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Combustion Behaviors of a Compression Ignition Engine Fuelled with Mosambipeel Blends Pyro oil using Ethyl Ether as an Additive

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***Abstract:**Diesel engines are principally employed in industries, transportation and agricultural fields because of their high efficiency and reliability. However, too much of smoke and nitric oxide emissions is one of the drawbacks. To regulate pollution and other negative effects of diesel engines, alternative fuels have come into existence. Ethanol produced from sugarcane in the biomass process is a recent example of it, due to its high octane number. But using raw ethanol is not a quality fuel for a solid ignition engine. It can be converted through a dehydration process to produce Diethyl Ether (DEE), which is an excellent compression-ignition fuel with a higher energy level than ethanol. DEE having a starting problem can't be used directly in large amounts in diesel engines, but using it in small amounts is an advantage. This paper highlights the performance of blended pyrolysis oil with diesel fuel in the combination of DEE used in a mono cylinder four-stroke diesel engine. The pyrolysis process was used to extract the pyro oil from the Mosambi peel biomass. The oil has been extracted from Mosambi peel at the reaction temperature of 750°C, in other words, the fast pyrolysis process. The study was conducted on composition of MDEE5 (5%MPPO+5%DEE+90D),MDEE10(10%MPPO+5%DEE+85% D) and MDEE15 (15% MPPO + 5%DEE + 80% D). Characteristics of the above combinations, MDEE5, MDEE10, and MDEE15 were analyzed and the properties like viscosity, density, flashpoint, fire point FTIR analysis of oils are also recorded. The blending of pyrolysis oil and DEE are mixed with diesel fuel with its volume. All the blended fuels were tested at 1500 rpm single-cylinder diesel engine. The maximum power output of brake thermal efficiency was recorded as 31.5% with MDEE5 as it was 30.0% with BD. The emission of smoke and NOx were considerably reduced.*

***Keywords:**Diesel Engine, Diethyl ether, Mosambi peel pyro oil, Engine performance and Emission.*

I. INTRODUCTION

The increase in prices of diesel reduced availability and made more stringent governmental regulations on exhaust emissions and the fast depletion of world-wide petroleum reserves provides strong encouragement to search for alternate fuels. It is generally acknowledged that noncontaminated combustion diesel engines can be achieved only if an engine is developed with fuel reformulation and the use of alternative fuels is implemented. In the name of energy security, regional air quality, and greenhouse gas emissions' reduction and use of oxygenated alternate fuels that advocates reduced emissions in diesel Engines. Pyrolysis of biomass may be defined as the direct thermal decomposition of the organic matrix in the nonappearance of oxygen obtained by an array of solid, liquid and gas products. The pyrolysis method has been used for commercial production of a wide range of fuels, solvents, chemicals, and other products from biomass feedstocks. The pyrolysis in liquids is a complex mixture of oxygenated aliphatic and Aromatic Compounds. Pyrolysis liquids are usually organic liquids in dark-brown color. These properties result in the chemical composition of the oils, which is significantly different from that of petroleum-derived fuels. Mosambi peel pyro oil is the bio-oil extracted from -mosambi peel, through fast pyrolysis technique by heating it in enhanced temperature in the absence of oxygen. Vegetable oil blends easily with diesel up to around 50% by its volume [1-4]. The mosambi peel oils are found to be a renewable natural resource of unsaturated phenols, with a long linear chain and a marked absence of an acaridic acid. The oil is completely miscible in diesel and is found to have a low corrosive effect and is possibly a potential fuel. The oil has low ash and water content. The properties of vegetable oil have been found to be amazingly nearer to that of petroleum fuels [5-6]. The vegetable pyro oil has a considerable smoke reduction and NOx emissions, and HC and CO emissions slightly increased with the vegetable fuel compared to BD at all power outputs [7-9].

II. PYROLYSIS SET UP AND EXPERIMENTS CONDUCTED

A. Working operation of Pyrolysis set

The reactor is made of steel and is placed on the floor with a temperature indicator.

