

Performance and Emission Characteristics of animal Fat fuel Blends in Diesel Engines

V.Moorthi, G.Nagarajan², N.Rajan³, P.Ganesan⁴

¹, Assistant professor, Department of Automobile Engineering, Annapoorana Engineering College, Salem

², Assistant professor, Department of Automobile Engineering, Annapoorana Engineering College, Salem

³, Assistant professor, Department of Automobile Engineering, Annapoorana Engineering College, Salem

⁴, Assistant professor, Department of Automobile Engineering, Annapoorana Engineering College, Salem

Abstract. Over the past few years, the increasing use of fossil fuels has created a supply and demand imbalance. In contrast, the increasing depletion of these oils, cost disruption, and significant greenhouse gas emission rises are among the scientific fraternity's debatable concerns. A sustainable solution to the above problems is to shift towards the renewable alternative fuels. During the present investigation, ternary blends of diethyl ether, jatropha biodiesel (JB) in diesel were prepared in different proportions. The physico-chemical properties and spray characteristics of the test fuels including density, viscosity, calorific value and Sauter mean diameter (SMD) were also calculated. The experimental results reveal that there is no significant effect of the addition of DEE and JB on the brake thermal efficiency. However, the ternary blend carrying 7.5 % of DEE and JB yields the maximum efficiency of 27.9% which is nearly equal to that of peak efficiency of diesel fuel i.e. 28.4%. The exhaust emissions studies reveal that the percentage of CO, HC, NO_x and smoke opacity were reduced significantly. Therefore usage of ternary fuel blends of diesel, JB and DEE is a viable approach for the partial replacement of diesel.

1. Introduction

A global crisis of crude oil and increasing threat to the environment due to emissions from prime movers like internal combustion engines have inhibited the attention of researcher fraternity towards the promising domain of alternative transportation fuels. As compression ignition engine has been used as a commercial prime mover in the Indian economy since a number of decades, so, the researchers are adhering to the field of alternative fuels for this stallion of Indian economy. Energy sources and alternative transportation fuels are a concern of utmost significance not only among the scientific and engineering area but also in framing economic and public policy. Elective energizes and vitality sources give a superb chance to presenting an assortment of science points and expanding understudy enthusiasm for those themes. Science and designing fields are progressively disciplinary - exercises on biodiesel can exhibit that unmistakably, by demonstrating the covering of science, science, and material science in concentrate this and other elective powers. Some of the promising effective alternatives are obtained from biodiesel, alcohols, Di ethyl ether (DEE) [1–7]. These can be used in neat form or with blends.

There are several issues found with biodiesel and vegetable oils in diesel engine [8–10]. However, higher alcohols are gaining limelight for being its greater compatibility in diesel engines. DEE is also a viable alternative because of its lower density and lower viscosity compared to diesel. Moreover, their easy blending and comparable calorific value have made them as a suitable substitute in a diesel engine. Their higher cetane number and higher oxygen content is a very beneficial aspect for its working in a diesel engine. Limited literature is available on the usage of various ternary blends of DEE-diesel-biodiesel in a diesel engine which is an important aspect for this study.

Based on the literature it is found that the usage of ternary fuel blends of diesel, biodiesel and DEE is not completely explored. In this study, usage of different blends of diesel, jatropha biodiesel and DEE were formulated. Several physico-chemical properties of the blends were determined. Emission and performance characteristics were determined for analyzing the usage of the blends in a diesel engine

2. Material and Methods

Jatropha biodiesel (JB) is prepared from the potassium hydroxide, methanol, sulphuric acid (analytical grade) purchased from the local vendor in New Delhi. Jatropha seeds were collected from the campus of DTU and the oil was extracted from the seeds with the help of an expeller. The free fatty acid content of the oil was 5.8%. It is converted to biodiesel using two-step transesterification process discussed in [19–21]. Table 1 describes the nomenclature of the test fuels.

Table 1. Nomenclature of the test fuels

S.NO.	BLENDS	DEE(% v/v)	BIODIESEL(%v/v)	DIESEL(%v/v)
1	D100	0	0	100
2	DEE2.5B	2.5	2.5	95
3	DEE5B5	5.0	5.0	90
4	DEE7.5B	7.5	7.5	85
5	DEE10B1	10	10	80



Figure 1. Test samples

Table 2 describes the equipment's used for determining density, kinematic viscosity calorific value, and Sauter mean diameter of the fuels.

