Study of Regulated and Unregulated Emission of Diesel Engine using Biodiesel

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Abstract-This research deals with the diesel engine and its performance characteristics and exhaust (regulated and unregulated) emission characteristics fuelled with Karanja biodiesel and diesel fuel. The regulated emission experimental results indicated the decrease in the value of CO with increasing BMEP while NOX & Smoke showed the increment in the values with increase in BMEP and HC results indicated higher emission for both biodiesel as well as diesel fuel. On the other hand, the unregulated emission results indicated continuous increase in benzene and toluene emission from higher to lower rpm while continuous decrease in poly xylene emissions. With the increase in percentage biodiesel in diesel engine result in increase the O2 content in the biodiesel blend showed complete combustion of fuel and conversion of CO to CO2.

In this research work, the comparison was made between the performances of diesel engine by using biodiesel and diesel fuel. The results showed the experimental values of Benzene, Poly xylene , Toluene, CO, HC and NOX emission for performance and exhaust emission characteristics.

Further study in this paper showed that unregulated and regulated emission with biodiesel gave better performance. Thus, biodiesel can be considered as a promising alternative fuel than diesel for diesel engine performance and exhaust emission characteristic.

Keywords: Emission, Benzene, Xylene, Toluene, CO, HC, NOx, Smoke.

I. INTRODUCTION

The growing concern about the depletion of fossil fuels resources, along with environmental pollution due to increasing in the amount of fossil fuel resources combustion and continuously growing the need for energy is a severe problem which causes great danger to the present world and affects the future.[1]

However, the increase in energy conservation with the awareness of environmental protection all the way through the global world, by giving a guideline to the research and development of the diesel engine to use clean, reliable and good quality of alternative fuels which will turn out to be an important subject. Renewable resources utilized in energy production which is considered to be better in comparison to nonrenewable resources, in order to the preservation of atmosphere, protection of various fuel resources, reduction and stability of emissions are of major importance.

At present, fossil fuels resources try to satisfy the world's primary energy consumption, which is increase with the rising population and transformation. The dramatic growth of greenhouse gases emission and other engine emissions take place which had created major serious environmental problems. Therefore, the growing concern toward these problems has been made to find and use the good alternative fuels to overcome the economic recession and environmental impact of non-renewable energy sources consumption around the world.

Moreover, the engine exhaust emissions (regulated and unregulated emission), as well as GHGs, came into existence due to combustion of fossil fuel, thus, there is about 22% of greenhouse gases emission that comes from transportation sector using petroleum fuel which is predicted by IEA (International Energy Agency) that, emissions will be increased between 1990 and 2020 up to 92% and estimated that 8.6 billion metric tons of CO2 will be emitted in the environment from 2020 to 2035, Since, vehicular emission consist of PM, HC, CO2, CO, and NOX exhaust parameters which are highly responsible for serious air pollution (including NOX, CO, HC, Smoke) that is having a gradual undesirable effect on a human life and its surroundings.[3]

Some exhaust unregulated emissions contain alkanes, aldehydes, benzene, toluene, xylene (BTX), alcohols and ketones. [4] The unregulated emissions of toluene and xylene decrease whereas benzene emissions increase with the increase in biodiesel blending.[5]

Thus, surrounding preservation mainly focuses on the reduction in Smoke and NOX emission parameters from a diesel engine. The transport sector is undergoing a rapid revolution in order to comply with these regulations.[6] The methods which are used to reduce emissions are DPF and SCR were used to reduce harmful emissions of NOX and PM respectively. The method which is used is based on valuable and costly metals used as catalysts[7]. In order to reduce diesel consumption and emission of different harmful ingredients, the use of alternative fuels has to be encouraged because of being environmentally friendly, clean-burning and economical as a fuel.[8]

However many alternative fuels have been derived such as bio-diesel from plant oils, which produce an insignificant amount of net greenhouse gases emissions rather than

