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Experimental Investigation On Performance And Emission Characteristics of Ci Engine Fuelled with Diesel And Mahua Biodiesel Using Additives

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Abstract: The increase in industrialization and motorization of world had led to a rise for the demand of using petroleum based fuels. The reserves of these petroleum based fuels are limited. Most of the countries depend on these petroleum based fuels. These fuels are widely used in industries like agriculture and automobile industries which consume a major part of these resource which leads in the rapid decrease of these limited resources. There is a necessity to look for alternative fuels that can be produced easily and can be used as alternative for petroleum based fuels.

Biodiesel can be a best alternative to replace the limited resources as biodiesel is a renewable fuel that is produced from non-edible vegetable oils and animal fat. Biodiesel is a non toxic renewable source that contributes small amount of net green house gases such as nitrous oxide (NOx), carbon dioxide (CO_2) emissions to the atmosphere.

The main objective of the present study is to experiment with alternative fuel to replace petroleum fuels using Non-edible Bio-fuels in CI engines.

The series of tests are to be conducted using Mahua Biodiesel with additive Di-Ethyl Ether along with diesel in Four Stroke Single Cylinder Direct Injection Diesel Engine. In each test Volumetric Efficiency, Brake Specific Fuel Consumption, Brake Thermal Efficiency, Indicated Brake Thermal Efficiency, Mechanical Efficiency and Exhaust Regulated Gas Emissions such as Nitrogen Oxides (NO_X), Carbon Monoxide (CO), Carbon Dioxide (CO_2) and total unburned Hydro Carbons (HC) are to be measured. The Performance Characteristics are to be compared for the blends of Mahua Biodiesel with 100% Diesel. Emissions from the engine for Bio-diesels are to be compared.

1. INTRODUCTION

A Bio-fuel is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological process such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matter. Bio-fuels can be derived directly from plants, or indirectly from agricultural, commercial, domestic, and/or industrial wastes. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates such as, Carbon Monoxide and Hydrocarbons from Diesel-powered vehicles. Biodiesel is produced from oils or fats using Transesterification and is the most common Bio-fuel in Europe.

In Bio-fuels there are two types of oils

- Edible oils
- Non-edible oils

Edible oils are most often plant-based oils, which are similar, if not the same as those produced by the industrial biotech industry for use as Bio-fuel such as Biodiesel, for use in cosmetics, and in other everyday biotech products. Edible oils may be solid or liquid at room temperature. Most Commonly Used Edible Oils are Coconut oil, Corn oil, Cottonseed oil, Olive oil, Palm oil, Peanut oil, Rapeseed/canola oil, Safflower oil, Sesame oil, Soybean oil, Sunflower oil.

Non-edible oils It is also known as the Mono-alkyl Esters of long chain fatty acids derived from vegetable oils or animal fats and alcohol with or without a catalyst.., therefore, Non-edible vegetable oils or the second generation feed stocks have become more attractive for biodiesel production. Some of those Non-edible Biofuels are Jatropha oil, Jojoba oil, Nahor oil, lamp oil, Paradise oil, Petroleum nut oil, Pongamia oil, Madhuca indica, Jatropha curcas, Tamanu oil and Pongamia pinnatatamanu oils.

2. LITERATURE REVIEW

Due to excess use of the petroleum based fuels for industry and automobile application in present time, the world is facing severe problems like global energy crisis, environmental pollution and global warming. Therefore global consciousness had started to grow to prevent the fuel crisis by developing alternative fuel sources for engine application. Many research programs are going on to replace diesel fuel with a suitable alternative fuel like biodiesel.

