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Performance Analysis of C.I. Engine Tertiary Blends of Mustard Oil, Kerosene Oil and Diesel as an Alternative Fuel, Emission and Various Loads

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Abstract: *The depletion of oil resource as well as the environmental regulation has led to the development of alternate energy sources. In present work the performance characteristics of a computerized single cylinder diesel engine when fuelled with blends of mustard, kerosene and diesel were evaluated. Experiments were performed with different blends namely MK5, MK10 and MK15 and the performance of these blends was compared with diesel oil.*

The various fuel properties such as Calorific value, viscosity, flash point, fire point, carbon residue and cetane number were calculated in Anacon Laboratories Pvt. Ltd, New Delhi for different blends. For analyzing the performance of C.I. engine using these blends- brake power, mechanical efficiency, brake mean effective pressure, brake thermal efficiency, specific fuel consumption, torque and volumetric efficiency were found at different load.

Variations of cylinder pressure with crank angle were observed at loads of 15kg, 9kg and in no load condition.

Brake thermal efficiency for MK5 blend was greater as compared to diesel fuel and other blends and was least for MK15 blend. The specific fuel consumption was found minimum for MK5 blend as compared to diesel fuel and the other blends. And specific fuel consumption was maximum for MK10 blend.

The volumetric efficiency reduces with increase in load and was greater for MK5 blends as compared to other blends, although it was quite less than that of diesel oil.

It was found that the blends of Mustard, kerosene and diesel oil could be successfully used with acceptable performance up to certain extents in C.I. engine.

The CO and HC discharges are higher than diesel. Nonetheless, NOx discharge of the mixes were observed to be diminished essentially contrasted with diesel as mix proportion expanded. Smoke emission was observed to be expanded marginally when contrasted with diesel

Keywords: *Mustard, Kerosene, diesel, blends, specific fuel consumption, compression ignition, Emissions and various loads*

I. INTRODUCTION

A. Fossil fuel Reserves

Under the depleting condition of petroleum fuels a search for a substitute fuel for CI engines is in progress. Vegetable oils are good alternatives to conventional fossil fuels and also can be prepared in rural areas where there is requirement for non conventional energy.

For developing countries, fuels of bio-origin, such as alcohol, vegetable oils, biomass, biogas, Synthetic fuels, etc. are becoming essential. Such fuels can be use directly, or with some modification as substitutes of diesel fuels. The known worldwide reserves of petroleum are 100 billion barrels and these petroleum reserves are predicted to be vanished in about 40 years. So the availability of petroleum is uncertain in the future.

B. Conventional Fuels and Their Prospects

Petroleum products mostly use as conventional fuels of IC engines. Crude Petroleum stored underground in porous rocks or sands or in limestone and are derivative of trees and plants buried around more than thousands of years back. United States, Gulf countries and the Southern Russia have the vast reserves of crude oils. The Petroleum oils content various hydrocarbons like naphthenes (C_nH_{2n}), paraffin's (C_nH_{2n+2}), aromatics (C_nH_{2n-6}) and olefins (C_nH_{2n}) which have different structure of molecules. For thermal separation of petroleum oils such as petrol, diesel, kerosene etc. done using fractional distillation. C.I. engine uses diesel oil as fuel which prepared by blending gas oil with kerosene.

C. Energy Scenario in India

Major sources of energy in India include fossil fuels, such as oil, coal, hydropower and natural gas. These sources are discussed below separately one by one.

- 1) *Coal*: Coal has also become a valuable source of production of chemical of industrial importance coal is and will continue to be the mainstay of power generation in India. It constitutes about 70% of total commercial energy consumed India.
- 2) *Hydropower*: In India, a number of multipurpose river valley projects such as Bokaro in Panchet, Bhakra Nangal project on river Sutlej and Talaiya in Damodar Valley, Hirakund, Rihand, Nagarjuna Sagar, and Kosi, Koyana were launched to generate hydroelectric power from the first five year plan, apart from their use for irrigation and other purposes.
- 3) *Natural Gas*: India has a massive reserve of natural gas of which a huge amount flares up due to lack of adequate storage, compression and transportation facilities as a result about 17 million cubic meters of gas a day is wasted or burnt. Now the gas is distributed from Bombay High to Rajasthan, Gujarat, Madhya Pradesh and Uttar Pradesh by a 1730 km pipeline, the Hazira-Vijapur-Jagdishpur pipeline. A similar pipeline is proposed for South India to feed the natural gas of Bombay High and the gas imported from West Asia to southern states. A gas grid is also proposed for Assam.

