Performance and Emission Characteristic Analysis of Honge and Mahua Biodiesel blend using CI Engine

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Abstract - *In this work, Pongamia oil and Mahua oil, a non-edible type is used in this investigation for studying its suitability for use in diesel engine. This work deals with the results of investigations carried out in studying the fuel properties of Honge oil, Mahua oil, methyl ester of these oils and its blends with diesel fuel from 10 to 50% by volume and in running a single cylinder four-stroke diesel engine with these fuels at different injection pressures. Various properties of these fuels are evaluated using ASTM standards and compared in relation to that of conventional diesel fuel. Engine tests have been carried out with the aim of obtaining comparative measures of Brake power, specific fuel consumption, brake thermal efficiency and compute the behavior of the diesel engine running on above-mentioned fuels.*

***Key Words*: Brake Thermal Efficiency, Compression Ignition, Brake Specific Fuel Consumption, Honge Methyl Ester, Calorific Value, Top Dead Centre.**

1. INTRODUCTION

Fast depletion of fossil fuels is demanding an urgent to carry out research work to find viable alternative fuels. Thermodynamic tests based on engine performance evaluations have established the feasibility of using a variety of alternative fuels such as CNG, Biogas, Alcohols, and Vegetable oils etc. To cut foreign exchequer and contribute towards protection of earth from the threat of environmental degradation, biofuels can be a good alternative for diesel for most of the developing countries. Vegetable oils have considerable potential to be considered as appropriate alternative as they possesses fuel properties similar to that of diesel. Review of the literature revealed that with the use of vegetable oils as fuels in diesel engines, harmful exhaust emissions, particularly HC, smoke and CO are considerably reduced as compared to diesel. Research on vegetable oils as diesel was conducted at least 60 years ago, but interest lagged because of cheap and plentiful supplies of petroleum fuel.

2. LITERATURE REVIEW

Suryawanshi. J.G. et al. [31] studied experimentally the use of Biodiesel made from safflower oil and maize oil by conducting experiments on an AVI type DI diesel engine. Apart from establishing the fact of suiting Biodiesel for unmodified engine they also used blends made from pure ester and diesel. They also studied engine performance at different fuel injection pressures. They were of the opinion that higher injection pressures lead to better performance. They selected two injection pressures only. They observed that substantial decrease in exhaust smoke density and NOx levels compared to base line experiments with diesel fuels.

Samoa B.S. [6] investigated the use of refined sunflower oil and unrefined groundnut oil as fuels in an AVI single cylinder water-cooled DI diesel engine. He did the experiments by varying the oil inlet temperature (Preheating), injection timing and fuel injection pressure to optimize these parameters. In order to optimize the parameters he concentrated only at 80% of rated load. Selection of parameters was as follows.

Fuel Injection Pressure: 160, 180 and 210 bar

Fuel Injection Timing: 24º, 29º and 34º BTDC

Oil Preheating Temperature: 34º C, 55º C and 65º C

He observed that performance of the engine with test fuels to be comparable with diesel fuel operation without any combustion knock and objectionable smoke at the following conditions: 160 bar, 65º C and 29º BTDC.

Nagaraja.A.M et al. [12] investigated the effect of injection pressure and combustion timing on engine performance with Ricebran oil as Biodiesel. They were chosen transesterification process to convert the vegetable oil in to Ricebran oil ethyl ester (biodiesel). They reported that, it could be burnt in any standard unmodified diesel engine blended with 20% to 30% Biodiesel with conventional diesel fuel.

Bhanodaya Reddy.G et al. [7] studied the use of non-edible oil (Pongamia oil) as an alternative to diesel fuel. They varied the fuel injection pressures from 140 to 220 bar on single cylinder air cooled vertical diesel engine of 6 hp at 1500 rpm. They adopted blends of 10, 20, 30, 40 and 50% Pongamia oil and diesel oil. They observed smooth running of the engine at 50% blend of Pongamia oil and also observed that the 20% blend of Pongamia oil with 80% diesel gave the better performance with lower emissions compared to all blends. They encountered no cold start problems and observed 200 bar as the optimum injection pressure for 20% Pongamia oil.

3. OBJECTIVE

It is seen from the literature survey that large progress has been made in the concept of vegetable oils used as alternative fuel for I C engines. However using of nonedible oils as substitute for diesel remains largely unexplored. In this research, two non-edible oils namely Honge and Mahua oil are used for investigation.

The following objectives were drawn up for this project work:

- To prepare the biodiesel from vegetable oils by Transesterification. Since chemically modifying the structure of vegetable oils by esterification reduces the viscosity.
- To study the comparison properties of two types of vegetable oils, methyl esters of these oils and its blends with diesel oil. For comparison, the same properties of the diesel oil were to be determined.
- To run a typical diesel engine on a two types of vegetable oil methyl esters in order to evaluate their performance in regard to BP, BTE, BSFC, EGT. For comparison, the same parameters were to be determined for engine operation with conventional diesel oil also.
- To blend vegetable oil methyl esters in different proportion with diesel 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.
- To run a diesel engine on a HME & blends at different Injector opening pressure since optimum IP gives the better performance.
- To compare the performance of different vegetable oil methyl esters (HME & MME) and its blends at optimum injection pressure. Thus optimum blend at optimum IP would gives the best performance.

4. PREPARATION OF BIODEISEL

4.1 TRANSESTERIFICATION OF VEGETABLE OIL

This section deals with steps involved in the preparation of Biodiesel from untreated Honge oil.

RICE HUSK TREATMENT FOR MAHUA OIL

The PH value of the Mahua oil is 20, which is very high so that it is difficult to convert to this raw oil in to ester. To reduce the PH value of the mahua oil, the concept of rice husk treatment is used. In this concept, first about 2 gm of rice husk is added to 100 ml Mahua oil and heated at about 65º C for 20 minutes. After 20 minutes the oil is filtered from bolting cloth. Repeat the same above procedure for 4-5 times. Then which is ready for further transesterification process. The PH value of the honge oil less i.e.6-7, so that it is easy to convert this oil in to ester.

