Experimental analysis of a Diesel Engine fuelled with Biodiesel Blend using Di-ethyl ether as fuel additives

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Abstract- This study investigates the use of di-ethyl ether (DEE) as an oxygenated additive with 20% Karanja methyl ester diesel blend (B20). Experiments were conducted to study the effect of adding 5%, 10% and 15% di-ethyl ether (DEE) with Karanja methyl ester (KME) on performance, emission and combustion characteristics of a direct injection diesel engine operated at a constant speed of 1500 rpm at different operating conditions. The results showed that the brake thermal efficiency slightly increased and the exhaust emissions are significantly decreased with DEE with biodiesel at full load conditions. The results revealed that an optimum blend of 10% DEE added with biodiesel resulted in a slight decrease in brake specific fuel consumption (BSFC) of 8.6% while the brake thermal efficiency increased by 4.8%. DEE added with 20% biodiesel showed lower nitrogen oxide (NO) emission and slightly higher carbon dioxide (CO_2) emission as compared to diesel. Carbon monoxide (CO), hydrocarbon (HC) and smoke emissions decreased by 40%, 26% and 12% respectively compared to B20 biodiesel. The combustion characteristics like higher cylinder pressure, heat release rate and shorter ignition delay period were observed with DEE added biodiesel at full load conditions.

Keywords— Biodiesel, diethyl ether, emissions, performance, Karanja methyl ester,

1. INTRODUCTION

The search of alternative fuels for diesel engines from the non-conventional energy sources are continuously growing owing to rising price of petroleum fuel, the threat to the environment from engine exhaust emissions, the depletion of fossil fuels, the global warming effect and so on [1,3]. Biodiesel is a well known alternative for diesel and has an advantage over the later because of it is renewable, biodegradable, sulphur free and non-less toxic in nature, superior lubricity and can significantly reduce exhaust emissions from the engine [4–6]. Many researchers found that non-edible source based biodiesel is more promising and attractive than that of edible source based biodiesel. Their results have shown that biodiesel fuels could significantly reduce the HC, CO and smoke emissions but have an adverse effect on NOx emissions compared to diesel combustion [7-10].

Experimental investigations to optimize the parameters for effective use of biodiesel in engine like the effect of injection parameters on performance and emission characteristics of a diesel engine fuelled with pongamia methyl ester–diesel blend; the effect of compression ratio and injection pressure and the effect of supercharging and fuel injection pressure by adopting Karanja methyl ester [12, 13] were also studied. Among the oxygenated alternatives which could work as ignition improvers are dimethyl ether (DME) and diethyl ether (DEE) with advantages of high cetane number and oxygen content. Di ethyl ester is a liquid at ambient conditions, is produced from ethanol by dehydration process which makes it attractive for fuel storage and handling. It can also assist to improve engine performance and reduce the cold starting problem and emissions when using as a pure or an additive in diesel fuel. The performance and emission characteristics of a diesel engine using fuels like DME and DEE offered promising alternatives. Many researchers have confirmed through their investigations that B20 could be better option for the countries which are in the early stage of adoption of biodiesel program both looking at the availability and benefits of biodiesel [14,15].

The objective of the present experimental study is to improve the performance, emission combustion of a biodiesel fuelled diesel engine, with addition of 10% and 15% diethyl ether (DEE) at various load conditions and the results were compared with diesel en biodiesel fuel.

2. Preparation of Bio-Diesel

Transesterification is a chemical process of transforming large, branched, triglyceride molecules of vegetable oils and fats into smaller, straight chain molecules, almost similar in size to the molecules of the species present in diesel fuel. The process takes place by the reaction of vegetable oil with alcohol in the presence of a catalyst.

In transesterification process, Karanja oil react with methyl alcohol in the presence of catalyst (NaOH) to produce glycerol and fatty acid ester. The methyl alcohol (200 ml) and 8 gram of sodium hydroxide were taken in a round bottom flask to form sodium methoxide. Then the methoxide solution was mixed with Karanja oil (1000 ml). The mixture was heated to 65^{o}C and held at that temperature with constant speed stirring for 2 hours to form the ester. Then it was allowed to cool and settle in a separating flask for 12 hours. Two layers were formed in the separating flask. The bottom layer was glycerol and upper layer was the methyl ester. After decantation of glycerol, the methyl ester was washed with distilled water to remove excess methanol. The transesterification improved the important fuel properties like specific gravity, viscosity and flash point. The properties of diesel, methyl ester of Karanja oil are listed in Table.1.