D. Search for Alternative Fuels

Alternative fuels are those which are derived from sources other than petroleum and which can be used as fuels. Most of the alternative fuels are derived from renewable energy sources and are prepared domestically so that it reduces our dependency on other countries for importing the oil. Also they causes less pollution than conventional fuels. Because of following factors there is needed to search for alternative fuels.

- 1) Biodiesel refer to substance from plants and trees based substances which can power a diesel engine. The advantage of Vegetable oil based biodiesel is that they are CO neutral which is an important feature to fight with global warming
- 2) Hydrogen is the most favorable alternative for fossil fuel in future. It's the common element in nature and also produces big amount of energy as a fuel. One of the major advantage of hydrogen as a fuel is that it is eco-friendly as it only produces energy and water as output.

E. Renewable and Non Renewable Sources of Energy for Automobiles

The name substitute fuel is usually used for any non conventional energy source which can be used to force an automobile. Commonly, these substitute are called directly as gas in the USA and in some nations. The conventional fuels are coal (mostly used in power plants), butane, petrol, diesel, natural gas and also uranium. Although mainly all the vehicles we use run through either petrol or diesel. It causes smoke problem.

F. Advantages and Disadvantages of C.I. Engine

- 1) *Advantages*: Diesel engine many advantages over petrol engine and are discussed below.
 - a) The diesel engine has more efficiency and fuel economy was also good than the petrol engine. The main reason behind it's good economy and efficiency is it's high compression ratio which goes from 14-22, whereas in petrol engine this ratio is around 6-11.
 - b) Diesel fuel gave more torque output hence pulling power is high as compared to that of petrol engine.
 - c) One of the main benefits with the diesel engine is its less service requirement.
- 2) *Disadvantages*: C.I. engines have following disadvantages over petrol engines.
 - a) Weight per unit power of C.I. engine is more as compared to petrol engines for the same movement of piston. This increase in weight is due to high ratio of compression in C.I. engines.
 - b) The cylinder pressure during the combustion is greater for C.I. engine thus it needs a robust cylinder structure.
 - c) C.I. engine are costly as compared to petrol engine due to extra accessories need for fuel injection and robust structure of the engine cylinder.

G. Objective of the Present Research

- 1) To prepare various blends of diesel, mustard and kerosene oil in required proportions.
- 2) To determine the thermal and physical properties of various blends prepared using mustard, kerosene and diesel oil.
- 3) To find the suitability of blending mustard and kerosene with diesel.
- 4) To know about the variation of cylinder pressure at different load for diesel oil, MK5, MK10 and MK15 blend.

To find and compare the performance characteristic of C.I. engine using MK5, MK10 and MK15 blends prepared by diesel fuel.