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The outlet of the reactor is directly connected to the condenser using a stainless steel tube which can withstand high temperature. One of the inlets is connected to the reactor from the nitrogen cylinder. The condenser is firmly connected with the help of an alloy gasket. The Counterflow condenser was selected. The flow of water is directed against the direction of Pyrolysis gases. In this Pyrolysis apparatus, chipped mosambi peel is filled in the reactor initially, and then the reactor is closed with the help of a bolt. A gasket was used in order to prevent any leakage. Nitrogen gas was supplied from the cylinder to the reactor for a period of 3 to 4 minutes, and later it is closed. The electrical supply is switched on and is initially set at a temperature up to 600°C in the temperature controller. Water is supplied to the condenser from inlet to outlet. Gases are collected in the balloon. Finally, the time is noted when the temperature reaches up to 750°C. The cooling time of the reactor is 10 to 12 hours. Finally, the Pyrolysis oil, char, and syngases are collected.

Fig.1. Photographic view of pyrolysis setup

B. Preparation of pyro oil blends

Pyro oil can be prepared by mixing the mosambi peel with DEE and diesel fuel. For preparing them MDEE5 (5%MPPO+5%DEE+90D),MDEE10(10%MPPO+5%DEE+85%D) and MDEE15 (15% MPPO + 5%DEE + 80% D) were taken in a container. The mixture was stirred vigorously until a homogenous mixture was formed. The stirrer speed was maintained at 750rpm. Stable oil preparation was obtained by stirring the mixture for 20 to 25 minutes and the stability of the homogeneous mixture was found as stable for four months. The blending of oil was mixed with the help of a mechanical stirrer, and it is found that up to 15% of MPPO pyro oil with DEE, blends easily with diesel fuels, without any separation for a long time. MDEE5, MDEE10 and MDEE15 blends of mosambi peel pyro oil and DEE have low viscosity, density, flash point, fire point, and calorific value when compared to diesel fuel. All the pyro oil properties of blends are nearer to that of diesel fuel.

C. Ternary diagram

It is found that the MPPO blend is stable for around a week, In order to make it an effective fuel for the diesel engine, it is made into an emulsion.Ternary diagram is the graphical representation of the possible proposition by which an emulsion can be made. MPPO, DEE, and Diesel are blended together at different proportions as per the ternary diagram and the sample is considered for after a week to check its stability. It is found that a combination of around 15% of MPPO, 5% DEE and 80% of Diesel is found to be stable for one month and others above 15% samples get separated at different time intervals.

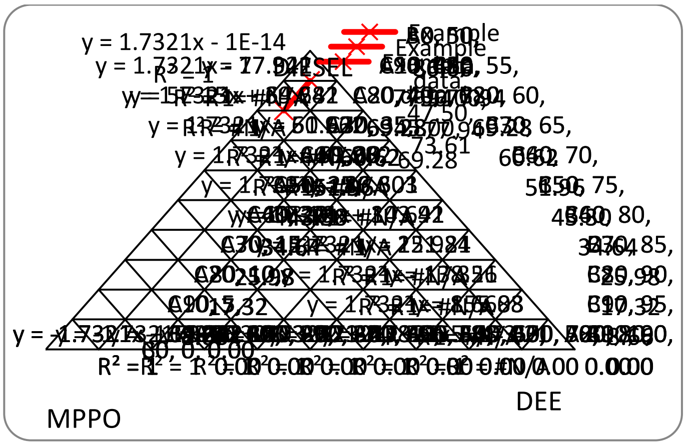

Fig. 2. Ternary Diagram of MPPO Emulsion

D. MPPO Biofuel FT-IR Analysis

FTIR is the largest and widely used equipment for the detection of functional groups in pure compounds and mixture and for compound comparisons. In terms of wavenumber, it extends from 500 cm^{-1} to 4000 cm^{-1}. The compounds absorb energy from a particular region since the vibrations are quantized. The position of a particular absorption bend is specified by a particular wavenumber. The graph which shows the variation of the percentage of transmittance with wavenumber (cm^{-1}) is called the infrared spectrum. In the range, 100% transmittance means 0% absorption and vice- versa. Atoms in a molecule can make stretching vibration as well as bending vibration in the sample of mosambi peel pyro oil and the spectra collect all the information at the same time and the computer with the assistance of Fourier transform program converts it into frequency domain spectrum. So direct structural analysis of samples within seconds is possible with the help of FTIR spectroscopy as given in figure 3.

