International Journal of Mechanical and Industrial Technology ISSN 2348-7593 (Online)
Vol. 6, Issue 2, pp: (6-12), Month: October 2018 - March 2019, Available at: www.researchpublish.com

Effect of Blending Acetone with Karanja biodiesel on Performance, Combustion and Emission Characteristics of Four Stroke Diesel Engine

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Abstract: **Vegetable oils are a potential alternative to partial or total substitution of diesel fuels. In this study, we used Acetone as an additive to investigate the possible use of increased percentages of biodiesel in diesel engine without any retrofitting. In this study, performance tests were carried out on diesel engine with neat diesel fuel and biodiesel mixture. Biodiesel was made by transesterification process. Karanja oil was selected for biodiesel production. Number 2 diesel fuel containing 30% biodiesel and 70% diesel fuel, is called here as B30. The effects of Acetone, blended with B30 in 4, 8, 12 % by volume were used in a single cylinder, four strokes direct injection diesel engine. The effect of test fuels on engine torque, power, brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature, were ascertained by performance tests. The influence of blends on CO, CO2, HC, NO and smoke opacity were evaluated by emission tests. The experimental results showed that the exhaust emissions were fairly reduced for 12% Acetone with B30; especially the NO is reduced remarkably by 48% while comparing diesel operation.**

Keywords: **Acetone, Emission, Karanja Biodiesel, Performance.**

I. INTRODUCTION

The introduction of paper Diesel engines are widely used for their low fuel consumption and better thermal efficiency. Also, fast depletion of petroleum fuels and its costs uncertainties have led to more rapid search for alternative fuels. Different vegetable oils such as soybean oil, castor oil, rapeseed oil, Jatropha curcas oil have been considered as alternative fuels for diesel engines [1]. Vegetable oils are not suitable direct replacements for diesel fuel in IC engines, due to their undesirable physical properties such as free fatty acid, lower pour points, lower calorific value, higher viscosities and higher flash points. These undesirable properties cause poor atomization, poor vapor–air mixing, low pressure, and incomplete burning and engine deposits. However, it is possible to reduce the viscosity of vegetable oil and remove the fatty acid content through dilution, pyrolysis, micro emulsion and esterification. Esterification is a kind of chemical reaction in vegetable oil is reacted with alcohol to form esters (biodiesel). Yongsheng Guo et al. [2] list the merits of biodiesel like biodegradable, nontoxic, low emission profiles compared to diesel. Essentially, no engine modifications are required to substitute biodiesel for diesel fuel that can maintain the engine performance. Vegetable oils and Acetone are obtained from farm products and are renewable, degradable and friendly with the environment [3].

The biodiesel fuelled diesel engine performance and combustion characteristics have been examined by many investigators [4]. The biodiesels used in their experiments were produced from different vegetable oils such as sunflower, rapeseed, soybean, karanja, and rubber seed to name a few. Altiparmak et al. reported that CO, smoke, HC and PM emissions experienced a reduction trend with biodiesel and blends of biodiesel–diesel fuels compared to mineral diesel fuel operation [5]. The additives kerosene and ethanol were blended with Palm biodiesel-diesel blends to improve cold flow properties [6]. Cao et al. tested the effect of ethylene vinyl acetate copolymer on cold flow properties of waste cooking oil biodiesel [7]. However, there were some experimental outcomes reporting that the break power increases and NOx emissions decrease when using biodiesel as fuel in diesel engine. The change in power and higher NOx emissions can be experienced to the engine modifications, the fuelling method, after treatment method, test procedures and test conditions.

The engine performance with the biodiesel and the vegetable oil blends of various origins was similar to that of the neat diesel fuel with nearly the same brake thermal efficiency, showing higher specific fuel consumption. The experimental results especially on emissions of various studies are not uniform and show different results as can be seen in the literature. The main objective of this study is to improve the performance and reducing the emissions in the diesel engine by using oxygenated compounds in the diesel fuel. Karanja oil is non-edible and also the potential for production of oil is more in India. As the calorific value such oil is moderate, we try to use it as an engine fuel and add additives to get the results nearer to that of mineral diesel fuel.

In the present research work, we interest to produce karanja biodiesel from Karanja oil by transestrification and enhance the fuel's properties with Acetone additive. Diesel fuel and a blend of Karanja biodiesel 30% by volume mixed with Acetone additive in the volume ratio of 4, 8, and 12 percentages were tested in a direct injection, water cooled diesel engine at maximum load operations.

