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Experimental Investigation On The Performance And Emission Characteristics Of A Single Cylinder Di Diesel Engine Using Mahua Biodiesel, Blends And Diesel On Adding Dee By Varying Number Of Injection Nozzle Holes

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Abstract:

Diesel engines have main contribution in air pollution by exhausting gases such as carbon monoxide, unburned hydrocarbons, oxides of nitrogen and other harmful gases or components. The formation of these harmful gases can be reduced by the use biodiesel as alternative fuel. This paper aims to present the experimental studies on the performance and emission characteristics of Mahua oil methyl ester (MOME), blends and diesel as a fuel for a single-cylinder direct injection diesel engine.

Experiments have been carried out to study the effects of performance characteristics like brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), and emissions such as hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (Co_2) oxides of nitrogen (NOx) in a diesel engine by varying number of injectors nozzle holes.

Mahua oil methyl ester blends prepared are M20[18%biodiesel+2%DEE+80%diesel], M40[38%biodiesel+2%DEE+60%diesel], M60[58%biodiesel+2%DEE+40%diesel] and 100% biodiesel. Testing is carried out by varying number of holes of nozzle as 2 hole, 3 hole and 4 hole nozzle at constant engine speed 1500rpm.

Increasing the number of nozzle holes improves the performance of diesel engine fueled with MOME in terms of increased BTE, reduced emissions like HC, CO, CO_2. However, NO_x emission increases with increased number of holes.

Keywords:

Diesel, Mahua Oil Methyl Ester (MOME), Di Ethyl Ester (DEE), nozzle holes, Performance, emission.

I. INTRODUCTION

Environmental degradation of petroleum products and their non-renewable nature has led to a world-wide search for renewable and greener alternatives in internal combustion. Vegetable oils are one of such alternatives, which have the advantage of reducing most of the regulated emissions such as carbon monoxide, unburned hydro carbons and nitrogen oxides. Vegetable oils are renewable source of energy with an energy content close to diesel. The major problem faced in utilizing vegetable oils as CI engine fuel is their higher viscosity, ranging from 10 to 20 times higher than that of diesel fuel. This higher viscosity results in poor fuel atomization, incomplete combustion and carbon deposition on the injector and the valve seats causing serious engine fouling. The higher viscosity of vegetable oils can be reduced through the processes like blending, transesterification, etc.

Presently energy demand in our country is 120575 MW but the availability of energy from all sources is 108212 MW. It shows 10.3 MW as deficit of energy. In order to overcome this energy scarcity and to meet the requirement bio fuels are introduced.

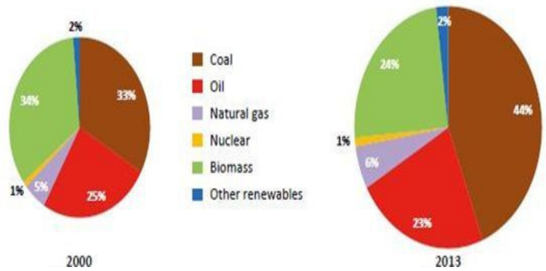

Fig.1 Primary energy demand in India by fuel

Fig 1 shows the pictorial representation for variation of energy demand in India. Since three-quarters shows the energy demand in India relates to the increased demand for fossil fuels. The main reason for this is rapid usage of energy from coal consumption and a decreasing role for bio energy. Earlier day's solid biomass was used for cooking. But now day's households decreased the usage of solid biomass for cooking. The energy consumption from coal is 44% of the primary energy demand. This increased demand for coal is due to the growth and expansion of the coal-fired power generation fleet and also the increased use of coal in industries. The easily availability of coal as compared to fossil fuels is also the reason for its increased usage, especially in the power sector. From fig.1 it can be noted that the demand for energy from alternative fuel (which consists of solid biomass, i.e. fuel wood, straw, charcoal or dung) has been decreased almost 10%.This is because of households switched from the usage of solid biomass to other fuels for cooking (i.e. Liquefied Petroleum Gas (LPG). Thus it is much necessary to the usage of alternative fuel in order to avoid the future scarcity of fossil fuel i.e. mainly petroleum products.

Various researches have been carried on neem oil, jatropa oil, cotton seed oil, mango oil, sesame oil, rice bran oil, etc but few researches have been carried on mahua oil. Most literature suggest that the use of biodiesel instead of diesel leads to an increase in the specific fuel consumption and decrease in brake thermal efficiency, the carbon monoxide, unburned hydrocarbon and smoke emissions reduced significantly. In this paper the investigation of performance and emission characteristic of MOME and its blends of M20, M40 and M60 and diesel by varying the number of nozzle holes as 2 hole, 3 hole and 4 hole is to be carried out.

