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Effect of Ethanol and Tetra Nitro Methane on Performance and Emission Characteristics of CI Engine Fuelled With Methyl Ester of Jatropha

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Abstract: *The use of biodiesel is rapidly increasing around the world, making it imperative to understand the impacts of biodiesel on the diesel engine performance and reduce the emissions. This paper is aimed to investigate the performance and emission characteristics of a direct injection (DI) diesel engine when fuelled with methyl ester of jatropha oil (MEJO). The ignition improver tetra nitro methane (TNM) and ethanol are added to methyl ester of jatropha oil to examine the performance and emissions of the diesel engine. The experimental results show that the maximum brake thermal efficiency was obtained with 20%Etanol-2%TNM blended with MEJO when compared with pure MEJO and methyl ester of jatropha oil blends. Among the TNM-Ethanol blends, the minimum brake specific fuel consumption was observed with 20% Ethanol-2%TNM. The lowest carbon monoxide (CO) and unburned hydrocarbons (HC) with 20%Ethanol-2%TNM blend. The smoke density of 20%Ethanol-2%TNM with MEJO was reduced by 20.69% when compared with diesel. Hence, the 20%Ethanol-2%TNM blended with MEJO could improve the performance and reduce the emissions of the diesel engine.*

Keywords: *Biodiesel, Diesel Engine, MEJO, Performance, Emissions*.

1. INTRODUCTION

Energy is very important for life quality and social development of people as well as economic growth. Fossil fuels have been an important conventional energy source for years. Energy demand around the world is increasing at a faster rate as a result of ongoing trends in industrialization and modernization. Most of the developing countries import fossil fuels for satisfying their energy demand. Consequently, these countries have to spend their export income to buy petroleum products [1]. The climate changes occurring due to increased Carbon Dioxide (CO_2) emissions and global warming, increasing air pollution and depletion of fossil fuels are the major problems in the present century. The present researchers have been focused on the biofuels as environment friendly energy source to reduce dependence on fossil fuels and to reduce air pollution. The biofuels can play an important role towards the transition to a lower carbon economy and also combine the benefits of low green house emissions with the reduction of oil import. The role biofuels can play within these economies becomes clearer when their relatively developed agricultural sector is taken into account [2]. Bioethanol, biodiesel and to a lesser extent pure vegetable oils are recently considered as most promising biofuels. Since 19th century, ethanol has been used as a fuel for diesel engines. Ethanol is a low cost oxygenated compound with high oxygen content (34.8%). Ethanol is an alcohol most often chosen because of the ease of production, can be obtained from various kinds of biomass such as maize, sugarcane, sugar beet, corn, cassava, red seaweed etc., relatively low-cost and low toxicity [3].

Diesel-ethanol blends are a more viable alternative and require little or no change in diesel engines. The use of diesel-ethanol blends can significantly reduce the emission of toxic gases and particulate matters when compared to pure diesel. Ozer Can et al; [4] investigated the effects of ethanol addition to Diesel No. 2 on the performance and emissions of a four stroke cycle, four cylinder, turbocharged indirect injection diesel engine with different fuel injection pressures at full load. They showed that the ethanol addition reduces Carbon monoxide (CO), soot and Sulphur Dioxide (SO_2) emissions, but increases Oxides of nitrogen (NOx) emissions. It was also found that increased injection pressure, reduced the CO and smoke emissions with some reduction in power. Andrzej Kowalewicz [5] showed that the injection of ethanol into the inlet port reduced CO_2, NOx and CO emissions and smoke at higher loads with both diesel fuel and rape oil methyl ester. Jincheng Huang et al [6] studied the performance and emissions of a diesel engine using ethanol-diesel blends. They showed that the thermal efficiencies of the engine fuelled by the blends were comparable with that fuelled by diesel, with some increase of fuel consumption. They also found reduced smoke emissions, CO emissions above half loads, and increased HC emissions with the blends comparing with the diesel fuel.