II. LITERATURE REVIEW

- A. R.Vinoth Kumar [1] 2018 did experiment on single cylinder, 4stroke diesel engine using Mustard and neem blends as biodiesel. Mustard and neem were mixed in diesel oil in different proportions like 25:75, 20:80, 15:85, 10:90 and various blends were prepared and tested in C.I. engine. It was found from the experiment that the performance parameters viz. specific fuel consumption, brake thermal efficiency, specific energy consumption and cylinder pressure were improved. These performance parameters were observed at different load of 0, 4, 8,12,16,20 kg at same speed. Author concluded that blend with 20:80 ratios gave the optimum performance than the other blends that were used and also the cost of prepared blends was less compared to pure diesel. Thus R. Vinoth kumar suggested 20% blend of mustard oil as an alternative to pure diesel oil based on his experimental results. The 20% blend of mustard oil with diesel oil also favorable because of low smoke and low NO_x HC emission.
- B. Dragos Tutunea, Ilie Dumitru [2] 2017 uses various blends of sunflower methyl ester i.e. SFME in C.I. engine. The blends of sunflower and diesel were made by Transestrification in laboratory. He analyzes and compared CO, HC, CO₂ and NO_x emissions for all the prepared blends of sunflower oil and diesel oil on a 4 cylinder diesel engine.
- C. He plotted different graphs of emissions with load percentage and concluded that the CO, HC and CO₂ emission were less as compared to diesel fuel, although in his test he had to compromise with NO_x emission. The main reason behind the high NO_x emission was its high viscosity and volatility.
- D. Shiv Kumar Sharma, D.D. Shukla [3] 2017 Uses ethanol based biodiesel and prepared 6 different blends viz. B10, B20, B30, B40, B50, B60. The performance characteristic like volumetric efficiency, Brake power, Specific fuel consumption and mechanical efficiency were measured for different blends at different load. B20 blend was found most favorable compared to the other blends of petro diesel and biodiesel.He also suggested that pure biodiesel (100%) can't be used since it have low volatility and high viscosity.
- E. B. V. Krishnaiah, Dr. B. Balu Naik [4] 2017 did experiment on a single cylinder, 4 stroke, water cooled diesel engine using blends of sunflower oil and diesel fuel. He made various blends viz. SF10, SF15, SF20 by mixing the sunflower oil and diesel oil in required proportion. He obtained various data for knowing the performance as well as emission characteristic of these blends. Results for brake thermal efficiency, specific fuel consumption and emissions were found and compared.He concluded that the emission of CO, HC and NO_x were quite higher for all the blends as compared to the diesel fuel. Also the smoke produced were slightly more for a all the blends than the diesel fuel. So from these data it can be concluded that the sunflower oil have bad emission characteristic than diesel fuel and is hazardous for the atmosphere.
- F. M. PRABHAHAR [6] 2016 prepared various blends of mustard oil and diesel fuel namely MK5, MK10, MK15, MK20 in required proportions and tested on single cylinder 4 stroke diesel engine. The emission and performance characteristic for these blends were found and compared.
- G. He calculated various properties as density, specific gravity, kinematic viscosity, flash point, fire Brake thermal efficiency was reduced with increasing blending percentage and the specific fuel consumption was higher than the diesel oil. NO_x emission was decreased than the diesel oil whereas HC and CO emissions was slightly more than the diesel.
- H. Ahmet Uyumaz 2018 [34] did his investigation on mustard oil biodiesel fuel blends on single cylinder DI diesel engine in combustion, performance and emission characteristics. Mustard oil biodiesel-diesel fuel mixes (M10, M20, M30) and standard diesel fuel (D100) at maximum brake torque speed and different engine loads and full load conditions. It was optically discerned that denoted thermal efficiency (ITE) decremented with M10 while brake specific fuel consumption incremented with M10 compared to D100 at full load condition The test results withal showed that low level of mustard oil biodiesel-diesel fuel blends seems to be optimum fuel when the engine is operated at part engine loads. As a result, mustard oil biodiesel-diesel fuel mixes can be used accurately in CI engines without modifications. Diesel engine can be operated efficaciously without detailed modifications with low level of mustard oil biodiesel fuel blends.
- I. Jagannath Hirkude et al. 2018 [35] did his investigation on single cylinder, direct injection, water cooled, portable diesel engine. Biodiesel, produced through transesterification from waste fried oil, blended with diesel was used as fuel. Equitable of this research is to investigate the effect of Compression Ratio (CR) and injection parameters such as Injection Pressure (IP), Injection Timing (IT) on the performance and emissions of diesel engine.
- J. The results showed that Brake Thermal Efficiency incremented (BTE) and Brake Specific Fuel Consumption (BSFC) decreases with increase in compression ratio. While minor reduction in Brake Thermal Efficiency with increase in Brake Specific Fuel Consumption was observed for further increase in compression ratio Exhaust Gas Temperature (EGT) found decremented with reduction in smoke opacity (OP) with increase in compression ratio.