Diesel. Countries which collect fuels from their own vegetable and animal reserves are known as biofuels. Biofuels consist of all kinds of fuels which are in liquid as well in gaseous state and derived from vegetables and animals. Biodiesel that can be obtained through oil acid and methyl ester produced from animal and vegetable oils and also from oil waste and debris.[9]

Biodiesels have a high flash point than diesel fuel and various other properties of biodiesels enable to be more reliable fuel to use and safer to transport and store. Biodiesel can be blended with petroleum origin diesel fuel which raises the quality of diesel fuel of petroleum origin. It reduces the exhaust emission by a vehicle driven by biodiesel blended with diesel fuel of petroleum origin as a result of burning in combustion. However, biodiesel can be produced by several methods, the most commonly used method today is trans-esterification, as it is an eco-friendly, clean and renewable fuel. [10]

The production made by crude oil during the year 2015-16 was 36.950 Million Metric Tonnes (MMT) as against production was 37.461 in the year 2014-15 which shows a decrease of 1.36% [11]. The data for the production of crude oil have been depicted in figure 1.

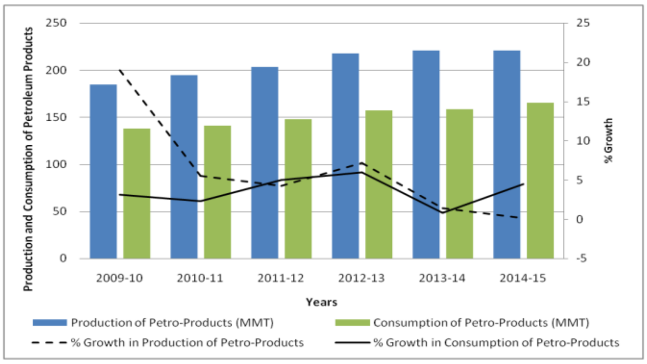


Figure 1.1 The production of crude oil.

Total OECD production of crude oil, natural gas and refinery feedstock degraded by 4.2% in 2016 compared to 2015. Overall, total OECD production downfallen by 1.9% in 2016 compared to 2015 [12].

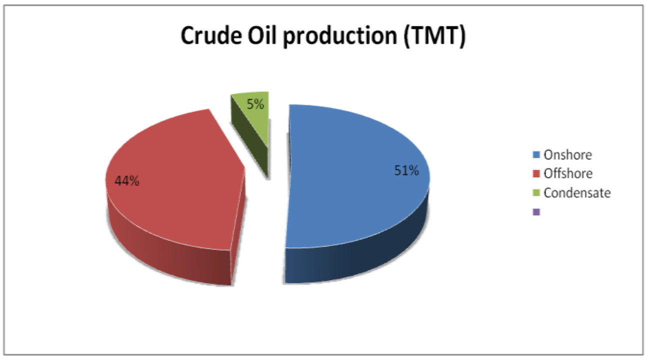


Figure 1.2 Total OECD production of crude oil [11]

Both biodiesel and ethanol are the category of renewable energy and can be synthesized from various crops, plants, recycled waste, and residue. Since existing engine can be modified to utilize pure biodiesel (100%) but it is not considered in this study. However, biodiesel and ethanol are the alternative fuel which is used as a diesel-alcohol blend in which the alcohol part is mainly produced by the hydrolysis and fermentation of cellulose, sugar, and starch. Biodiesel blending with ethanol results in a reduction of hazardous emissions because Ethanol is an oxygenate additive and helps to enhance the octane number along with the increment of O2 content which results in better combustion efficiency.[13]

Research had shown that BSFC and exhaust emission of nitrogen oxide were enhanced while BTE, smoke, emission of carbon monoxide and hydrocarbon were decreased with bio diesel-ethanol blends and also adding of ethanol in petroleum origin diesel fuel with certain proportion result in improving the engine power as well as SFC and reduces the exhaust emissions whereas in few cases ethanol blended with biofuels to reduce the viscosity.