SELECTION OF RAW MATERIALS

Moisture free oil sample: Every time 2 kgs of oil was taken in to the round bottom reactor. To make it moisture free, the oil sample was placed in the electrical furnace at about 110º C for one hour. Raising the oil temperature and cooling it back to room temperature has not varied the properties of oil.

Anhydrous methyl alcohol: 99% grade laboratory reagent type methyl alcohol was chosen.

Catalyst: Sodium hydroxide was selected for the purpose of catalyzing the reaction.

TRANSESTERIFICATION PROCEDURE

Widely used accepted and process to reduce the viscosity of Triglycerides is Transesterification. In the Transesterification of vegetable oils, Triglycerides reacts with an alcohol in the presence of a strong acid or base, producing a mixture of fatty acid alkyl esters and glycerol. The experimental set up for the transesterification process is shown in figure and the flow chart for this process is shown in figure. The chemical reaction involved in this process is shown below. Say R = C18 H36 O2 for honge oil and R = C17 H34 O2 for Mahua oil.

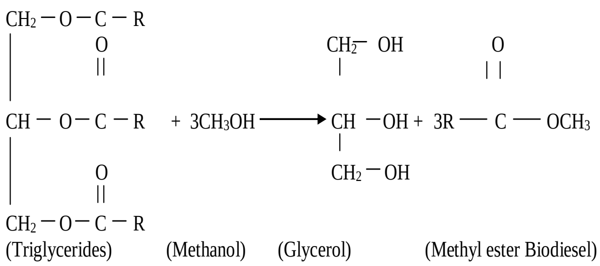

Fig-1: Transestirification Reaction

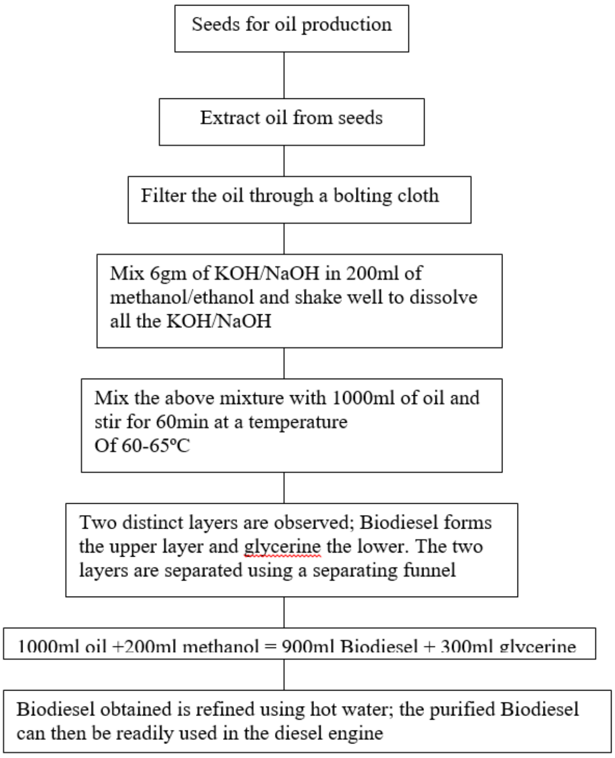

Fig-2: Flow Chart of Operation for Biodiesel production

Fig-3: Instrument used for the Transesterification process

5. EXPERIMENTAL TESTING AND INSTRUMENTATION

The existing 4-stroke single cylinder diesel engine of Kirloskar make was retrofitted with some of additional equipment and is interfaced with data acquisition system which in turn is interfaced with a personnel computer.

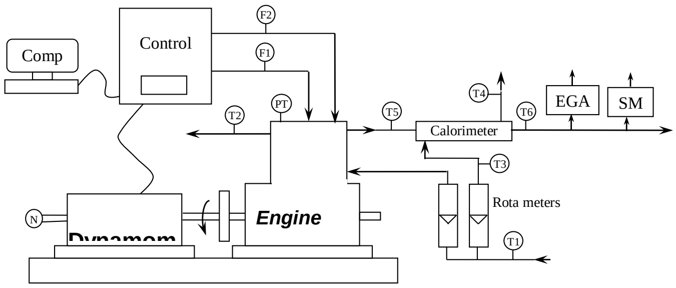

Fig-4: Experimental Setup

The engine tests were conducted on a computerized single cylinder four-stroke, naturally aspirated, open chamber (Direct Injection) and water-cooled diesel engine test Rig.

It was directly coupled to an eddy current dynamometer that permitted engine motoring either fully or partially. The engine and the dynamometer were interfaced to a control panel, which is connected to a digital computer. The computer software Engine Soft Version 2.4 supplied by the test rig supplier "Apex Innovations Pvt.Ltd " was used for recording the test parameters such as fuel flow rate, temperatures, air-flow rate, load etc and for calculating the engine performance characteristics such as brake thermal efficiency, brake specific fuel consumption, volumetric efficiency etc. The calorific value and the density of the particular fuel was fed to the software for calculating the above said performance parameters.

5.1 MEASUREMENT SYSTEM

1. Flow measurement

Airflow measurement is done by the conventional method U-tube manometer as well as by Air Intake DP unit present in the control panel.

2. Engine speed Measurement

Engine speed is sensed and indicated by an inductive pickup sensor in conjunction with a digital RPM indicator, which is a part of the Eddy current dynamometer controlling unit.

3. Load Measurement

The Eddy current dynamometer is provided to test the engine at different loading conditions. A strain gauge type load cell mounted beneath the dynamometer arm measures the load and signals are interfaced with ADC card to give load in kg.

4. Temperature Measurement

Temperature sensors of RADIX Pvt.Ltd. make are positioned at different locations to measure the following temperatures.

