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Experimental Analysis of Performance of Diesel Engine Using Kusum Methyl Ester With Diethyl Ether as Additive

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Abstract
The fossile fuels are widely used in diesel engine and continually depleting with increasing consumption and prices day by day. The fatty acid methyl ester has become an effective alternative to diesel. Various types of vegetable oil such as Jatropha, karanja, cottonseed, neem, sunflower, palm, mahuva, coconut etc. can be used as fuel in diesel engine. Kusum oil is one of the fuel used in present work. The viscosity of kusum oil is very high, so it was reduced by Transesterification process.

This study presents effect of diethyl ether as additive to biodiesel of kusum (schliechera oleosa) methyl ester on the performance and emission of diesel engine at different load and constant speed and two different injection pressure (170 and 190 bar). From literature it was observed that very few studies had been conducted on use of neat biodiesel and diethyl ether blends and use of kusum methyl ester (KME) in diesel engine found to be very less as compared to different biodiesel. Hence this topic was taken under study. The fuels and its blends used are 100% diesel, B100 (100% KME), BD-1 (95% KME, 5% DEE), BD-2 (90% KME, 10% DEE), BD-3 (85% KME, 15% DEE) respectively. It was observed that the performance of engine increases at high injection pressure. The results indicate that lower BSFC was observed with BD-3 as compared to B100, BD-1 and BD-2. Brake thermal efficiency of BD-3 decreased at 170 bar injection pressure but it increase at 190 bar. Drastic reduction in smoke is observed with all blends at higher engine loads. DEE addition to biodiesel reflects better engine performance compared to neat biodiesel.

Keywords- Biodiesel, Kusum methyl ester, Diethyl ether, injection pressure.

I. Introduction

Diesel engine continues to be reliable power source for light, medium and heavy duty applications and as such there can be no replacement for it in agriculture and transportation sectors. Although CI engines have a higher thermal efficiency when compared with SI engine, advanced research in the combustion of diesel fuel in CI engine shows that the Brake thermal efficiency, Brake power can further be increased by allowing the fuel to combine with more oxygen atoms to form complete combustion. The steady increase in energy consumption coupled with environmental pollution has promoted research activities in alternative and renewable energy fuels. Biodiesel is produced from vegetable oils (edible & non edibles) and animal fats. The methyl ester of vegetable oils, known as biodiesel are becoming increasingly popular because of their low environmental impact and potential as a green alternative fuel for diesel engine and they would not require significant modification of existing engine hardware. Biodiesel cannot be used purely for combustion because of their high viscosity and low calorific value. Transesterification is most attractive method to reduce viscosity of raw vegetable oil [1]. Another approach is it can be blended with diesel fuel as the result, the performance and emission values are found to be nearly same with diesel fuels at high injection pressure [2]. Preheated biodiesel can also used, because preheating of oil decreases viscosity of oil considerably as the temperature increases and are close to diesel fuel [3-4]. Biodiesel is non-toxic and biodegradable. The combustion of biodiesel contributes less CO_2 to the atmosphere. Studies on using biodiesel as fuel in diesel engines have shown greater reduction in emissions of hydrocarbons, smoke, particulate matter, oxides of sulphur and carbon and polyaromatics as compared to diesel. Another option for further reduction of emission and to improve thermal efficiency is to improve oxygen content of fuels. oxygen contents can be increased by mixing oxygenated additivs with diesel or biodiesel. Present study is related to evaluate the effect diethyl ether as oxygenated additive and its blend with neat biodiesel. Various researches had been conducted on blends of oxygenated additive with diesel and biodiesel. The information of researches are discussed as follows.