However, ethanol and diesel fuel are inherently immiscible because of their difference in chemical structures and characteristics. The addition of ethanol to diesel affects properties such as viscosity, lubricity, Cetane number, energy content and mainly, volatility and stability. Phase separation occurs at relatively low temperatures, which are still used in the blending of anhydrous ethanol. The phase separation can be prevented in two ways. First is the addition of an emulsifier, which acts by lowering the surface tension of two or more substances and the second is the addition of a co-solvent, which acts by modifying the power of solvency for the pure solvent. [7]. Diesel and ethanol fuels can be efficiently emulsified into a heterogeneous mixture of one micro-particle liquid phase dispersed into another liquid phase by mechanical with suitable emulsifiers. The emulsifier would reduce the interfacial tension force and increase the affinity between the two liquid phases, leading to emulsion stability [8]. A suitable emulsifier for ethanol and diesel fuel is suggested to contain both lipophilic part and hydrophilic part, in order to obtain an emulsion of diesel and alcohol. Such chemical structures can be found in biodiesel. [9].

Biodiesels are used because of their similarity to diesel oil, which allows the use of biodiesel-diesel blends in any proportion. The biodiesel allows the addition of more ethanol-blended fuel, keeps the mixture stable and improves the tolerance of the blend to water, so that it can be stored for a long period. The large Cetane number of the biodiesel offsets the reduction of Cetane number from addition of ethanol to diesel, thus improving the engine ignition. The addition of biodiesel increases the oxygen level in the blend. Also biodiesel have lubricating properties that benefit the engine, and are obtained from renewable energy sources such as vegetable oils and animal fats. Similar to ethanol, biodiesel have a great potential for reducing emissions, especially particulate materials [10].

The above studies reveal that the diesel-ethanol-biodiesel blends can be used as alternative fuels for diesel engines. Recent research has shown that the use of diesel-ethanol-biodiesel blends can substantially reduce emissions of CO, total hydrocarbons (HC), and particulate matters (PM) [11]. The mixing of biodiesel and bioethanol with diesel significantly reduces the emission of particulate matter because the blended biofuel contains more oxygen [12]. Hadi rahimi et al [13] showed that the bioethanol and sunflower methyl ester can improve low temperature flow properties of diesel-ethanol-biodiesel blends due to very low freezing point of bioethanol and low pour point of sunflower methyl ester. The power and torque produced by the engine using diesel-ethanol-biodiesel blends and conventional fuel were found to be very comparable. The CO and HC emission concentration of diesel-ethanol-biodiesel blends decreased compared to the conventional diesel fuel and even diesel–biodiesel blends. Hwanam Kim, Btungchul Choi. [14] Investigated the exhaust gas characteristics and particulate size distribution of PM on a CRDI diesel engine using diesel, biodiesel and ethanol blends. They observed the reduced CO, HC, smoke emissions and total number of particles emitted, but increased NOx emissions. Xiaobing Pang et al [15] reported that the use of biodiesel-ethanol- diesel blend could slightly increase the emissions of carbonyls and NOx but significantly reduce the emissions of PM and THC. Prommes Kwanchareon et al; [16] studied solubility of a diesel-biodiesel-ethanol blend, its properties and its emission characteristics from diesel engine. They found that the blended fuel properties were close to the standard diesel except flash point. It was also found that CO and HC emissions reduced significantly at high engine load, whereas NOx emissions increased compared to those of diesel.

The above studies reveal that the diesel-biodiesel-ethanol blends reduce CO, HC, PM, Smoke emissions and increase NOx emissions compared with the diesel fuel. There is a little research on the use of rice bran oil biodiesel in diesel-biodiesel-ethanol blends for diesel engines. The performance and emission characteristics of the biodiesel blended up to 20% were close to that of diesel fuel [17, 18]. In the present investigation the performance and emission characteristics of a diesel engine were studied by using methyl ester of jatropha oil biodiesel as an additive in the diesel-biodiesel-ethanol blends and compared with that of the diesel fuel.

In the present investigation the performance and emission characteristics of a diesel engine were studied by using (5-25%) Ethanol-(1-3%) TNM with MEJO blends and compared with that of the diesel fuel.

2. MATERIALS AND METHODS

In the present investigation, tests have been conducted on diesel engine using pure diesel and MEJO. The experimental investigation has been carried out on diesel engine using diesel, methyl ester of jatropha oil (MEJO) and MEJO with ignition improver and Ethanol. The ignition improver used in this investigation is Tetra Nitro Methane (TNM). The ignition improver, TNM is added to the methyl ester of jatropha oil at different proportions such as 1 to 3%, Ethanol is added to the methyl ester of jatropha oil at different proportions such as 5 to 25%. The performance parameters such as brake thermal efficiency, brake specific fuel consumption are studied with respect to load. The exhaust emissions such as carbon monoxide, carbon dioxide, hydrocarbons, oxides of nitrogen and unused oxygen and smoke opacity were studied with respect to load. The experimental set up consists of a diesel engine, engine test bed, fuel and air consumption metering equipments, gas analyzer, and smoke meter. The specifications of the diesel engine are given in Table 1. The schematic diagram of the engine test rig is shown in Figure. 1.

