Experimental investigation on a CI Diesel Engine fuelled with Mosambi peel bio-oil blended Toluene Emulsions

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Abstract

In the current state, the incredible rise of the cost of Diesel fuel, stringent emission regulations, and the reduction of petroleum reserves are driving us to search for new sources of energy. Fossil fuels are the cheapest and the majority abundant source for petroleum and thus lead to the growth of gazillions of petroleum-established products. So, the NO_X emission was raised. The work within this project mainly focuses on the act of blended Pyrolysis oil with Diesel fuel and toluene oil which was used in a single-cylinder, Four-stroke Diesel Engine. The Pyro oil was extracted during the pyrolysis process as of the Mosambi Peel biomasses. All the bio-oil properties were studied with the fuel blends used within this experiment were MPOT5 (5%MPO+5%TU+ 90D), MPOT10 (10%MPO+5%TU+85%D) and MPOT15 (15% MPO + 5%TU + 80% D). Characteristics of fuel for Diesel, MPOT5, MPOT10, and MPOT15 are analyzed. The blending test of Pyrolysis oil and toluene was done by mixing diesel fuel by volume. The flashpoint, fire point, Viscosity, Density of oils was observed. The entire blended pyrolysis fuel was tested in a 1500 rpm single-cylinder water-cooled Diesel Engine for testing their performance like blend fuel. The test results show the performance of all MPOT5, MPOT10, and MPOT15 associated with diesel fuel. The highest power output of the brake thermal efficiency is found to be 31.2% with MPOT5 and whereas it was 30.5% with BD respectively. There be a narrow decline for the Smoke and NOx Emissions and HC and CO emission slightly which reduces the chances of MPOT5 while fuel compared to BD at all Power outputs.

Keywords: Mosambi peel Pyro Oil, Toluene oil emulsion, Diesel Engine, Engine Performance, Exhaust Emission.

1. Introduction

The Internal combustion Diesel engine has Exhaust emissions and Global Warming has generated intense interest in developing alternative non-petroleum fuels for Engines. Large quantities of toluene are available throughout the world. Estimates of the quantity of toluene produced in India range from 1.2 Billion to 2.5 Billion gallons per year. It is an aromatic hydrocarbon and hence it has high hydrogen content, so it is very useful to improve efficiency [1-4]. Toluene is Renewable, non-toxic, and Biodegradable and it is properties are comparable with Diesel fuel.

Diesel Engines include been designed to run over a wide range of heavy to light hydrocarbon fuels. The consumption of biomass materials as a Renewable Energy cause is attracting Global attention over the previous two decades and this is much more predominant in countries where Agricultural activities are rich [5-8]. Bio-oil fuels are Renewable Energy fuels coming from biological raw materials and have proven to be good substitutes for oil in the automobile sector. Biodiesel can be blended in any proportion with Petroleum Diesel fuel. It does not require a divided infrastructure for storage of the Bio-oil. The use of bio-fuel in conventional Diesel Engines results in a considerable reduction of NOx, HC, CO, and Particulate matter. Biofuel is considered to be clean fuel since it has almost no Sulfur contents, and has above 15% built-in Oxygen, which helps it to burn entirely its greater amount of cetane number to improve the combustion even when blended in the Diesel fuel. Because of its combustion characteristics biofuel can be worn as fuel for Diesel Engines there is a reduction in Smoke and NOx Emissions, and also HC and CO Emissions are lightly increased [9-10]. Beyond 15%, the separation was noticed and therefore the quantity of Mosambi peel pyro oil used was limited up to 15%. The work was performed on a Single-Cylinder Diesel Engine using the MPOT5, MPOT10 and MPOT15 prepared with the volume of Mosambi peel Pyro Oil and toluene to examine the Performance of the Engine. All the blend fuel results were compared with conventional Diesel Fuel and analyzed.