II. MAHUA OIL BIODIESEL

[i] **Mahua Tree**: Mahua tree is one of the popular significant Indian forest trees belonging to the family of Sapotaceae tree. It is a multipurpose tree in India, its species and location named such as Madhuca latifolia are found in Uttar Pradesh, Madhya Pradesh and Telangana, Madhuca butyracea are found in Sub-Himalayas in kumaon and Gharwall region, Madhuca neriifolia are in Mumbai, Chennai, South Karnara and Mysore, Madhuca bourdillonii are found in Mysore and the Western Ghats and Madhuca longifolia are found in South India. The people in India mahua tree are named as Mahua, Mohua, Mahula, Mowrah, Moha, Mova, Mahuda, etc. based on the religion and places.

The mahua seed shows a very good commercial potential as oil. Mahua oil is elicited from the dried-up seed of the Mahua tree. These mahua seeds are in 0.49-0.51 million tons, which are being collected to make use of oil by the organized sectors in India. The yield of mahua seeds varies from 5-200 kilograms per tree. The yield of mahua seeds mainly depends on the age and size of the tree. The estimated mahua seed oil production is 1.8 million metric tons per year in India. The total oil content percentage of the mahua seed ranged from 44.43 to 61.5[1]. The aflatoxin and aflatoxin B1 are the most poisonous and cancer-causing chemicals. 80% of mahua seed samples were found to be contaminated with aflatoxin and aflatoxin B1. So, due to the presence of aflatoxin, AFB1, saponins, and tannins the mahua oil seeds are considered as non-edible oil. Biodiesel from the non-edible oils has a great potential as an alternative fuel. The non-edible mahua seed oil has great oil potential to obtain for biodiesel production. Mahua seed oil is transesterified with the help of acid catalyst at 60^0 to produce the mahua oil methyl ester. And glycerin is the byproduct used for making cosmetics.

Fig.2 pictorial view of mahua seed

[ii] **Additives**:

The most important additives for diesel and otto engine are oxygenated additives. The fuels that are containing oxygen and blending components contain at least one oxygen atom by the molecules at the side of the hydrogen and carbon atoms. The oxygenated additives are very useful to develop the combustion process and octane rating. Oxygenated additives are blended with diesel fuels and the oxygenated additives must be capable of mixing any ratio without separation of its two phases with various diesel and biodiesel fuels. By blending oxygenated additives in biodiesel and diesel sufficient, sufficient cetane number should be there in oxygenated additives and allowed the blend to increase the cetane number. The oxygen helps to support for burning the fuel without emitting any high amount of inert material such as nitrogen into the air and it causes the harmful material such as NOx emission at some operating load condition in CI diesel engine. The generally used oxygenated additives are alcohols, ether and ester. The few names of ether are diethyl ether [DEE], dimethyl ether etc. By addition of oxygenated additives, the ignition temperature of biodiesel will be minimized and also reduction in smoke emission is observed in the diesel engine. According to the composition of diesel and biodiesel, the oxygenated additives will affect directly the properties such as cetane number, density, viscosity, volatility, flash point and calorific value. To ignite the fuel more efficiently oxygenated additives will support and as well as diminish environment pollution. The engine fuels will burn more completely due to the presence of oxygenated additives.

[iii] **Fuel injector nozzles:**

The fuel injector nozzle is one of the main significant parts of the diesel engine. For a long era, the mechanism of atomization of the fuel sprays through the injector nozzle is commonly thought to be aerodynamic atomization theory. The geometry of the fuel injector nozzle and its nozzle fuel flow characteristics strictly affects the development of fuel atomization, performance, combustion process and harmful emissions in a CI engines. The fuel injection system in a CI diesel engine is to make a high amount of atomization for better penetration of the fuel, to promote more evaporation in a very short time to meet better combustion process [2].

