NOx).Serdari et al. (2000) [6]. conducted emission tests using sunflower, corn and used frying oil biodiesel and its blends with diesel. The test results indicated increase in NOx emission and significant decrease in PM. Nabi et al. (2006) [7]. investigated the exhaust emissions of a diesel engine using neem biodiesel and its blends with diesel.

II. LITERATURE REVIEW

Diesel fuel is the single largest source to power vehicles both in transportation and agricultural sectors. With the increasing demand on the use of fossil fuels, a stronger threat to clean environment is being posed as the burning of fossil fuels is associated with emissions. These emissions are major causes of air pollution and hence of the environment. The most appealing alternative fuels are those, which can be used minimum modification of existing engines. In India biodiesel will be produced from oil-bearing trees like Honge, Mahua and Jatropha. Fortunately in India those plants are abundantly available. In this chapter, characterization of vegetable oils and biodiesel, performance and emission studies carried out by earlier researchers with regards to the use of various types of vegetable oil as fuel in diesel engines are presented.Nirav H. Rathod. [1] An experiment study has been carried out for MAHUA oil blended with diesel used in single cylinder CI engine. MAHUA oil is non edible vegetable oil which is available in large quantities in India. Blending of mahua oil with diesel in maximum possible proportion helps to reduce the specific fuel consumption of diesel fuel. This study applies the L16orthogonal array of the taguchi method to find out the best injection pressure blend proportion and load for minimum specific fuel consumption. The result of the taguchi experiment identifies that 0% blend ratio, engine load 10 kg and injection pressure 160 bar are optimum parameter setting for minimum specific fuel consumption. Engine performance is mostly influenced by engine load and least influenced by injection pressure. Confirmation experiment was done using optimum combination showed that specific fuel consumption was found by experiment is closer to the predicated value.blends of transesterified mahua oil with diesel were tested at 200bar injection pressure.

III. OBJECTIVES OF PROJECT WORK

1. To prepare the biodiesel from vegetable oils by trans-esterification. Since chemically modifying the structure of vegetable oils by esterification reduce the viscosity.
2. To study the comparison properties of Mahua and ethanol blends with diesel oil. For comparison, the same properties of the diesel oil were to be determined.
3. To run a typical diesel engine on a mahua oil, diesel are blend with ethanol in order to evaluate their performance in regard to BP, BTE, BSFC, EGT , emission such as NOX, UBHC, CO ,and combustion characteristics such as crank pressure ,cumulative pressure. For comparison, the same properties were to be determined for engine operation with conventional diesel oil also.
4. To blend mahua oil and diesel in different proportion with ethanol oil and carryout the tests. This would serve the double objectives of reducing the viscosity of these esters and achieving partial substitute of diesel oil.
5. To run a diesel engine on a Mahua oil blends with diesel like B5, B20, B35 and B50 with ethanol 5 percentage constant in all blend, at injection opening pressure (180 bar) since optimum blend gives the better performance.
6. To compare the performance, emission and combustion of Mahua ,Ethanol and Diesel oil blends at optimum injection pressure. Thus optimum blend at would gives the best performance.

IV. INFORMATION OF BIODIESEL

Mahua oil (MO oil) is an underutilized non-edible vegetable oil, which is available in large quantities in India that is extracted from mahua flower and leave as shown in fig 4. The fuel properties of the MO Oil biodiesel were found to be within the limits of biodiesel specifications of many countries. Fuel properties of diesel, mahua oil and blends are comparable. The calorific value of mahua oil was found as 96.30% on volume basis of diesel. It was found that mahua could be easily substituted up to 20% in diesel without any significant difference in power output, brake specific fuel consumption and brake thermal efficiency. The specific gravity of mahua oil was 9.11% higher than that of diesel. The kinetic viscosity of mahua oil was 15.23 times more than that of diesel at temperature of 40oc. the kinetic viscosity of mahua oil reduced considerably with increasing the proportion of diesel in fuel blend.

Fig 4: Mahua Flowers

For the present experiment, MBO from de-oiled seed cake was obtained by pyrolysis process. Figure.4 show the steps involved in production of MBO. The pyrolysis process for deriving MBO was carried out at 420-500 0C. The products of pyrolysis in the form of vapour were sent to a water cooled condenser and the condensed liquid was collected in a container.