Table 1. Properties of diesel and Karanja oil methyl ester and DEE

S.N	Properties	Diesel	KME	DEE
1.	Density(kg $^{-3}$)	830	890	713
2.	Calori1c value (MJ kg^{-1})	42.490	37.91	33.9
3.	Viscosity (cSt)	4.59	6.87	0.23
4.	Cetane number	45 –50	49	>125
5.	Flash point (˚C)	50	187	-
6	Auto ignition Temperature(˚C)	260	≥300	160

2.2 Experimental setup

The performance and exhaust emission tests were carried out in a constant speed, direct injection diesel engine. The specifications of the test engine are listed in Table 2. The engine was coupled with rope dynamometer consisting of a loading platform to provide the brake load. Two separate fuel tanks were used for the diesel fuel and fried cooking oil methyl ester. The fuel consumption was determined by measuring the time taken for a fixed volume of fuel to flow into the engine. The exhaust emissions were measured by the AVL 444 five gas analyzer and the smoke opacity were measured by Bosch smoke meter. The combustion parameters were measured with the help of pressure sensor, TDC encoder and data acquisition chord with the help of computer. The schematic of the experimental set up as shown in fig.1

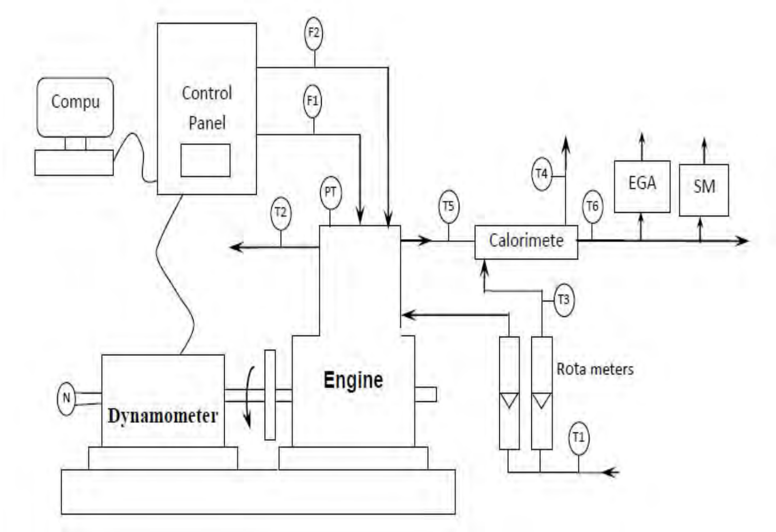

Figure 1. Schematic of the experimental setup

Table 2.Test engine specifications

Engine	**Kirloskar, AV-I,**
Power	4.44 kW
Bore (mm)	87.5
Stroke(mm)	110
Compression ratio	17.5:1
Speed (rpm)	1500
Injection pressure(bar)	200
Injection timing	23^{o}bTDC

3. RESULTS AND DISCUSSION

The experiments were conducted with 20% Karanja methyl ester diesel blend with Diethyl ether (DEE) in the proportions of 10% and 15% have been studied extensively through performance, emissions and combustion parameters. The calculated parameters like brake thermal efficiency, BSFC and measured values are EGT, CO, HC, NO, smoke opacity and the combustion parameters are cylinder peak pressure, heat release rate, maximum rate of pressure rise and ignition delay are analyzed and compared with base engine.

3.1 Combustion characteristics

The variation of peak pressure with crank angle for all test fuels are shown in Figure 2. The peak pressure mainly depends upon the combustion rate in the initial stages, which is influenced by the fuel taking part in uncontrolled heat release phase. A similar kind of results was obtained for addition of DEE with biodiesel. The peak pressure for neat biodiesel with DEE blends increases compared to neat biodiesel at full load. This may be due to the higher cetane number and high flammability of DEE which increases the premixed combustion phase results in higher peak pressure. The peak pressure for biodiesel with 10% and 15 % DEE are 67.1 bar and 68.3 bar respectively at full load whereas for the diesel and biodiesel are 70 bar and 64.6 bar respectively at full load. The peak pressure reduces at high power output with the introduction of diethyl ether along with biodiesel due to reduction in ignition delay compared to diesel fuel.