An attempt has been made by Sudheer Nandi [1] to find out the suitability of Transesterified Mahua oil as a fuel in C.I. Engine. Experimental work was carried out on 7B.H.P single cylinder four stroke and vertical, water cooled Kirloskar Diesel Engine at rated speed of 1500rpm different blends of Transesterified Mahua oil with diesel were tested at 200bar Injection Pressure. 800-850ml of Esterified Mahua Oil is extracted from 1000ml of Mahua Oil during Esterification. Percentage increase in Esterified Mahua Oil increases the viscosity of Diesel. Increase in percentage of Mahua Oil increases the Cetane Number of the Blend. Smooth running of engine is observed with Esterified Mahua Oil compared with that of diesel. Slight increase in Brake Thermal Efficiency and decrease in Specific Fuel Consumption is observed in the case of Esterified Mahua oil compared to that of Diesel.

Swarup Kumar Nayak [2] suggested an investigation about the neat Mahua oil that is used in Single Cylinder Water Cooled Diesel Engine at various load conditions to evaluate the Performance and Emission Parameters of the Engine. The results of investigation show increase in Rake Power and Brake Thermal Efficiency with load for all Prepared Test Fuels. It is also noticed that Brake Thermal Efficiency increases with the percentage of additive in all the Test Fuels. The Brake Specific Fuel Consumption decreases with increase in Additive Percentage. Exhaust gas temperature increases almost linearly with load for all Test Fuels and decreases with increase in Additive Percentage. It is also seen from the results that both CO and HC Emissions tend to decrease with increase in Additive Percentage in Biodiesel. The smoke and NOx Emissions also decrease with increase in Additive Percentage in the Biodiesel Fuel.

In this test Harisankar Bendu [3] suggested the production, characterization and possible utilization of a Bio-oil obtained from Mahua Oil Seed, which is potentially available in India. The Combustion, Performance, and Emission Behavior of the Diesel Engine operated with the different MPO-Diesel Blends were assessed and compared with those of Diesel operation at different loads. The results indicated that the Engine Thermal Efficiency was dropped by about 2% for MPO-Diesel Operation from no load to Full load Operation in comparison to Diesel. As the MPO-Diesel Blend Ratio increases, the NO Emission decreases from 4.5 to 2.8%, and the Smoke Emission increased from 10 to 75% from no load to Full load respectively. From the obtained results, it is suggested that the 30% MPO Blend can be considered as a Potential Candidate to be used as a Fuel in Compression Ignition Engines.

In this Investigation N. Kapilan [4] suggested Mahua Oil Biodiesel (MOB) and its Blend with Diesel as they were used as fuel in a Single Cylinder, Direct Injection and Compression Ignition Engine. The Mahua Oil Biodiesel was prepared from Mahua Oil by Transesterification using Methanol and Potassium Hydroxide. The fuel properties of MOB are close to the Diesel and confirm to the ASTM standards. From the Engine Test Analysis, it was observed that the MOB, B5 and B20 Blend results in lower CO, HC and Smoke Emissions as compared to Diesel. But the B5 and B20 Blends results in Higher Efficiency as compared to MOB. Hence MOB or Blends of MOB and Diesel (B5 or B20) can be used as a substitute for diesel in Diesel Engines used in Transportation as well as in the Agriculture Sector.

S. Santhana krishnan [5] conducted an Experiment on the Performance and Emission Characteristics of a Mahua Oil Biodiesel that was evaluated on a Kirloskar make, Single Cylinder, Water Cooled Diesel Engine. The Brake Thermal Efficiency, Exhaust Gas Temperature, Specific Energy Consumption, Carbon Monoxide, Unburned Hydro Carbon and Smoke Emissions of the Mahua Oil Biodiesel were measured at various loads and compared with Diesel. The use of Biodiesel instead of diesel leads to an increase in the Specific Fuel Consumption and decrease in Brake Thermal Efficiency, mainly due to the lower heating value compared with Diesel. The Carbon Monoxide, Unburned Hydrocarbon and Smoke Emissions reduced significantly with Biodiesel as Fuel.

3. SELECTION OF BIOFUEL

In the present work non-edible oil namely Mahua oil is chosen for for experimentation on variable compression ratio research engine. Mahua Oil is an under-utilized non-edible vegetable oil, which is available in large quantities in India. The fuel properties of the Mahua Oil biodiesel were found to be within the limits of biodiesel specifications of many countries.