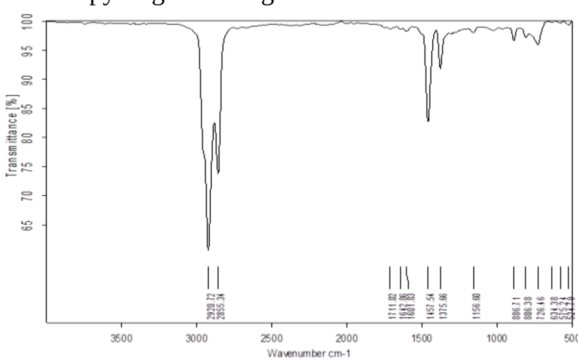

Fig. 3. Mosambi peel pyro oil FTIR analysis

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The MPPO pyrolysis oil obtained at a fast pyrolysis temperature of 750ºC was analyzed for its functional group compositional analysis by using Fourier transform infrared spectroscopy (FTIR). The C-H stretching vibration 2920.12 cm^{-1} and 2855.34 cm^{-1} indicates the presence of alkane compounds. The C-H stretching 1711.02 cm^{-1} indicates the presence of alkanes and alkynes strong C-H stretching. 1457.54 cm^{-1} indicates the carboxylic acid functional group strong broad and O-H stretching (please check the line). FTIR analysis shows that the mosambi peel pyro oil contains a number of HC present in the fuel which is helpful for combustion.

Table 1 shows the Properties of different fuels of all blends of pyro oil related to diesel fuel. All properties of blends show that they are near to diesel fuel. The blends of MDEE5, MDEE10, and MDEE15 show that viscosities of3.45, 3.56 and 3.69 Cst respectively.

Table 1 properties of different pyro fuel blends

properties	Diesel	MDEE5	MDEE10	MDEE15
Density (kg/m^3)	842	810	816	825
Flash Point (C)	50	42	45	47
Fire Point (C)	55	46	48	50
CalorificValue (MJ/kg)	43.5	42.65	42.10	41.89
Viscosity (cst)@50C	3.4	3.45	3.56	3.69
Water Content (%)	0	0.1	0.15	0.17

E. Engine Setup

A monotype cylinder (KIRLOSKAR), 4-Stroke, water-cooled, direct injection diesel engine develops a power output of 4.4 kW at 1500rpm. A water-cooled eddy current dynamometer was used for loading the engine. The test engine setup can be seen in figure 4.

Fig. 4. Experimental Engine set-up

The fuel stream rate was calculated on the volumetric basis by means of a burette and stopwatch. An AVL444 exhaust gas analyzer was used for measuring HC, CO, and NO in the exhaust. Black carbon smoke levels were measured by using an AVL smoke meter.Tests were conducted for four different loads such as 1kw, 2kw, 3kw and 4kw of the maximum power output with the fixed engine speed of 1500 rpm. All the tests were carried out with the injection timing of 27° before TDC for all the tested fuels. All the tests were repeated three times to get an optimum value. Initially, the diesel engine was run on diesel fuel. Then the engine was run on MDEE5, MDEE10, and MDEE15 fuel blends.

III RESULTS AND DISCUSSION

A. Performance Characteristics

The figure5 shows that variation of brake thermal efficiency of diesel, MDEE5, MDEE10, and MDEE15 fuel. There is a gradual increase in MDEE5 when compared to diesel. However, there is a significant increase in the thermal efficiency in MDEE5 with diesel blends. Adding 5% DEE to Mosambi peel pyro oil diesel blends. (check the line) .The results indicate that the addition of DEE increases the thermal efficiency marginally due to the higher heating value of DEE. Mosambi peel pyro oil has a heating value higher than diesel which results in higher peak cycle temperature. MDEE10 and MDEE15 fuel show reduced peak cycle temperature compared to diesel fuel. The usage of blended vegetable oil as a fuel indirect injection diesel engine suffers from problems of incomplete combustion and low brake thermal efficiency due to high viscosity [10-15].