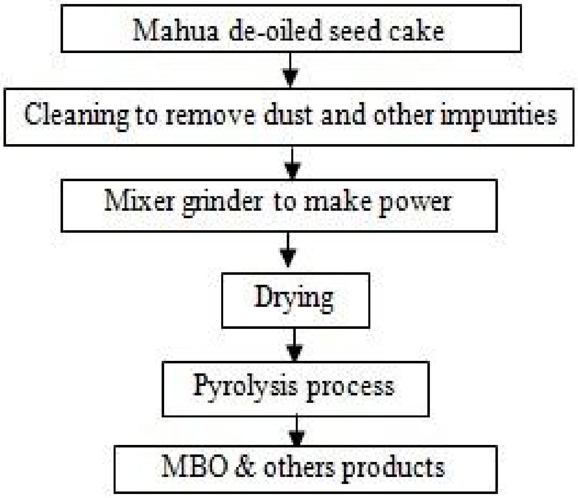

Fig. 4: Production Of MauhaBio-Oil

Table4. Show the physical properties of bio-oil. The density of the crude bio-oil 880(kg/m3) is higher than base diesel 830 (kg/m3). The higher fuel density would severely affect the spray characteristics of diesel engines resulting in poor mixing of fuel with air. The moisture content of the crude bio-oil is about 25% which is not desirable for diesel engine applications. Since the viscosity if bio-oil is 10.2 cSt which is much higher than diesel 3.05 cSt, hence direct use of bio- oil is not suitable as an alternative fuel in diesel engine. MBO is denser, highly viscous and calorific value is less than the commercial fuels which makes it not suitable to use in diesel engine.

Table 4: Physical Properties Of Bio-Oil

Properties	MBO
Appearance	PoleYellow
Odor	Smokysmell
Densityat 15^{0}C	880Kg/m^3
Viscosityat 25^{0}C cSt	10.2
Gross calorific value MJ/kg	38.999
Moisture contentWt.%	25.0
AshWt.%	0.09
FlashPoint^{0}C	116

Ethanol is a convenient liquid fuel and can act as a substitute for petrol and diesel.Usually 95% (hydrous) ethanol can be directly used in modified engines.. The excellent combustion properties of ethanol enable an engine to produce up to 20% more power. Mass, density and calorific value of ethanol are less than that of diesel but on account of its improved combustion proper ties of ethanol fuel consumption from for ethanol; gasohol or petrol is more or less than the same. Ethanol as petrol additive raises the octane rating of the mixture, as anhydrous ethanol is an octane fuel. Distinctive advantage of ethanol is that it can be produced by renewable sources unlike non renewable fossil fuels.

V. METHODOLOGY OF THE PROJECT

It studies characteristic fuel properties and experimental procedure adopted to evaluate performance of a single cylinder four stroke diesel engine on the blends. The experiments were conducted in the Internal Combustion Engine Laboratory, Department of Mechanical Engineering, PDA college of Engineering, kalburgi. The transesterification process setup and the required utensils are arranged in proper manner for production of biodiesel. The fuel properties have been determined by using equipments such as hydrometer, Redwood viscometer, closed cup flash and fire apparatus, cloud and pour point apparatus and bomb calorimeter. Properties of the biodiesel obtained after transesterification.

Viscosity

The viscosity of a fluid is its resistance to shear or flow, and is a measure of the fluids adhesive/cohesive or frictional properties and is measuring the amount of time taken for a given measure of oil to pass through an orifice of a specified size. It is determined by redwood viscometer instrument shown in fig5.1 Fuel of low viscosity has inferior this will increase wear of the fuel injection pump and nozzle.