Table 2. Equipment's used for determining different properties

Property	Equipment
Density	Anton Parr DMA 4500
Kinematic Viscosity	Capillary tube
Calorific Value	Parr 6100 Oxygen Bomb
Sauter Mean	Malvern Spraytec

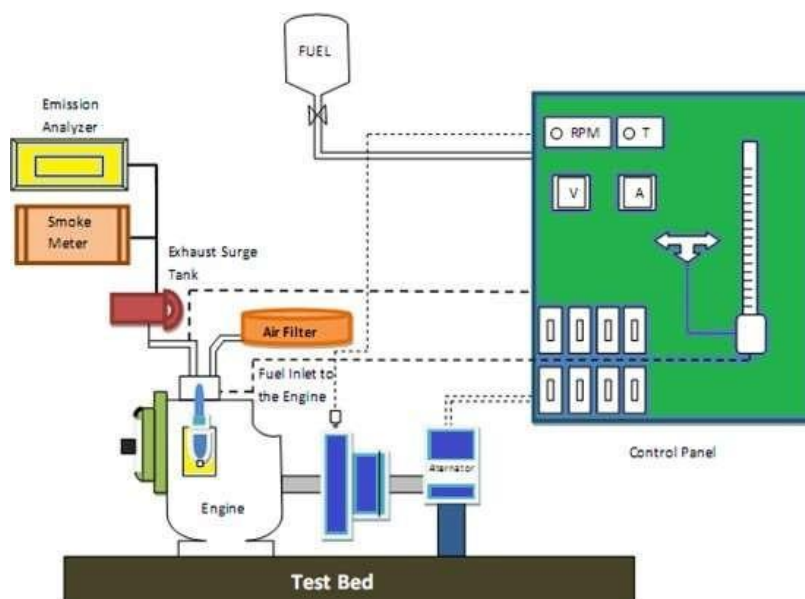
Table 3 shows the properties of the test fuels determined using the equipment.

Table 3. Properties of the test fuels

BLENDS	Density (g/cm ³)	Kinematic viscosity (cSt)	Calorific Value (MJ/Kg)	Sauter Mean diameter (μm)
DEE2.5B2.5	0.82456	2.65	42.57	21.1
DEE5B5	0.8235	2.82	41.94	21.7
DEE7.5B7.5	0.82444	2.99	41.72	22.2
DEE10B10	0.82667	3.14	40.64	22.9
D100	0.825	2.6	44.50	20.8

Figure 2. Setup of diesel engine test rig

Table 4 gives about the typical specification of the diesel engine used for the testing. The engine used was a Kirloskar make unmodified air cooled diesel engine.

**Table 4.** Specifications of the diesel engine

Make	Kirloskar
Model	DAF8
Type	Single cylinder, vertical. DI diesel engine
Speed	1500 rpm, constant speed
Bore (mm)	95
Stroke (mm)	110
Compression Ratio	17.5
Cooling System	Air cooled
Cycle	4 stroke
Maximum output power (KW/HP)	5.9/8.0

All the tests were performed on the developed test rig at varying loads. The results were taken thrice and an average of the three was taken for the better accuracy of the results. Emission tests were carried on AVL Digas analyzer and AVL smoke meter.

3. Performance characteristics

3.1. Brake Thermal Efficiency

From Figure 3 the brake thermal efficiency with BMEP variation at different loading conditions is seen. The efficiency shows an increasing trend to near about 60% load and decreases afterward. BTE decreases sharply after 80% load.

Maximum efficiency of 28.4% is witnessed with 100% diesel at about 60% load and for blends in which diesel is replaced by DEE and Jatropa biodiesel shows a maximum efficiency of 27.9% with the DEE7.5B7.5 blend.