Alcohols are produce from fossile resources such as methanol and ethanol are generally added to diesel fuel to reduce emission. Ethanol fuel blends promote also higher combustion pressure and therefore better combustion and lower amount of exhaust components [5]. In the transportation sector, ethanol produced from biomass shows promice as a future fuel for SI engine. Because of high octane quality. But it is not high quality CI engine fuel ethanol can be easily converted through a dehydration process to produce di ethyl ether (DEE). It is an excellent compression ignition fuel and higher energy density than ethanol. It is also called as cold start aid additive for engine and having very high cetane number compared to diesel [6]. N. K. Miller Jothi, G. Nagaraja in their experimental study with homogeneous charge CI engine fueled with LPG using DEE as an ignition enhancer and it was found that the maximum reduction in smoke and particulate emissions is observed to be about 85% and 89%, respectively, when compared to that of diesel operation, however an increase in CO and HC emissions was observed [7]. Similarly can cinar, H. Serdar Yecesu [8] investigated the use of premixed diethyl ether in a HCCI-DI diesel engine and it was observed that increase in in-cylinder pressure and higher heat release in the premixed stage of combustion. Masoud Iranmanesh, [9] in their study it was concluded that 8% DEE add to the D-E10 (diesel-ethanol) blend is the optimum combination based on the performance and emission analysis with the exception of smoke opacity in which 15% DEE addition made the lowest smoke opacity. At this optimum ratio the minimum peak heat release rate, the lowest NOx emissions and the maximum BTE were occurred at full load condition. similarly Saravanan D., Vijayakumar T. [10] found that 10% DEE and diesel blend was optimum combination in term of BTE and BSFC. Obed M. Ali, Rizalman Mamat [11] in their study an oxygenated additive diethyl ether (DEE) was blended with palm oil biodiesel (POME) in the ratios of 2%, 4%, 6% and 8% and tested for their properties improvement. These blends were tested for energy content and various fuel properties Blends of DEE in POME resulted in an improvement in acid value, viscosity, density and pour point with increasing content of DEE. Vara Prasad U. SATYA [12] concluded that Brake specific fuel consumption and hydrocarbon emissions values are lower with 20% blend of JOME with 5% DEE whereas B20 with DEE15 yielded lower NOx emissions. Similarly B40 of JOME with DEE10 performed better in terms of brake specific energy consumption. The higher cetane rating of DEE is advantageous for obtaining lower smoke opacity and also lower NOx emission [13]. 15% Mahuva methyl ester blend with 80% diesel and 5% diethyl ether shows slightly lower BSFC and Drastic reduction in smoke is observed at higher engine load [14]. Whereas the BTE of B40 NOME with 15% DEE was higher than B100 at injection pressure of 210 bar [15].

II. Objective of the present study

The main objective of present investigation was to study the effect of diethyl ether as oxygenated additive on diesel engine performance and emission when blended with neat biodiesel. In this work, kusum (Schlichera Oleosa) oil derived from the kusum seeds was used to produce biodiesel. The fuel blends investigated for performance analysis were 100% diesel (B00), B100, BD-1, BD-2, BD-3. These blends were tested on diesel engine at 170, 190 bar injection pressure. Performance parameter considered were brake thermal efficiency, brake sp. fuel consumption, exhaust gas temperature etc.

III. Material and methodology

Kusum oil extracted from kusum seeds by mechanical extraction process in screw type expeller. The viscosity of raw kusum oil is very much higher than diesel. Hence it cannot be directly used for experimentation. Hence it is necessary to lower the viscosity of raw kusum oil by transesterification process.

IV. Transesterification of kusum biodiesel

The transesterification is two stage process i) Acid catalyzed esterification and ii) Alkaline catalyzed transesterification to convert esterified oil in to methyl ester and glycerol. The esterified oil (below 4% FFA) was taken for transesterification in the quantity of 1000 ml. 5 g of KOH was dissolved in to 250 ml of methanol and continuously stirred for 15 minute. After that this mixture was dissolved in to the 1000 ml of oil. This solution was then continuously heated and stirred at constant temperature of 55-60˚C for 2 hours. After the reaction is over, solution was allow to settle down for 24 hours. Glycerine settles at the bottom and kusum methyl ester rises at the top. Methyl ester was then separated and purified with warm water.