Table 1. *Specifications of the diesel engine.*

Type	Four- stroke, single cylinder, Compression Ignition engine, with variable compression ratio.
Make	Kirloskar, AV-1
Rated power	3.7 KW, 1500 RPM
Bore and stroke	80mm×110mm
Compression ratio	16.5:1, variable from 13.5 to 20
Cylinder capacity	553cc
Dynamometer	Electrical-AC Alternator P.F.=0.8
Exhaust Gas Analyzer	Make :MARS Technologies Inc., Banglore Model :MN-05 Principle : Non-dispersive infrared based technology. Measurement :CO,CO$_2$,O$_2$ in % of volume NOx & HC in PPM Measuring Range: CO (0-10%vol in res of 0.01%) CO$_2$(0-20%vol in res. of 0.1%) HC(0-1500ppm res. of 1ppm) NOx(0-1500ppm res. 1ppm) O$_2$(0-25% in res. 0.01%) Gas flow rate :1000ml/min Zero Calibration: every 25 min

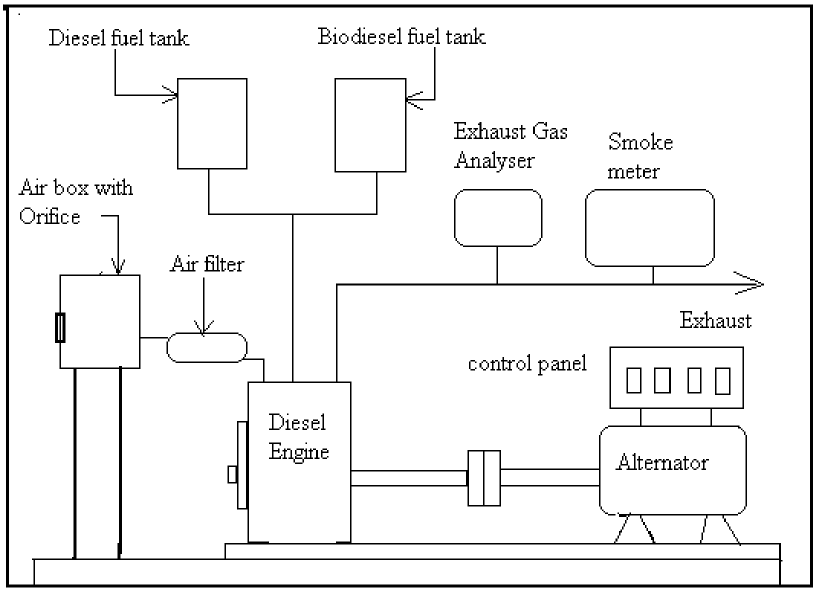

Figure 1. *Schematic Diagram of Engine Test Rig*

The engine was first operated o using diesel with no load for few minutes at rated speed of 1500 rpm until the cooling water and lubricating oil temperatures comes to 85˚C. The same temperatures were maintained throughout the experiments with all the fuel modes. The baseline parameters were obtained at the rated speed by varying 0–100% of load on the engine with an increment of 20%. The engine was tested with MEJO and blends of MEJO Ethanol and TNM. The tests were conducted with these blends by varying the load on the engine. The brake power was measured by using an electrical dynamometer. The exhaust gas temperature was measured by using an iron-constantan thermocouple. The exhaust emissions such as CO, CO_2, Oxides of nitrogen (NOx), HC, and unused oxygen (O_2),were measured by AVL Di-Gas 444 exhaust analyzer. The results of the engine operating on MEJO and its Ethanol-TNM blends were compared with the baseline parameters obtained during engine fuelled with diesel at rated speed of 1500 rpm.

3. RESULTS AND DISCUSSION

3.1 Brake Thermal Efficiency

The variation of Brake Thermal Efficiency (BTE) with Brake Power (BP) is shown in Figure2.