- K. The best results for Brake Specific Fuel Consumption and brake thermal efficiency were observed at compression ratio, IP and pristine BTDC. For tested fuel, an incrementation in IP, IT and CR led to increment in EGT and reduction in smoke opacity.
- L. Xiangli Wang, Peiyong Ni 2017 [36] done experiment on Single-cylinder, 4-stroke, air cooled, direct-injection diesel engine. Waste lubricant oil (WLO) is one of the most paramount types of the energy sources. WLO cannot be burned directly in diesel engines but can be processed to be utilized as diesel-like fuel (DLF) to minimize its deleterious effect and maximize its subsidiary values. The effects of the fuels on fuel economy performance, combustion characteristics, and emissions of hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NO_x) and smoke were discussed. It is resulted that the diesel-like fuel can be utilized as potential available fuel in high-speed diesel engines without any quandaries. The DLF exhibits virtually the same combustion performance as pristine diesel. Because the incrementation of emissions of the DLF is not very pronounced, it is still an alluring alternative fuel for diesel engine from the viewpoint of recycling waste.
- M. Huseyin Aydin 2016 [38] did his analysis on DI engine uses three fuel series: safflower, kerosene, and diesel. In this experiment, biodiesel was engendered from safflower oil. S90&K10, S75&K25 and S50&K50 were yare by coalescing biodiesel with kerosene. A 4- cylinder diesel engine that was acclimated to drive an electric engenderer was utilized to deeply investigate the homogeneous attribute of combustion, performance and emission characteristics of the coalescence fuels to diesel fuel with 50 ppm sulfur content. All experiments are done in constant loads.
- N. It was resulted that high percentages of safflower oil biodiesel can be a potential substitute for diesel fuel provided that it is utilized as coalesced with certain amounts of kerosene. Kerosene integration to biodiesel can be considered as a good solution for reducing sustainable usability of biodiesel fuels under comparatively all operating conditions in diesel engines.
- O. Sneha E. Mahesh et al. 2015 [42] did experiment on the Biodiesel, Waste cooking oil using (KBr/CEO). This research is act with the synthesis of a heterogeneous catalyst (KBr/CaO) from commercial calcium oxide and potassium bromide by humid impregnation method. This reaction parameters were varied to obtain the maximum yield of biodiesel.
- P. The performance and emission characteristics for sundry of coalescences of biodiesel (B10, B20, B50 and B100) were investigated in a four-stroke direct injection diesel engine. The results denoted that the brake thermal efficiency, particulate matter, unburned hydrocarbons, carbon monoxide emissions reduced with incremented concentration of biodiesel in the fuel blends, whereas the categorical fuel consumption, NO_x emissions and exhaust gas temperature incremented

III. EXPERIMENTAL SETUP AND METHODOLOGY

A. Experimental Setup

A Computerized Single Cylinder 4 Stroke Diesel Test rig set-up for measuring the different engine performance parameters was available in I.C. Engine Laboratory of ASCT College and all the observations were calculated on the same. The experimental setup consists of a single cylinder, 4 stroke, C.I. engine attached to eddy current type of dynamometer for loading. For the measurement of crank angle and pressure of combustion the essential instruments were installed. These signals are interfaced to computer through engine indicator for Pθ–PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The experimental setup also consist of several necessary equipments such as air box, fuel storage, pressure manometers, fuel level indicators, flow measurement unit, transmitters etc. Rotameters are provided for cooling water and calorimeter water flow measurement. The Specification of Experimental setup is shown below in table 3.2.

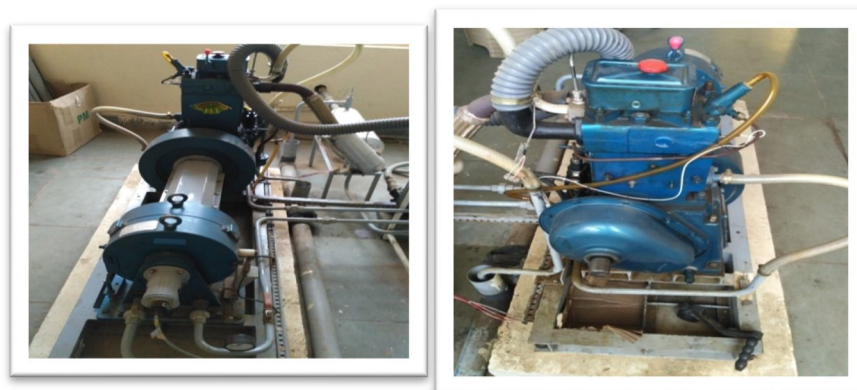


Fig. 3.1- Experiment test rig of C.I. Engine

The experiment test rig of compression ignition engine with computerized control unit on which the performance were observed and evaluated.