Transesterification process

V. Experimental fuels

The commercial Diesel fuel employed in the tests was obtained locally. Diethyl ether, also known as ethyl ether, sulfuric ether, is an organic compound in the ether class with the formula ($C_4H_{10}O$). It is a colorless, highly volatile flammable liquid. Diethyl ether has a high cetane number of 125 and is used as a starting fluid, in combination with petroleum distillates for gasoline and diesel engines because of its high volatility and low flash point. The diethyl ether is an analysis-grade anhydrous diethyl ether (99.5% purity). In the study, four fuels are prepared diesel as baseline fuel. B100 (neat KME), 95% KME 5% DEE, 90% KME 10% DEE, 85% KME 15% DEE. The properties of fuels used and its blends are given in table 1 and 2.

Table I
Properties of diesel, KME and diethyl ether

Properties	Diesel	Biodiesel	DEE
Density (Kg/m3)	823	850	713
Calorific value (KJ/Kg)	43000	40800	36840
Viscosity @40°C (cst)	3.9	9.2	0.23
Cetane number	48	42-48	125
Auto ignition temperature °C	315		160
Oxygen content %	0	11	21.6
Flash point ˚C	56	140	-40
Boiling point ˚C	188		34

Table II
Properties of various blends

Fuel	Density Kg/m^3	Calorific value KJ/Kg	Kinematic viscosity @ 40˚C	Flash point ˚C
Diesel	823	43000	3.9	85
B100	850	40800	9.2	140
BD-1	833	40602	8.7	131
BD-2	827	40404	8.2	122
BD-3	821	40206	7.8	133

VI. Experimental setup and Procedure

The engine used was a single cylinder, naturally aspirated four stroke, and direct injection diesel engine with a bowl in piston combustion chamber. The specifications of the engine used are given in Table III. With the liquid fuel injection, a high-pressure fuel pump was used, a three hole injector nozzle. Engine was directly coupled to a dynamometer. exhaust gas temperatures measured by thermocouple which indicates reading on digital display, loads are applied by rope brake dynamometer at constant rpm 1500 which is measured by contact type tachometer. Smoke was measured by a opax 2000 II smoke meter Before running the engine to a new fuel, it was allowed to run for sufficient time to consume the remaining fuel from the previous experiment. The smoke meter was also allowed to adjust its zero point before each measurement. To evaluate performance, some operating parameters like speed, power output and fuel consumption were measured.

Table III
Engine specifications

1	General details	Single cylinder 4-stroke DI engine
2	Bore (mm)	80
3	Stroke (mm)	110
4	Swept Volume (CC)	553
5	Compression Ratio	16:1
	Rated RPM	1500

VII. RESULTS AND DISCUSSION

Brake thermal efficiency

The BTE of different fuels is shown as a function of load. The variation in brake thermal efficiency for various blends was less at part load and higher at peak load due to the raised temperatures inside the cylinder. The brake thermal efficiencies of diesel and the blends of biodiesel with diethyl ether were seen increased with increase in load but tends to Decrease with further increase in load. The brake thermal efficiency of diesel was higher than Kusum methyl ester throughout the range of load because of high viscosity and poor volatility of biodiesel. The brake thermal efficiency increases with increase in percentage of diethyl ether. Figure 1&2 shows variation in BTE of various blends at 170 and 190 bar injection pressure. It was seen that BTE of diesel increases by 2.8% at 190 bar compared to 170 bar injection pressure. Because of increase atomization and spray penetration characteristic fuel injector. BTE of all blends was higher than 100% KME. But it was lower than diesel. Higher BTE was achieved with BD-2 at 170 bar, but it was observed that BTE of BD-3 was lower by 2.05% than BD-2.This is due to lower calorific value of DEE. At 190 bar BTE of BD-3 was increased by 6.7% compared to 170 bar. Viscosity of biodiesel decrease with increase in percentage of DEE cause improvement in the shape of fuel spray and atomization. Due to this fuel droplets get mix thoroughly with inside air and improving the combustion characteristic of engine. BTE of BD-1, BD-2 and BD-3 was higher than 100% KME.