Diesel and Biodiesel along with their blends as fossil fuels are widely used in industry, agricultural field and also in the transportation sector, and have various performance and vibration characteristics in the IC engines. With the addition of biofuels to the fossil fuels has an interesting effect on the mentioned characteristics. Ethanol is considered as a renewable fuel all over the world, which is obtained from decaying plants, sugary and starchy biomass. Ethanol can be used as an additive to diesel and biodiesel fuel which can improve the engine performance and reduce emissions and smooth running of the engine which will have a considerable effect on the vibration analysis. A reciprocating and rotational engine having many movable which are the main source of engine vibration component and other source is an explosion of fuel in combustion chamber. The factors on which vibration depends are engine speed, type of fuel and fuel injection method. Vibrations on spark ignition and compression ignition engines have been studied in order to achieve minimum vibration. The combustion of the fuel inside the combustion chamber causing vibration and sound in the engine may have significant effects on durability and reliability of engine parts. [14]

The different studies had already been conducted on noise and vibration analysis of diesel engines because vibration and noise generation processes are very highly complex processes. Vibration signals emitted from the engine can have dynamic and invisible information for the current machine condition. These signals are composed of vibration which consists the combustion characteristics, faulty and normal acoustic signal, along with background noise [15]–[18].

The recent development of the IC engine, the reduction of the vibration emission is important task alongside maintaining power and efficiency. Hence, in many transportation applications using a diesel engine, a vast amount of attention is paid to the vibratory behavior of engine systems, particularly in relation to the comfort, efficiency, and safety [19]. In this paper, the study on the attractiveness of biodiesel and ethanol as an alternative source of fuels due to their better compatibility with engine, lower engine wear, ease availability, portability, higher combustion and energy efficiency, biodegradability with lower sulphur and aromatic content also having a higher cetane number as the relevant properties of fuel will be used for fulfilling the purpose in order to determine the performance characteristics and analysis of engine vibration using experimental values.

II. EXPERIMENTAL SETUP AND PROCESS

Karanja biodiesel was prepared by the trans-esterification in the biodiesel reactor of 10 L capacity using the 40 % methanol, and 0.75 % KOH at 60˚C in a reactor and stirred continuously for approx 90 minutes as shown in figure….After 90 minutes two distinct layers of Karanja biodiesel and triglyceride formed and got settled. Once the glycerol layer settled down, the biodiesel layer formed at the upper part of the reactor and above the glyceride layer. From there, Glycerol can be separated from the lower part of the reactor via a valve. The 88% of Karanja biodiesel was obtained from overall oil through trans-esterification process. After separating biodiesel it is been washed gently using warm distilled water to remove some unreacted portion of methanol and KOH catalyst, which if not removed can damage storing and fuel carrying parts by reacting with them. After washing, two distinct layers formed and settled down at the bottom most part having water and impurities and then both of them also removed. The upper layer is mainly biodiesel but, may or may not some amount of water is also present, thus, for removing the water contained in the Karanja biodiesel a heating process at about 60 oC was applied, and was finally, left to cool down for some time. The properties of the diesel, prepared biodiesel are presented in

Table 2.1 Fuel Properties

Properties	Test method	Diesel	Karanja Biodiesel
Kinematic viscosity @ 40 ˚C, cSt	D445	2.4	5.5
Density @ 15˚C, kg/m^3	D1298	822.4	891.8
Flashpoint, ˚C	D93	67	136
Net calorific value, MJ/kg	D240	42.7	37.58
Water and sediments % volume	D2709	0.01	0.02
Sulfur, %wt	D4294	0.28	Nil