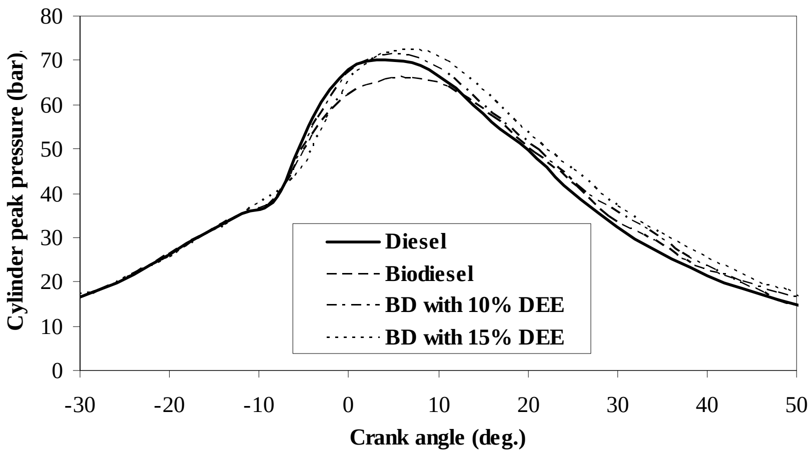

Figure 2. Variation of cylinder peak pressure with CA

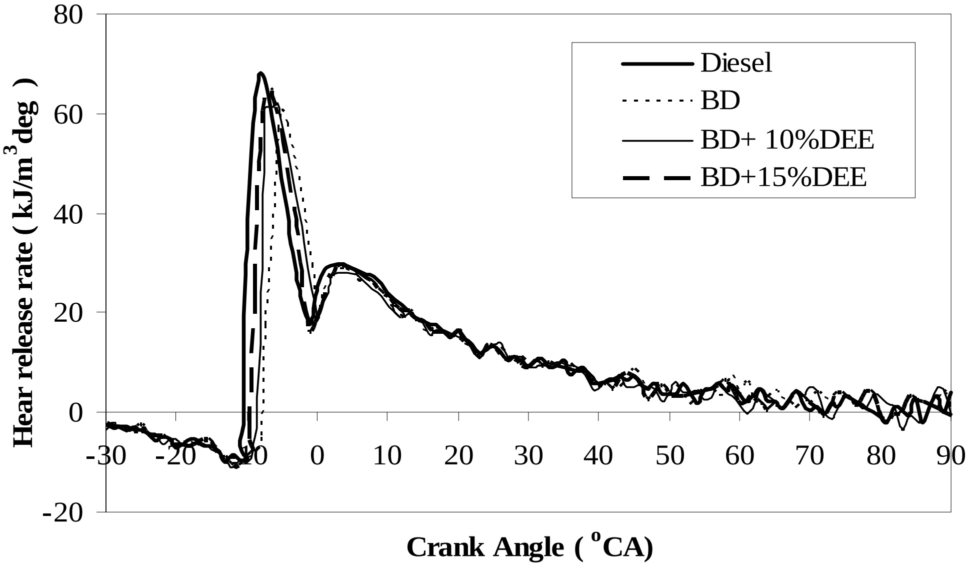

Figure 3. Variation of Heat release rate with CA

Figure 3 shows the variation of heat release rate with crank angle for diesel biodiesel and with DEE at full load. The premixed combustion phase is increased for biodiesel with 15%DEE compared to biodiesel blend. This may be due to the shortening of ignition delay as compared to 20% biodiesel at full load. The heat release rate obtained for diesel and B20 biodiesel are 68 J/deg and 66 J/deg CA respectively, and for neat biodiesel with 10% DEE and 15% DEE are 70 J/deg and 72 J/deg at full load. This increase in heat release rate may be due to DEE which acts as an ignition improver for biodiesel, and hence it increased the premixed combustion rates. Thus resulting in increased heat release rate.