2. Pyrolysis set up and Experiments conducted

2.1 Working Operation of Pyrolysis Set

The Pyrolysis Reactor arrangement consists of a Square-shaped thermal Reactor which is made of Copper with a thickness of 0.8 cm. The reactor has an inlet for supplying Nitrogen gas (1.01kg/cm^2)

and transfers unstable gases at the outlet. The outlet of the Reactor is directly linked to the condenser using an Aluminum tube which can hold out temperatures. The Aluminum condenser is used for the condense process of a Counterflow and is coupled to the gas-liquid separator unit. The condensate Pyrolysis liquid dripped into the gas-liquid Separator. The non-condensable gas was exit through the exhaust tube to attach the gas burner. An auto controller chromel-alumel thermocouple connected with a Digital temperature indicator was used to compute the temperature inside the reactor. The Nitrogen gas is supplied into the reactor to purge the oxygen present in the reactor to reduce the burning inside the reactor. Initially, the Mosambi peel was cut into tiny pieces and dried in the sunlight. The dried Mosambi peel is then fed into the reactor through the feeder of the pyrolysis reactor. The pyrolysis reaction was executed at a temperature of about 625°C. The Vapor up coming out from the Pyrolysis reactor was allowed to pass through the Aluminum condenser which acts as a counter-flow type heat exchanger and condenses the circulating Cooling water. The Mosambi peel pyro oil is then collected in a steel container. Extracted pyro oil is then purified and analyzed for its physical and chemical properties to be used as a pyro fuel.

2.2 *Preparation of pyro oil blends*

Pyro oil can be prepared by mixing the Mosambi peel Pyro oil with toluene and Diesel fuel. For preparing them MPOT5 (5%MPO+5%TU+90D), MPOT10 (10%MPO+5%TU+85%D) and MPOT15 (15% MPO + 5%TU +80%D) were taken in a container. The blend was stirred vigorously until a homogenous blend was formed. The stable oil was obtained by stirring the mix for 15 to 20 minutes and the stability of the homogeneous blend was found to last for a minimum of four months. The blended oil was mixed with the help of a mechanical stirrer, and it is found that up to 15% of Mosambi peel pyro oil with toluene blends easily with Diesel fuels, without any separation. MPOT5, MPOT10 and MPOT15 blends of Mosambi peel pyro oil and toluene have low Viscosity, Density, Flashpoint, Fire point, and Calorific value when compared to the Diesel fuel. All the pyro oil properties of blends are nearer to that of the Diesel fuel.

Table 1. Properties of Different Pyro Fuel blend

Properties	Neat Diesel	Neat MPO	Toluene	MPOT5	MPOT10	MPOT15
Density (kg/m^3)	840	926	832	865	885	895
Flash Point (C)	52	61	6	57	61	64

Fire Point (C)	56	67	11	63	65	69
Calorific value (MJ/kg)	43.50	44.0	42.5	44.0	42.85	41.26
Viscosity (cst)@50C	3.41	6.3	3.5	4.3	5.3	5.9
Water Content (%)	0	5.5	0	1.0	1.5	1.75

2.3. Engine Setup

A Monotype Cylinder (KIRLOSKAR), Four Strokes, water-cooled, direct injection Diesel engine which develops a power output of 4.4 kW at 1500 pm. A water-cooled Eddy current Dynamometer is used for giving a load to the engine. The test engine arrangement can be seen in figure 1. The Diesel fuel flow rate was calculated on a volumetric basis using a Burette.

Figure 1. A photographic view of the experimental engine set-up

An AVL 444 exhaust gas analyzer is used for measuring HC, CO, and NO in the exhaust in this work. Black Carbon Smoke levels were calculated by AVL Smoke meter. Tests were conducted for five different loads such as 1 kW, 2kW, 3kW, and 4kW of the maximum power output with the engine speed of 1500 rpm. All the tests with blended fuels were carried out with the Injection timing of 27^{o} before TDC. The above-conducted tests were repeated three times to get an optimum value. First, the test was conducted using only Diesel fuel, then the engine was run with MPOT5, MPOT10, and MPOT15 fuel blend.