The blend that resulted in most inferior efficiency is for DEE2.5B2.5. In overall prospect, the performance of the engine in terms of BTE is quite comparable to that with diesel, no significant hampering to engine performance is witnessed with ternary blends of DEE and biodiesel in diesel. The most superior fuel among the blends was DEE7.5B7.5 giving highest efficiency among all blends because of its comparable viscosity and energy content. Moreover, added oxygen from DEE and JB is helping in better combustion. DEE10B10 is having slightly lower BTE because of higher viscosity,

lower energy content and less Sauter mean diameter (SMD) than DEE7.5B7.5. All other test fuels have lower BTE owing to the lower oxygen content of the fuels. DEE also has higher cetane number

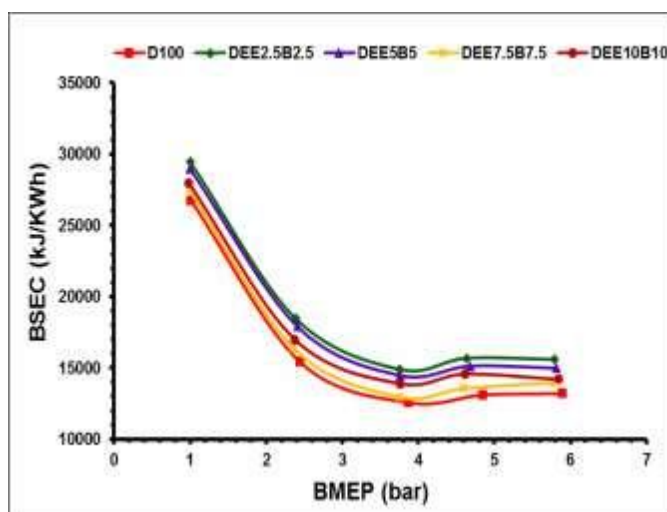


Figure 3. BTE vs BMEP

which also promotes better combustion and hence shall help in achieving better BTE. SMD of the blends were comparable to diesel which exhibits similar spray characteristics and helps in promoting combustion.

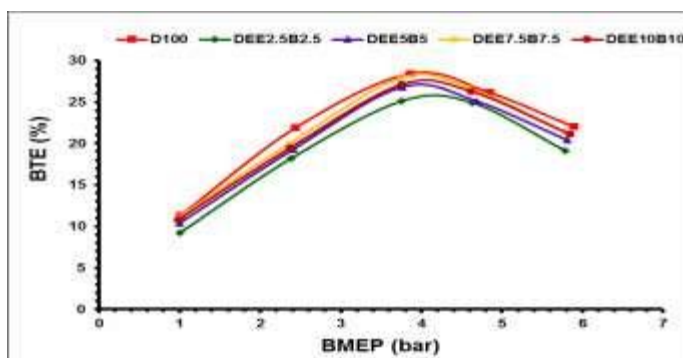


Figure 4. BSEC vs BMEP

3.2. Brake Specific Energy Consumption

From Figure 4 the brake specific energy consumption (BSEC) variation at different loading conditions is seen. BSEC in general for all blends and diesel as well decreases sharply with increasing load. Maximum BSEC is observed for DEE2.5B2.5 because of lowest BTE among all prepared test fuels. It is observed that on adding DEE and JB to diesel, the BSEC values decrease. However, for DEE10JB10, owing to low energy content and high viscosity, BSEC is lower as compared to DEE7.5B7.5. Calorific value of DEE and JB is quite lower as compared to petroleum diesel. It therefore needs more energy input for producing the same efficiency. Therefore, BSEC of the blends are higher as compared to diesel fuel.

4. Emission Characteristics

4.1. Exhaust Gas Temperature

From Figure 5, the variation in exhaust gas temperature is plotted against BMEP under different loading conditions. Temperature of exhaust shows a growing trend with load. The maximum exhaust temperature achieved is 332 °C at full load with diesel fuel. DEE2.5B2.5 provides a peak exhaust temperature for the blends. The exhaust gas temperature is greater than the percentage of DEE in the lower blends. DEE helps to lower the blend temperature due to the quenching effect in the cylinder. Overall, diesel shows higher exhaust temperatures than ternary blends for the respective loads and BMEP

