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Experimental analysis of diesel engine for variable compression ratios using alternate fuel along with additive

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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 (CO2) 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

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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].

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 65oC 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

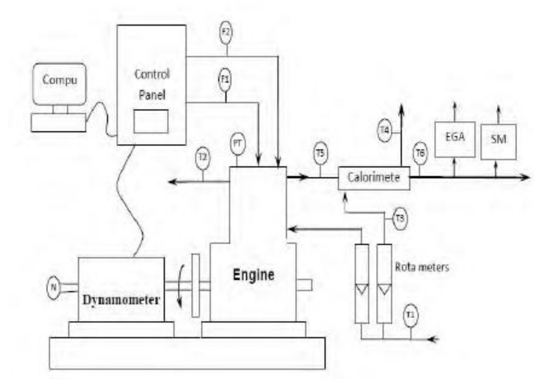

Figure 1. Schematic of the experimental setup

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

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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.

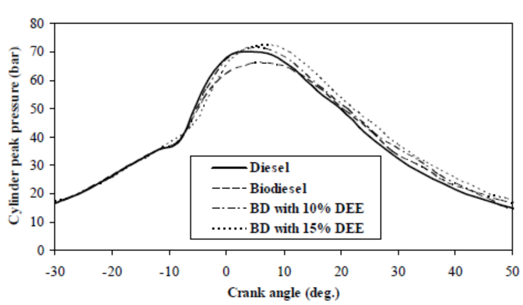

Figure 2. Variation of cylinder peak pressure with CA

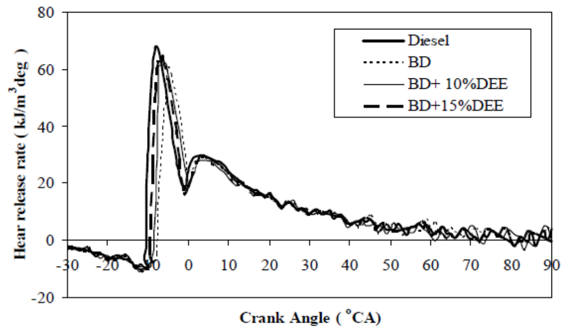

Figure 3. Variation of Heat release rate with CA

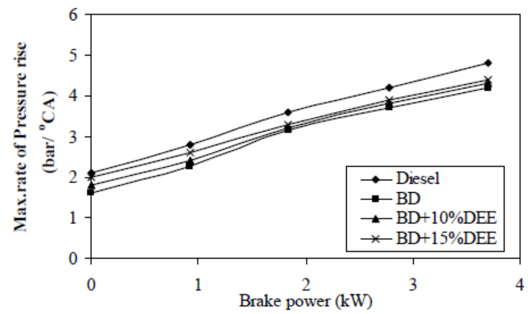

