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Diethyl ether additive effect in the performance of single cylinder D I diesel engine with B20 Biodiesel blend fuel

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***Abstract*—*The present work involves in production of methyl ester (Biodiesel) from inedible oils like Jatropa oil and application of its B20 blend fuel with diethyl ether (DEE) as an alternative fuel in D I diesel engine to investigate the performance and properties of test fuel. The methyl ester was obtained by base catalyzed transesterification process and 20% of biodiesel blended with 80% of diesel to form B20. The use of oxygenative additive in blend fuel reduces the ignition delay and combustion period of a diesel engine. This lowers the sulfur and nitrogen oxide emissions with less combustion period by the additive. The results show that the brake thermal efficiency increases with increase in load. The maximum brake thermal efficiency is obtained for diesel, B20 and B20DEE3 respectively at full load. The brake specific fuel consumption decreases and minimum fuel consumption occurred for B20DEE6 fuel at full load. The exhaust gas temperature increases linearly with load and is minimum for B20DEE3. The test fuel property results show that significant improvement in flash point, fire point, viscosity and density, whereas increase in energy content is observed with addition of DEE in B20 blend fuel.*

Keywords*—*Performance, Emissions, Blend fuels, Viscosity, Biodiesel, Additive, Diethyl ether, Properties.

I. INTRODUCTION

Mostly for transportation sector future energy requirements can be replaced by alternative fuels like biodiesels derived from edible and inedible oils. Biodiesel is becoming a significant, renewable, future alternative fuel, lubricant and also as an additive to the existing petroleum fuels. Biodiesel is a biodegradable, non-toxic and mostly renewable and alternative fuel. It can be produced from various edible and inedible oils, waste cooking oil or animal fats [**1**]. The properties of biodiesel may change when different feed stocks are used. In comparison of biodiesel properties with diesel fuel, it has higher viscosity, density and cetane number. But the energy content in biodiesel is about 10-12 % less than that of conventional diesel fuel on the basis of mass [**2**].

Biodiesel properties are similar to diesel fuel; hence there is no need to modify the diesel engine when it is fueled with biodiesel or biodiesel blends with diesel fuel. Additive is a chemical material added in base fuel to improve desirable chemical properties and also functions as a detergent or dispersed. Oxygenated additives like triacetin, diethyl ether etc. solve problems occur prior to burning and promote complete combustion of fuel in the combustion chamber which reduces engine deposits, smoke and other emissions [**3**], [**4**].

Additives can be considered to improve combustion, fuel economy, to decrease the emissions and to make biodiesel quality equivalent to diesel. The metal based additives, cetane number additives, antioxidant additives and oxygenated additives help in improving the quality of the biodiesel [**5**]. Alcohols lower the flash point slightly and reduce the viscosity and density of blend fuel marginally. With this fuel, ignition can start at lower temperature and able to burn completely to extract total energy content. The combustion rate of fuel is increased due to more oxygen availability in alcohol, that results in reducing the levels of pollutants in exhaust gases [**6**]. Additives significantly improve the quality of biodiesel and its blends; enhance biodiesel properties, reduction from fuel system cleanliness with optimized performance and economy of fuel [**7**].

DEE has the required properties to use in diesel engines, such as miscibility in diesel and biodiesel with high oxygen content, low ignition temperature and high cetane number. The effect of DEE addition in mahua oil methyl ester (MOME) is revealed that carbon monoxide and smoke were reduced more than 50% [**8**]. Diethyl ether has been identified as a potential renewable bio-based fuel and oxygenated additive. Tests on diesel engine with neat Karanja oil methyl ester as a base fuel and blends of 5, 10, 15 and 20% of DEE by volume basis improves, the fuel properties like combustion characteristics, viscosity and cold starting problems [**9**]. With the experiments conducted on a single cylinder D I diesel engine fuelled biodiesel with various percentage of DEE addition (5%, 10%, 15%), concluded that 5% DEE addition lowered the CO and smoke emissions with increased HC and NOx formation [**10**].