Two species of the genus madhuca indica and madhuca longifolia are found in India. The seeds of the tree are popularly known as Indian butter tree. The specific gravity of mahua oil was 9.11% higher than that of diesel. The Kinematic Viscosity of mahua oil was 15.23 times more than that of diesel at temperature of 40°C. The kinematic viscosity of mahua oil reduced considerably with increase in temperature to 80°C and by increasing the proportion of diesel in fuel blends. Fig.3.1 shows Mahua oil.

Fig.3.1 Mahua Oil

Transesterification is the process of using an alcohol (Methanol, Ethanol, Propanol, or Butanol) in the presence of catalyst to chemically break the molecule of the raw renewable oil into methyl or ethyl esters of the renewable oils with glycerol as by-product.

From the literature review many researchers conducted experiments on Mahua oil. They used various blends of Mahua oil by adding some additives and diesel on CI engine. They got satisfactory result after the experiment.

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In the current study Mahua is blended with Diesel and additive the various blends composition is shown in table 3.1

Table.3.1 Blends and its Percentages

S.NO	Mahua Oil	Di-Ethyl Ether	Diesel
01	20%	20%	60%
02	30%	20%	50%

The properties of blends used are shown in table 3.2

Table.3.2 Properties of Mahua Oil

S. no	Parameters	Units	Diesel 100%	M-20%, DEE 20%, D-60%	M-30%, DEE 20%, D-50%
1	Kinematic viscosity @40˚C	cSt	2.98	2.79	3.42
2	Gross calorific value	K cal/kg	10,666	8730	8420
3	Density @30˚C	g/cc	0.845	0.8184	0.8240
4	cetane index	----	52	51	54

4. EXPERIMENTAL SETUP

VARIABLE COMPRESSION RATIO RESEARCH ENGINE

The setup consists of Single Cylinder Four Stroke VCR (Variable Compression Ratio) Research engine connected to an Eddy Current Dynamometer. It is provided with necessary instruments for Combustion Pressure, Crank-Angle, Air Flow, Fuel Flow, Temperatures and Load Measurements. These signals are interfaced to computer through high speed data acquisition device. The set up has stand-alone panel box consisting of Air Box, Twin Fuel Tank, Manometer, Fuel Measuring Unit, transmitter for Air and Fuel Flow measurements, Process Indicator and Piezo Powering Unit. Rotameter are provided for cooling water and Calorimeter Water Flow measurement. In Petrol Mode Engine works with programmable Open ECU, Throttle position sensor (TPS), Fuel Pump, Ignition Coil, Fuel Spray Nozzle, Trigger Sensor etc. The setup enables study of VCR Engine Performance for both Diesel and Petrol mode and study of ECU programming. Engine Performance study includes Brake Power, Indicated Power, Frictional Power, BMEP, IMEP, Brake Thermal Efficiency, Indicated Thermal Efficiency, Mechanical Efficiency, Volumetric Efficiency, Specific Fuel Consumption, Air Fuel Ratio, Heat Balance and Combustion Analysis. Fig.4.1 shows the computerized Variable Compression Ratio Research engine.

Fig.4.1 Variable Compression Ratio Research Engine Test Rig

SOFTWARE

EngineSoft is Lab view based software package developed by Apex Innovations Pvt. Ltd. for Engine Performance Monitoring System. Engine Soft can serve most of the engine testing application needs including monitoring, reporting, data entry, data logging. The software evaluates Power, Efficiencies, Fuel Consumption and Heat Release. Various graphs are obtained at different operating condition. While on line testing of the engine in RUN mode necessary signals are scanned, stored and presented in graph. Stored data file is accessed to view the data graphical and tabular formats. The data in excel format can be used for further analysis. Fig.4.2 is the screen shot of IC Engines Software.