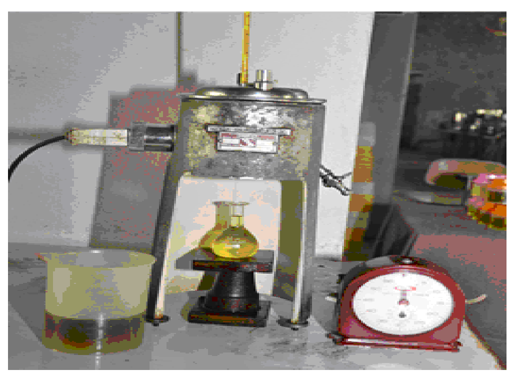

Fig.5.1: Redwood Viscometer

A. Density

It is characterized as the proportion of the mass of a liquid to its volume. Accordingly mass per unit volume of a liquid is called thickness. The image regularly utilized for thickness is ρ (the lower case Greek letter rho). The SI unit given by (kg/m3). Fig 5.2 show the hydrometer is utilized to decide the thickness. The thickness of mahua biodiesel is 880.16 (kg/m3).

Fig.5.2: Hydrometer

B. Calorific Value

It is the amount of heat liberated by burning unit mass of fuel. Two types of calorific values are higher calorific value and lower calorific value. The calorific value of diesel fuel is 42500 (kJ/kg), mahua biodiesel is 38999.12 (kJ/kg). After the transesterification even calorific value gets improved.fig 5.3 show the bomb calorimeter.

Fig 5.3: Bomb Calorimeter

C. Flash Point And Fire Point

Flash Point: At the flash point, a lower temperature, a substance will ignite briefly, but vapor might not be produced at a rate to sustain the fire, i.e. will ignite but not burn.

Fire Point: The fire point of a fuel is the temperature at which it will continue to burn for at least 5 seconds after ignition by an open flame, i.e. will ignite and burn. Fig 5.4 show the pensky marten's.

Figure: 5.4: Pensky Marten's

D. Properties Of Fuels Used

Table 5.1 shows the values of different properties such as density, kinematic viscosity, flash point, fire point and calorific value of Ethanol, Diesel and Mahua biodiesel.

Table 5.1:Properties Of Ethanol, Diesel And Mahua Biodiesel

Fuel samples Properties	Diesel	Mahua oil	Ethanol	Testing Equipments
Fuel density in $\frac{kg}{m^3}$	830	880	798	Hydrometer
Kinematic viscosity at 40^{o}C in cst	2.90	42.75	40.2	Redwood viscometer
Flash point in ^{o}C	64	116	12	Pensky marten
Calorific value in $\frac{kJ}{kg}$	42500	38999	30575	Bomb calorimeter
Fire point in ^{o}C	75	132	13	Pensky marten

In above table 5.1 shows that, the properties of diesel,ethanol and mahua oil in 100% , To runa diesel engine ona mahua oil blend with diesel like B5, B20, B35 and B50 percentage. In these blending ethanol is consider as 5% constant. as shown in the table 5.2.

Table.5.2: Blending % Of Biodiesel

Si. No	Fules Proportion
1	5%MahuaOil And5%Ethanol+90% Diesel (B5e5d90)
2	20%MahuaOil And5%Ethanol+75%Diesel (B20e5d75)
3	35%MahuaOil And5%Ethanol+60%Diesel (B35e5d60)
4	50%Mahua Oil And 5%Ethanol +45%Diesel (B50e5d45)

VI. EXPERIMENTAL SETUP

The experimental setup consists of single cylinder, four strokes, diesel engine connected to eddy current dynamometer for loading. The set as standalone type independent panel box consisting of air box, fuel tank, manometer etc. The setup enables study of engine for brake power, BMEP, brake thermal efficiency, specific fuel consumption, volumetric efficiency, and emissions characteristics like CO, K, HC and NOX. Combustion characteristics The various components of experimental setup are described below. Fig 6.1 shows line diagram.

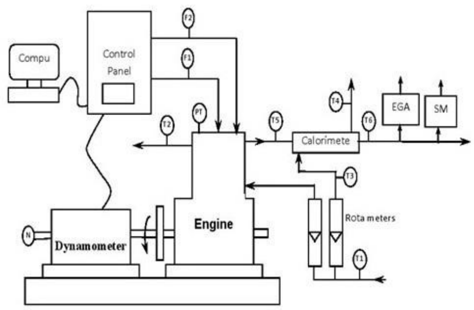

Fig 6.1: line diagram of the experimental setup

The engine chosen to carry out the experimentation is single cylinder, Kirloskar oil engines ltd India, water cooled, computerized diesel engine. Fig 6.2 photograph taken from the IC engine laboratory, PDA College of Engineering shows engine connected with controlling unit. Table 6.1 shows Kirloskar oil engines ltd, India. Diesel engine specifications