All sensors, which sense the temperatures of respective locations, are connected to the control panel, which gives the digital reading of the respective temperatures.

6. EXPERIMENTAL PROCEDURE AND OBSERVATIONS

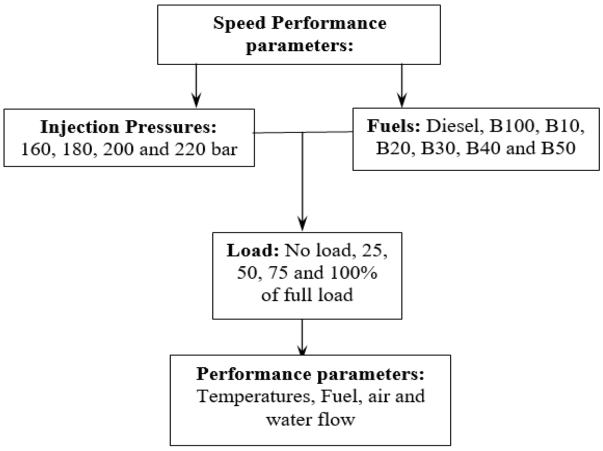

Fig-5: Experimental investigation scheme

6.1EXPERIMENTAL PROCEDURE

Switch on the mains of the control panel and set the supply voltage from servo stabilizer to 230V.The main gate valve was opened and pump is switched ON, water flow rate to engine cylinder jacket (350 its/hr), dynamometer. The injection pressure (IP) is set to 180bar.Engine is started by hand cranking and allowed to run for few minutes to reach steady state condition. The engine soft version 2.4 is run to go on ONLINE mode. The theoretical constants such as calorific value, density etc were entered. The engine was run at no load. For metering the fuel the log button in the software is clicked and at the same time the two-way knob in the control panel is turned to the measuring mode .Now the fuel is flowing from the burette to the engine and at the end of 1 minute, the fuel flow rate is recorded in the computer. Then the knob is turned to the tank mode so that fuel flows from the tank. The engine soft calculates the performance parameters such as brake power, BTE, BSFC, volumetric efficiency, BMEP .The results were stored. The engine is loaded through the rotation of a knob in the dynamometer-loading unit and the loading is displayed through the indicator in the control panel. Similar experiments are done at 1/4th, 1/2nd, 1/3rd and full load with same conditions. Experiments are conducted with neat bio-diesel and its blends. The experiments are repeated at IP of 180, 200 and 220 bar for all fuels tested.

6.2 Observation and Calculation

The specimen calculations for 100% of full load, with diesel at 27ºBTDC with injection pressure of 160bar is done below.

The following observations are done for the above conditions.

Speed N=1500RPM

Weight on dynamometer W=18.25 Kg

Fuel Consumption Rate F_1= 1.55 Kg/hr

Air Flow Rate F_3= 33.32Kg/hr

Calorific value of fuel C.V= 42,960 kJ/kg

1) Brake Power (BP):

$$BP = \frac{2\Pi NWgR}{60000} KW$$

Where, g = Acceleration due to gravity, 9.81 m/sec^2
R = Arm length of dynamometer in meters, 0.175 m

$$BP = \frac{2\Pi * 1500 * 18.25 * 9.81 * 0.175}{60000}$$

$$= \underline{4.92\ KW}$$

2) Brake specific fuel consumption (BSFC):

$$BSFC = \frac{FuelConsumptionRate}{BrakePower} \text{ Kg/kW-hr}$$

$$BSFC = \frac{1.55}{4.92} = 0.315 \underline{\text{ kg/kW-hr}}$$

3) Brake Thermal Efficiency (BTE):

$$BTE = \frac{BrakePower * 3600 * 100}{C.V * FuelConsumption}$$

$$= \frac{4.92 * 3600 * 100}{42960 * 1.55}$$

$$= 26.\underline{59\%}$$

4) Air fuel ratio

$$= \frac{AirFlowRate}{FuelConsumptionRate}$$

$$= \frac{33.32}{1.55}$$

$$= \underline{21.49}$$

7. RESULTS AND DISCUSSIONS

7.1 PERFORMANCE OF THE ENGINE WITH METHYL ESTER OF HONGE OIL AND ITS BLENDS AT OPTIMUM INJECTION PRESSURE (200 bar)

BRAKE THERMAL EFFICIENCY:

It is observed that the B10, B20, B30 and B40 fuels gave the higher efficiency than the diesel fuel at full load condition as well as at part load conditions and the efficiency for B50 and B100 fuels is slightly lower than the diesel. For B20 blend the maximum brake thermal efficiency is obtained as 29.15% at full load .It is observed that this efficiency is the highest one compared with diesel (27.23% at full load). This can be attributed to more area coverage of spray formed with B20 blend in the combustion chamber and utilizing the air effectively resulting in more effective combustion. The higher blends generate coarse spray due to increase in viscosity of the blend. This leads to decrease in area of spray formed, resulting in improper combustion.