3. Results and discussion

3.1 Performance parameters

The tests were done at different loads 1 kW, 2kW, 3kW, and 4kW with static injection timing 27˚ BTDC at the rated injection opening pressure of 180 kg/cm^2. The specific fuel consumption and the brake thermal efficiency can be calculated with the help of the engine speed, torque, and mass of the fuel consumption. Fig. 2 and 3 show the SFC and the BTE fluctuations under different brake power for 1500 rpm. The SFC of the blended pyro oil MPOT10 and MPOT15 was slightly increased as compared to diesel fuel and for MPOT5 it's slightly lower than diesel fuel. This occurs due to the influence of viscosity, density, and mixture formation of cashew shell pyro oil and toluene blends of pyro oil [11-14]. The increase in the percentage of pyro oil causes the calorific value to decrease. Hence MPOT5 blend gives less SFC when compared to MPOT10 and MPOT15.

From the results achieved, BTE increases with an increase in brake power. The BTE of all MPOT10 and MPOT15 blends of pyro oil is lower than that of diesel fuel. This is mainly because of the high viscosity and density of MPOT blends. MPOT5 blend gives a slightly higher BTE than compared to other fuels namely MPOT10 and MPOT15. Hence because of an account of the secondary atomization of fuel resulted in better mixture formation. For the maximum power output, the brake thermal efficiency was found to be 31.0% with MPOT5 and 30.5% with diesel fuel respectively.

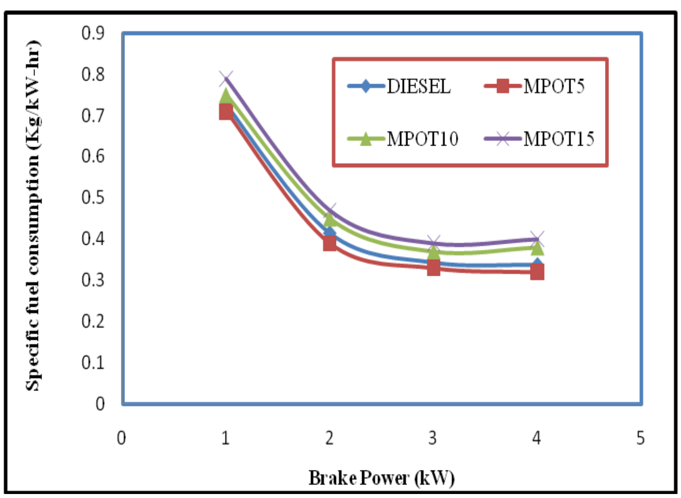

Figure. 2 Comparison of Specific fuel consumption with Brake power

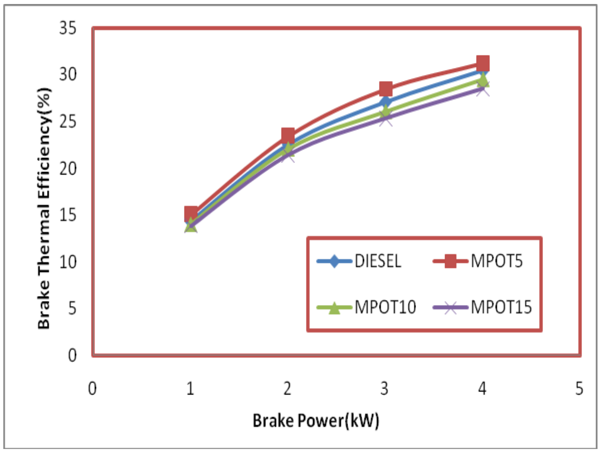

Figure 3. Comparison of Brake thermal efficiency with Brake power

Figure 4. Illustrates exhaust gas temperature with brake power. It is clear from the figure that as brake power increases, the exhaust gas temperature also increases with all the pyro oil fuel blends. The exhaust gas temperature rises with an increase in the volume of pyro oil diesel blends. The increase in the exhaust gas temperature was observed due to the higher viscosity and density of the oil than diesel fuel [15-20]. The increase in exhaust gas temperature of MPOT10 and MPOT15 blended with these fuels is due to more complete combustion in the diffusion stage.