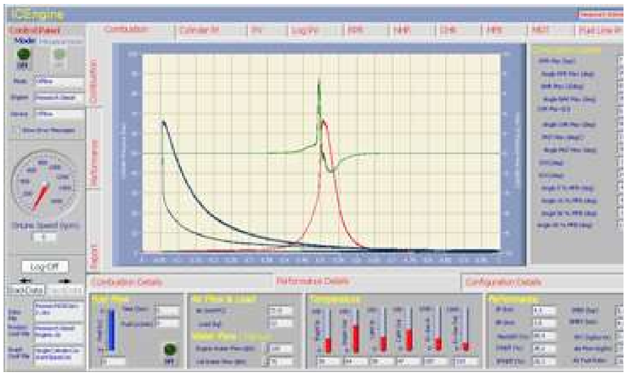

Fig.4.2 Screen Shot of the Software

ENGINE DIESEL MODE

Single Cylinder Four Stroke water cooled Kirloskar Engine modified to VCR Diesel and VCR Petrol. The Compression Ratio can be changed without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. Fig.4.3 describes the Engine Diesel Mode.

Fig.4.3 Engine Diesel Mode

INSTRUMENTATION

Product is supplied with best quality instruments. The Eddy Current Dynamometer is SAJ, Pune make. The components like Open ECU (PE USA), Combustion pressure sensor (PCB Piezotronics, USA), Crank Angle sensor (Kubler, Germany), Fuel flow transmitter(Yokogawa, Japan), Pressure transmitter (Wika, Germany), High speed data acquisition device (National instruments, USA) are of MNC grades.

5. PROCEDURE

The experiment was performed initially with the diesel and then with two different blends of Mahua oil (B20 and B30).The steps used are described as below:

- Initially the diesel was filled in a fuel tank.

- Compression Ratio of 16:1 was adjusted.
- After setting the water supply, the cooling water and calorimeter flow was set up at 250 LPH and 150 LPH respectively.
- All the electrical connections were checked properly and then the electric supply was started.
- The Engine Performance analysis software package "Engine soft" for on screen performance analysis was opened.
- Then the valve provided at the Burette was opened to supply the diesel to the engine.
- Then engine was started and ran for few minutes at no load conditions.
- The log option of the software was selected after that fuel supply was turned on. After one minute the display was changed to input mode and then value of flow of water in cooling jacket and calorimeter was entered. The first reading for the engine was noted for no load condition. Then the fuel knob was turned back to regular position.
- The same steps were repeated for different loads.
- All the readings were saved and then same procedure was done.
- After noting all the readings engine was brought to no load conditions and after that engine and computer was turned off to stop the experiment. The fuel supply was also stopped after some time.

6 RESULTS

Description

From the Experimental setup (Variable Compression Ratio Engine) the engine test had been carried out with compression ratio of 16:1 for various Loads with different blends of Bio-fuels. Hence to obtain the Performance Parameters such as Brake Specific Fuel Consumption (BSFC), Brake Thermal Efficiency (BTE), Volumetric Efficiency (VE), Mechanical Efficiency (ME) and Indicated Brake Thermal Efficiency (IBTE) along with

Emission Parameters such as Carbon Monoxide (CO), Carbon Dioxide (CO_2), Hydro Carbons (HC) and Nitrous Oxide (NO_x).

Brake specific fuel consumption (BSFC)

Mahua 20%, Di-ethyl Ether 20%, Diesel 60%; Mahua 30%, Di-ethyl Ether 20%, Diesel 50% and Diesel 100%.