The experimental studies were carried out to evaluate the effect of Triacetin (T) as an additive with biodiesel on D I diesel engine performance and combustion characteristics. By adding triacetin additive to biodiesel, the results showed that the engine knocking problem can be alleviated to some extent and the tail pipe emissions were reduced. Experiments were conducted to compare the results with Petro-diesel, biodiesel and triacetin additive blends of biodiesel on the engine. Coconut oil methyl ester (COME) was used with an additive at various percentages by volume for all load ranges of the engine from zero up to full load. The results showed that performance is better compared with neat diesel in respect of engine efficiency and exhaust emissions. Among the all blend fuels tried, 10% Triacetin combination with biodiesel shows encouraging results [**11**], [**12**].

The results with oxygenated additives indicate that smoke and particulate emissions are reduced without sacrificing other emission characteristics and thermal efficiency due to the high oxygen content in the fuels [**13**]. Addition of 10% DEE improved the BTE, lowered the smoke and CO emissions without affecting NOx emissions [**14**]. The report with 5% addition of DEE resulted in higher BTE with lower CO and smoke emissions compared to diesel. At higher percentages of DEE (20% and 25%), decreases BTE, with increase in CO and smoke emissions as compared to diesel. This is due to phase separation of DEE, injector nozzle cavitations and improper fuel droplet injection in cylinder chamber [**15**]. The performance with diesel-biodiesel-ethanol blends in CI engine show that, BSFC increased at lower loads with reducing BTE (21.7%). CO emissions decreased with increasing CO_2 and NOx emissions. HC emissions reduced in all engine load conditions [**16**]. Triacetin being antiknock fuel, with 10% blend emanated as a best blend fuel with coconut oil methyl ester to reduce HC, NO, CO_2, CO and smoke emissions with high performance and no cylinder vibration in vertical direction of the engine [**17**], [**18**] .

The results with ethanol in biodiesel decreases oxides of nitrogen, smoke, carbon monoxide and hydrocarbon emissions at higher loads and increase at lower loads. Increase of maximum heat release rate and maximum pressure for the blends at higher loads and decreases at lower load. Brake thermal efficiency of the blends is similar to that of diesel fuel [**19**]. In this work diethyl ether additive was uesd to conduct the experiments with Jatropa oil methyl ester (JOME), the main advantage of this additive is easily soluble in biodiesel, suppress the knocking of engine, improve efficiency and reduce emissions. DEE additive at 3, 6, 9 and 12% with B20 test fuels were used to study the properties and performance of engine to replace it as an alternative to diesel fuel.

II. MATERIAL AND METHODS

2.1 Preparation of Biodiesel: Jatropha oil methyl ester (Biodiesel) blends B20 with oxygenated additive DEE is considered to study the properties. Raw jatropha oil is filtered and heated up to 105^0C temperature in order to remove solid particles and water content. In acid treatment methanol of 120ml and 2ml of concentrated highly pure H_2SO_4 per liter of oil is added and heated with magnetic stirrer at 62^0C for about half an hour in a closed conical flask. The mixture is allowed to settle down in a decanter. The settled glycerin is separated at bottom of decanter from methyl ester. *Sodium Methoxide* was prepared by mixing thoroughly 200ml of methanol (20% by vol.) with 6.5 grams of NaOH per liter of oil. This solution is added to the oil obtained from acid treatment, then stirred continuously at 62^0C for one hour in the base treatment and allowed to settle down in decanter. The collected Jatropha oil methyl ester (JOME) is bubble washed with pure water in order to remove soap contents, acid and methanol. The sequence of biodiesel making, reaction takes place and prepared biodiesel are shown in figures **1** to **3** respectively. The washed JOME is heated further above 100^0C for some time to remove water content. This biodiesel is used to prepare B20 (20% JOME + 80% diesel by volume) blend fuels and then test fuels from B20 with DEE additive.