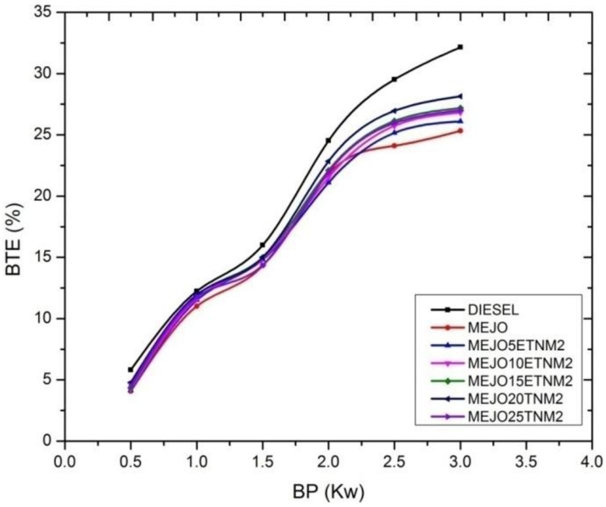

Figure 2. *Variation of brake thermal efficiency with brake power*

It is observed from the results that brake thermal efficiency increased with load. The brake thermal efficiency of MEJO, MEJOTNM2, and all biodiesel – ignition improver (1-3%)-ethanol blends (5%-25%) was less than diesel fuel over the entire range of the load. The BTE was lower by 18.84%, 16.63%, 15.48%, 12.53% and 16.04% was respectively with MEJO5ETNM2, MEJO10ETNM2, MEJO15ETNM2, MEJO20ETNM2 and MEJO25ETNM2 blends compared with diesel fuel. The maximum BTE 28.13% was observed with MEJO20ETNM2. The Brake Thermal Efficiency of Biodiesel ignition improver (MEJOTNM2) increases with increasing ethanol percentage. It is due to the presence of oxygenated molecules in the ethanol so that complete combustion takes place.

3.2 Brake Specific Fuel Consumption

The variation of brake specific fuel consumption (bsfc) with brake power is shown in Figure 3.

The BSFC reduced with load for all fuel blends the BSFC was increased by 12.5%, 7.5%, 10%, 7.5%, 5% and 10% respectively with MEJO, MEJO5ETNM2, MEJO10ETNM2, MEJO15ETNM2, MEJO20ETNM2 and MEJO25ETNM2 at full load compared with diesel fuel. The calorific value of Jathropa bio diesel is 11% lower than the diesel fuel. It is due to lower heating value of the biodiesel and higher mass flow to meet the engine loads. The BSFC increased with the increase of ethanol percentage in biodiesel-ignition improver blends. The BSFC of MEJO20ETNM2 was lower than the out of all ethanol blends to MEJOTNM2. The BSFC of MEJO20ETNM2 lower by 7.14%,2.38%,4.76%,2.4% and 4.78% respectively when compared MEJO, MEJO5ETNM2, MEJO10ETNM2, MEJO15ETNM2 and MEJO25ETNM2.

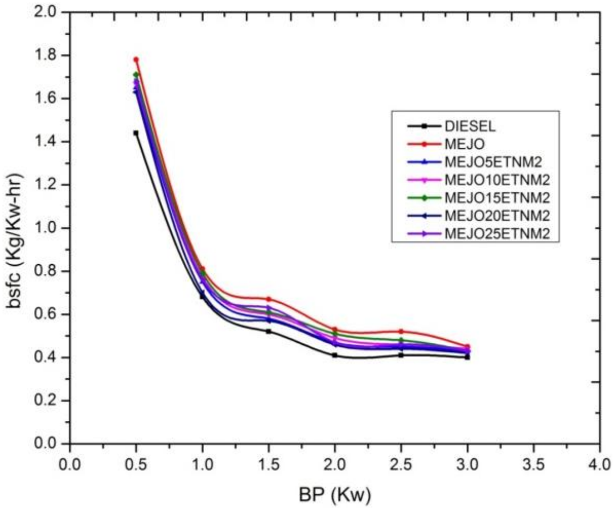

Figure 3. *Variation of brake specific fuel consumption with brake power*

3.3 Carbon Monoxide

The variation of carbon monoxide (CO) with brake power is shown in Figure 4.