III. LITERATURE REVIEW:

Khandal SV,et al.(2015) has investigated that performance, emission and combustion characteristics of a single-cylinder direct injection diesel engine when fueled with HOME for 3 and 4 hole injectors using RSM based quadratic models. The BTE increases with increased compression ratio for any given value of injection pressure. The smoke density decreases with increased compression ratio for a specified value of injection pressure. The smoke density decreases with increased compression ratio for a specified value of injection pressure. NOx emission increases with increased compression ratio for a given value of IT and with a further advanced IT, NOx increases. Increasing the number of nozzle holes improves the performance of diesel engine fueled by HOME in terms of increased BTE with reduced CO, HC and smoke emissions and increased NOx, peak pressure and HRR.

M. Vijay Kumar,et al.(2017) has investigated the BTE and BSFC are improved with the B20 fuel and with smaller orifice NHD. The HC, CO, and smoke opacity exhaust emission are decreased whereas the NOX is increased with B20 fuel and also with smaller orifice NHD. From these conclusions, it can be concluded that the engine can be successfully run with the B20 fuel by modifying the smaller orifice NHD which results in the better performance, combustion, and emission than the baseline diesel.

K. Prasada Rao,et al.(2016) has investigated that DEE mixed with the Mahua methyl ester (MME) at different proportion such as 3%, 5% 10% and tested **at** different loads on diesel engine. 15% DEE blend with biodiesel is adjudged as the best combination, which yielded better results than other fuel blends, especially 3% blend which is the nearest competitor. Emission levels are decreased substantially with 15% DEE blend with MME at full load. The thermal efficiency rise and SFC are better in the case of 15% additive blend.

N.vadivel,et al.(2015) An experimental study has been conducted to evaluate the effects of using diethyl ether as an additive to biodiesel/diesel blend on the performance and emission of a direct injection diesel engine. The results obtained were compared with neat diesel, there was slightly lower brake specific fuel consumption for diesel-biodiesel-DEE blend. Strong reduction in emissions was observed with diesel-biodiesel-DEE at various engine loads. Methyl ester of mustard biodiesel at 25% and DEE 5% blend with 70% diesel gave best performance in terms of low smoke intensity and emissions characteristics.

K. Sandeep Kumar,et al.(2017) has investigated the performance and emission analysis of Mahua oil methyl ester (MOME) blended with diesel along with additive of diethyl ether. The various test fuels are prepared by varying the percentage of MOME in the bio-diesel blend keeping volume of diethyl ether constant. Results shown that there is rise in Brake Specific Fuel Consumption (BSFC) with rise in percentage of MOME in biodiesel blend when compared to diesel, but Break thermal efficiency (BTE) is slightly increases with increase in percentage of MOME in biodiesel blend. The emissions of CO, NOX and HC were reduced with increase in percentage of MOME in biodiesel blend, but CO2 emissions were increased.

Swarup Kumar Nayak,et al.(2013) Brake thermal efficiency increases with increase in additive percentage in Mahua biodiesel. Brake specific fuel consumption is highest for pure biodiesel at all loads. Exhaust gas temperature is found highest for pure biodiesel. CO and HC emissions are highest for diesel and lowest for pure biodiesel Smoke and NOx emissions are found highest for pure biodiesel.

A.V.Tumbal,et al.(2014) has studied on the feasibility of HOME in diesel engine and found that its performance is lower compared to diesel. By suitably adjustments made in the engine parameters such as injection timing, injector opening pressure, nozzle geometry and swirl intensity it is found that performance can be improved. Increasing the number of nozzle holes in the fuel injector from 3 to 4 improve the performance of the engine with reduced emissions for HOME operation. However further increasing nozzle holes reduced the engine performance.

Arulprakasajothi mahalingam,et al.(2017) has investigated that by adding octanol at a portion of 10% and 20% on volume basis to neat mahua oil biodiesel revieled that CO emissions decreases with increase in octanol in the blends. HC emissions decrease with increase in octanol in the blend. NO_x emission decrase with increase in octanol in the blends. Smoke emission decrease with increase in the octanol blend.

Present work:

In the current study an experimental investigation was carried out to study the effect of injector nozzle holes on diesel engine performance and emission characteristics fueled with Mahua Oil Methyl Esters(MOME) blends with diesel by volume 20%,40%,60%,100%and pure diesel. The experimental setup for this works was developed on a single cylinder, direct injection, water cooled compression ignition engine. The different nozzle holes of 2 hole, 3 hole and 4 hole were used for the study of various performance and emission characteristics of the engine.