II. EXPERIMENTAL SETUP AND PROCEDURE

A. Experimental apparatus and procedure

The engine used is Kirloskar make single cylinder, naturally aspirated, four stroke, water cool, 16.5:1 compression ratio, direct injection diesel engine, and the maximum engine power is 3.7 kW at 1500 rpm. A Kirloskar A.C generator with resistance bank loading arrangement was also incorporated. The main components of the experimental set up are combustion pressure and volume measurement (piezo electric sensor and shaft encoder) fuel flow sensor unit, electrical loading arrangement, voltmeter, ammeter, cooling water sensor unit and air flow sensor unit .The outlet temperatures of cooling water and exhaust gas were measured directly from the thermocouples (Cr–Al) attached to the corresponding passages. All the data were interfaced with computer using software.

The engine exhausts Nitrogen oxide, Carbon monoxide, Hydrocarbon, Carbon dioxide were measured with AVL-444 Di gas analyzer. The exhaust emissions were measured at 250 mm from the exhaust valve. The smoke opacity was measured by AVL-437C smoke meter after reducing the pressure and temperature in the expansion chamber. The engine speed was kept fixed at 1500 rpm. The engine was loaded step by step to keep the speed within the allowable range. After the engine reaches equilibrium condition, the various performance, combustion and emission characteristic parameters were observed and recorded. The accuracies of the measurements and the uncertainties determined by uncertainty analysis based on the Gaussian distribution method with a confidence limit of $\pm 2\sigma$, and the calculated results are shown in TABLE I.

TABLE I: The Accuracies of measurements and the Uncertainties in the calculated results

Measurements	Accuracy
Speed	± 2 rpm
Temperature	± 1^{o}C
CO	± 0.03 %
CO_2	± 0.5 %
NO	± 50 ppm
HC	± 10 ppm
Opacity	± 0.1 %
Calculated results	Uncertainty
Brake power	± 2.50 %
BSFC	± 2.64 %
Pressure	± 1 bar

B. Test fuel and Preparation of Blends

From the previous study by the author [8] using 30% blend of Karanja biodiesel with diesel would give the anticipated results, so 30% blend is taken for analysis. Some authors narrate that addition of additives will improve on the drawback of biodiesel [9] and therefore in this study Acetone is taken as additive and observed the performance and emissions in C.I engine. The properties of fuel and additives are given in TABLE II.

TABLE II: Properties of the Fuel and Additive

Properties		No-2 Diesel	B30	Acetone
Kinematic Viscosity	[cSt]	2.82	3.67	0.46
Density	[kg/m^3]	840	856	791
Lower Heating Value	[MJ/kg]	42.3	38.4	28.8
Cetane Number	-	46	53	-
Flash Point	[^{o}C]	70	60	-20

The Karanja biodiesel is utilized to prepare the blends, the volume ratio of Karanja biodiesel and diesel, 30/70 is called B30, and the volume ratio of B30 blend and 4%, 8%, 12% of Acetone is called B30+A4, B30+A8, and B30+A12 respectively.

III. RESULTS AND DISCUSSIONS

A. Combustion pressure and Crank angle

In Fig. 1 the variation in the cylinder pressure with crank angle for B30 A12 blends at maximum engine load was shown. The maximum pressure was observed at 66.6 bar, 64 bar and 47.8 bar for diesel, B30 and B30A12 respectively, at full loads. However the peak cylinder pressure obtained nearly the same crank angle positions that were 6 to 9 degree after top death centre for all fuels. It was clear that the peak cylinder pressure was lower when compared to diesel fuel at the full load. The ignition delay is the vital parameter in the diesel engine combustion.

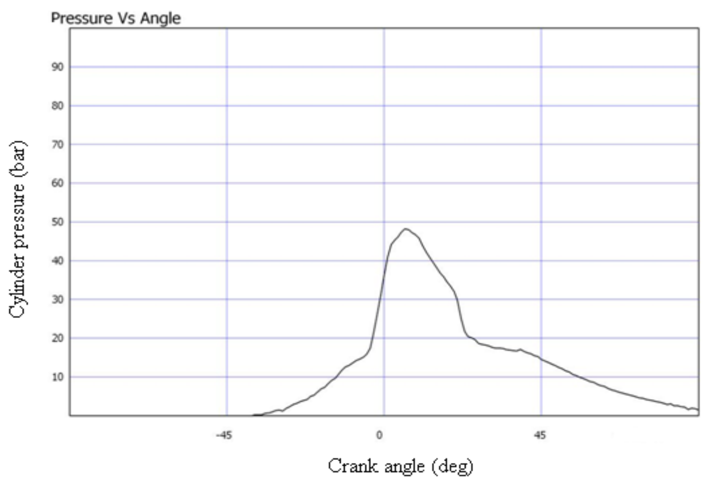

Fig 1: Variations of cylinder pressure with respect to crank angle for B30A12 at 0.579MPa load.