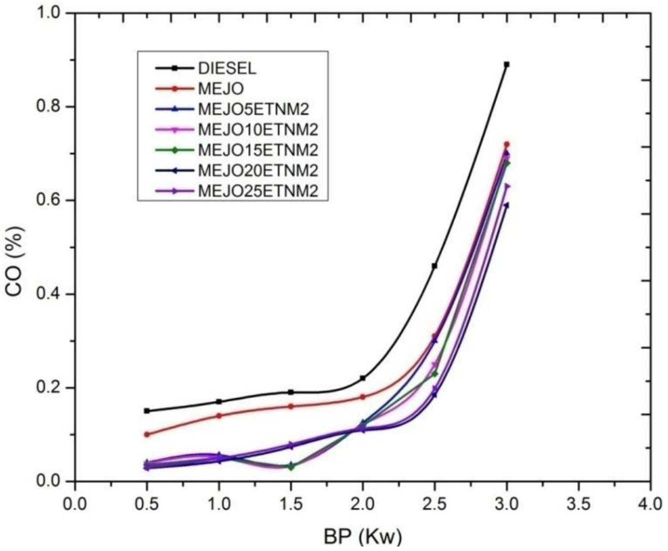

Figure 4. *Variation of carbon monoxide emissions with brake power*

The results show that the CO emissions slowly increased at low and medium loads and rapidly increased at high load for all the fuel samples. The CO emissions reduced with the increasing ethanol percentage in diesel-ethanol blends. The CO emissions of diesel-ethanol blends were significantly lower than the corresponding diesel fuel at high loads of the engine. The CO emissions were decreased by 19.10%, 21.34%, 22.47%, 23.59%, 33.7% and 29.21% respectively with MEJO, MEJO5ETNM2, MEJO10ETNM2, MEJO15ETNM2, MEJO20ETNM2 and MEJO25ETNM2 when compared with diesel fuel at full load condition. The CO emission reduced with increasing of ethanol percentage in the biodiesel-ignition improver blend. It is due the presence of oxygenated molecules in the ethanol so that proper combustion takes place.

3.4 Unburned Hydrocarbon Emissions

The variation of unburned hydrocarbon (HC) emissions with brake power is shown in Figure 5.

The HC emissions of biodiesel-ignition improver-ethanol blends were 44ppm, 48ppm, 47ppm, 46ppm and 45ppm respectively with MEJO20ETNM2, MEJO5ETNM2, MEJO10ETNM2, MEJO15ETNM2 and MEJO25ETNM2 at full load of the engine. The HC emissions were decreased with increasing percentage of ethanol to MEFOTNM2.The HC emissions of MEJO20ETNM2 were reduced by 20% when compared with diesel, 10.20% when compared to MEJO at full load of the engine.

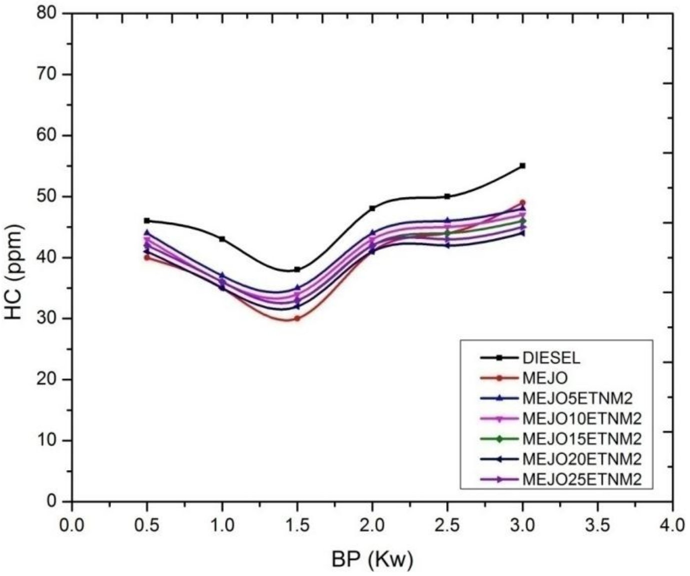

Figure 5. *Variation of hydrocarbon emissions with brake power*

3.5 Oxides of Nitrogen

The variation of oxides of nitrogen emissions (NO_X) with brake power is shown in Figure 6.