The following are the important factors, which influence the choice of fuel:

- Viscosity of the fuel
- Density
- Calorific value

- Fire point and flash point
- Water and sediment present
- Ash content of fuel
- Ignition quality of fuel

THE PROPERTIES OF DIESEL FUEL AND MAHUA SEED BIODIESEL

The different properties of diesel fuel and Mahua seed biodiesel are determined and shown in table1. After transesterification process the fuel properties like kinematic viscosity, calorific value, density, flash and fire point get improved in case of biodiesel. The calorific value of mahua seed biodiesel is lower than that of diesel because of oxygen content. The flash and fire point temperature of biodiesel is higher than the pure diesel fuel this is beneficial by safety considerations which can be stored and transported without any risk.

TABLE -1: FUEL PROPERTIES

Fuel Properties	Diesel	Mahua-seed biodiesel	Apparatus used
Fuel density in	830	881	Hydrometer
Calorific value (kJ/kg)	42500	36963	Bomb calorimeter
Flash point in ^{o}C	56	196	Pensky-martien's apparatus
Fire point in ^{o}C	65	203	Pensky-martien's apparatus
Kinematic viscosity at $40^{o}C$ in cst	3.9	6.04	Redwood viscometer

IV. EXPERIMENTATION

Fig-3: Pictorial view of Experimental set up

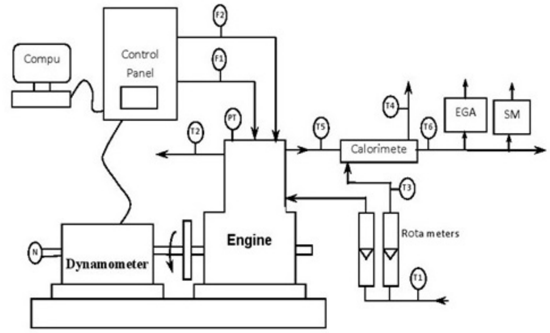

Fig -4: Line diagram of Experimental set up

TABLE -2: ENGINE SPECIFICATIONS

Sl No	Parameters	Specification
01	Manufacturer	Kirloskar oil engines Ltd. India
02	Model	TV-SR, naturally aspirated
03	Engine	Single cylinder, DI
04	Bore/stroke	87.5mm/110mm
05	C.R.	16.5:1
06	Speed	1500 RPM, constant
07	Rated power	5.2KW
08	Working cycle	Four stroke
09	Response time	4 micro seconds
10	Type of sensor	Piezo electric
11	Crank angle sensor	1-degree crank angle
12	Injection pressure	200bar/23 def TDC
13	Resolution of 1 deg	360 deg with a resolution of

V. RESULTS AND DISCUSSIONS

A. Introduction

This chapter consists of two types of experimental analysis at 180 bar injection pressure, with three different injector nozzle holes 2, 3 and 4. first one is performance characteristics like brake thermal efficiency, specific fuel consumption, exhaust gas temperature, against brake power, second one is emission characteristics like carbon monoxide (co), unburned hydrocarbon(HC), carbon dioxide (co2), NOx against brake power.

B. Performance characteristics of diesel, blends of Mahua seed biodiesel on diesel engine with 2, 3 and 4 injection nozzle holes