The existing PC based experimental setup consisting of single cylinder, four stroke, water cooled IC engine with 5.2 kW brake power coupled with eddy current dynamometer will be used to run on diesel,mahua oil and ethanol and its blends at a constant speed of 1500 rpm under variable load conditions. Engine performance (brake specific energy consumption, thermal efficiency and exhaust gas temperature), Emissions (CO, NOx , Smoke and UBHC)Combustion (cylinder peak pressure, heat release rate combustion pressure and mass fraction burned) will be measured to evaluate and compute the behaviour of diesel engine running on blends.All themeasured parameters will be compared with that of diesel to find the suitability of the bio-diesel oil as fuel for diesel engine.

Fig 6.2: Photograph Of The Experimental Setup.
Table 6.1 Technical specifications of the kirloskar dieselengine

Manufacturer	Kirloskar oil engines ltd. India
Model	TV SR II, naturally aspirated
Engine	Single cylinder, direct injection diesel engine
Bore / stroke/ compression ratio	87.5mm/110mm/17.5:1
Rated power	5.2KW
Speed	1500 rpm, constant
Injection pressure/ advance	200 bar/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	Piezoelectric
Time sampling	4 micro seconds
Resolution crank	1 degree crank angle
Angle sensor	360 degree encoder with resolution of 1 degree

Fig 6.4: Emission testing machine

The emissions test is done with AVL DITEST MDS 350 Exhaust Gas Analyser as show fig6.4. It is designed with sophisticated modules. The product has extra features to save a vehicle and customer database, radio-connected diesel measuring chamber up to the designing the protocols individually. Due to the robustness and initiative application of the device, the tester can be used to get sophisticated and accurate emission measurements. This provides for motivation and satisfaction.

VII. RESULTS AND DISCUSSION

A. PERFORMANCE CHARACTERISTICS

1.Variation Of Brake Thermal Efficiency With Brake Power.

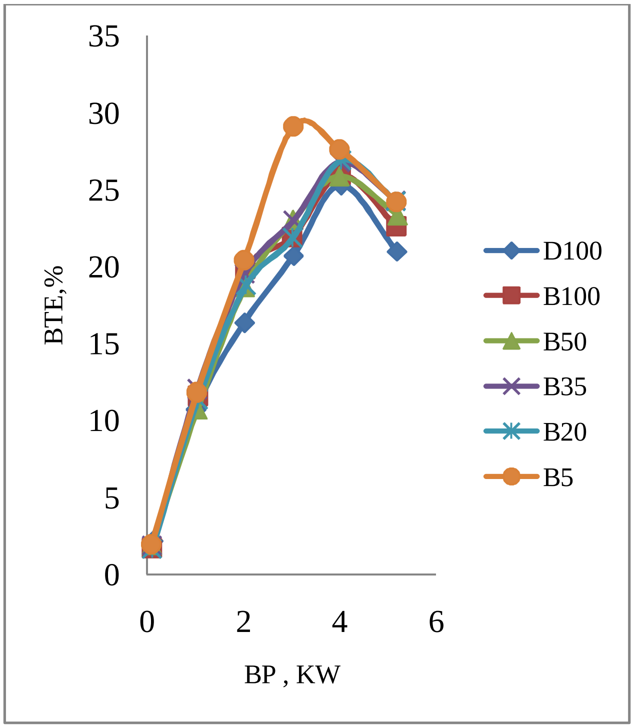

Fig.7.1: Brake Thermal Efficiency

The above fig 7.1 shows the variation of brake thermal efficiency with brake power for diesel and blends of mahua biodiesel. 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. The maximum value of brake thermal efficiency for B5 blend is at 29.12 %. The brake thermal efficiency is almost constant between range of 25 % to 30 %, brake thermal efficiency of all the blends are lower than that of B5, this is attributed to more amount of fuel consumption for blends as compare to B5. And B5 biodiesel is 29.12% and against 20.99% for that of diesel on normal engine. At full load conditions, the brake thermal efficiency of B5 biodiesel is more than all blends and pure diesel. Brake thermal efficiency of biodiesel blend is above the diesel for entire range of operation.