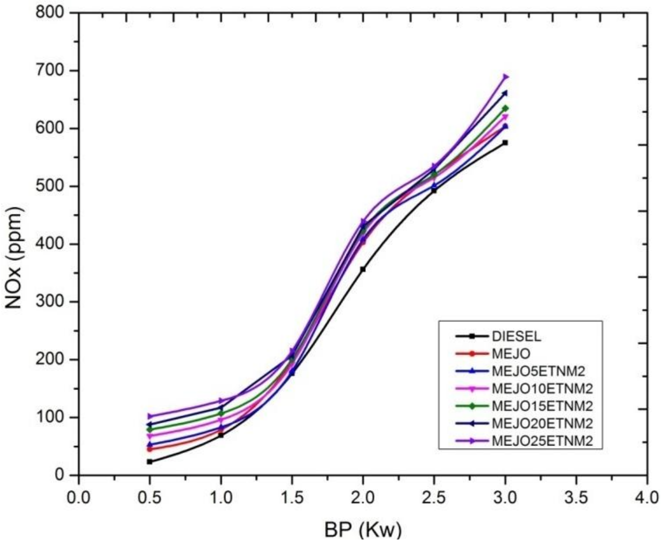

Figure 6. *Variation oxides of nitrogen with brake power*

The NOx emissions are increased as the engine load increases due to increase in combustion temperature. The NOx emissions of biodiesel-ignition improver-ethanol blends were higher than MEJO, and diesel fuel at full load condition The NOx emissions of MEJO5ETNM2, MEJO10ETNM2, MEJO15ETNM2, MEJO20ETNM2 and MEJO25ETNM2 are respectively 4.86%, 8.0%, 10.43%, 14.95% and 19.2% higher than that of diesel fuel at full load of the engine. The lower NOx emissions were produced by MEJO20ETNM2 among biodiesel-ignition improver-ethanol blend.

3.6 Carbon Dioxide Emissions

The variation of carbon dioxide emissions with brake power is shown in Figure 7.

The carbon dioxide emissions increased with brake power for all fuel modes. The CO_2 emissions of biodiesel-ignition improver-ethanol were higher than the, biodiesel, biodiesel-ignition improver and diesel fuel The CO_2 emissions of MEJO5ETNM2, MEJO10ETNM2, MEJO15ETNM2, MEJO20ETNM2 and MEJO25ETNM2 were respectively 7.19%, 10.13%, 21.87%, 33.62% and 8.03% higher than that of diesel fuel at full load of the engine.

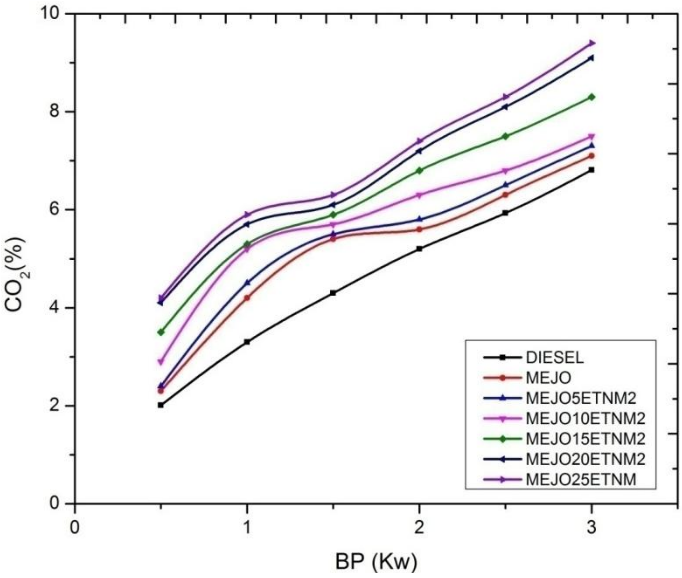

Figure 7. *Variation of carbon dioxide emissions with brake power*

3.7 Unused Oxygen

The variation of unused oxygen with brake power is shown in Figure 8.