The combustion for biodiesel begins earlier than for diesel fuel combustion. This is because of short ignition delay and pre injection timing for biodiesel [10]. In spite of the slightly higher viscosity and lower volatility of biodiesel, the ignition delay seems to be lower for biodiesel than for diesel [11]. Due to the longer ignition delay, the peak cylinder pressure was reduced [12]. In this experiment, the ignition delay was calculated in terms of the crank angle degree. The ignition delay was measured by crank angle between the start of fuel injection and the start of burning.

B. Engine Performances

The Brake Specific Fuel Consumption (BSFC) was found to increase with the increasing proportion of biodiesel blends with diesel, whereas it decreased sharply with increase in load for all blends. For bio oil and various percentages of Acetone blends, the BSFC are higher than that of diesel. Lei Zhu et al. [13] attributed the increase of BSFC due to lower calorific value. It is observed that with increases in Acetone percentage in the blends the calorific value of the blend decreases. The brake thermal efficiency (BTE) obtained for different volumetric blends were recorded in Fig. 2. In general, the BTE increases gradually with the increasing the percentage of Acetone in the blends. This could be noted that the rich amount of oxygen in the blends, which might have resulted in its better combustion as compared to mineral diesel [14].

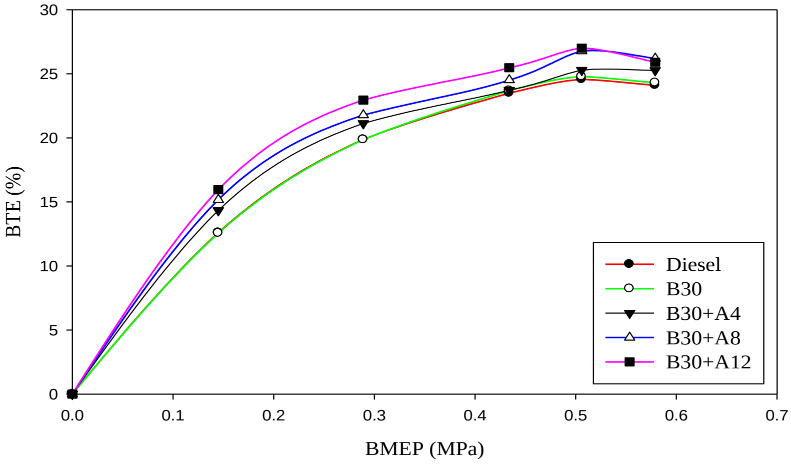

Fig 2: Comparison of BTE variation with load and fuel blends.

C. Pollutant Emissions

The emission of Carbon monoxide (CO) with engine loading for tested fuels was compared in Fig. 3. The CO emitted by 4%, 8% and 12% addition of Acetone with B30 biodiesel blends increase by 87, 83 and 82 percentages respectively at full load while comparing B30. The higher amount of oxygen content in the biodiesel and Acetone will lead to further oxidation of CO during combustion [19]. At the medium loads of engine, test fuels gave the lower CO emissions. It can be explained that the enriched oxygen in the combustion chamber produce the better turbulence caused increased piston mean speed. The sharp increase in CO emission at full load was because of the supply of rich mixture to the engine at higher load ranges [15].

HC emission is an important parameter for finding the exhaust emission behaviour of the engines. It is observed from Fig. 4, the 4% Acetone blend with B30 gives relatively higher HC emissions at full load as compared with other blends. At low engine loads, the HC emissions increased because of the cooling skin of unburned Acetone present in the combustion chamber. In addition to that, the higher latent heat of vaporization of Acetone results in low combustion chamber temperature, which is the main factor to produce HC emissions. The lowest percentage of HC emission was observed with 12% Acetone blend with B30 at full load, this is because of better combustion inside the combustion chamber.