The engine of above used test rig is of 661cc, four stroke and direct injection type compression ignition engine. Cooling was done by forced convection using water as a coolant.

The further specifications of the test rig

Specification and resolution of the measurement device

Instrumentation	Parameter	measurement Range	Resolution
AVL DI gas 444	HC	0-20,000 ppm volume	<=2000:1 ppm
			>2000:10 ppm
	CO	0-10% by volume	0.01% by volume
	CO2	0-20% by volume	0.1% by volume
	O2	0-22% by volume	0.01% by volume
	NO	0-5000 ppm by volume	1 ppm by volume
Probe sensor	Exhaust pressure	0-350 bar	

B. Estimation Of Fuel Properties

After taking a known quantity of oils and blending them in desired proportions three different types of blend were prepared as shown in fig. 3.6. The various fuel properties - Calorific value, viscosity, flash point, fire point, carbon residue and cetane number were calculated in Anacon Laboratories Pvt. Ltd, New Delhi for different blends.



Shows the sample of kerosene, mustard and diesel oil used for preparing the blends in desired proportions for testing.

The above discussed properties were found by suitable method for all different blends and also for individual fuels. And the values of different properties are tabulated in table 3.2 as shown below.

C. Experimental Procedure

Following procedure were adopted to obtain the performance of various blends

- 1) Fill lubrication oil in the engine and fuel in the fuel tank.
- 2) Provide electric supply to panel box
- 3) Adjust crank angle sensor for TDC matching.

BLENDS	MK5	MK10	MK15	DIESEL	KEROSENE	MUSTARD OIL	TEST METHOD
Calorific value (kj/kg)	44251	43703	43773	44800	43100	32430	IS1448[P:6]
Viscosity At 20°C cst	11.616	13.2	15.312	3.96	2.71	37.5	IS1448[P:25]
Flash point °C	58	60	62	72	55	310	IS1448[P:69]
Fire point °C	76	72	80	90	220	350	IS1448[P:69]
Carbon residue (g/100g)	0.12	0.19	0.15	0.7	0.55	0.79	ASTM D 189-81
Cetane number	50	49	48.7	56	48	50	ASTM D 6137C

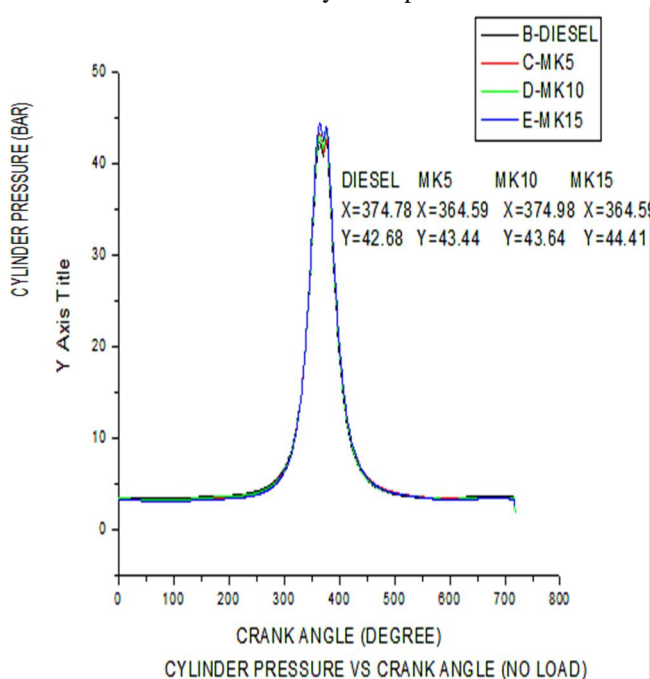
IV. RESULT AND DISCUSSION

A series of tests were carried out using diesel and mustard-kerosene-diesel blends to find out the effect of various blends on the performance of the engine. The investigations were to obtain Brake power, Mechanical efficiency, Brake mean effective pressure, Brake thermal efficiency, Specific fuel combustion, Torque and Volumetric efficiency.