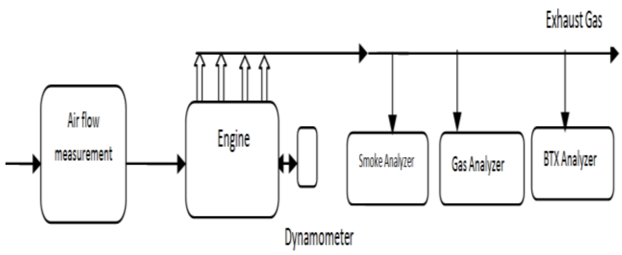


Figure 2.1 Experimental setup

2.1 Experimental setup

The experimental set up was consist of 4-stroke, 4-cylinder naturally aspirated water-cooled direct injection diesel engine. To measure the quantity of intake air and exhaust gas temperature a k-type thermocouple used in the experimental setup. The air flow measurement had been done using air box connected with hot wire type anemometer. Electronic weighing balance (EWB) was used to measure fuel consumption by a diesel engine. In the experimental setup, fuel was stirred continuously using stirrer (at 250 rpm) to avoid separation of phases. The specifications of the engine are given in Table 1 to analyze the exhaust gases a Testo made gas analyzer was used with an electrochemical sensor, Airchek PCXR8 Universal Sample Pump is a constant flow (from 5 to 5000ml/min) air sampler which was used to measure BTX emission. And, a Metrix+TM Vibro Measurer was used to measure the amplitude of engine vibrations.

Table 2.1.1 Engine Specification

Make	Force Motors
Cylinder numbers and type	Four, four cylinder
Injection	Direct
Fuel injection	Mechanical
Bore(mm)	78
Stroke (mm)	95
Capacity (CC)	1797
Compression ratio	18.65:1
Rated power (H.P.)	27
Rated speed (RPM)	2200

Table 2.1.2 Specification of gas analyzer

S.N.	Name of equipment	Range	Resolution	Accuracy
1	Testo Gas analyzer	CO 0-2500ppm	1ppm	±10 ppm
		HC 0-20,000	1 ppm	±10 ppm
		NO_x 0-4000	1 ppm	±10 ppm

The NOx, CO, and HC were measured with a Testo 350 is a portable combustion & emission analyzer, whereas a modular flue gas probe detector was employed for the measurement of the exhaust flow.

2.2 Experimental test procedure

The process of engine testing is made at different rpm and the reading, were taken and the mean of all reading is considered. The performance parameters, such as BSFC and BTE were calculated in experimental analysis. However, the exhaust emissions from a vehicle driven by fossil fuel include CO, HC, NOx, and smoke, were measured.

Table 2.3.3 Percentage uncertainty of the various parameters

Measure	Percentage
BSFC	±2.1
BTE	±2.1
CO	±0.7
HC	±0.8
NO_X	±0.8
Smoke	±1
SPL	±0.9

The process of BTX emission testing is made at variable rpm and reading was taken by PCXR8 Universal Sample Pump which is a constant flow (from 5 to 5000ml/min) air sampler that used to measure BTX emission from the exhaust pipe of the vehicle. The engine was operated for few min at every operating condition in order to obtain thermally steady condition before sampling of the exhaust unregulated and regulated emissions. Than after exhaust gas samples of regulated and unregulated emissions were drawn simultaneously for measurement. Exhaust emissions samples were drawn at 1000 and 2000rpm.