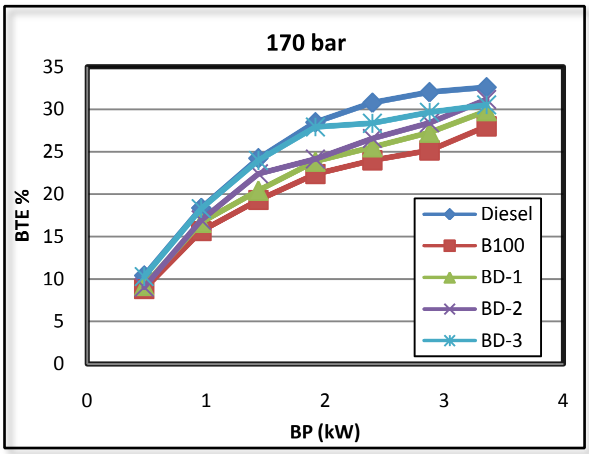

Figure-1 Brake thermal efficiency Vs brake power (170 bar)

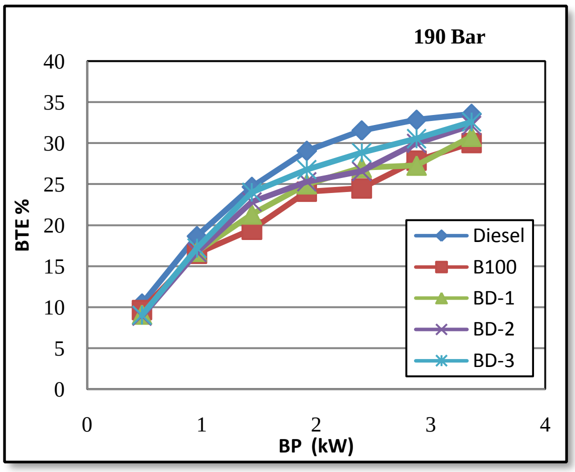

Figure-2 Brake thermal efficiency Vs brake power (190 bar)

Brake specific fuel consumption

Brake specific fuel consumption decreases with increase in load. One possible explanation for this could be due to more increase in brake power with load as compared with fuel consumption. The BSFC of B100 were higher compared to diesel over entire load range. And it is also higher than all blends This is due to its lower heating value, greater density and hence higher bulk modulus. The higher bulk modulus results in more discharge of fuel. BSFC of BD-2 and BD-3 comes to be 286 and 293 gm/Kw-hr, and were observed lower by 10.9% and 8.7 % compared to B100 at 170 bar pressure. The BSFC of BD-3 was lower than B100 and BD-2 at 190 bar pressure. And it comes to be 274 gm/Kw-hr. This is due the fact that with increase in injection pressure the fuel droplets size decreases. One of the reason for higher BSFC for B100 is that lower heating value of bio-diesel. Heating values are also lower for additive blends because of lower calorific value of DEE. Though addition of DEE reduces calorific value, but it improve other properties of biodiesel such as it reduce viscosity and autoignition temperature, improve cetane no. and flash point. and it increases with further increase in DEE concentration. Further increase in injection pressure beyond 190 bar has resulted in higher value of BSFC because of increase in momentum of fuel droplets.

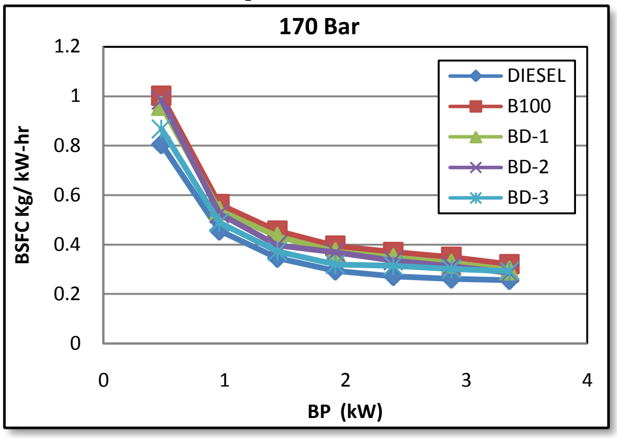

Fig. 3 BSFC Vs brake power (170 bar)