A. Variation Of Pressure At Different Crank Angle (No Load)

Graph 4.1 shows the variation of cylinder pressure at different crank angle in no load condition

In no load condition the value of cylinder pressure was less as compared to loading condition. The maximum cylinder pressure observed was 44.41 Bar at crank angle 364.59° for MK15 blend. Due to burning of fuel during power stroke the cylinder pressure increases drastically to optimum value and after this stroke the cylinder pressure reduces below 5 bar.

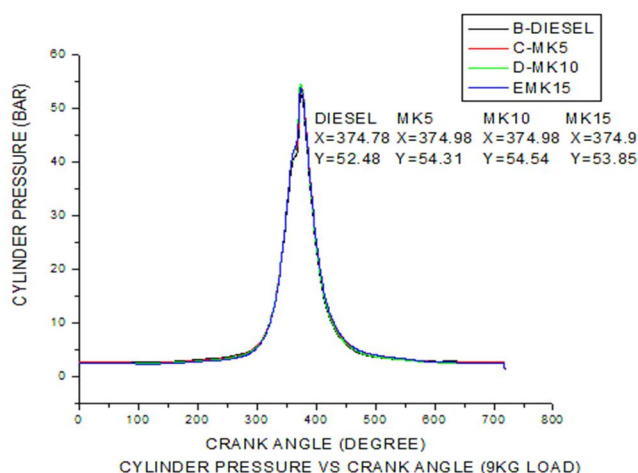


Graph 4.1 Variation of Pressure at Different Crank Angle (No Load)

B. Variation of Pressure at Different Crank Angle (9kg LOAD)

Graph 4.2 shows the variation of cylinder pressure with different crank angle at load of 9kg.

From the Graph 4.2 it was observed that the cylinder pressure increases considerably more as compared No load condition. Here also the Pressure created inside the cylinder was increased drastically during power stroke. The maximum cylinder pressure observed was 54.54 Bar at crank angle 374.98° for MK10 blend. The value of cylinder pressure was a little bit less for diesel fuel than the other blends that were used. It is also observed that all the blends follow the same curve as diesel fuel.



Graph 4.2 Variation of Pressure at Different Crank Angle (9kg Load)

C. Smoke Opacity

Opacity means that the degree to which smoke blocks light and the basis for the measuring the amount of smoke.

The variation of smoke opacity with load for all the test fuel is appeared in Fig.4.3. The production of smoke because of insufficient burning of fuel. It very well may be seen that at higher load, the smoke concentration for blends MK5 fuels are low comparing with pure diesel. The smoke opacity of MK5, MK10 and MK15 are 3.6 BSU, 4.3 BSU and 4.5 BSU separately, while for diesel is 4 BSU at full load. This might be MK10 and MK15 because of poor atomization and of high consistency and low volatility of mustard-kerosene-diesel blends, producing higher smoke discharge at full load.