1. BRAKE THERMAL EFFICIENCY

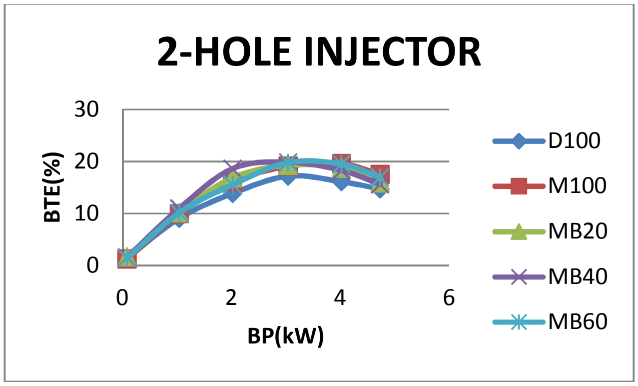

FIG -5: VARIATION OF BRAKE THERMAL EFFICIENCY WITH 2 NO OF HOLES

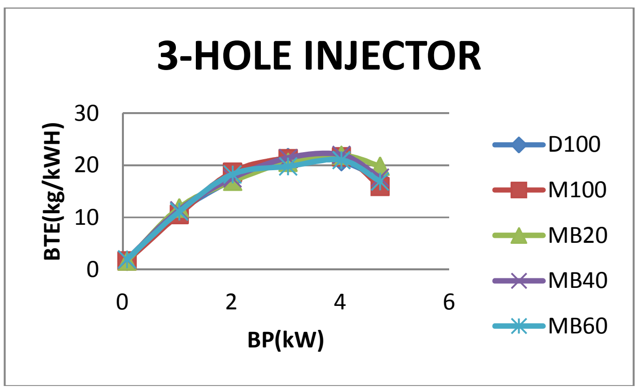

FIG -6: VARIATION OF BRAKE THERMAL EFFICIENCY WITH 3 NO OF HOLES

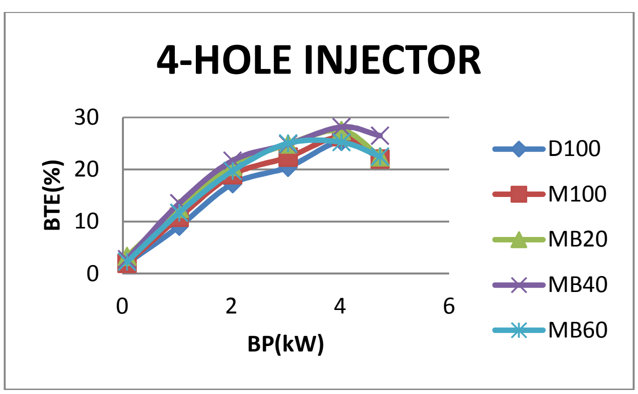

FIG -7: VARIATION OF BRAKE THERMAL EFFICIENCY WITH 4NO OF HOLES

The variation of brake thermal efficiency with no of holes for diesel and blends of Mahua seed biodiesel are shown in figures. For same injection pressure ,increasing the no of nozzle holes from 2 to 3 and 3 to 4 results in increased BTE. As MOME is more viscous than diesel and hence increasing the number of holes will ensure proper mixing of the injected fuel with air, which ensures improved fuel combustion process.

The BTE was found to be 28.15 % at 80 % load and its maximum value obtained with 4-hole nozzle at an IOP of 180 bar. The BTE reported for 3-hole and 2-hole nozzles were 22.03 % and 18.28 % at 180 bar respectively. In view of this, the results revealed that, BTE was found to be more with 4-hole nozzle.