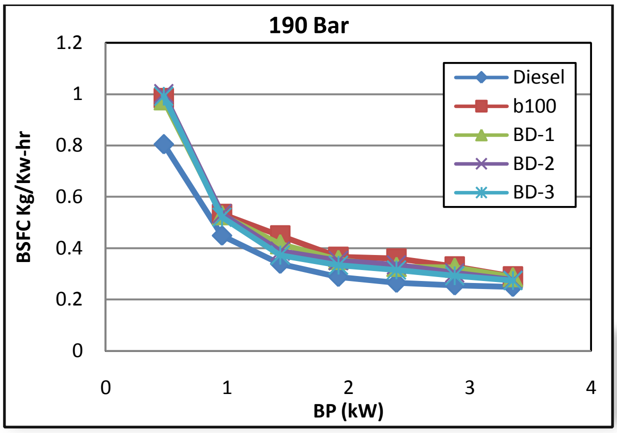

Fig. 4 variation BSFC Vs. brake power (190 bar)

VIII. Exhaust gas temperature

Fig. 5 shows graph of Exhaust gas temperature vs. brake power. EGT of fuels increase with increase in load because more fuel require to take additional load. EGT of diesel was observed higher than all fuels used in the experiment. The exhaust gas temperature of 100% biodiesel was lower than diesel and additive blends. This could be due to lower heat transfer rate in case of biodiesel. EGT increased With increase in concentration of DEE. This may be due to higher cetane number which reduce the ignition delay period and reduce the chance of burning in exhaust stroke. The exhaust gas temperature of BD-2 and BD-3 were observed to be higher compared to B100. At 190 bar BD-3 gives higher value of EGT because of improved combustion process.

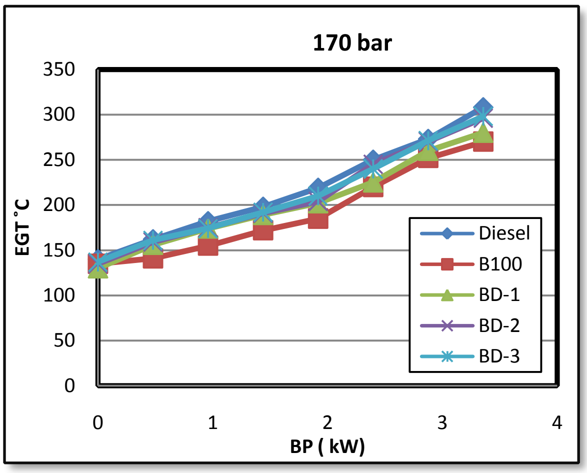

Fig. 5 Variation of EGT Vs. brake power (170 bar)

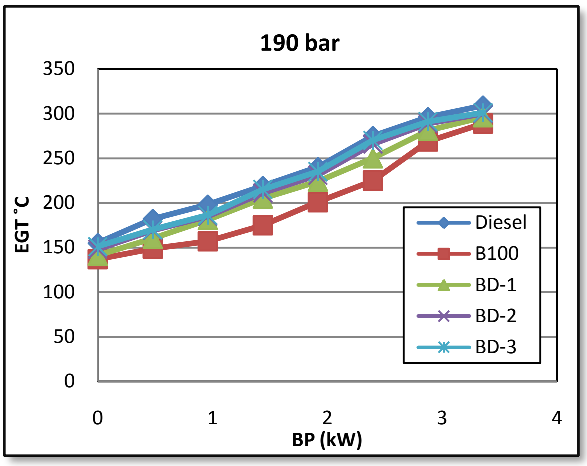

Fig.- 6 Variation of EGT Vs. brake power (190 bar)