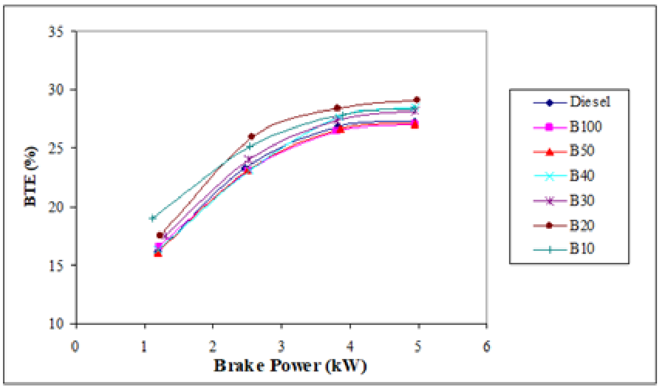

Chart-1: Variation of BTE with Load at IP 200 bar for HME & its blends

BRAKE SPECIFIC FUEL CONSUMPTION

The variation of BSFC with load of HME and its blends at 200 bar IP is shown in chart -2. The chart shows that the BSFC for B100 and B50 fuels is higher than diesel fuel, which was observed due to lower calorific value of biodiesel. The higher brake specific fuel consumption values in the case of vegetable oil esters and its blends can be attributed to the higher density and lower energy content. Higher the density more will be the discharge of fuel for the same displacement of the plunger of the fuel injection pump. It is observed that the BSFC for B10, B20 and B30 fuels was considerably lower than the diesel fuel at full load condition. In case of B20 the BSFC is obtained was the minimum and is lower than the all blends and diesel fuel. This is due to more area coverage of spray formed with B20 blend in the combustion chamber and utilizing the air effectively. In case of B20 the BSFC is obtained as 0.293 kg/kW-hr, which is lower than the all blends and diesel fuel (0.307 kg/kW-hr).

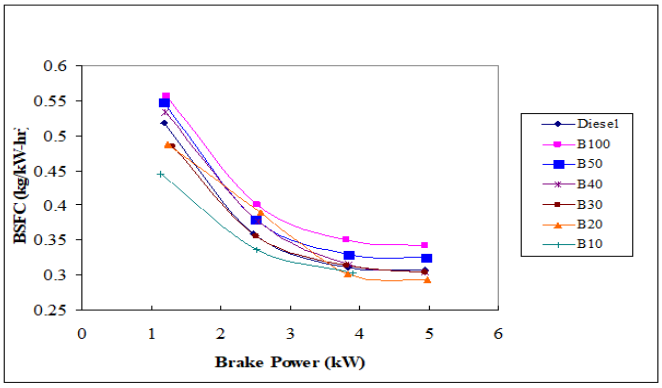

Chart-2: Variation of BSFC with Load at IP 200 bar for HME & its blends

EXHAUST GAS TEMPERATURE

It is observed that the EGT is increased with increase in load. The EGT for 100% HME and its blends except B20 is higher than the EGT of diesel fuel. This is because of more amount of fuel being consumed per hour for biodiesel. It is observed that there was no much variation in the EGT for blend fuels as compared to diesel. This could be due to nearly same quantity of fuel being consumed per hour for both diesel and blends. From the chart -3, it is found that the EGT is less for B20 fuel compared to all fuels tested. This reveals that effective combustion is taking place during the early part of expansion stroke and the saving in exhaust energy loss is reflected in minimising the energy consumption per unit power output.

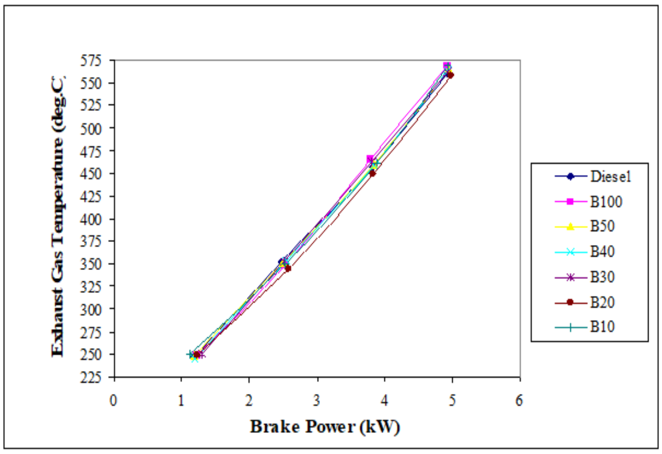

Chart-3: Variation of EGT with Load at IP 200 bar for HME & its blends

7.2 EFFECT OF INJECTION PRESSURE ON ENGINE PERFORMANCE WITH USING HME AND ITS BLENDS

The experiments were conducted at four different injection pressures for studying the effect of injection pressure on the performance of the diesel engine with using 100% HME, 20%HME and 40%HME. The results obtained with diesel fuel at 180bar are taken as baseline data for comparison with biodiesel and blends for four injection pressures.

BRAKE THERMAL EFFICIENCY

The variation of BTE with load at four injection pressures for three above fuels is shown in chart -4. It is observed that the efficiency of all fuels is low at lower pressure this is due to poor atomisation and mixture formation of vegetable oils during injection. However with increase in injection pressure the BTE is increased this is due to the reduction in the viscosity, improved atomisation and better combustion. It is observed that the maximum efficiency for all fuels tested is obtained at 200 bar IP. It is also observed that, the efficiency is again decreased at 220 bar, this may be due to that at higher pressure the size of fuel droplets decreases and very high fine fuel spray will be injected, because of this, penetration of fuel spray reduces and momentum of fuel droplets will be reduced. At 200 bar pressure the maximum efficiency of B20, B40and B100 fuel is obtained as 29.15, 28.51 and 27.06% respectively at full load condition. It is also observed that the efficiency of B20 fuel at 160 bar and 180 bar is 27.6 and 28.22% respectively. With increase in injection pressure to 200 bar, the efficiency is increased to 29.15 % indicating that 0.93%efficiency is improved by the increase of 20bar and 1.55 % is improved by the increase of 40bar. From the chart it is also observed that, for B40 fuel the 0.44% efficiency is improved by the increase of 20bar and 1.2% efficiency is improved by the increase of 40bar.