2. SPECIFIC FUEL CONSUMPTION

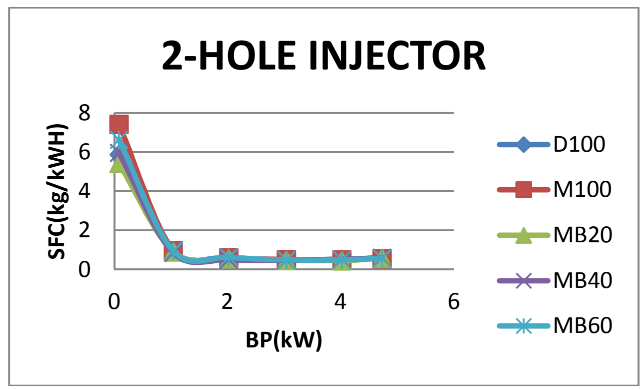

FIG -8: VARIATION OF SPECIFIC FUEL CONSUMPTION WITH 2 NO OF HOLES

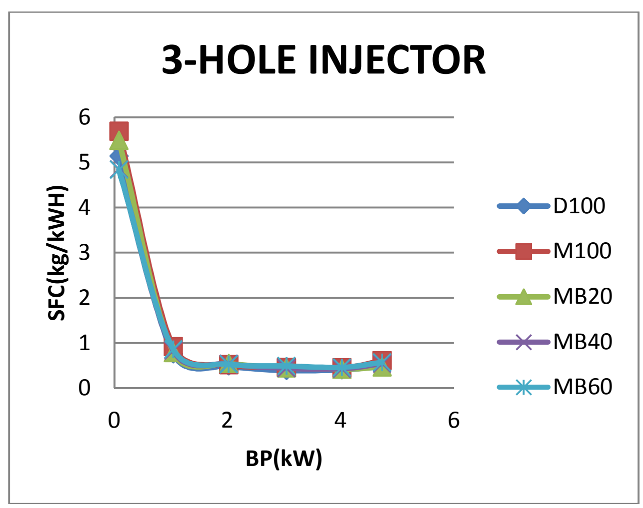

FIG-9: VARIATION OF SPECIFIC FUEL CONSUMPTION WITH 3 NO OF HOLES

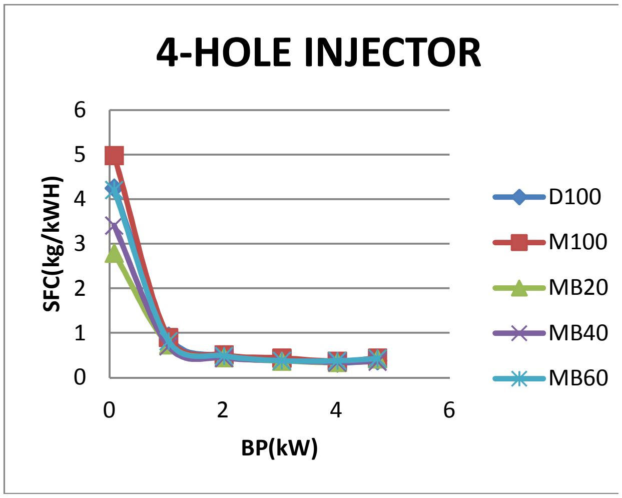

FIG -10: VARIATION OF SPECIFIC FUEL CONSUMPTION WITH 4 NO OF HOLES

The variation of specific fuel consumption with respect to BP for diesel and blends of Mahua seed biodiesel are shown in figures. For same injection pressure, increasing the no of nozzle holes from 2 to 3 and 3 to 4 results in decreased SFC. The power developed increases the specific fuel consumption decreases for all the tested fuels. The specific fuel consumption of mahua seed biodiesel blends 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.

C. EMISSION CHARACTERISTICS

1. Carbon monoxide

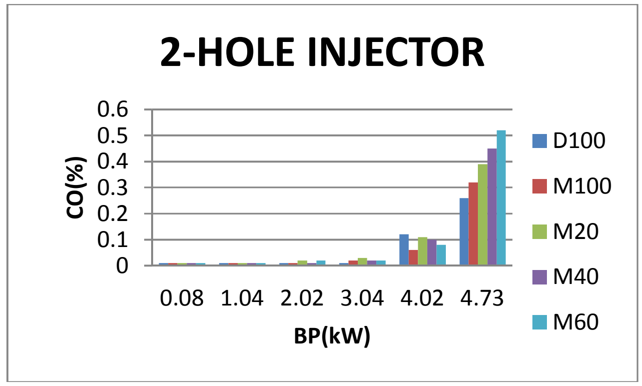

Fig -11: Variation of carbon monoxide with brake power.

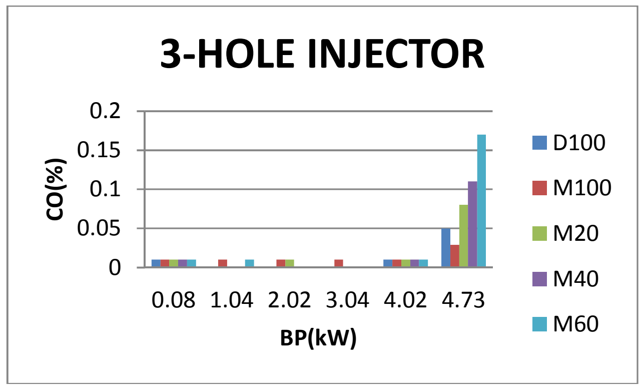

Fig -12: Variation of carbon monoxide with brake power.

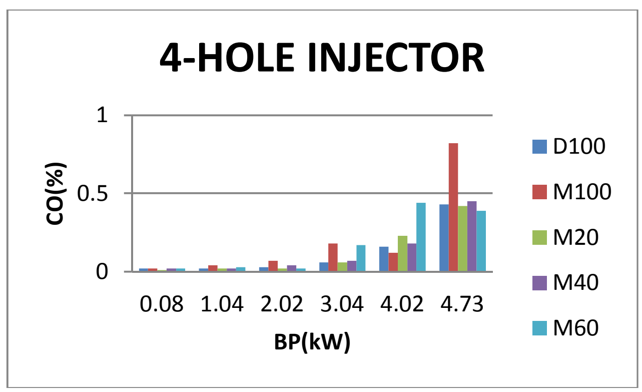

Fig -13: Variation of carbon monoxide with brake power.