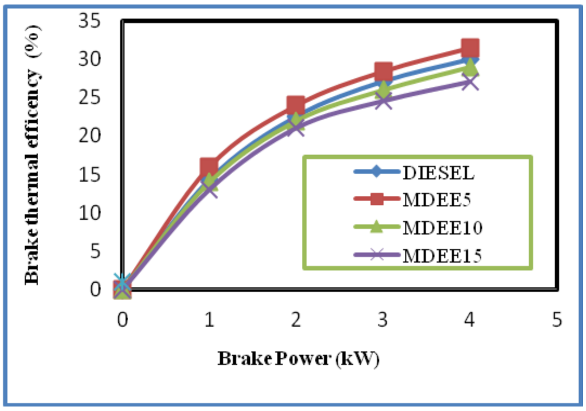

Fig.5. Brake power vs Brake thermal efficiency

Figure 6 shows the variation of brake specific fuel consumption with brake power output for diesel, MDEE5, MDEE10, and MDEE15. The trends show that the performance of all blends is quite similar to diesel fuel. MDEE5 a blend of mosambi peel pyro oil has the lowest BSFC compared to the other blends, mainly due to the higher calorific value of the mosambi peel pyro oil with DEE and diesel fuel blends. At rated load, the BSFC of MDEE5 is lower compared to diesel. This phenomenon was observed due to lesser viscosity and density of fuel blends.

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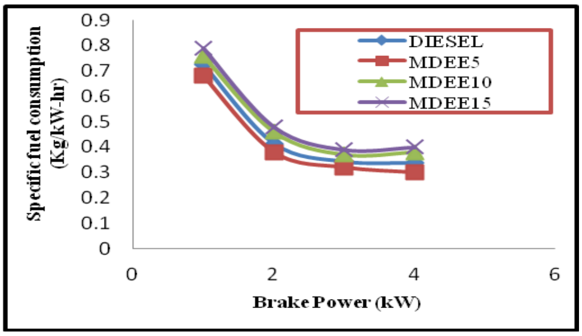

Fig. 6. Brake power vs Specific fuel consumption

B. Emission Characteristics

Figure 7 shows the variation of HC emission with brake power output for mosambi peel pyro oil is due to poor combustion of MDEE10 and MDEE15. The HC emissions are on the higher side. The addition of DEE in the mosambi peel oil in the blend enhances the unburning combustion and hence the HC emission is increased. On the other handMDEE10 and MDEE15, the viscosity and density are quite high when compared to diesel, which will result in poor atomization, increasing the HC emission.

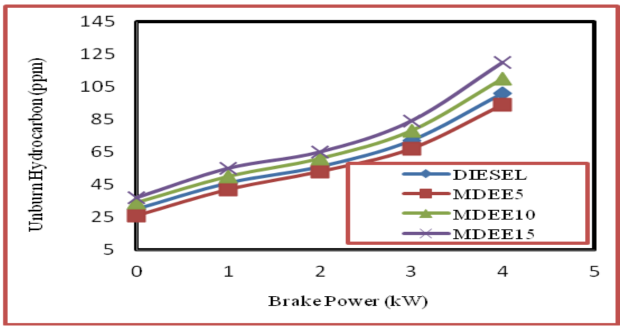

Fig. 7. Brake power vs unburned hydrocarbon

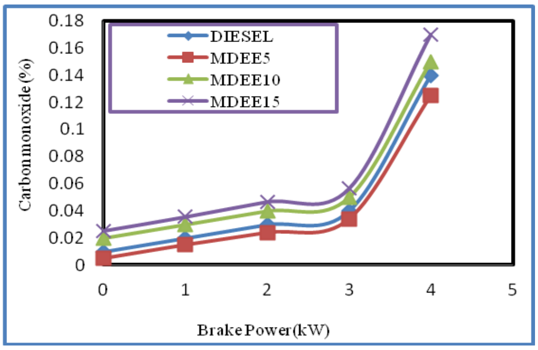

Fig. 8. Brake power vs Carbon monoxide

In this phenomenon, the formation of a rich air-fuel mixture plays a vital role. The variation of CO emission with load is shown in figure 8. It is observed that the CO emission increases with the load. MDEE5 produces lesser CO emission as compared to diesel. In order to reduce CO emission further mosambi peel is blended with DEE oxygenated fuel where there is a drastic reduction in CO level as compared to diesel. This is the result of the complete combustion of the fuel. On the other hand in other fuels, MDEE10 and MDEE15 show that high CO emissions are recorded compared to diesel and MDEE5 because of the insufficient oxygen present in the blended fuels.