2. Variation Of Brake Specific Fuel Consumption With Brake Power.

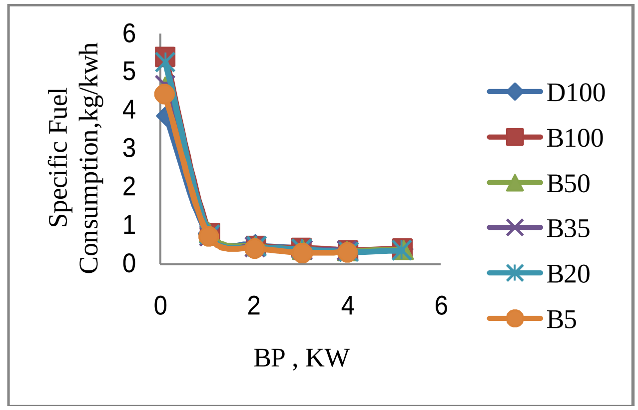

Fig.7.2: Specific Fuel Consumption

The variation of specific fuel consumption with brake power for diesel and blends mahua seed biodiesel are shown in figure 7.2.as the power developed increases the specific fuel consumption decreases for all the tested fuels. The specific fuel consumption of mahua seed biodiesel are higher than diesel because of lower calorific value and high density of biodiesel. From the graph it is clear that the specific fuel consumption is more for initial loads and further it is almost constant for remaining loads.

3. Variation Of Exhaust Gas Temprature With Brake Power

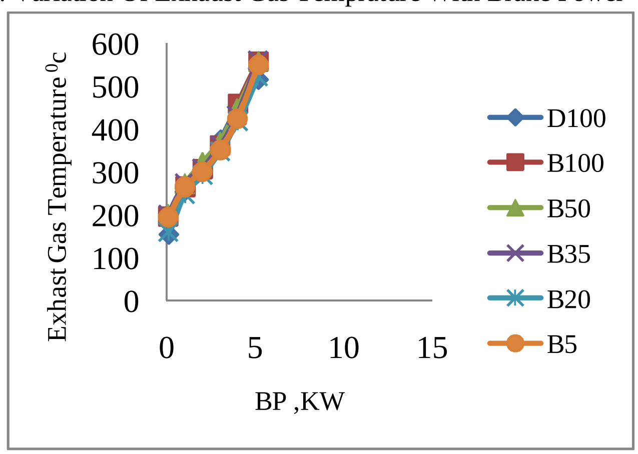

Fig.7.3 :Exhaust Gas Temperature

The variation of exhaust gas temperature (EGT) for diesel,pure biodiesel and different blends with respect to the brake power is indicated in fig 7.3.The exhaust gas temperature for all the fuels tested increase with increase in the brake power ,.Exhaust gas temperature of pure biodiesel and all the blends is higher as compared to diesel because of oxygen content which enables the combustion process and hence the exhaust gas temperature is higher .The Maximum EGT occur at full load .Maximum EGT of pure biodiesel is 560 0C against 522 0C for that of diesel on normal engine .By increasing % of Mahua oil in biodiesel , the decreases the EGT.