Figure 4 shows the variation of the maximum rate of pressure rise with brake power for all test fuels. The maximum rate of pressure rise obtained for diesel and 20% biodiesel are 4.8 bar/^{o}CA and 4.2 bar/^{o}CA respectively, at full load, whereas for biodiesel with 10% and 15% DEE are 4.4 bar/^{o}CA and 4.6 bar/ ^{o}CA respectively, at full load. The maximum rate of pressure rise is increased for 15% DEE with DEE at full load. This may be due to more oxygen content present in the DEE and biodiesel blend, resulting in increased premixed combustion phase and hence increased maximum rate of pressure rise.

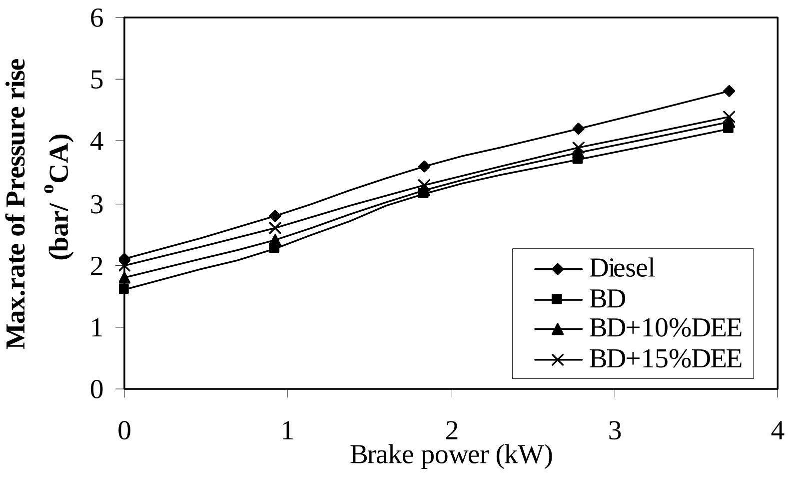

Figure 4. Variation of Maximum rate of pressure rise with BP

Figure 5 shows the variation of ignition delay with brake power for diesel, biodiesel and with DEE at full load. The ignition delay obtained for diesel and 20% biodiesel are 6°CA and 8°CA respectively at full load, whereas for the B20 with 10% and 15%DEE, are 7^{o}CA and 6.5°CA respectively at full load. The desrease in ignition delay for biodiesel with DEE may be due to faster combustion of the biodiesel with low boiling point of DEE,which improves the fuel air mixing rate before combustion. Also high cetane number DEE minimizes the ignition delay period. The presence of oxygen in the DEE also will take part in the combustion process. The

DEE has a high octane number, low auto ignition temperature, and good atomization and ignition properties, results decrease in ignition delay.