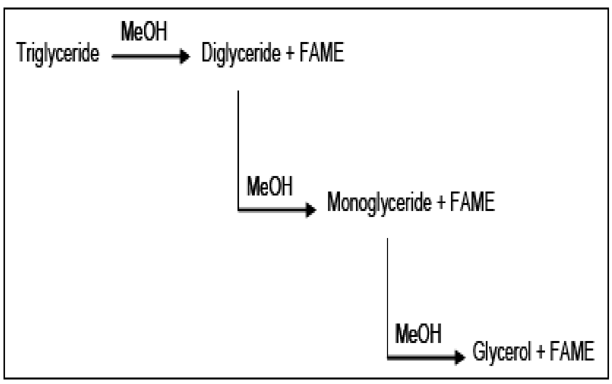

Fig.1:Stages of Biodiesel (JOME) preparations

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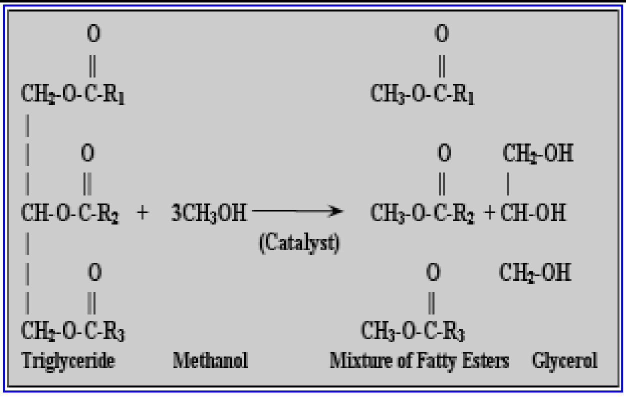

Fig.2: Reaction in formation of Biodiesel (JOME)

Fig.3: Biodiesel (JOME)

2.2 Methodology Used

The required test fuels were prepared with B20 and at different percentages of diethyl ether (DEE) as shown in table **1** with their percentages to study the properties and performance of the engine. Diethyl ether and B20 blend fuel are easily miscible homogenously.

The properties like flash point, fire point, viscosity, density and heat value were measured as per the ASTM standard procedures recommended by manufacturers. These tests were conducted in a controlled room temperature, pressure and relative humidity to ensure that the result will not be influenced with change in environment and compared the same with B20 blend fuel. Performance experiments were carried out on single cylinder diesel engine with the test fuels at different load conditions 0, 25, 50, 75 and 100 in percentage. Engine performance parameters such as mechanical efficiency, brake thermal efficiency, brake specific fuel consumption and exhaust gas temperatures results were compared with B20 blend fuel.

Table.1: Blend fuels for Test

S. No	Type of Fuel	Percentages in Blend Fuel
1	Diesel	100% Diesel
2	B20	20% Biodiesel (BD) + 80% Diesel
3	B20DEE3	97%B20+ 3%DEE
4	B20DEE6	94%B20+ 6%DEE
5	B20DEE9	91%B20+ 9%DEE
6	B20DEE12	88%B20+ 12%DEE

III. RESULTS AND DISCUSSIONS

The properties of biodiesel blend fuels B20 with diethyl ether additive at different percentages provide important data to further investigate and analyze the operation of DI diesel engine in terms of performance and compare the results with diesel fuel.

***3.1 Fuel properties*: The following general properties of B20 blend fuel with diethyl ether results are summarized:**

i) Viscosity: High viscosity of biodiesel causes poor atomization in fuel spray system and inaccurate fuel injectors operation causes improper combustion in the engine cylinder, results increased exhaust smoke and emissions as compared to diesel fuel. Biodiesel can be used as a substitute to diesel fuel at lower viscosity with minimum environmental pollution. Under low temperatures viscosity has a greater impact on fuel to flow smoothly from the storage tank into the engine cylinder. From the figure **4** it is observed that the viscosity of B20 is 28.57% more than diesel fuel due to concentration of free fatty acid (FFA) in biodiesel. Due to the low viscosity of DEE additive in blend fuels (B20) viscosity decreases as the increase in percentage of additive. On the other hand, viscosity of B20 blend fuel decreases by 11.12%, 13.89%, 22.24% and 27.49% with the addition of 3%, 6%, 9%, and 12% of DEE as compared to B20 blend fuel.