IX. Smoke emission

Smoke intensity with diesel fuel was higher than biodiesel. Smoke is formed due to incomplete combustion of fuel. This is because of oxygen content in fuels. Oxygen content of biodiesel is higher than diesel. Smoke emission was observed lower with DEE blends. Improved and complete combustion could be the reasons for obtaining lower smoke emission values with oxygenated additives. Smoke emission with 5% DEE addition was slightly lower than B100 at all part load but gives more difference at peak load. This is due to fact that addition of DEE to biodiesel improve oxygen content and reduce viscosity. Smoke emission with BD-2 and BD-3 gives Lower value smoke and it was lower by 21% and 28% compared to B100. Fig-7 shows the graph of smoke emission Vs brake power. At high pressure (190 bar) it was seen that smoke emission slightly decreases than at 170 bar injection pressure.

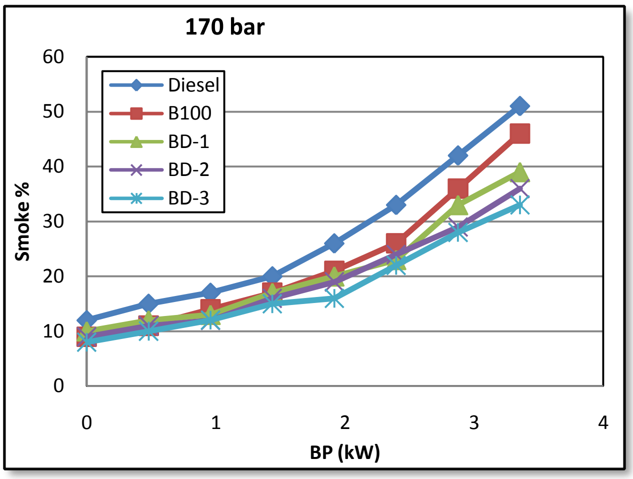

Fig. 7 Variation of smoke opacity Vs brake power (170 bar)

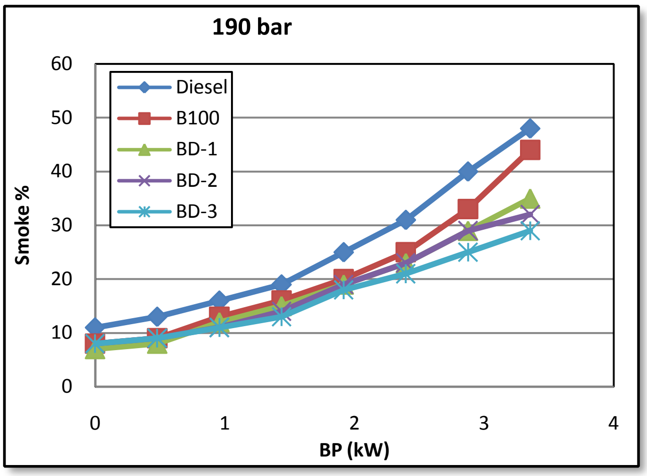

Fig. 8 Variation of smoke opacity Vs brake power (190 bar)

X. Conclusion

Based on the experimental investigation carried with blends of kusum methyl ester and diethyl ether with simultaneous influence of fuel injection pressure following conclusion are drawn.

- The performance of BD-1 increases slightly compared to B100 .
- Brake thermal efficiency and BSFC is better in case of BD-2 at 170 bar injection pressure.
- 15% DEE blend (BD-3) is adjudged as the best combination which yielded better results than other fuel blends tested especially 5% blend (BD-1) which is the nearest competitor.
- BD-3 perform better in case of BTE and BSFC at 190 bar injection pressure. Because of better mixing and proper utilization of air converted more heat into the useful work resulting in higher BTE.
- Smoke emission have decreased with addition of 5%, and 10% additive but it decreased substantially with 15% DEE addition at full load. Be-

cause of high oxygen contents of DEE. It also reduced at 190 bar injection pressure.

- Higher cetane rating of DEE and oxygen content are also advantageous for obtaining lower smoke emission.

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