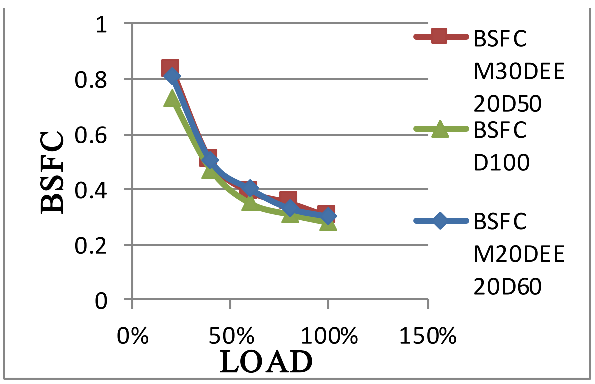

Fig.6.1 Brake Specific Fuel Consumption (BSFC) VS Load

In the Fig.6.1 it is shown that the variation in BSFC for Diesel, M30DEE20D50 and M20DEE20D60. It is observed that BSFC first decreases for all the test fuels with increase in load. It is seen that BSFC is highest for pure biodiesel and lowest for diesel because of high viscosity, density, low volatility and low heat content of pure biodiesel when compared with that of diesel. However, increase in the additive percentage in biodiesel, BSFC decreases with respect to load and shows close results to that of diesel.

Brake Thermal Efficiency (BTE)

Mahua 20%, Di-ethyl Ether 20%, Diesel 60%; Mahua 30%, Di-ethyl Ether 20%, Diesel 50% and Diesel 100%.

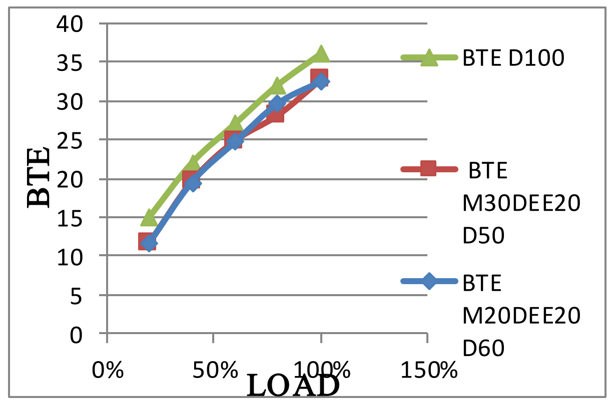

Fig.6.2 Brake Thermal Efficiency (BTE) VS Load

Fig.6.2 shows variation in Brake Thermal Efficiency (BTE) in case of Diesel, M30DEE20D50 and M20DEE20D60. It is observed that the Brake Thermal Efficiency first increases with increase in load. It is observed that diesel has highest Brake thermal efficiency than that of the other test fuels which is because of the higher heat content, lower viscosity, lower density and higher volatility in comparison to mahua diesel blend. However increase in blend

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Volume 04 Issue 01
January 2017

percentage of biodiesel with the diesel the Brake thermal efficiency increases with respect to load and shows a very close behaviour to that of diesel.

Volumetric efficiency (VE)

Mahua 20%, Di-ethyl Ether 20%, Diesel 60%; Mahua 30%, Di-ethyl Ether 20%, Diesel 50% and Diesel 100%

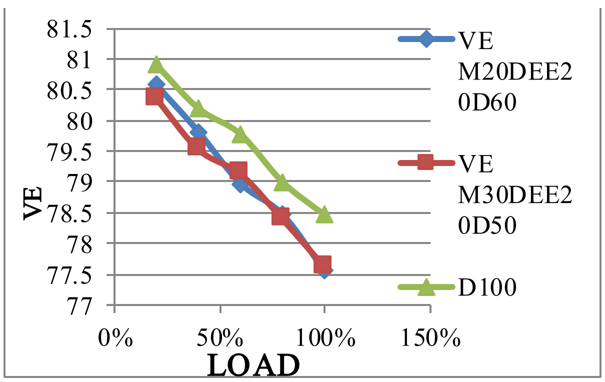

Fig.6.3 Volumetric efficiency VS Load

Fig.6.3 shows the variation in Volumetric Efficiency in case of Diesel, M30DEE20D50 and M20DEE20D60. It is observed that the Volumetric Efficiency decreases with increase in load. From the graph it is observed that Diesel has highest Volumetric Efficiency than that of the other test fuels which is because of the higher heat content, lower viscosity, lower density and higher volatility in comparison to mahua diesel blend. However increase in blend percentage of biodiesel with the diesel the Volumetric Efficiency increases and decreases with respect to load and shows a very close behavior to that of Diesel.