B.EMISSION CHARACTERISTICS

1. Variation Of Unburnt Hydrocarbons With Brake Power.

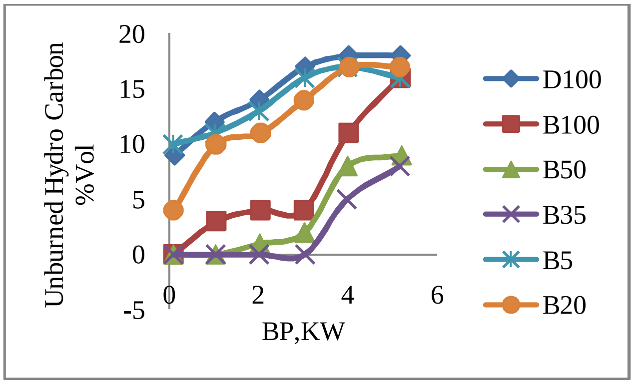

Fig.7.4: Hydro Carbon Emission

The variation of hydrocarbon emission with engine load is shown in Fig 7.4 The use of biodiesel and its blends in the internal combustion engine decreases the hydro carbon emission when comparing with neat diesel fuel .it is observed that for mahua biodiesel 100%, emission of HC is less than that of the diesel and ethanol – mahua biodiesel blends the emission of HC is more than that of the biodiesel .the maximum HC emission occurs at full load .Maximum HC of pure diesel is 18 ppm against 16ppm for that of pure bio diesel on normal engine.the B35E5D60 blends gives lower emission compared to other blends.

2.Variation Of Carbon Monoxide With Brake Power.

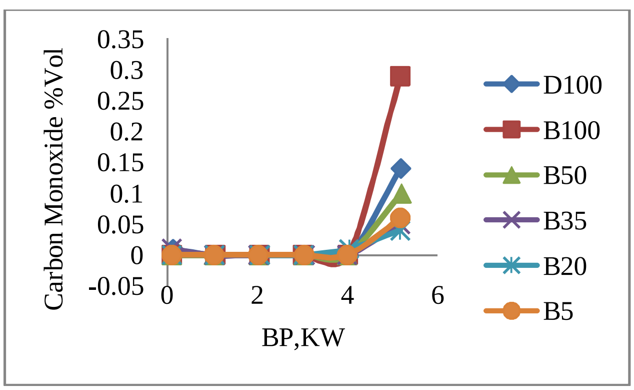

Fig .7.5: Carbon Monoxide Emission

The variation of carbon monoxide emission with brake power for diesel,pure biodiesel and blends of ethanol –mahua biodiesel and diesel in test engine are show in Fig 7.5 The CO emission depends upon the strength of the mixture ,availability of oxygen and viscosity of fuel .CO emission of pure biodiesel is higher than that of diesel and all blends, the blend B20E5D75 has lower CO emission that of diesel and all blend .The maximum CO emission occurs at full load .maximum CO of pure biodiesel 0.29 % vol against 0.13% vol for that of diesel on normal engine. B20E5D75 blends give lower emission with respect to other blends.

3. Variation Of Nox With Brake Power.

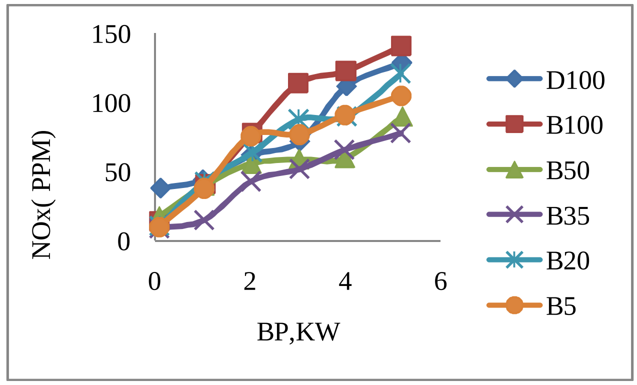

Fig.7.6: Oxides Of Nitrogen Emission

NO formation in a compression ignition engine depends on the oxygen availability and combustion temperature .The variation of nitrogen oxides emission with brake power output for diesel, neat biodiesel and blends of ethanol –mahua bio diesel and diesel in the test engine are show in fig 7.6 The NOx emissions occurs at full load. Maximum NO x of pure bio diesel is 204 ppm against 130 ppm for that of diesel on normal engine by increasing the % of ethanol in bio diesel it decreases the NOx .The blend B35E5D60 gives Lower emission compared to other blends at maximum load.