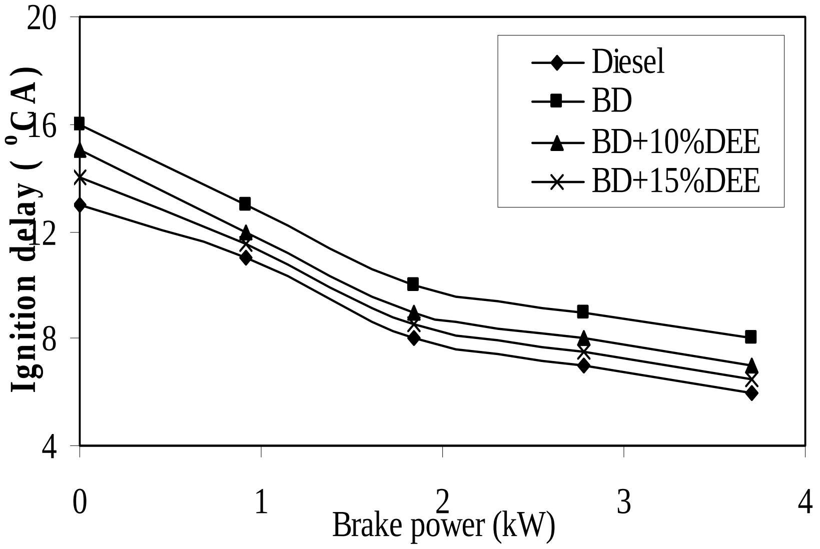

Figure 5. Variation of ignition delay with CA

3.2 Performance characteristics

The variation of brake thermal efficiency with brake power for different concentration of DEE with biodiesel is shown in Figure 6. It is observed that the BTE of neat biodiesel with 15% DEE is higher than 20% biodiesel and 10% DEE biodiesel blend at full load and lower than diesel fuel. The maximum BTE of 10% DEE biodiesel blend is 28.46%, and of 15 % DEE is 29.32% whereas for diesel and 20% biodiesel are 30.45% and 27.54% respectively at full load. This increase in BTE may be due to the presence of oxygen in the DEE helps to reduce the surface tension or inter facial tension between two or more interacting immiscible liquids helped the better atomization of fuel, which improves the combustion of diesel, resulting in complete combustion of the fuel and raising the BTE at full load.

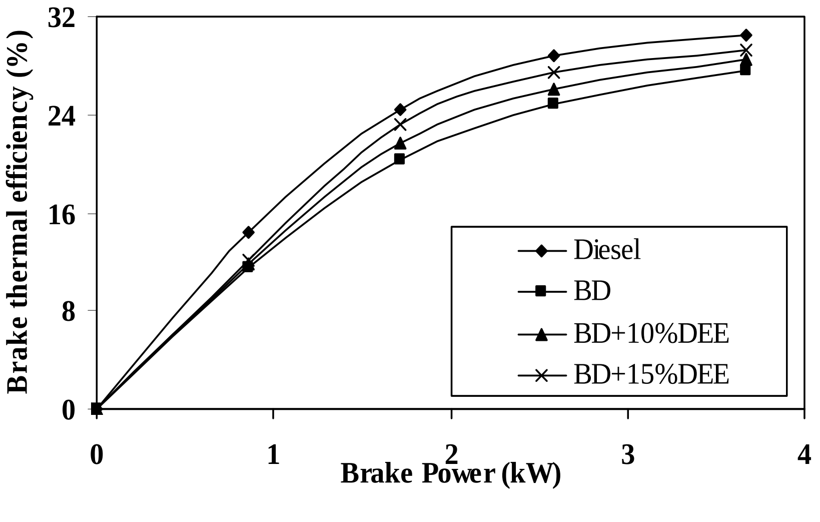

Figure 6 Variation of Brake Thermal Efficiency with BP

Figure 7 shows variation of brake specific fuel consumption with brake power for different concentration of DEE with 20% biodiesel. The BSFC is higher for lower loads and it decreases in high loads. The BSFC for 15 % DEE biodiesel blend is same as biodiesel and for 10% DEE biodiesel blend it higher than 20% biodiesel at full load. The BSFC of diesel fuel and neat biodiesel are 0.24 kg/kW-h and 0.257 kg/kW-h where as for 10% and 15% of DEE with neat biodiesel are 0.264 kg/kW-h and 0.269 kg/kW-h respectively, at full load. This may be due to more oxygen and higher cetane number in DEE which increases the flammability, resulting in better combustion of biodiesel fuel.

Figure 8 shows variation of exhaust gas temperature (EGT) with brake power for different concentration of DEE with biodiesel blend. The exhaust gas temperature almost same for the increase in the proportions of DEE in biodiesel. The exhaust gas temperature for 15% DEE is slightly higher than 10% DEE at full load. This may be due to the difference in calorific value of the fuel. The diethyl ether has a high latent heat of evaporation value than diesel; hence it gives lower exhaust gas temperature. The maximum exhaust gas temperature for 10% and 15% DEE blends are 326^{o}C and 319^{o}C respectively, whereas for diesel and 20% biodiesel it is 302^{o}Cand 338^{o}C respectively at full load.