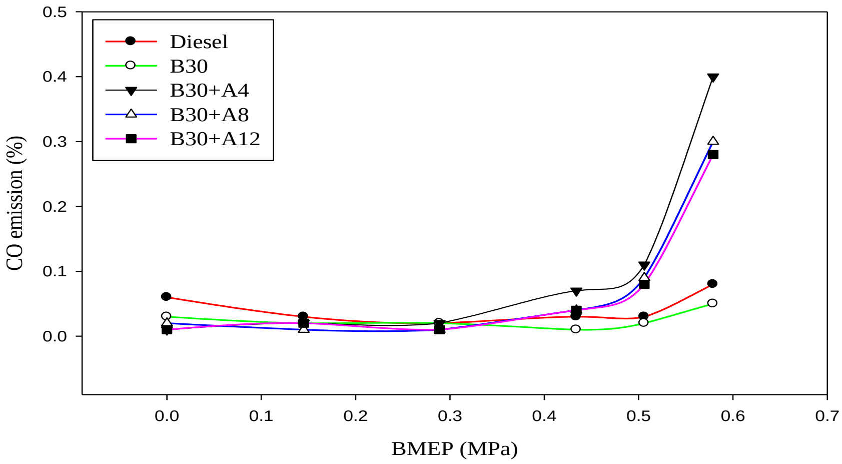

Fig 3: Comparison of CO variation with load and fuel blends.

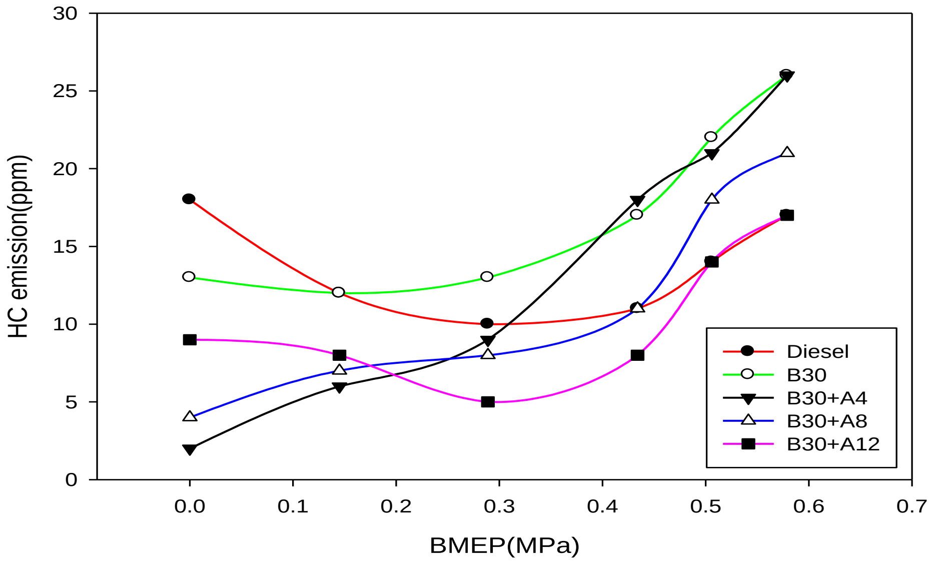

Fig 4: Comparison of HC variation with load and fuel blends.

The Nitrogen Oxide (NO) content in exhaust emissions of engine for various percentages of Acetone addition in B30, are plotted as a function of load in Fig. 5. From this figure, it can be seen that the NO emission decreases remarkably by 48% for 12% Acetone blends with B30, respectively at full load conditions. The NO level was depending directly to the exhaust gas temperature. This may be explained due to Acetone blended with B30 produces a cooling effect in the combustion chamber leading to reduction of NO emission. On the other hand, the higher oxygen content of B30 blend and premixed burning phase might result in high temperatures and hence higher NO formation [16].