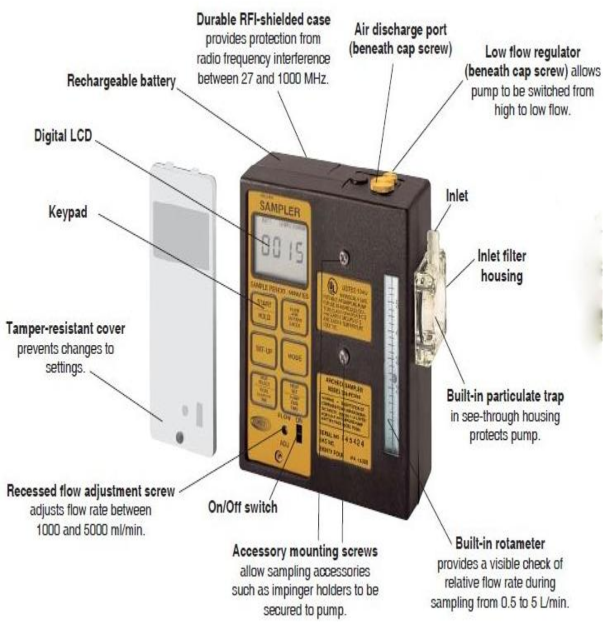
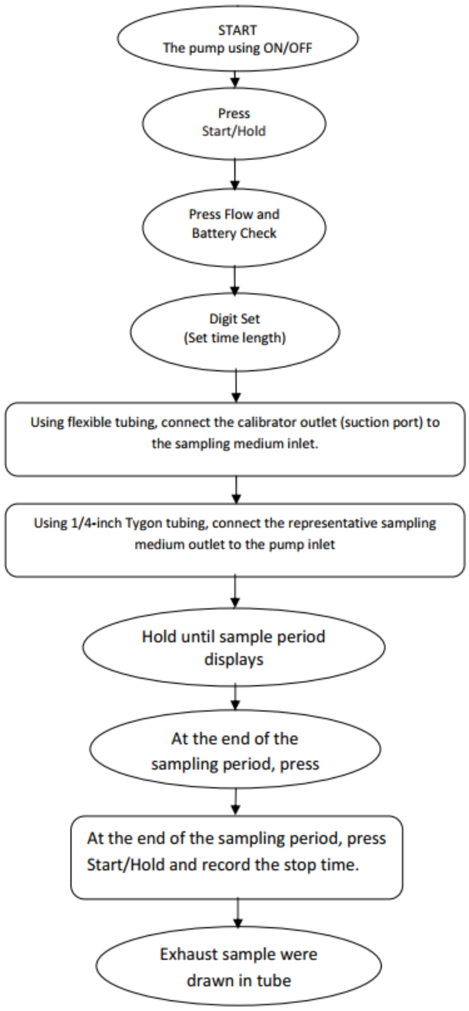


Figure 2.2.1PCXR8 Universal Sample Pump



2.2.1 Flow Chart of operating condition of by PCXR8 Universal Sample Pump

III. RESULTS AND DISCUSSIONS

3.1 NOX

The variation of NOx emissions increases with the increase in BMEP plot shown in figure 3.1. The result indicated that the NOx increased with the increase in load. The Karanja biodiesel and its blend percentage showed higher NOx emission than diesel fuel. The average percentage increase in NOx emission was found to be 18.1% for B100 Karanja Biodiesel respectively compared to neat diesel fuel. The formation NOx mainly depends on the in-cylinder temperature, and with the rise in temperature of combustion chamber leads to more NOx formation. However, by increasing the load the fuel air ratio increases, similarly increasing the biodiesel percent blend increases the oxygen contents, therefore complete combustion of fuel took place which eventually increased the temperature of the combustion chamber which leads to the increase in the formation of NOx. NOx emission was found to be decreased when operated with Exhaust Gas Recirculation.