Figure 4. Variation of Maximum rate of pressure rise with BP

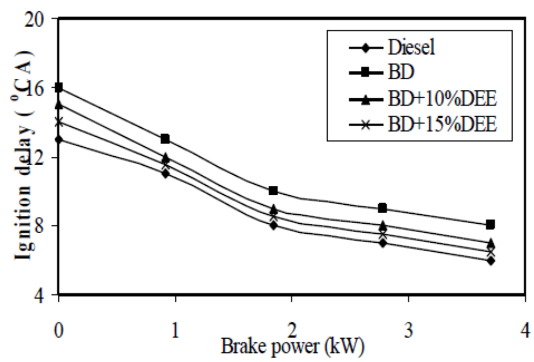

Figure 5. Variation of ignition delay with CA

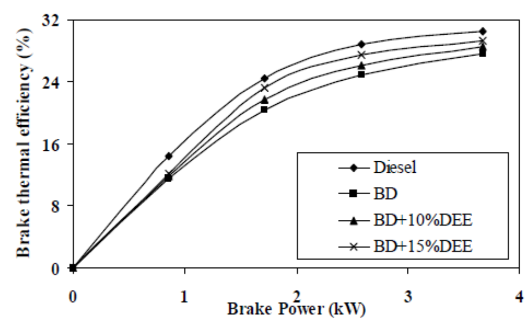

Figure 6 Variation of Brake Thermal Efficiency with BP

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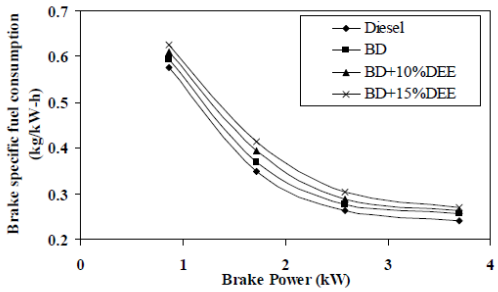

Figure 7. Variation of BSFC with BP

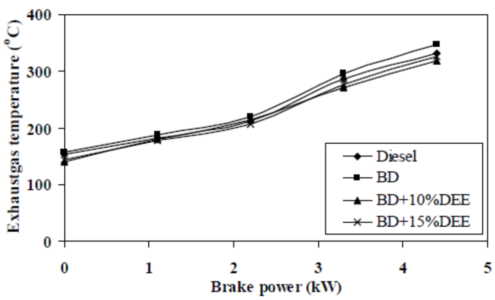

Figure 8. Variation of Exhaust gas temperature with BP

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.

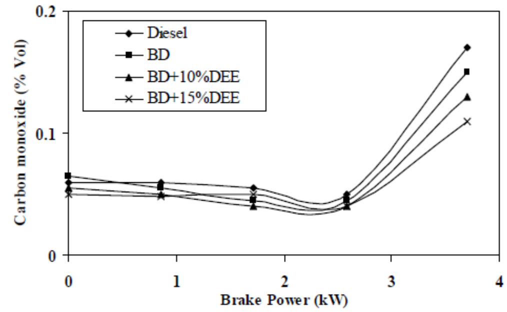

Figure 9. Variation of Carbon monoxide emissions with BP

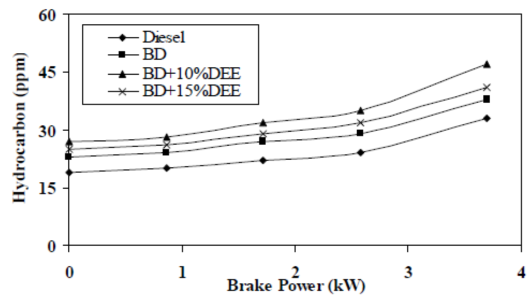

Figure 10 Variation of Hydrocarbon emission with BP

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.

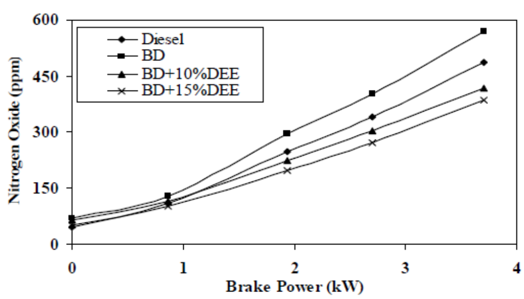

Figure 11 Variation of Nitrogen oxide emission with BP

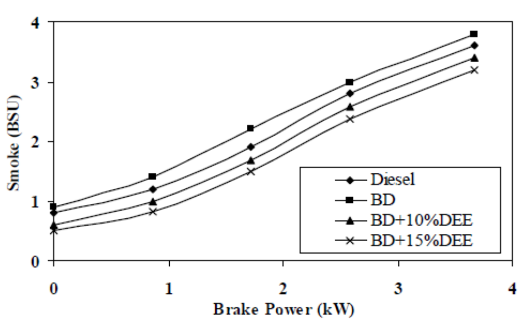

Figure 11. Variation of Smoke emission with BP

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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