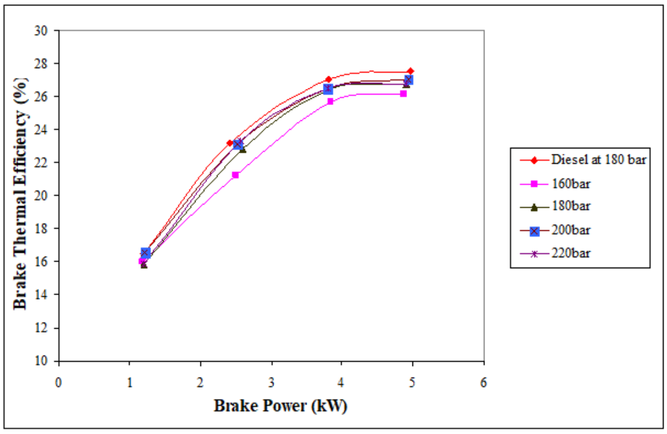

Chart-4: Variation of BTE with Load for 100% HME at different IPs

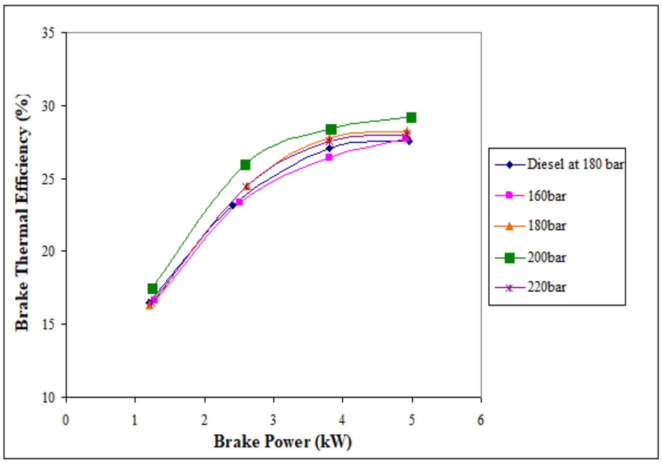

Chart-5: Variation of BTE with Load for 20% HME at different IPs

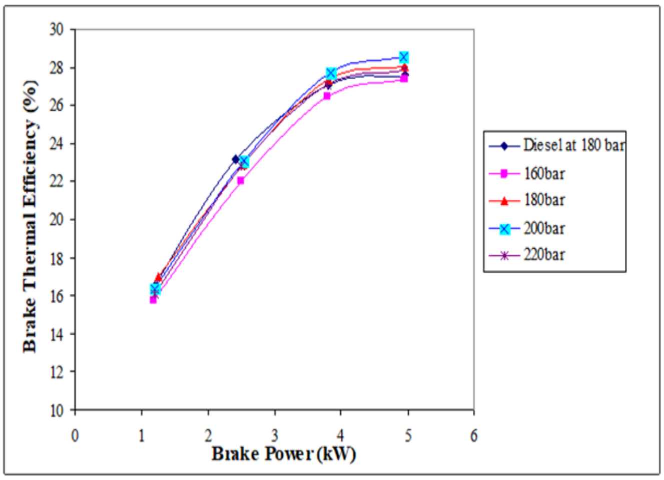

Chart-6: Variation of BTE with Load for 40% HME at different IPs

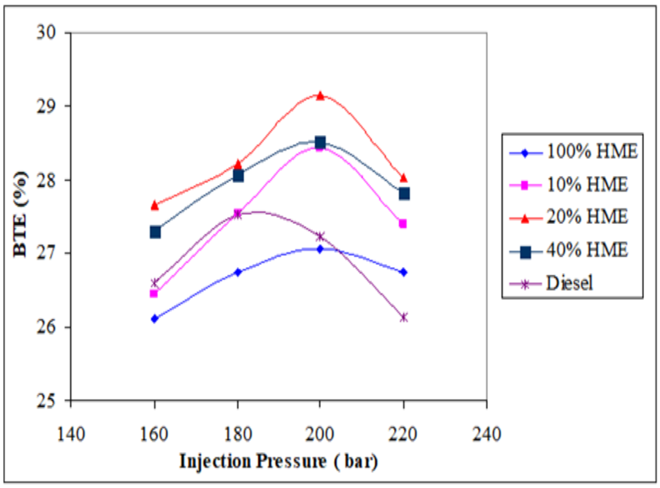

Chart-7: Variation of BTE with IP at Full Load for different Fuels

BRAKE SPECIFIC FUEL CONSUMPTION

The figure shows the variation of BSFC with load at four different IP for different fuels. The chart-9 presents the variation of BSFC with varying injection pressures at full load condition for different fuels. It is found that the BSFC is decreased with increase in injection pressure for all fuels. This may be due to that, as injection pressure increases the penetration length and spray cone angle increases, so that at optimum pressure, fuel air mixing and spray atomization will be improved. The lowest BSFC for all fuels tested was found to be at 200 bar IP. It is observed from this figure that the BSFC for B20 and B40 fuels is 0.293 and 0.305 kg/kW-hr at 200 bar. From the chart it is noticed that, with increase in injection pressure from 160 to 200 bar the BSFC for B20 and B40 fuel is reduced from 0.309 and 0.319 to 0.293 and 0.305 kg/kW-hr.