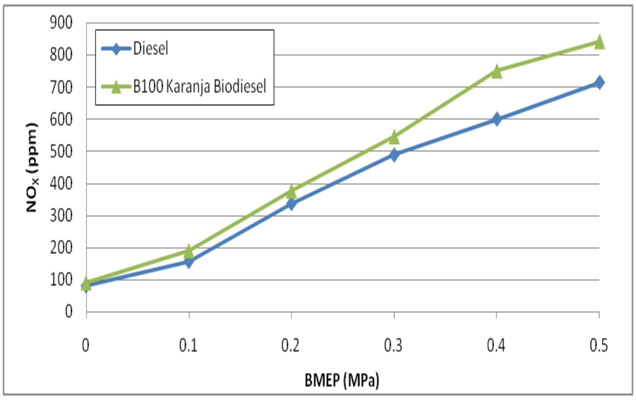


Figure 3.1 NOx emission with increasing BMEP plot

3.2 HC

The result of unburned hydrocarbon (HC) emissions plotted with the BMEP is shown in Fig. 3.2. It shows that the increase in BMEP resulted in higher unburned hydrocarbon (HC) emissions for both biodiesel and diesel fuel. The pure Karanja biodiesel showed lower HC emission in comparison to diesel fuel which indicates the cleaner combustion. [20] At no load condition the HC emission from diesel was found to be 1 ppm more than biodiesel fuel. Similarly, at BMEP 0.1, 0.2, 0.3, 0.4 Mpa the emission from diesel is found to be 1.6, 2.8, 3.0, 2.6 ppm more than biodiesel fuel when used in a diesel engine.

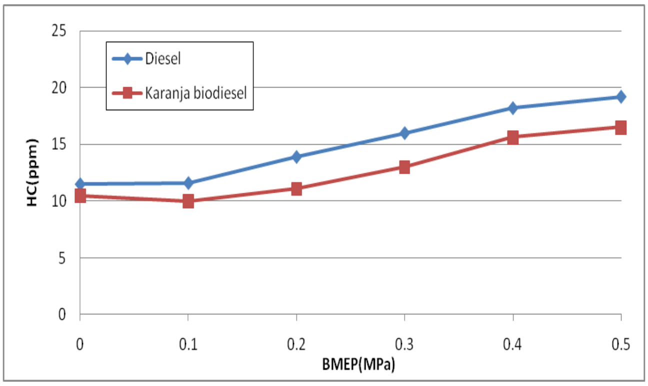


Figure 3.2 HC emissions plotted with the BMEP

3.3 CO

Figure 3.3 shows the carbon monoxide emission characteristic with the BMEP. It was observed that the CO emission decreases with the increase in BMEP. The experimental result subjected an average reduction in CO emissions using diesel fuel and biodiesel, the average percentage decrease of CO emission using biodiesel is 16.26% which is less than diesel fuel. The reduction in CO emission may be attributed to the oxygen molecules concentration in the Karanja biodiesel which promotes the conversion of CO into CO2 gas. [20] At no BMEP condition the percentage reduction in the emission of CO using bio-diesel is 20.46% less than diesel. Similarly, at 0.1, 0.2, 0.3, 0.4, 0.5 Mpa the percentage decrease in CO emission is 15.2, 9.01, 7.2, 10.6, 17.7 ppm.

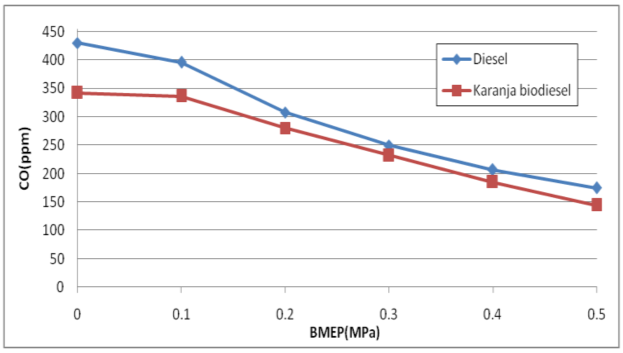


Figure 3.3 Carbon monoxide emission characteristic with the BMEP

3.4 Smoke

The smoke emission characteristic plotted with the BMEP is shown in Fig. 3.4. The increase in BMEP subjected to in higher smoke emission. An average of 11.8% reduction in smoke was seen with the use of Karanja biodiesel. It is because of the presence of oxygen molecules concentration in Karanja biodiesel which promotes the complete combustion of fuel, especially in the various zone of the combustion chamber by the oxidation of pre-formed soot[21]. At no load condition, the smoke from diesel was found to be same as biodiesel fuel. Similarly, at BMEP 0.1, 0.2, 0.3, 0.4 Mpa the emission from biodiesel is found to be 3.8, 11.4, 16.6, 18.8, 23.9 ppm less than diesel fuel when used in a diesel engine.