Above figures shows the variation of carbon monoxide emission with brake power for diesel and blends of Mahua seed biodiesel for different nozzle injectors 2, 3, 4 respectively. The CO emission depends upon the strength of the mixture, availability of oxygen and viscosity of fuel. At low and middle engine loads, the percentage of CO emissions of biodiesel and its blends are higher compared to diesel. This may be due to relatively poor atomization and lower volatility of biodiesel. CO emissions were found to be lower at IOP 180 bar for 3-hole compared to 2 and 4-hole nozzle geometry respectively.

2. Hydrocarbon

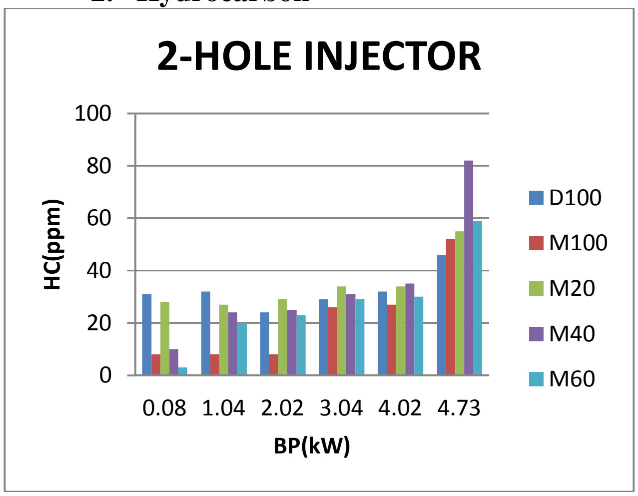

Fig -14: Variation of hydrocarbon with brake power.

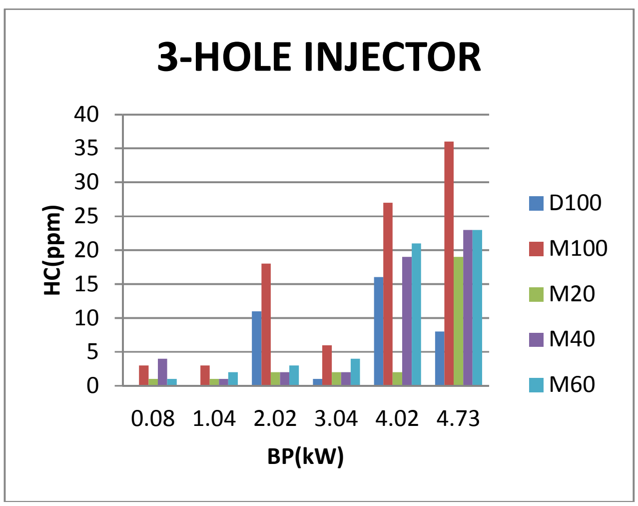

Fig -15: Variation of hydrocarbon with brake power.

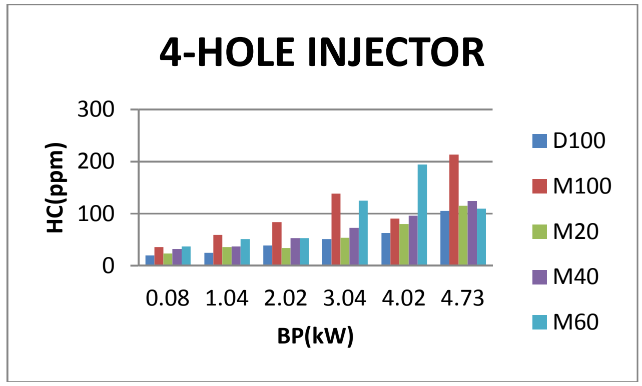

Fig -16: Variation of hydrocarbon with brake power.

Above figures shows the variation in the quantity of unburnt hydrocarbons with change in brake power for different nozzle holes. A significant drop in HC emission is observed with 3-hole nozzle geometry compared to 2 and 4 holes because of better combustion. It is observed from the figure that the emission of HC decreases as the diesel is substituted by biodiesel. Cetane number of biodiesel is higher than diesel, due to this it exhibits shorter delay period, which contributes to better combustion of fuel resulting in low emission of HC. Another reason can be the oxygen molecules present in the structure of biodiesel, which helps complete combustion of the fuel and hence decreases the HC emissions.