Mechanical efficiency (ME)

Mahua 20%, Di-ethyl Ether 20%, Diesel 60%; Mahua 30%, Di-ethyl Ether 20%, Diesel 50% and Diesel 100%

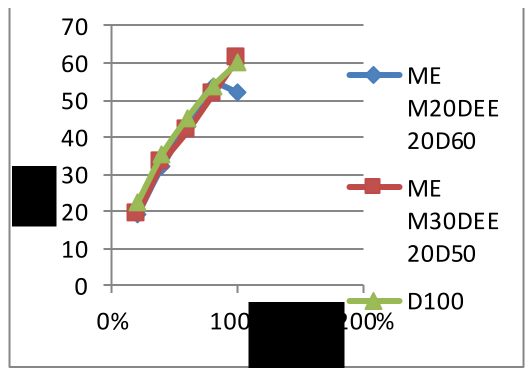

Fig.6.4 Mechanical efficiency VS Load

Fig.6.4 shows the variation in Mechanical Efficiency in case of Diesel, M30DEE20D50 and M20DEE20D60. It is observed that the Mechanical Efficiency is increasing with increase in load. It is observed that Diesel has lower Mechanical Efficiency than that of the other test fuels. Mechanical efficiency of Diesel is higher and the blend of M20DEE20D60 is low as the blend percentage is increased to M30DEE20D50 the mechanical efficiency is

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Volume 04 Issue 01
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also increasing which is because of the higher heat content, lower viscosity and lower density in comparison to mahua diesel blend. However increase in blend percentage of biodiesel with the diesel the Mechanical Efficiency increases with respect to load and shows a very close behavior to that of Diesel.

Indicated Brake Thermal efficiency (IBTE)

Mahua 20%, Di-ethyl ether 20%, diesel 60%; Mahua 30%, Di-ethyl ether 20%, diesel 50% and diesel 100%.

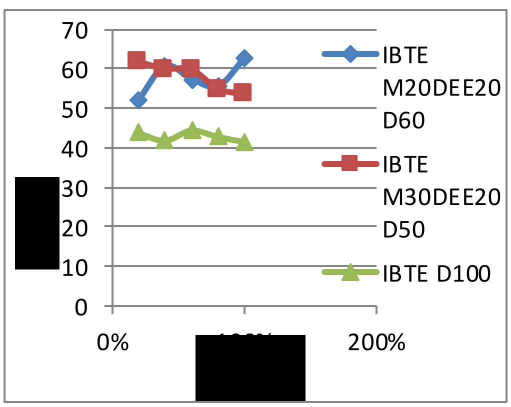

Fig.6.5 Indicated Brake Thermal efficiency VS Load

Fig.6.5 shows the variation in Indicated Brake Thermal Efficiency in case of Diesel, M30DEE20D50 and M20DEE20D60. It is observed that the Indicated Brake Thermal Efficiency is varying with respect to load. It is observed that Diesel has lower Indicated Brake Thermal Efficiency than that of the other test fuels which is because of the higher heat content, lower viscosity and lower density in comparison to mahua diesel blend. However increase in blend percentage of biodiesel with the diesel the Indicated Brake Thermal Efficiency is decreasing with respect to load.

Carbon monoxide (CO)

Mahua 20%, Di-ethyl ether 20%, diesel 60%; Mahua 30%, Di-ethyl ether 20%, diesel 50% and diesel 100%.