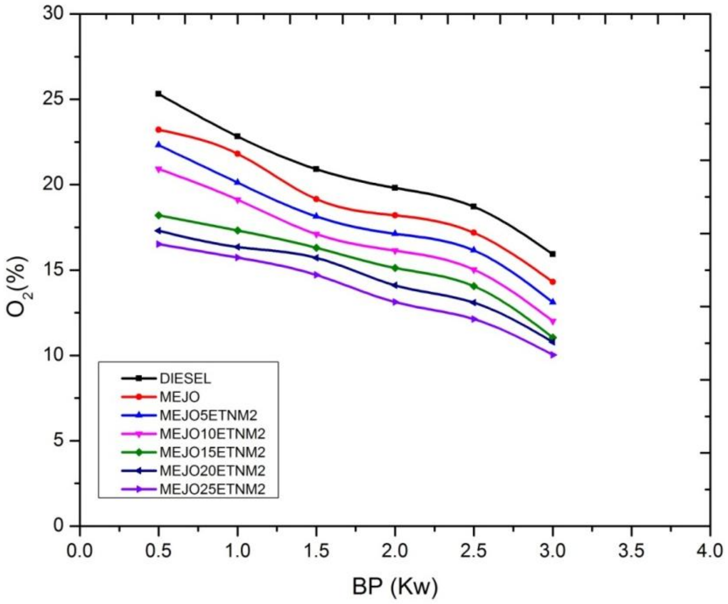

Figure 8. *Variation of unused oxygen with brake power*

The unused oxygen emissions reduced with brake power for all the fuels. These emissions are lower than diesel fuel for all biodiesel, biodiesel-ignition improver-ethanol blends The unused oxygen emissions of MEJO, MEJO5ETNM2, MEJO10ETNM2, MEJO15ETNM2, MEJO20ETNM2 and MEJO25ETNM2 were respectively 10.16%, 36.53%, 38.29%, 43.33%, 44.19% and 46.09% lower than that of diesel fuel at the full load of the engine

3.8 Smoke Opacity

The variation of smoke opacity with brake power is shown in Figure 9.

The smoke opacity increased with brake power for all the fuel modes. The smoke produced by MEJO was 8.86% higher than diesel fuels at full load of the engine. The smoke opacity reduced with the increased percentage of ethanol in biodiesel-ignition improver-ethanol blends at all load conditions of the engine The smoke opacity of MEJO5ETNM2, MEJO10ETNM2, MEJO15ETNM2, MEJO20ETNM2 and MEJO25ETNM2 were respectively 10.94%, 13.70%, 16.43%, 20.69% and 23.16% lower than that of diesel fuel at full load of the engine.

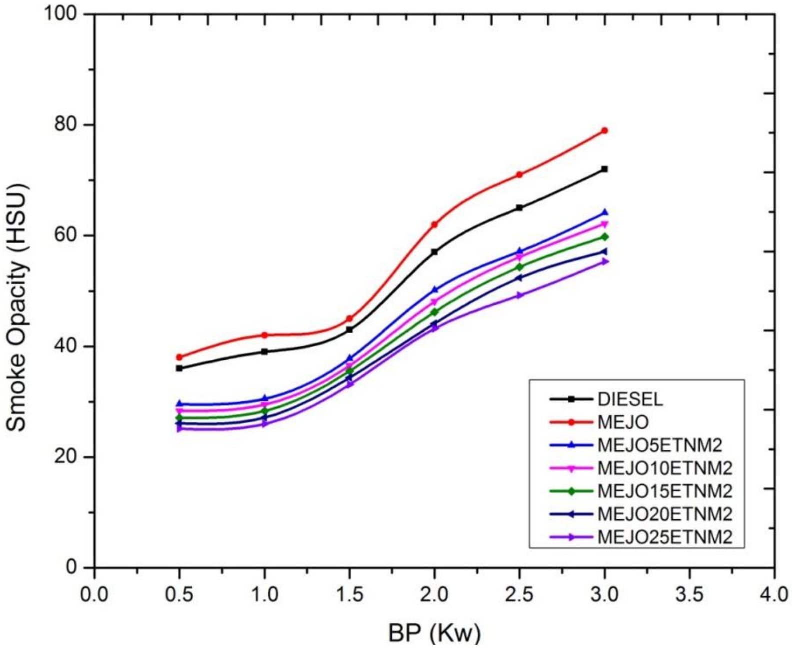

Figure 9. *Variation of smoke opacity with brake power*

4. CONCLUSION

The above results reveal that the performance parameters such as brake thermal efficiency, brake specific fuel consumption increased with the increasing percentage of ethanol to biodiesel-ignition improver blend. The emission parameters such as CO, unused oxygen and smoke intensity reduced with ethanol addition. The CO_2, NO_x increased with increasing percentage of ethanol in biodiesel-ignition improver blend. The blend MEJO20ETNM2 is an optimum blend with respect to both performance and emissions. Hence ethanol can be added up to 20% to the methyl ester of jatropa oil to improve the performance of the diesel engine.

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