Figure 9 shows the disparity of nitrogen oxide release with brake power output for mosambi peel pyro oil and its blends with diesel in the test engine. MDEE5 and diesel have higher NOx emission compared to the other two blends. It is inferred that MDEE5 produces higher oxides of nitrogen emission as compared to diesel. Although the literature[21-23] survey suggests that NOx emission with this mosambi peel pyro oil would be high, it is observed that NOx emission shows a favorable trend. This is due to the basis of the slow-burning rate of NOx which is very sensitive to the maximum temperature of MDEE5 which has relatively higher heating value and cetane number. As compared with mosambi peel pyro oil and diesel, this results in a longer delay period. However when MDEE5 and dieselblend give higher NOx emission due to peak cycle temperature as compared to other fuels.

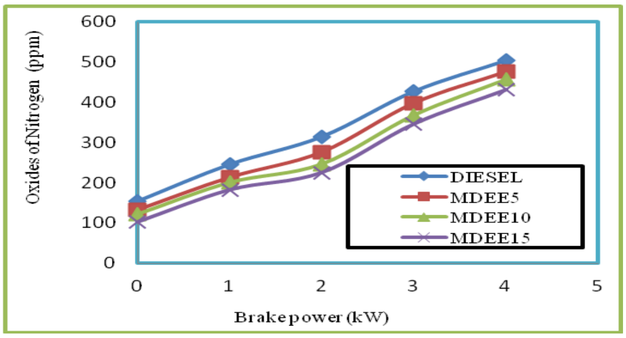

Fig. 9. Brake power vs Nitrogen oxide

Figure 10 shows the variation of Smoke emission with brake output for mosambi peel pyro oil and its blends with diesel and DEE. All MDEE5, MDEE10 and MDEE15 blended experience lower smoke emissions as compared to diesel, due to its viscous nature which results in poor atomization and thus paves way for reduced premixed combustion and prolonged diffusion combustion. This effect is due to incomplete combustion which leads to all blended fuel. There are significant reductions in nitric oxide (NO) emissions by 2.5% when fuelled with X_1JOE15. The smoke opacity decreases by 25%, 26.7%, 22.1% and 18.2% for JME and its emulsions with WPO respectively, in comparison with diesel at full load [16-20].

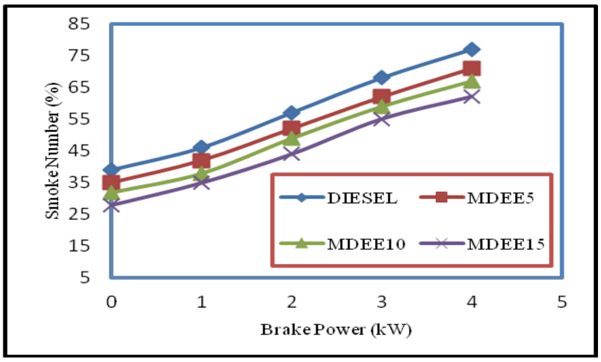

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Fig. 10. Brake power vs Smoke emission

IV. CONCLUSION

1. From the experimental work carried out, it is observed that the engine is able to run on 15% of pyrolysis oil, 80% of diesel fuel and 5% of DEE. Engine failed to run satisfactorily with above 15% of pyrolysis oil blends.
2. Brake thermal efficiency increases with an increase in the percentage of blends but MDEE5 shows a slightly higher level than that of diesel fuel.
3. Specific fuel consumption gradually reduced with increasing load. An MDEE10 and MDEE15 blend show a higher level than that of diesel fuel.
4. HC emissions are MDEE5 emission is very low at fuel load compared to diesel fuel. HC emission is slightly higher at peak load for MDEE10 and MDEE15 blends.
5. CO emission is higher than that of diesel fuel. This may be due to the fuel-air mixture filled inside the cylinder which is very weak and the flame will not propagate through the cylinder.
6. NOx is lower by about 12.5% for MDEE5, 13.1% for MDEE10 and 14.0% for MDEE15 full load operation than that of diesel fuel.
7. The smoke opacity of MDEE5, MDEE10, and MDEE15 are lower than the smoke opacity of diesel fuel.

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