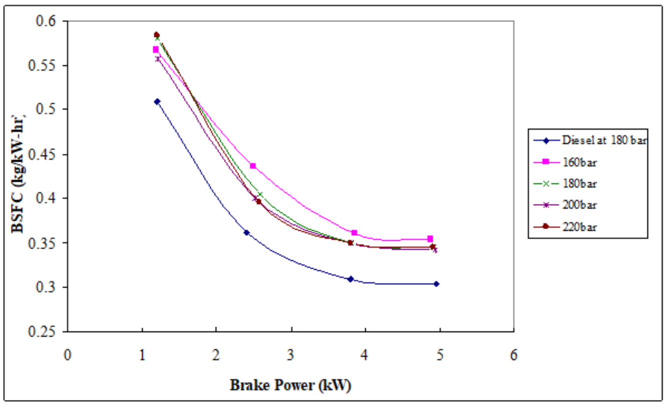

Chart-8: Variation of BSFC with Load for 100% HME at different IPs

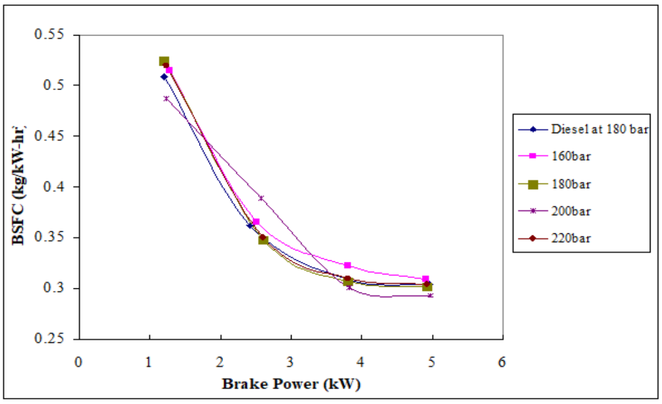

Chart-9: Variation of BSFC with Load for 20% HME at different IPs

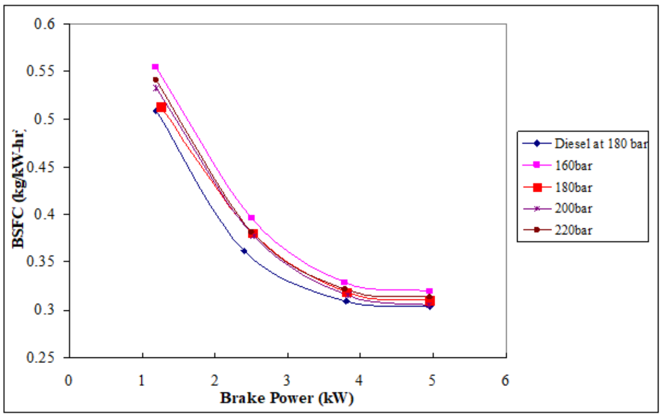

Chart-10: Variation of BSFC with Load for 40% HME at different IPs

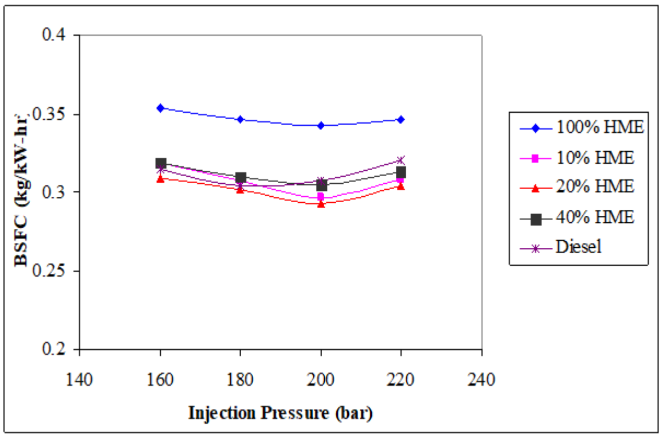

Chart-11: Variation of BSFC with IP at Full Load for different Fuels

EXHAUST GAS TEMPERATURE

The variation of exhaust gas temperature with load is shown in Chart-14 for different injection pressures. The EGT is high for lower injection pressure (160 bar). This may be due to coarse spray formation and delayed combustion. The EGT is low for 200 bar indicating that effective combustion was taking place during the early part of expansion stroke. The Chart shows the variation of EGT with varying injection pressures for different fuels. The EGT for B20 fuel at full load is measured as 570.53°C at 160 bar and when injection pressure is increased to 200 bar the EGT is decreased to 556.98°C.