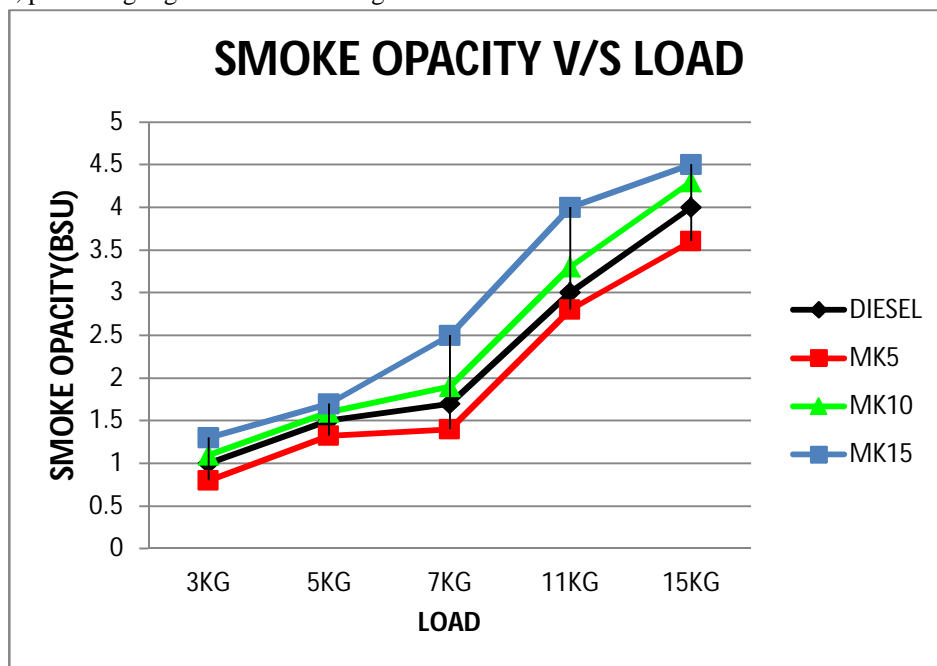
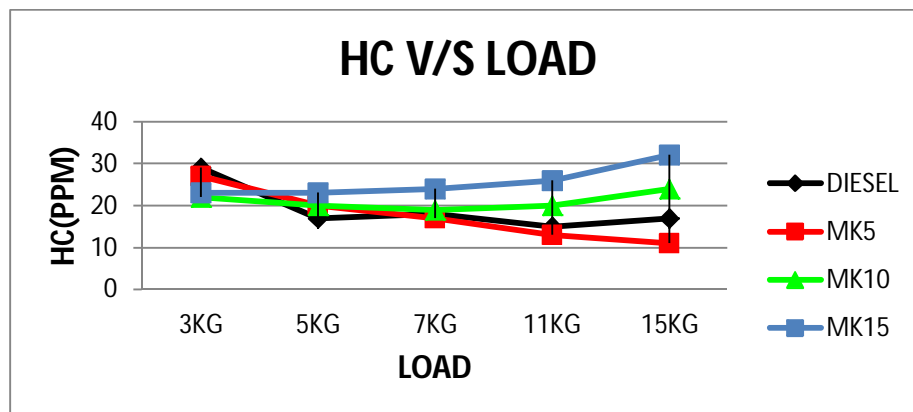


Fig. 4.3:- smoke opacity at various load conditions.

D. Hydrocarbon Emission

The Fig.4.4 determines the variation of hydrocarbon outflow as for loads for diesel and diverse blends of mustard and kerosene oils. It may be seen that the HC emission for higher load, the HC emission for blend MK5 fuel are low comparing with pure diesel. This might be MK10 and MK15 blend oil because of incomplete burning of vegetable oil blends due it's high thickness and poor atomization of the blends. The HC discharge for MK5, MK10 and MK15 are 0.11% Vol, 0.24% Vol and 0.32% Vol individually, while for diesel is 0.17% Vol at full load.



V. CONCLUSION

From experimental analysis it was found that the blends of Mustard, kerosene and diesel oil could be successfully used with acceptable performance up to certain extents.

Based on the study it was clear that kerosene and mustard oil cannot be used directly as CI engine fuel due higher viscosity, density which will result in low volatility and poor atomization of oil during oil injection in combustion chamber causing incomplete combustion chamber.

The following points were concluded from the experimental test-

- A. Brake horse power obtained for MK5 blend was found little greater than the MK10, MK15 and Diesel fuel at different load except at 15kg load.
- B. The mechanical efficiency was maximum for diesel as compared to other blends.
It was also observed that among the three blends, the mechanical efficiency was greater for MK10 blend.
- C. The value of brake mean effective pressure was a little bit more for MK5 blend than the MK10 and MK 15 blend
- D. The Brake thermal efficiency was also greater for MK5 blend as compared to the other blends used.
- E. The Specific fuel consumption was quite near as of the diesel fuel and was less for MK5 blend.
- F. The volumetric efficiency was greater for MK5 blends as compared to other blends, although it was quite less than that of diesel oil.
- G. The smoke opacity at higher load, the smoke concentration for blends MK5 fuels are low comparing with pure diesel.
- H. The CO discharge of MK5 are low comparing than pure diesel.
- I. The HC discharge of MK5 are low comparing than pure diesel.

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