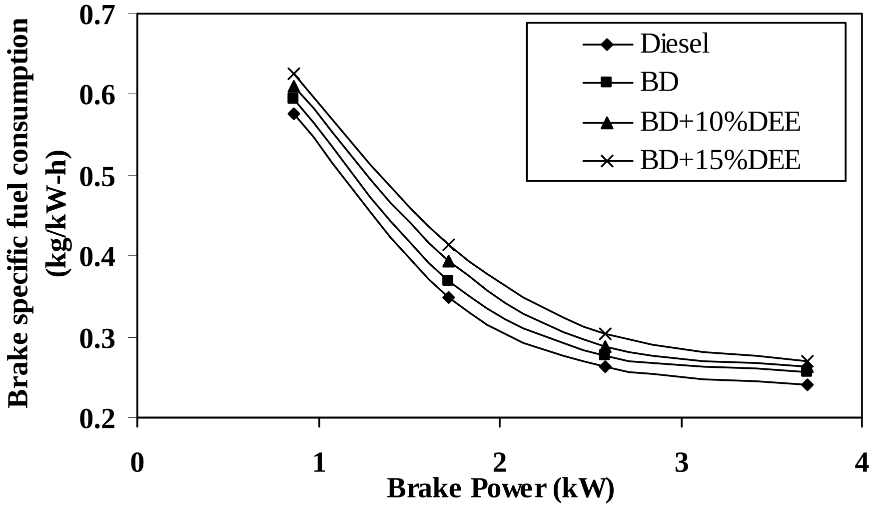

Figure 7. Variation of BSFC with BP

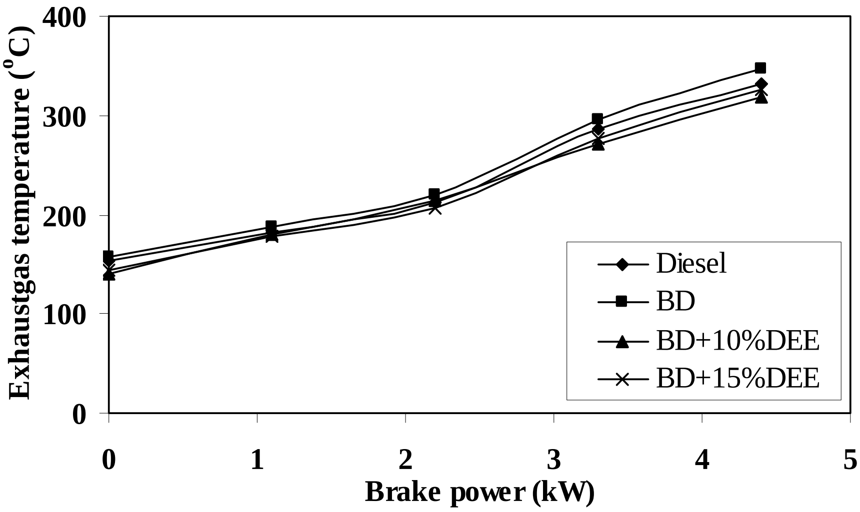

Figure 8. Variation of Exhaust gas temperature with BP

The variation of carbon monoxide emission (CO) with brake power for different blends of DEE with 20% biodiesel shown in Figure 9. The CO emissions increases with increase in DEE concentrations at all loads compared to 20% biodiesel. This may be due to high latent heat of vaporization of DEE results in cooling the charge at full load compared to biodiesel. It is observed that the CO emission of 10% and 15% DEE are 0.15% Vol and 0.13%Vol, whereas for diesel and B20 are 0.17% Vol and 0.15%Vol respectively at full load. The decrease in CO emission for 15% DEE blend may be due to the presence of more oxygen (21.6% by mass) in the DEE and biodiesel contains 11% by mass, which makes the combustion complete, resulting in lower CO emission at high loads compared to diesel.