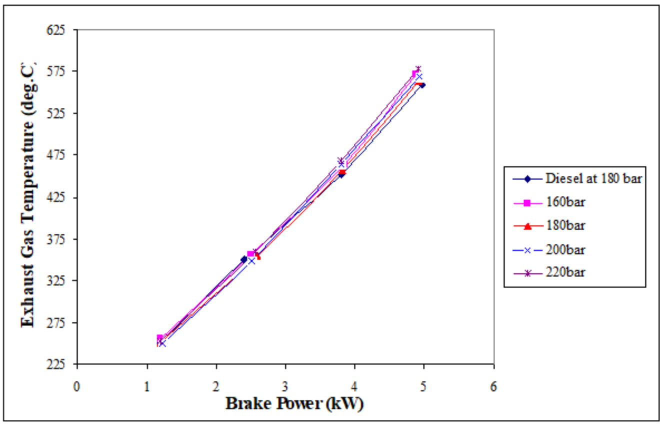

Chart-12: Variation of EGT with Load for 100% HME at different IPs

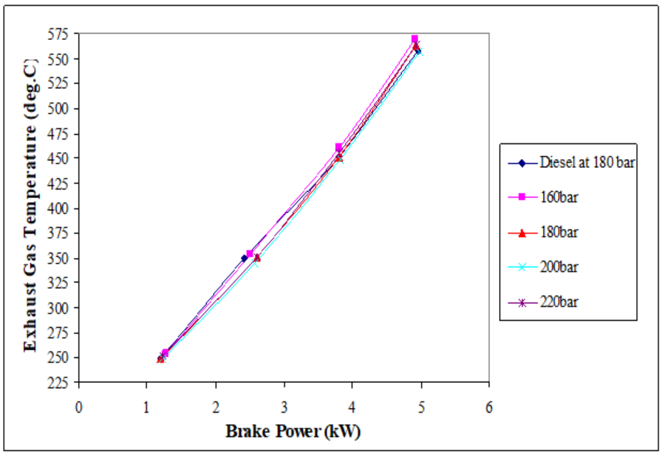

Chart-13: Variation of EGT with Load for 20% HME at different IPs

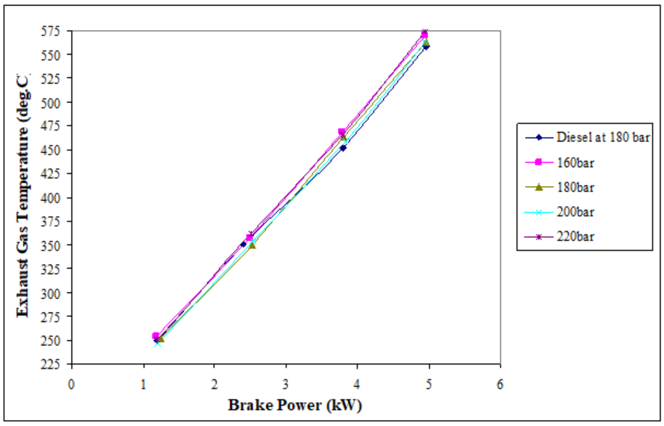

Chart-14: Variation of EGT with Load for 40% HME at different IPs

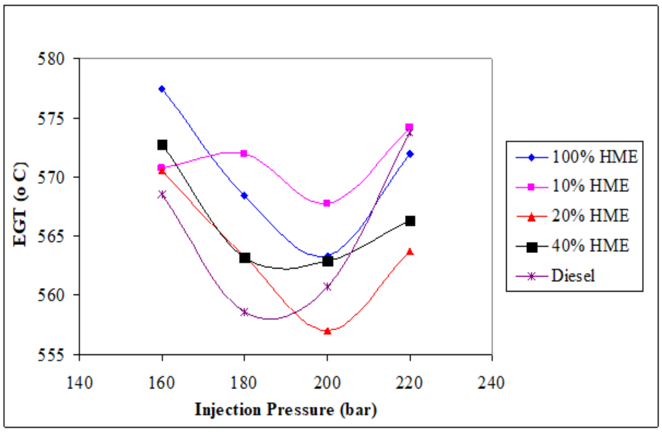

Chart-15: Variation of EGT with IP at Full Load for different Fuels

7.3 PERFORMANCE OF THE ENGINE WITH METHYL ESTER OF MAHUA OIL AND ITS BLENDS AT OPTIMUM INJECTION PRESSURE (200 BAR)

BRAKE THERMAL EFFICIENCY

The variation of BTE with load for MME and its blends at 200 bar IP is shown in Chart-16. For all fuels, the BTE is improved with increase in load. It is observed that the BTE for 100% MME is higher than the diesel fuel at 200 bar injection pressure. This may be due to that, at this pressure the spray penetration is fine and atomization may be improved. For B20 blend the maximum brake thermal efficiency is obtained as 29.05% at full load.

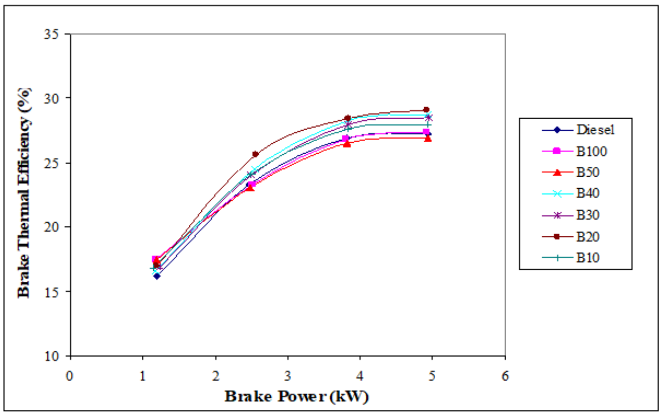

Chart-16: Variation of BTE with Load at IP 200 bar for MME & its blends

BRAKE SPECIFIC FUEL CONSUMPTION

The variation of BSFC with load of MME and its blends at 200 bar IP is shown in Chart-17. The chart shows that the BSFC for B100 and B50 fuels is higher than diesel fuel, which was observed due to lower calorific value of biodiesel. It is observed that the BSFC for B10, B20 and B30 fuels was considerably lower than the diesel fuel at full load condition.

In case of B20 the BSFC is obtained was the minimum and is lower than the all blends and diesel fuel. In case of B20 the BSFC is obtained as 0.296 kg/kW-hr, which is lower than the all blends and diesel fuel (0.307 kg/kW-hr).

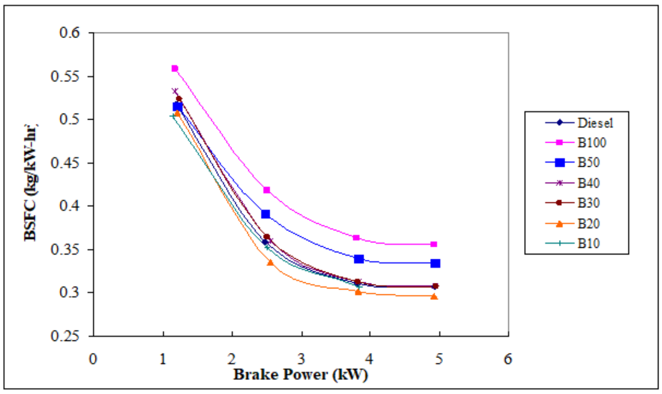

Chart-17: Variation of BSFC with Load at IP 200 bar for MME & its blends

EXHAUST GAS TEMPERATURE

The chart-18 shows the variation of exhaust gas temperature with load. It is observed that the EGT is increased with increase in load.The EGT for 100% MME and its blends except B20 is higher than the EGT of diesel fuel. From the figure 7.18, it is found that the EGT is less for B20 fuel compared to all fuels tested. This reveals that effective combustion is taking place during the early part of expansion stroke and the saving in exhaust energy loss is reflected in minimising the energy consumption per unit power output.