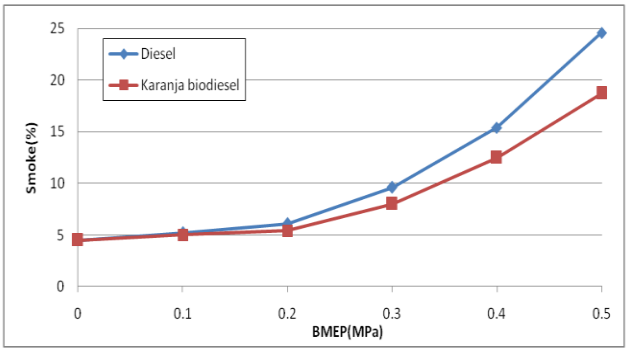


Figure 3.4 Smoke emission characteristic plotted with the BMEP

3.5 BTX Emission

Table 3 Specification of BTX analyzer

Name of fuel	RPM	Benzene	Poly Xylene	Toluene
Biodiesel	1000	0.50	0.13	1.05
Diesel		0.45	0.40	0.59
Biodiesel	2000	0.22	0.19	0.55
Diesel		0.29	0.25	0.74

The engine was operated for few min at every operating condition in order to obtain thermally steady condition before sampling of the exhaust unregulated and regulated emissions. Than after exhaust gas samples of regulated and unregulated emissions were drawn simultaneously for measurement. Exhaust emissions samples were drawn at 1000 and 2000rpm.

Benzene

The emission of benzene due to the utilization of diesel and biodiesel fuel in diesel engine at 1000 and 2000 rpm showed in figure 3.3. The experimental result showed that there is a decrease in benzene emission at 1000Rpm is less using diesel fuel than biodiesel, the percentage decrease of benzene emission is 10% less than biodiesel. On the other hand, at 2000rpm the experimental result showed an increase of benzene emission for diesel fuel than biodiesel, the percentage increment of benzene emission using diesel fuel was 31.81% than biodiesel.

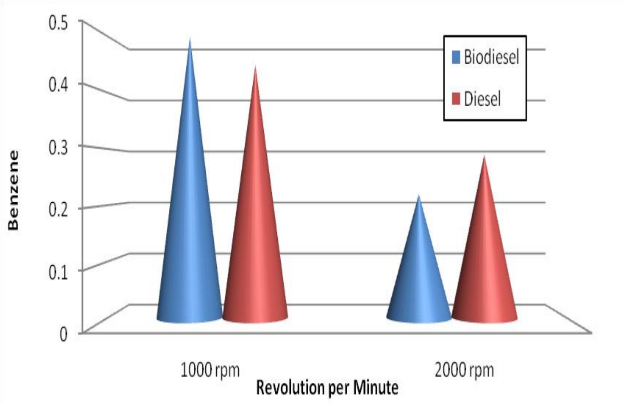


Figure 3.3 Benzene emissions plotted with the RPM

Polyxylene

The emission of poly xylene take place due to the utilization of diesel and biodiesel fuel in diesel engine at 1000 and 2000 rpm showed in figure 3.4. The experimental result showed that there is a decrease in Polyxylene emission at 1000 rpm and 2000 rpm is less using biodiesel than diesel fuel, the percentage decrease of poly xylene emission at 1000rpm and 2000rpm are 67.5% and 24% which is less than diesel fuel.