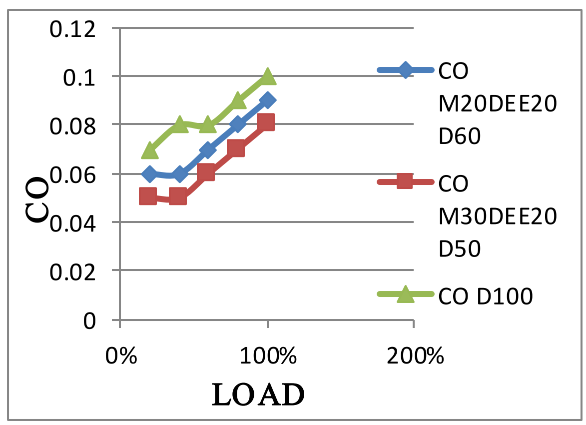

Fig.6.6 Carbon monoxide (CO) VS Load

From the Fig.6.6 results shows the variation in CO emission with respect to variation in load for the blends Diesel, M30DEE20D50 and M20DEE20D60. It is observed that CO emission initially decreases at lower loads and then increases

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Volume 04 Issue 01
January 2017

sharply for all the prepared test fuels. CO emission is highest for pure Diesel because of spray characterization that results in proper combustion which gives rise to CO formation. However, with increase in additive percentage CO decreases for all the prepared test fuels because of good spray characterization, good air-fuel ratio and proper combustion.

Carbon dioxide (CO_2)

Mahua 20%, Di-ethyl ether 20%, diesel 60%; Mahua 30%, Di-ethyl ether 20%, diesel 50% and diesel 100%.

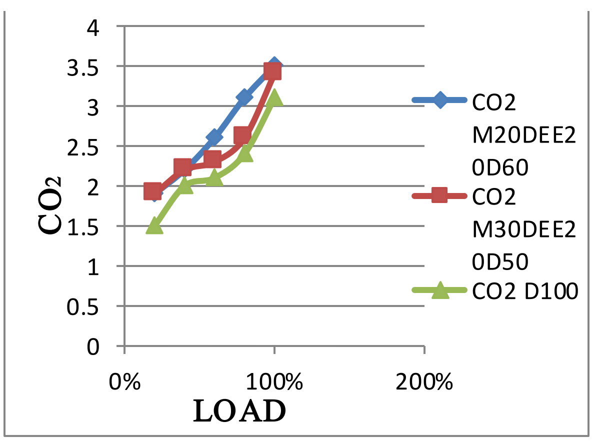

Fig.6.7 Carbon dioxide (CO2) VS Load

From the Fig.6.7 results shows the variation in CO_2 emission with respect to variation in load for the blends Diesel, M30DEE20D50 and M20DEE20D60. The present test results show that CO_2 emission increases almost linearly with increase in engine load. CO_2 is high for biodiesel blends because of low oxygen content which results in incomplete combustion causing low combustion temperature. CO_2 of diesel is low when compared to the blend of biodiesel. Results also reveal that CO_2 decreases with increase in percentage of additive.

Hydro carbons (HC)

Mahua 20%, Di-ethyl ether 20%, diesel 60%; Mahua 30%, Di-ethyl ether 20%, diesel 50% and diesel 100%.

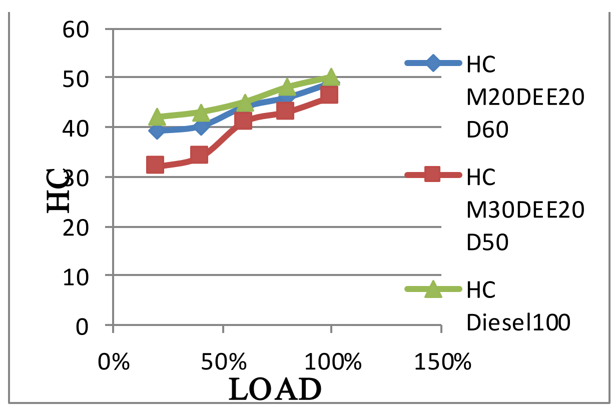

Fig.6.8 Hydro Carbons (HC) VS Load

From the Fig.6.8 it is shown that the variation in HC emission at different load conditions for Diesel, M30DEE20D50 and M20DEE20D60 with varying additive percentages. It is seen that un-burnt hydrocarbon emission increases with that of load for all prepared test fuels. It is understood that biodiesel produces Low HC emission in comparison to that of diesel because of combustion of the test fuel and its blend with additive.