3. NO_X

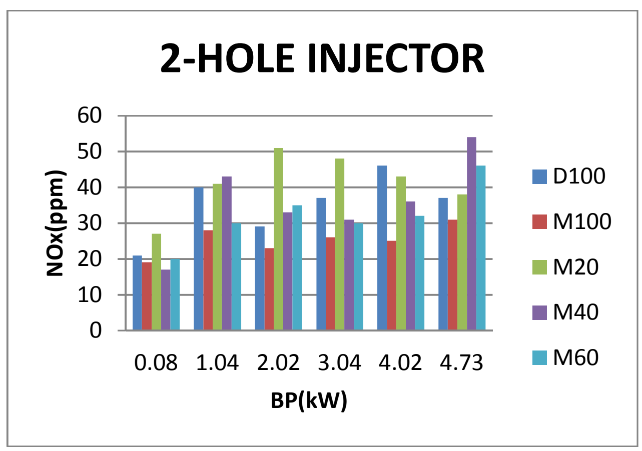

Fig -17: Variation of NO_X with brake power

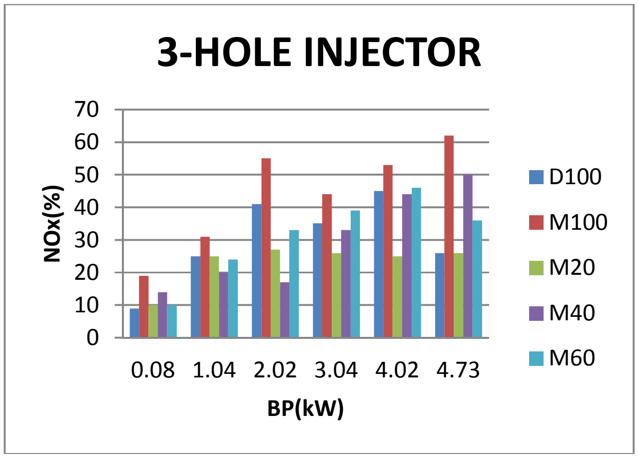

Fig -18: Variation of NO_X with brake power

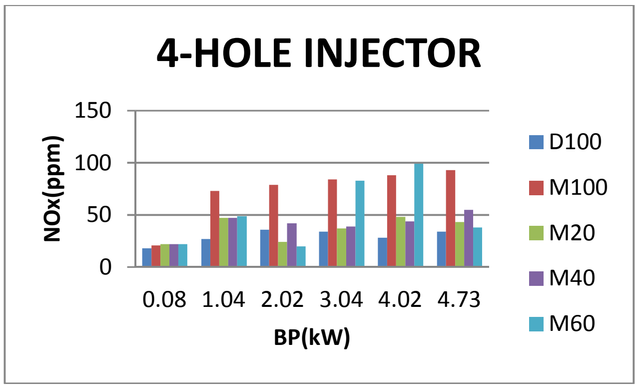

Fig -19: Variation of NO_X with brake power

Above figure shows the variation of nitrogen oxides emission with brake power output by varying number of nozzle holes. As the number of holes increases the NO_X emissions also increases. Maximum NO_X emissions are found in 4 holes as compared to 2 and 3 holes. This is the result of higher peak temperatures existing inside the combustion chamber in addition heat release rate during the pre mixed combustion stage increases the cylinder temperature causing higher NO_X concentrations.

VI. CONCLUSIONS

The injection nozzle holes of 2, 3 and 4 holes are used with diesel, MOME and blends as fuels for the experimental investigation. The most important conclusions of experimental results and based on literature survey on mahua tree is summarized as follows:

- The mahua tree has much important of its each and every part for commercial uses such as preparing of alcohol and edible items from flowers, furniture's from wood, medicines from roots, bark, leaves, and fruits, biodiesel production from seeds. To acquire benefits from mahua tree, the plantation of mahua tree is very much essential in a future generation.
- The properties of MME biodiesel were in the limits expect calorific value. The MME of other fuel properties were found to be higher than the diesel fuel. The chemical composition is more appreciable due to the O2 concentration present in MME.
- The present investigation reveals that MOME biodiesel is perfectly suitable as an alternative fuel based on the chemical composition and physical properties.
- The BTE increases with the increases in number of injector nozzle holes.
- The SFC decreases with the increase in number of injector nozzle holes.
- The HC and CO emissions were found to be lower for 3 hole injector as compared to 2 and 4 injector nozzle holes.
- The NO_X emissions were found to be increase as the number of injector nozzle holes increases.

At present scenario environmental protection is more important than fuel economy. So, decreasing the emission is the primary concern which require moderate injection nozzle hole for a light duty diesel engine. Hence, from the above results it is concluded that nozzle which is having 4 holes gives good performance results but with high rate of emissions.

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