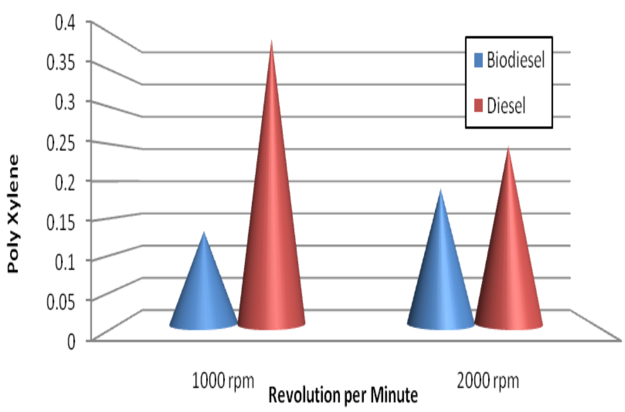


Figure 3.4 3 Polyxylene emission plotted with the RPM

Toluene

The emission of Toluene due to the utilization of diesel and biodiesel fuel in diesel engine at 1000 and 2000 rpm showed in figure 3.5. The experimental result showed that there is a decrease in benzene emission at 1000Rpm is less using diesel fuel than biodiesel, the percentage decrease of toluene emission is 43.81% less than biodiesel. On the other hand, at 2000rpm the experimental result showed an increase of toluene emission for diesel fuel than biodiesel, the percentage increment of toluene emission using diesel fuel was 34.5% than biodiesel.

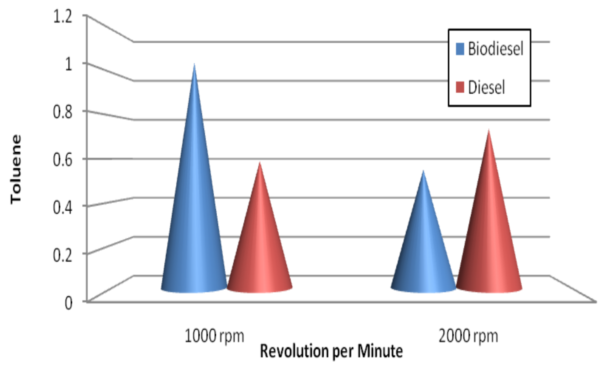


Figure 3.5 3 Toluene emissions plotted with the RPM

IV. CONCLUSION

The use of biodiesel and blend effects on the CI engine's emissions (CO2, CO, NOx, Smoke and unregulated emissions of benzene, xylene, toluene) characteristics were investigated in detail for steady-state operation conditions. The following conclusions are drawn for this specific fuel and engine configuration:

- The diesel engine running on biodiesel fuel highlights a significant decrease in CO2, CO, HC, and Smoke emission under working engine operation conditions. It is also found that when the biodiesel content increases a further reduction in aromatic compounds (poly-xylene) emissions is observed in results. This emission reduction is most likely a result of the oxygen concentration in biodiesel fuel and the low HC ratio.
- In the case of all biodiesel the concentration of NOx and benzene emission increases in a diesel engine. NOx emission increases due to higher oxygen molecule content present in biodiesel.
- BTX emissions consist of benzene (C6H6), toluene (C7H8), and xylene (C8H10). It is observed that at 1000rpm by using biodiesel fuel, benzene emissions & toluene emissions increase significantly by 11.11% and 77.96% than diesel fuel whereas, at 2000rpm percentage reductions is benzene and toluene emissions by 24.13% and 25.67%. However, poly-xylene emissions percentage reductions take place at 1000 and 2000rpm by 67.5% and 20%.

Overall, the study gave an insight into unregulated and regulated emissions from blends of alternative fuels (Karanja biodiesel). Though the species evaluated in this study are not regulated by the emission regulations worldwide, they certainly cause several harmful effects.

ABBREVIATIONS

TBC	Thermal Barrier Coating
D	Diesel
BD	Biodiesel
O_2	Oxygen
CO	Carbon mono-oxide
CO_2	Carbon-di-oxide
HC	Unburnt Hydrocarbons
PM	Particulate Matter
NOX	Nitrous Oxides
NO2	Nitrogen Oxide
IOP	injector opening pressure
CC	Combustion Chamber
MMT	Million Metric Tonnes
BTX	Benzene, Toluene, and Xylene
BTE	Brake thermal efficiency
BSFC	Brake Specific Fuel Consumption
KOH	Potassium Hydroxide
EWB	Electronic weighting balance
BMEP	Brake mean effective pressure
RPM	Revolution per minute
SCR	Selective Catalytic Reduction
DPF	Diesel Particulate Filter

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