***ii) Flash and Fire point*:** Flash and fire points of B20 biodiesel blends with diethyl ether at various percentages were tested are shown in figure **5**. Biodiesels are non volatile due to higher molecular weight and produce sufficient vapours at higher temperatures to form a combustible mixture with air, hence flash and fire points of biodiesel and B20 blend with diethyl ether are much higher than diesel fuel. The flash and fire points of test fuels gradually decreases with increase in percentage of diethyl ether in B20 blend fuel. For the test fuels B20 with 3, 6, 9 and 12% of DEE the flash point decreases by 3.07, 7.46, 9.7, 13.43% and fire point decreases by 5.97, 8.45, 7.74, and 10.56% when compared with B20 blend fuel. The decrease flash and fire points of test fuels makes it as a convenient fuel to use it in diesel engines.

iii) Heating value: The amount of heat energy released by combustion of one unit fuel is known as heat value. The heat value of fuel varies with the amount of moisture content in fuel. In the biodiesel standards (ASTM D6751) heat value is not specified but is prescribed in EN 14213 (for heating purpose of biodiesel) with a minimum of 35 MJ/kg. Figure **6** shows that the heat values of neat diesel, B20 and B20 with DEE additive blends at 3, 6, 9, and 12% by volume are gradually increasing. Heat value increases as the percentage of DEE increases in the blend fuel because the heat value of DEE additive is much higher than biodiesel. The maximum heat value obtained for 12% of DEE additive with biodiesel blend (B20DEE12) was 41.7MJ/kg, which is 7.48% higher than the heat value of B20 used for testing. The heat values of all blend fuels are within the requirement of standards as compared to diesel fuel.

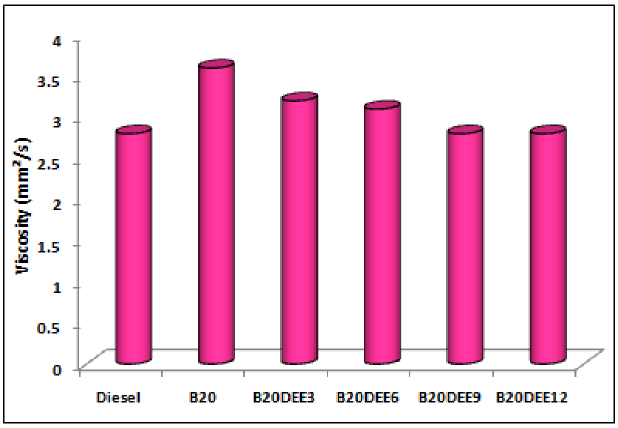

Fig.4: Viscosity values of B20 with DEE

iv) Density: Biodiesel density is higher than the diesel fuel and this can be improved with the addition of additives for better combustion and high output of the diesel engine. Density is measured by using Portable Density/Gravity Meter. High viscosity of fuel leads to problem in pumping and spray characteristics such as atomization, penetration and combustion etc. The improper mixing of fuel with air contributes to incomplete combustion that leads to low power output and with high exhaust pollutants. Figure **7** shows the density of diesel; B20 and B20 with DEE blend fuels. It is observed that the density of B20 is higher at 0.889 kg/m^3 and the density of diesel is lower at 0.842 kg/m^3. The addition of diethyl ether additive in B20 decreases the density by 1, 1.7, 2.24 and 3.15% for 3, 6, 9 and 12% of DEE as compared to B20 blend fuel.