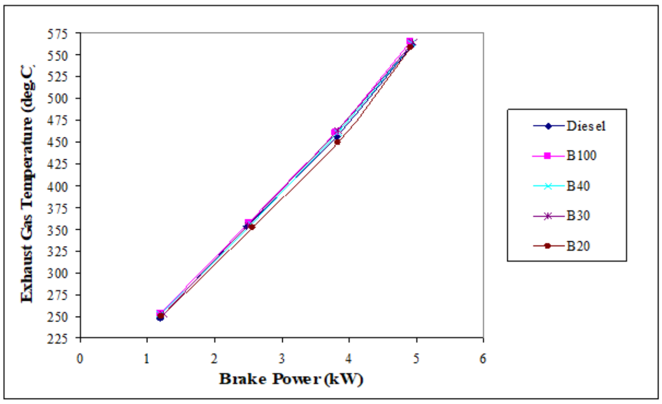

Chart-18: Variation of EGT with Load at IP 200 bar for MME & its blends

7.4 COMPARISON OF PERFORMANCE AT OPTIMUM INJECTION PRESSURE (200 Bar) FOR DIFFERENT VEGETABLE OIL METHYL ESTERS

In this section, the performance parameters were compared between the HME, HME 40%, MME, 20% MME and diesel fuel. The results of diesel at 180 bar is taken as baseline data for comparison with results of above oils at 200 bar. The chart-19 presents the variation of BTE with load. It is observed that the 20% HME gave the efficiency of 29.15 which is almost equal to the efficiency of 29.05% for 20% MME. Therefore B20 fuel from both vegetable oil esters gave the better efficiency compared to diesel fuel and other blends. It is also observed from chart that 0.35% efficiency is improved in 100% MME compared to HME fuel. This is due to lower density and viscosity of MME compared to HME, the spray penetration and atomization may be improved. The variation of BSFC with load is shown in chart-20 for different fuels. It is found that the BSFC for 100% MME is higher than HME and its blends. This may be due to lower calorific value of MME and BSFC for 20% HME is lower compared to all fuels. The BSFC for 20% MME is just 1% higher than 20% HME fuel. Therefore there was no significant difference in regard to BSFC between 20% HME and 20% MME fuels.The chart-21 presents the variation of EGT with load for different fuels. It is observed from the figure that the EGT for 100% MME is higher and EGT for 20% HME is less than all fuels but there was also no significant difference was found between 2 types of vegetable oil esters.

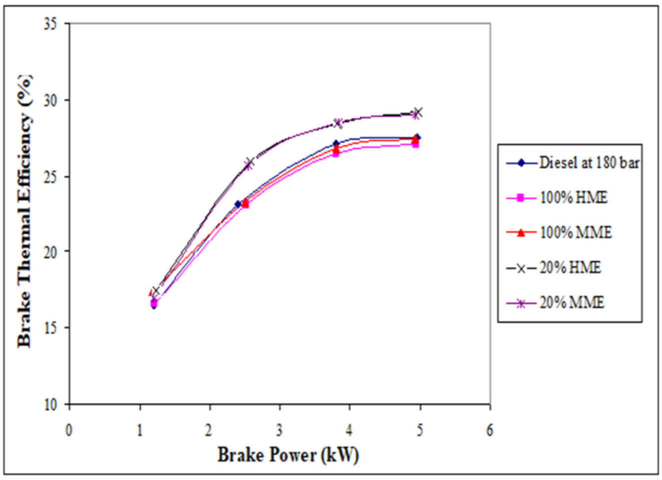

Chart-19: Comparison of BTE with Load for different fuels

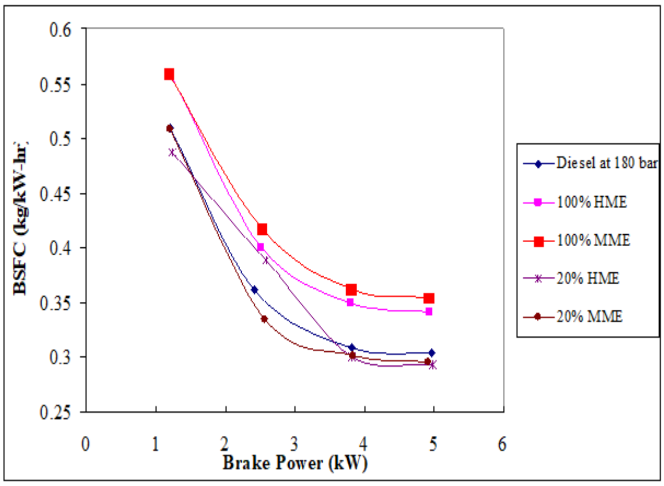

Chart-20: Comparison of BSFC with Load for different fuels

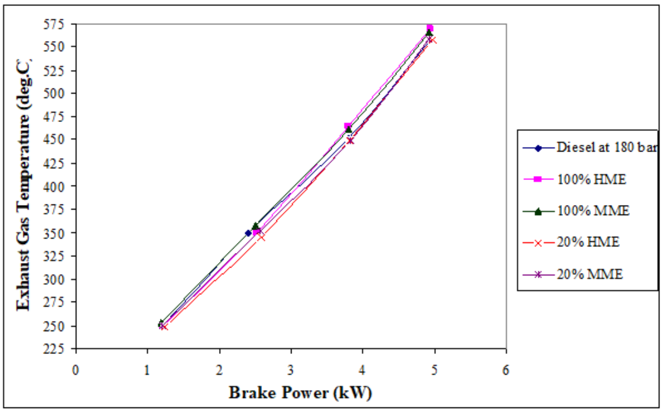

Chart-21: Comparison of EGT with Load for different fuels

8. REFERENCES

[1] Suryawanshi.J.G & Bhoyar.A.B "Experimental investigation on IC engine using Biodiesel" pp. 189-196, XVII NCICEC, 2001.

[2] Samaga.B.S "Vegetable oil as alternative fuels for the CI engine" pp. B-10to B-12, VIII NCICEC, 1983.

[3] Nagaraja.A.M & Prabhukumar.G.P "Effect of injection pressure on the engine performance with Ricebran oil as Biodiesel", pp. 581-587, XVIII NCICEC 2003.

[4] Bhonadaya.G. Reddy, Redy.K.V and Ganeshan.V "Utilization of non-edible vegetable oil in diesel engine" pp 211-214, XVII NCICEC, 2001.