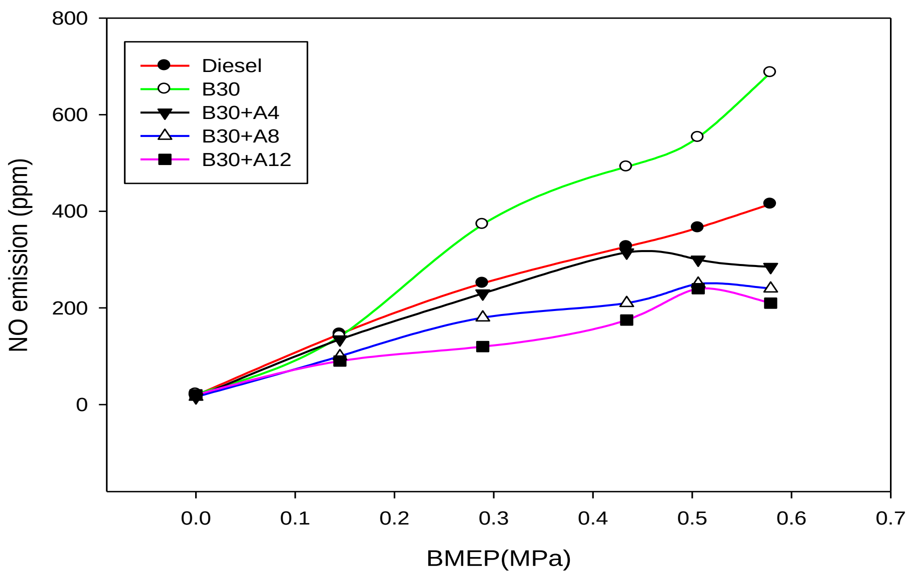

Fig 5: Comparison of NO variation with load and fuel blends.

The smoke content from the engine using biodiesel and its blends with diesel is shown in Fig. 6, as a function of engine load versus smoke opacity percentage. From this figure, it can be seen that B30 blend produced less smoke than diesel fuel operation. This is due to more amounts of oxygen molecules in the biodiesel which produce more burning efficiency as compared to mineral diesel. The B30+A4 blend produce more smoke emission at full load. The higher smoke emission influenced by the cooling effect of Acetone. In general higher smoke emission at full load for all fuel blend were observed. This is because, when the engine load is increased, more fuel is burned with inadequate air [17]. The B30+A12 blend produce relatively less smoke emission for entire load operation then that of tested fuel blends.

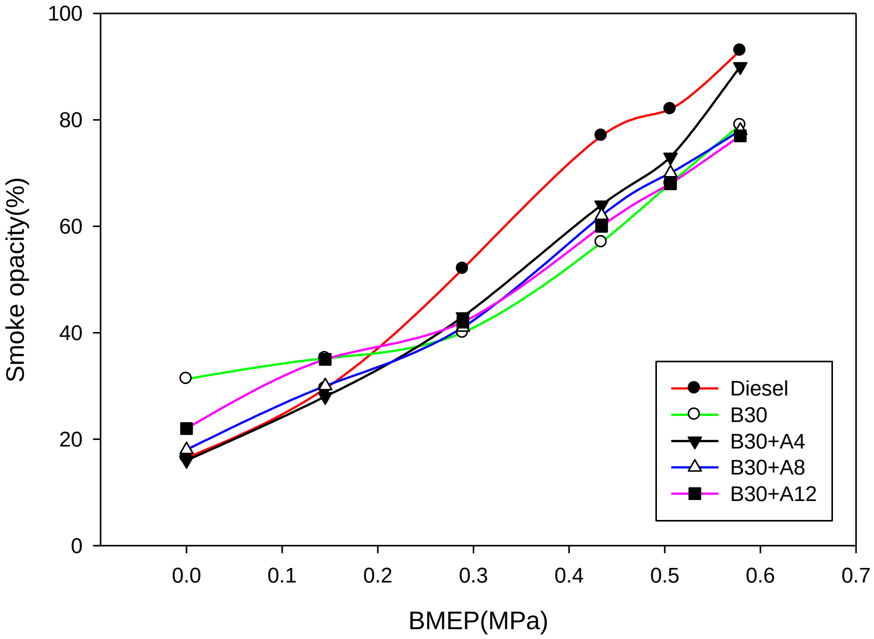

Fig. N Comparison of smoke opacity variation with load and fuel blends.

IV. CONCLUSIONS

The Karanja biodiesel is cheaper and it was obtained from low cost non-edible Karanja oil. Some fuel properties of B30 such as cetane number, Calorific value, sulphur content, and flash point are very close to diesel fuel. In addition, Acetone as additive improves the lubricant capacity. Exhaust gas emission for 12% Acetone blend reduces NO emission by 48 % and smoke opacity decreases by 17% at full load while comparing with diesel. In general, low NO and smoke emissions were measured with the 12% Acetone as additive in B30 blend. Therefore Karanja biodiesel blends could be used as fuel in diesel engines in village area for their energy requirement in various agricultural and power needs. Consequently 30% Karanja biodiesel and 12% Acetone as additive was the better alternate fuel blend for diesel engines without any engine modification.

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