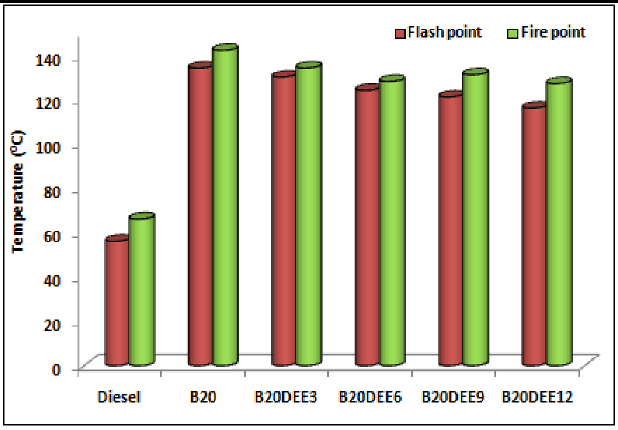

Fig.5: Flash & Fire point values of B20 with DEE

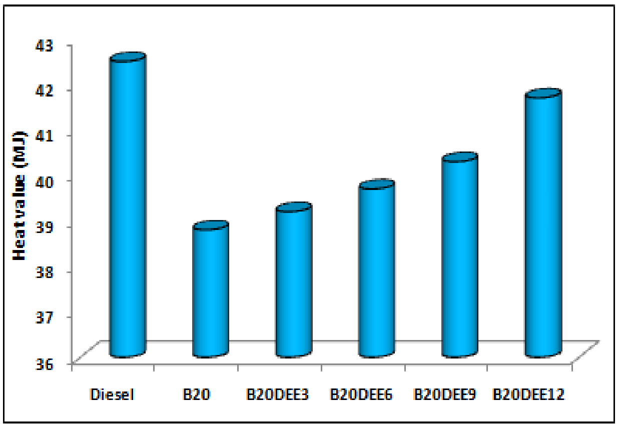

Fig.6: Heat values of B20 with DEE

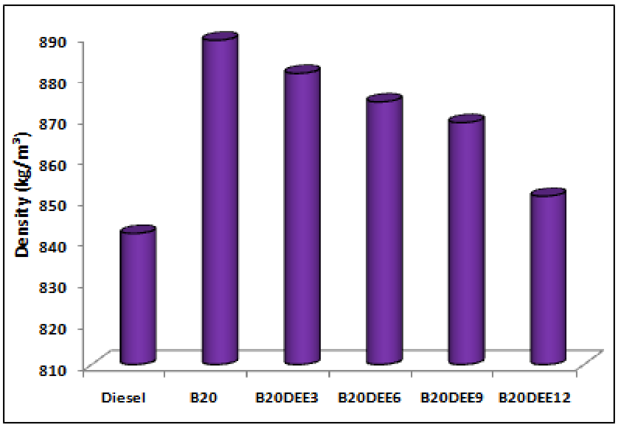

Fig.7: Density values of B20 with DEE

3.2 Performance:

i) Brake Thermal Efficiency (BTE)**:** Brake thermal efficiency variation with respect to load is shown in fig. **7** for B20 blend fuel at different percentages of DEE additive. The BTE of DEE blends with B20 and B20 are higher as compared to JOME biodiesel. This is because of DEE addition decreases the viscosity of mixture and improves the atomization of fuel; hence combustion is better to release more heat that improves the efficiency.

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ii) Brake specific fuel consumption: The consumption of blend fuel variation with the addition of DEE is shown in the fig **8**. The fuel consumption is less in case of B20 and 3, 6% of DEE, whereas for 9 and 12% are higher with B20 when compared to diesel fuel. Addition of DEE with B20 leads to decrease in BSFC, but further increase in the concentration of additive, it is clearly observed that the value of BSFC tends to increase. The BSFC is higher due to its lower heating value, greater density and high bulk modulus at higher percentages of additive. The minimum *BSFC* is less than diesel fuel for 6% DEE additive with B20 and is at 3.32%, whereas it is 9.27, 18.3% more than diesel fuel for 9 and 12% addition of DEE additive with B20 blend fuel.

***iii) Exhaust Gas Temperature (EGT)*:** Fig. **9** shows temperature of exhaust gas with respect to the load on engine. Blend fuels EGT increases with increase in load on engine because more fuel is drawn at higher loads. EGT of diesel fuel is observed higher than all blend fuels tested. In case of biodiesel, EGT is lesser due to lower calorific value than diesel fuel. EGT increased as the percentage of DEE increases, this may be due to higher cetane number which reduces the ignition delay period that changes the burning rate of blend fuel. The exhaust gas temperature of 9 and 12% of DEE additive blend fuels with B20 are 6 and 2.1% below the temperature of diesel fuel at full load on engine because of improvement in the process of combustion.