4. Variation Of Smoke With Brake Power.

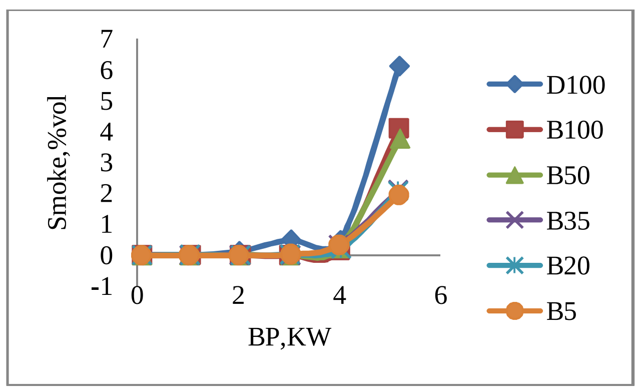

Fig.7.7: Smoke Emissions

Smoke density is dependent on presence of oxygen in the fuel and the amount of air in the cylinder. It is evident that fuel composition affects the amount of smoke produced by engine.The variation of exhaust smoke with brake power for diesel, pure biodiesel and blends of methanol –mahua biodiesel and diesel in the test engine are show in Fig 7.7 it can be clear found up to certain load all blend and pure diesel and bio oil having same smoke that exhaust smoke of pure diesel and pure biodiesel is higher than that of all blend of biodiesels .The Maximum smoke emission occurs at full load Maximum smoke of diesel 6.12% against 4.12% for that of pure biodiesel on normal engine .by increasing % of bio diesel in blend gives increasing the smoke at full load condition. The ethanol in B5E5D90 blends give better emission compared to other blends and pure diesel.

C. COMBUSTION CHARACTERISTICS OF SINGLE CYLINDER DIESEL ENGINE.

1. 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, pure biodiesel and different blends of ethanol –mahua biodiesel and diesel are show Fig 7.8 peak pressure of Neat mahua biodiesel and blends ethanol is higher than diesel. Maximum pressure of pure bio diesel is 69.38 bar against 65.86 bar for that biodiesel diesel. On typical motor. By expanding level of ethanol in biodiesel it decreases the pressures.

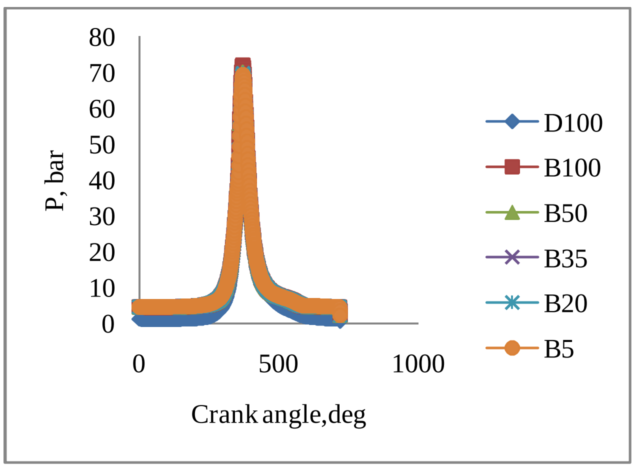

Fig 7.8: Variation Of Pressure With Crank Angle

2. Variation Of Cumulative Heat Release With Crank Angle.

The variation of cumulative heat release rate with crank angle is show in fig 7.9 The neat mahua biodiesel and blends ethanol and diesel similar to diesel .The two main phase 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 characteristic ,the fuel burn characteristic are obtained . Maximum net heat release rate of is B5E5D90 blends 2.26 kj against 2.12 kj for that of diesel on normal.