3.3 Emission characteristics

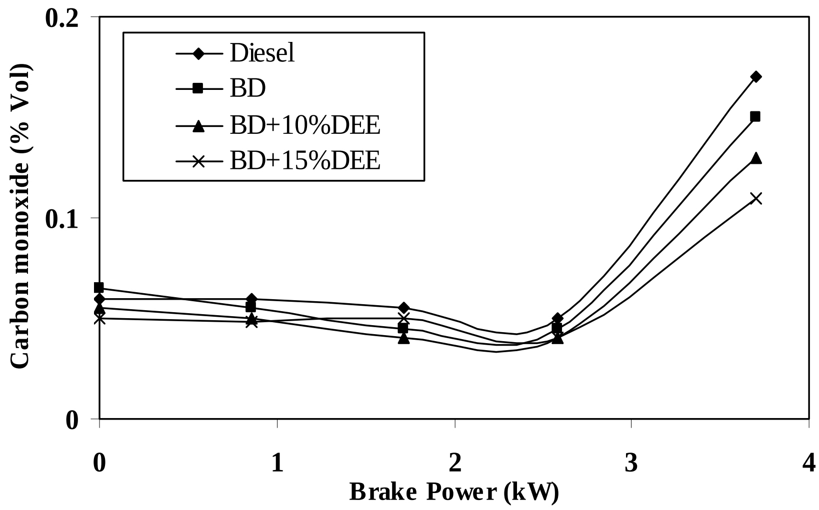

Figure 9. Variation of Carbon monoxide emissions with BP

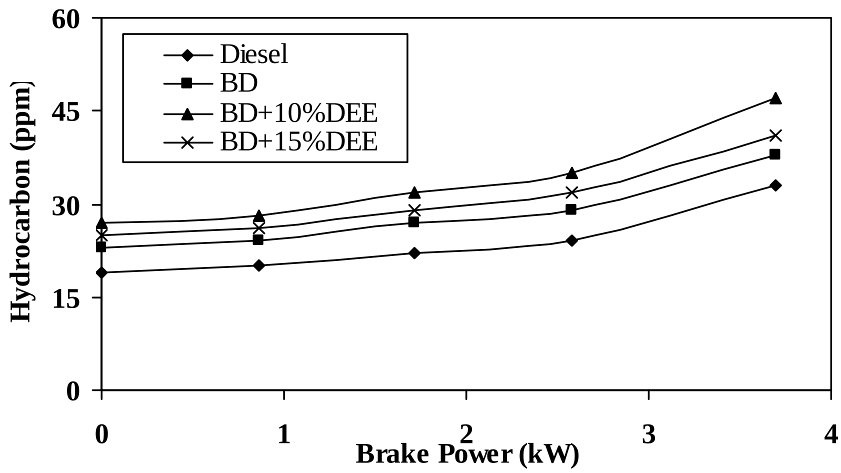

Figure 10 Variation of Hydrocarbon emission with BP

Figure 10 shows the variation of HC emission with brake power for different concentration of DEE with 20% biodiesel. It is observed that the HC emission is increased for 20% biodiesel and it is increased with increase in blend of DEE with 20% biodiesel at full load. The maximum HC emissions for 10% and15% DEE are 47ppm and 40ppm, whereas for diesel and B20 are 33ppm and 38ppm respectively at full load. This increase in HC emission for DEE blends may be is due to incomplete combustion at very high loads and low calorific value of DEE which results in higher HC emissions. Also the another reason for HC emission at full load is the high latent heat of vaporization of DEE results in cooling the charge at full load conditions.

Figure 11 shows the variation of NO emission with brake power for different concentration of DEE with B20 biodiesel. It is observed that the NO emission was increased for 20% biodiesel and it is decreased with increase in blends of DEE with biodiesel at full load. The maximum NO emissions for 10% and 15% DEE are 410ppm and 385ppm, whereas for diesel and B20 biodiesel are 486ppm and 568 ppm respectively at full load. The NO emission decreased by 32% for 15% DEE and 26% for 10%DEE at full load compared with 20% biodiesel. The decrease in NO emission for DEE may be due to high latent heat of vaporization of DEE results in cooling the charge at full load compared to 20% biodiesel.