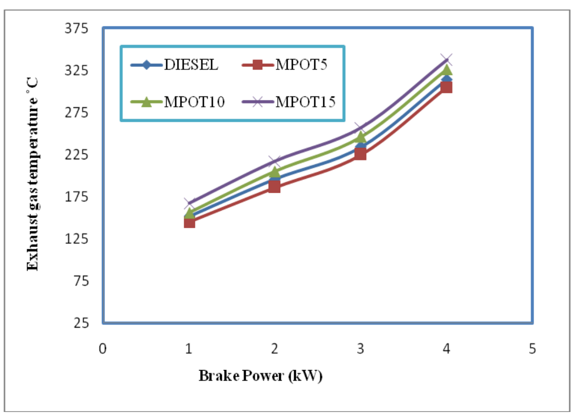

Figure4. Comparison of Exhaust gas temperatures with Brake power

3.2 Emission Characteristics

The smoke emission analysis from the burning of diesel fuel and pyro oil blends is shown in figure 5. From the figure, it can be seen that smoke level increases with an increase in engine power. It can be seen that the level of smoke emission was found to be lower for all the pyro oil blends at all power outputs after compared to diesel fuel operation. This reduction in smoke emission with blended pyro oil is due to the presence of oxygen in-build with the fuels. The high oxygen content in the mosambi peel pyro oil helps in secondary atomization which in turn helps to occur in the combustion process. The lowest smoke emission was found with MPOT5 as 69 ppm then followed by MPOT10 as 67 ppm and CPOT15 as 63 ppm. In diesel fuel operation, smoke was found to be formed at 72 ppm.

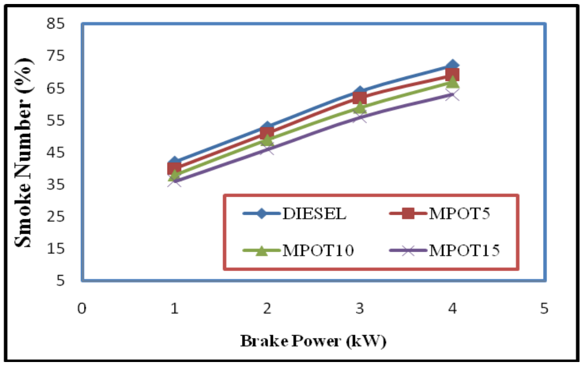

Figure 5. Comparison of Smoke emissions with Brake power

All the Pyro oil blends result in a substantial reduction in NO_X emissions in contrast to the diesel fuel as shown in figure 6. Because of the presence of oxygen, there happened to be built-in fuel blends which reduced premixed burning followed by ignition delay. Low heat release was attained by the pyrolysis oil due to the increase of the oil percentage in fuel blends [21-22]. For the maximum power of 4.4 kW, the NO_X emission was found as 426 ppm, 478ppm, and 498 ppm respectively with MPOT5, MPOT10, and MPOT15. Whereas it was 458 ppm with diesel fuel. MPOT5 shows that 426 ppm when compared with diesel fuel. The reduction in NOx emission is due to the amount of air-fuel ratio of the injected fuels and slightly higher heating value for the given power output.

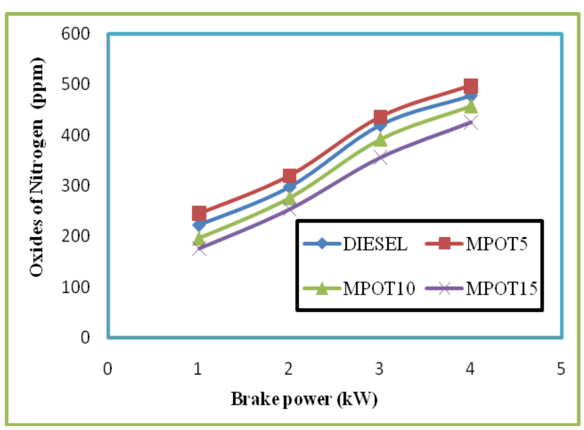

Figure 6. Comparison of nitrogen oxide with Brake power

The dissimilarities found in hydrocarbon discharge with brake power of MPOT5, MPOT10, and MPOT15 are shown in figure 7. The figure shows that all the MPOT10 and MPOT15 tested fuels resulted in slightly more HC emissions at all operating conditions after being compared to diesel fuel operation. The most probable cause may be the minute fraction of the fuel-air blend in the combustion chamber when it comes in contact with the combustion chamber wall and quenching occurs [23-25].