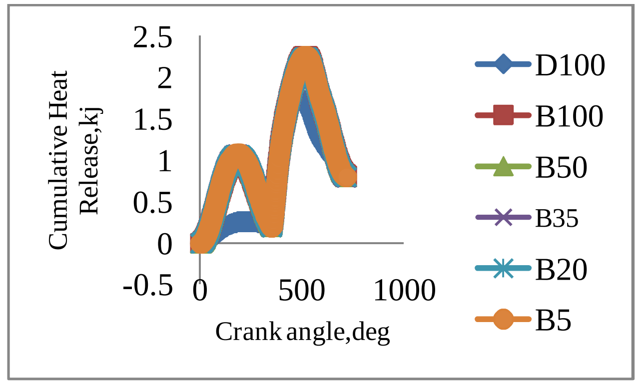

Fig 7.9 : Variation Of Cumulative Heat Release Rate With Crank Angle

3. Variation Of Net Heat Release With Crank Angle.

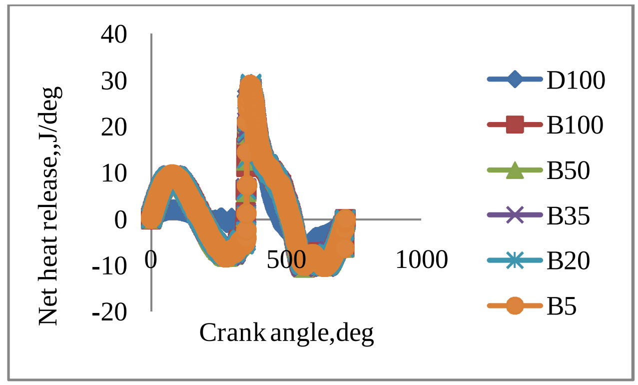

Fig 7.10 :Variation Of Net Heat Release Rate With Crank Angle

The variation of cylinder net heat release rate with respect to crank angle for diesel, pure biodiesel and different blends of ethanol –mahua biodiesel and diesel are show in Fig.7.10The net heat release rate for all the tested fuel is more than that of diesel .Maximum net heat release rate of biodiesel is 28.85 j/deg against 26.02 j/deg for that of diesel on normal engine. By increasing % of ethanol in biodiesel and it decreases the heat release rate .The B5E5D90 gives a 30.11 j/deg highest peak net heat release.

4. Net Mass Fraction Burned With Crank Angle.

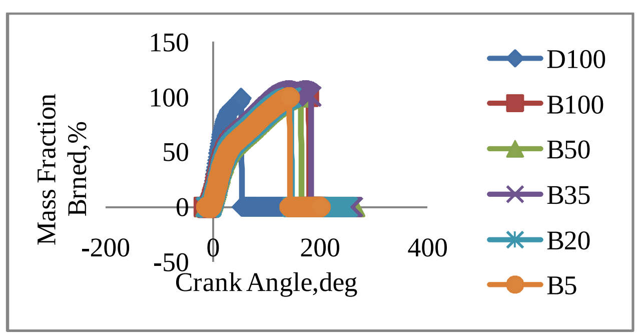

Fig 7.11: Variation Of Net Mass Fraction Burned With Crank Angle

Fig7.11 shows that the variation of mass fraction burned with different crank angles. it is observed from the above graph that for all blends at zero crank angle the value of mass fraction burned is zero, but whereas for D100 it is in negative from certain value i,e -9deg . And there is a gradual increase of MFB for B35 up to the maximum value of 100.97 % at 36deg. And for B100 (105.79 at 37deg), B20(101.86% at 38deg), B5(100.77% at 38deg), B50(104.04% at 36deg), D100 (101.33% at 36deg). Since from this observation we conclude that B35.

VIII. CONCLUSIONS

From the present experimental investigation, following conclusions were derived,

- Biodiesel is prepared and their characteristic has been made density, viscosity, flash point and fire point are higher and calorific value is lower than that of diesel.
- There diesel is increase in brake thermal efficiency as compared to biodiesel. Because of complete combustion. The B5%blend is well as compared to diesel.
- There biodiesel is increase in specific fuel consumption as compared to diesel. The 20% blend is well as compared to diesel.
- Exhaust gas temperature of pure biodiesel and all the blends is higher as compared to diesel because of oxygen content which enables the combustion process and hence the exhaust gas temperature is higher in B35% (564 ^{0}C)
- It was observed that the CO emissions for the B35% blends of mahua oil are less as compared to pure diesel and all biodiesel blends.
- It was observed that NO_x emission in pure diesel is higher than that of all blend of biodiesels. In B35%blend having less emission of $NO_{x.}$
- It was observed that the HC emissions for the blend of B35% biodiesel are less as compared to pure biodiesel. And all biodiesel blends and pure biodiesel are less unburned hydrocarbons compared to diesel.
- The maximum peak pressure is found for biodiesel as compared to diesel. From the test it is observed that the peak pressure variations are less.
- The biodiesel shows higher heat release rate during premixed burning phase compared to diesel.
- In this project experimental investigations were conducted on a Kirloskar make single cylinder water cooled naturally aspirated 5.2 kW at 1500 rpm. B35% biodiesel and can be used alternate fuel to the diesel
- Then the ethanol in the B35% biodiesel gives an optimum performance.

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