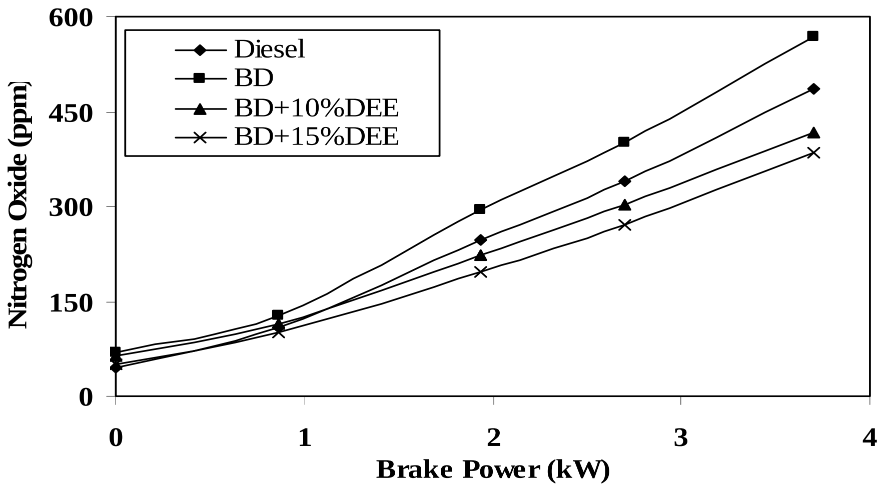

Figure 11 Variation of Nitrogen oxide emission with BP

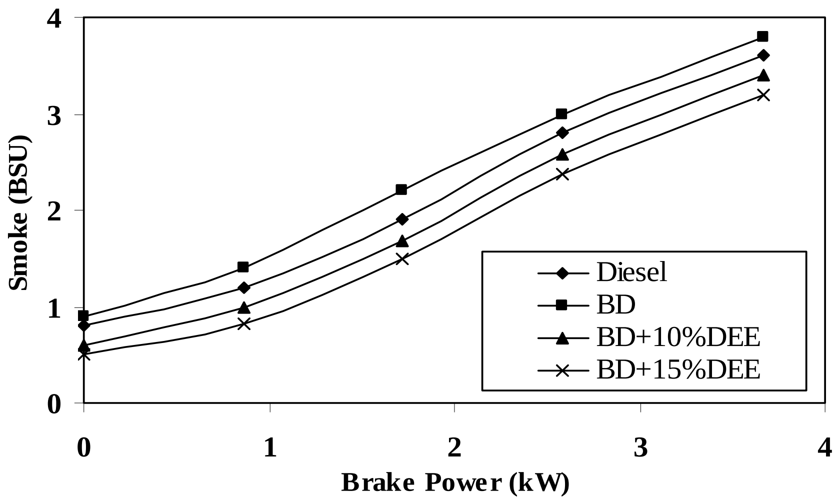

Figure 11. Variation of Smoke emission with BP

Figure 11 shows the variation of smoke emission with brake power for different concentration of DEE with 20% biodiesel. It is observed that the smoke emission is decreased with increase in blends of DEE with 20% biodiesel at full load. The maximum smoke emissions for 10% and 15% DEE are 3.4BSU and 3.2BSU, whereas for diesel and 20% biodiesel are 3.6BSU and 3.8BSU respectively at full load. The 10% reduction in smoke emission for biodiesel with 15%DEE may be due to the presence of more oxygen(21.6% by mass) in the DEE which makes the combustion complete and also since the biodiesel fuel itself contains 11% oxygen in it which may promote the oxidation of soot during the combustion process.

CONCLUSIONS

The experiments were conducted with 20 % Karanja methyl ester (KME: B20) using Diethyl ether (DEE) has been studied extensively through performance, emissions and combustion parameters. The following are the important conclusions drawn from the present investigations with the effect of DEE additives with biodiesel on a direct injection diesel engine.

- The brake thermal efficiency of 20% KME with 10% and 15% DEE increased by 0.94% and 1.76% respectively at full load compared with neat KME. The BSFC slightly decreased as compared with neat biodiesel at full load.
- The CO emissions for 20%KME with 10% and 15% DEE decreased by 27% and 14% respectively as compared to neat biodiesel. The HC emissions increased by about 24 % and 8% for 20%KME with 10% and 15% DEE as compared to B20 biodiesel at full load.
- The NO emissions decreased by 27% and 32% for 20% KME with 10% and 15% DEE compared to diesel fuel at full load, while the smoke emission increased by 14% and 10% for neat KME with 10% and 15% DEE respectively at full load as compared with B20 biodiesel.

- The peak pressure and the heat release rate increased and the ignition delay was decreased for both the DEE blends as compared with 20% biodiesel at full load.

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