Nitrous oxide (NOx)

Mahua 20%, Di-ethyl ether 20%, diesel 60%; Mahua 30%, Di-ethyl ether 20%, diesel 50% and diesel 100%.

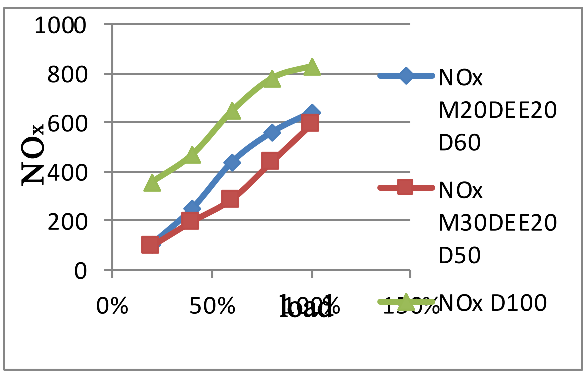

Fig.6.9 Nitrous oxide (NOx) VS Load

From the Fig.6.9 variation in NOx Emission with load for Diesel, M30DEE20D50 and M20DEE20D60 is shown. From the literature it is revealed that NOx is directly proportional to power output of the engine because NOx emission increases with increase in combustion and exhaust temperature. The present test results show that NOx emission increases almost linearly with increase in engine load which is because of higher cylinder pressure and temperature when the loads are increased. NOx is low for biodiesel blends because of high oxygen content which results in complete combustion causing high combustion temperature. Results also reveal that NOx decreases with higher additive percentage because of reduction in engine in-cylinder temperature because of smooth combustion, causing reduction in EGT (Exhaust gas temperature).

7. CONCLUSIONS

Based on the results of this study, the following specific conclusions were drawn:

- The fuel properties of Mahua Bio-diesel were within limits except calorific value; all other fuel properties of Mahua Bio-diesel were found to be higher as compared to Diesel.
- The Brake Specific Fuel Consumption increased and Brake Thermal Efficiency decreased with increase in the proportion of Biodiesel in the blends. A reverse trend was observed with increase in engine load.

- The Volumetric Efficiency is increased with increase in the percentage of Bio-diesel blend.
- Mechanical Efficiency of Biodiesel is increasing with increase in percentage of blend and Mechanical Efficiency for diesel is less when compared to Mahua oil blends.
- Indicated Brake Thermal Efficiency is high when compared to Diesel. Indicated Brake Thermal Efficiency is varying with respect to load.
- The amount of CO, NOx, CO_2 and HC in exhaust emission reduced with increase in percentage of Mahua Bio-diesel in the blends. However, the level of emissions increased with increase in engine loads for all fuels tested. The Emission Parameters for different blends were better compared with Diesel.
- Some Physical and Chemical properties of the blend such as Ignition quality, Boiling point , O_2 content and Distillation profiles were improved by addition of Diethyl ether
- The heating value, density and viscosity of blends reduced with addition of Di-ethyl Ether.
- The addition of Di-ethyl Ether with blend reduces the Exhaust Emission well and improves Performance and Reduce NOx emissions.

Hence it is concluded that Mahua Biodiesel could be safely blended with Diesel up to 30% without significantly affecting the engine performance (Brake Specific Fuel Consumption (BSFC), Brake Thermal Efficiency (BTE), Volumetric Efficiency (VE), Mechanical Efficiency and Indicated Brake Thermal Efficiency) and Emissions (HC, CO, NOx, CO_2) and thus could be used as a suitable alternative fuel for diesel engines.

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