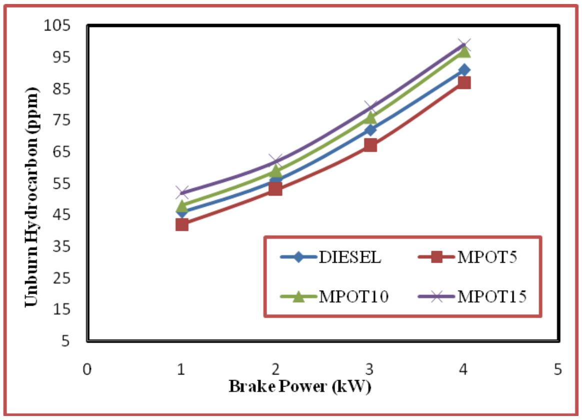

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Figure 7. Comparison of Hydrocarbon emissions with Brake power

At peak load, the hydrocarbon emission was found to be 97 ppm and 99 ppm respectively for MPOT10 and MPOT15. This is due to more amount of hydrocarbon emissions with the pyro-oil blends as the high latent heat of vaporization of water is present in the fuel. But MPOT5 blending fuel resulted in fewer hydrocarbon emissions as compared to diesel fuel. It was noted as 91 ppm with diesel fuel and 87ppm for MPOT5.

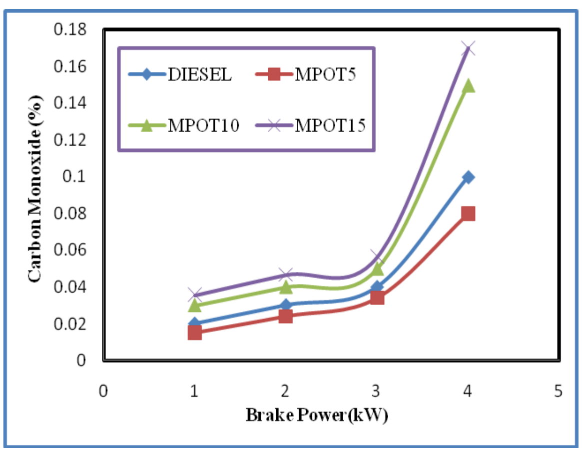

Figure 8. Comparison of Carbon monoxide emissions with Brake power

Figure 8. indicates the test outcomes of carbon monoxide emissions of MPOT5, MPOT10, MPOT15, and diesel fuel at various engine power outputs. All MPOT10, MPOT15 pyro oil blends led to more CO emissions when compared to MPOT5 at various power outputs. The highest CO emission was

found to be 0.15% and 0.17% for MPOT10 and MPOT15 respectively at the power output of 4.4 kW. It was noted as 0.1 % for diesel and 0.08% for MPOT5. The CO discharge from MPOT10 and MPOT15 was due to the inadequate oxygen present in the pyro oil fuel blends which results in partial oxidization of carbon in the blended fuel.

4 Conclusions

The engine does not run while using pure waste Mosambi peel pyro oil due to its high viscosity and density of the fuel. Mosambi peel pyro oil has higher efficiency than diesel and due to the less amount of emissions produced.

1. All Blends of pyro oil with diesel blends are MPOT10 and MPOT15 resulted in incomparable performance with a slight reduction in BTE at all power outputs.
2. MPOT5 indicated a slight increase in BTE as compared to the other two blends.
3. The significant reduction of NOx and smoke emissions MPOT10 and MPOT15 show that the HC and CO emission showed slightly increased than diesel fuel.
4. Use of Mosambi peel pyro oil and toluene blends can be used as alternative fuels in diesel fuel without engine modification and partial replacement of diesel by pyro oil blends with diesel.

5. References

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