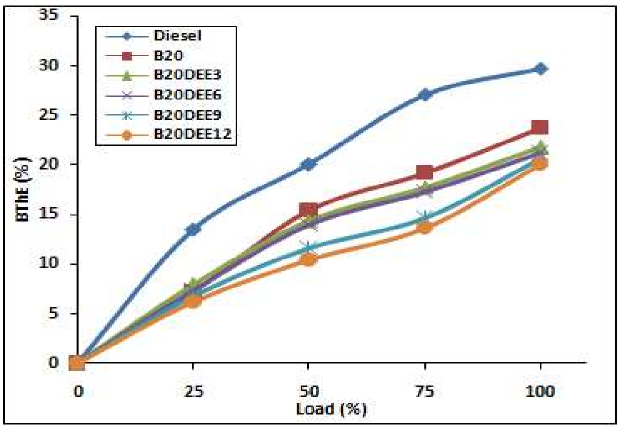

Fig.8: Thermal Efficiency variation with Load

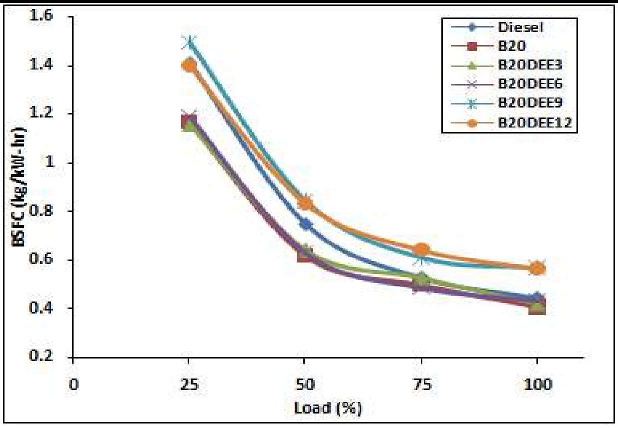

Fig.9: BSFC variation with Load

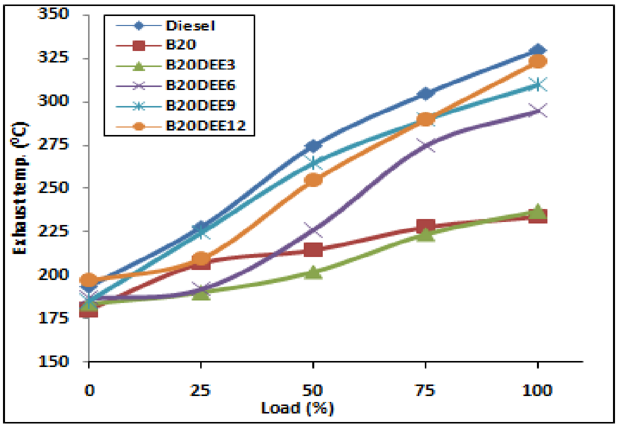

Fig.10: Temperature variation with Load

IV. CONCLUSIONS

From the experiments conducted the following conclusions are drawn:

- The minimum *BSFC* is for 6% DEE with B20 blend and 3.32% less than diesel fuel. Brake thermal efficiency of engine increases by addition of DEE additive which provides complete combustion to release heat and reduce carbon emissions.
- Exhaust gas temperature of 9 and 12% of DEE additive with B20 blend fuels are 6 and 2.1% below the temperature of diesel fuel at full load on engine because of improved rate of combustion.
- The addition of DEE additive in B20 decreases the viscosity and density of blend fuel, which leads to better performance.
- A maximum heat value is obtained for 12% of DEE additive with B20 blend fuel was 41.7MJ/kg, which is 7.48% higher heat value than B20 blend fuel used for testing.
- Higher cetane rating of DEE and oxygen content are also advantageous for obtaining lower smoke emission.

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