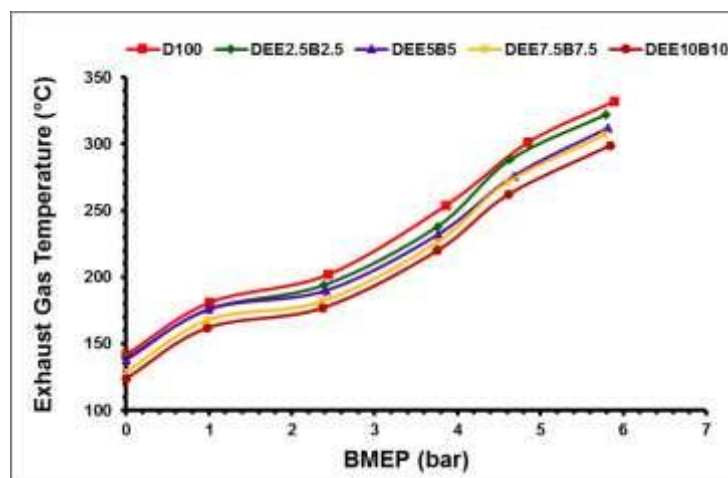


Figure 5. Exhaust gas temperature vs BMEP

4.2. CO Emissions

Figure 6 shows the variation in CO emissions being plotted against BMEP at different loading conditions. After 60 percent load CO emissions rise sharply, CO emissions are steady up to 60 percent load conditions. Due to the lack of oxygen, CO emissions of diesel fuel are highest. Because of the inclusion of oxygenated compounds, the ternary fuel blends prepared had lower CO emissions. In addition, there was stronger combustion of ternary fuel blends. It can be due to the addition of DEE and JB with a better cetane number than diesel, which is expected to show better combustion and thus lower CO emissions. However, DEE10B10 has slightly higher CO emissions than DEE7.5B7.5 because of its higher viscosity, lower heating values and higher SMD of the DEE10B10 blend as compared to DEE7.5B7.5.

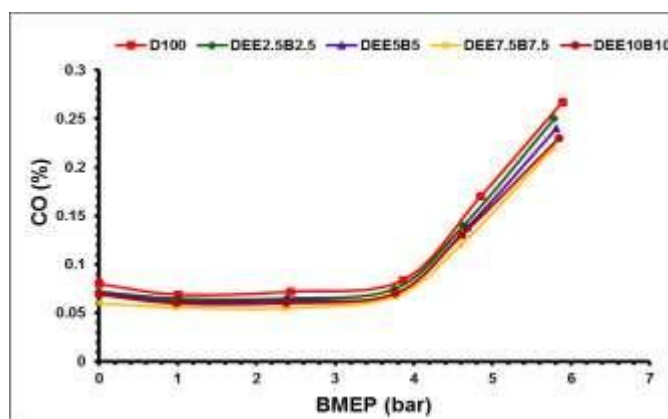


Figure 6. CO vs BMEP

4.3. HC Emissions

The HC emission variance is plotted against BMEP at various loading conditions from Figure 7. HC emissions are increasing as the load increases for all the fuel used in engine testing. DEE2.5B2.5 reveals lower emission characteristics of HC at component load up to 40% load, despite a sharp increase in emissions. Compared to other blends, HC emissions for DEE10B10 are higher at all loads. More HC emissions in the atmosphere were released due to lower energy content, higher viscosity and higher DEE10B10 blend SMD. However, diesel fuel HC emissions are higher than the DEE 7.5 percent or lower blends due to the complete combustion of the blends and longer biodiesel effect in them.

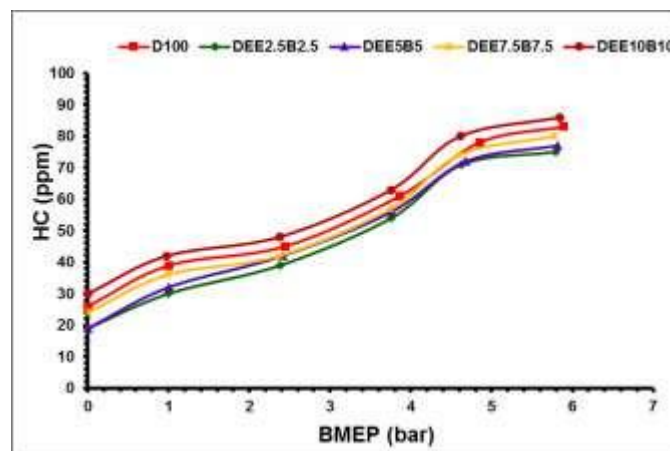


Figure 7. HC vs BMEP

4.4. NO_x Emissions

From Figure 8 the variation of NO_x levels is plotted against BMEP at different loading conditions. NO_x emissions are quite comparable for diesel and DEE2.5B2.5 and are higher compared to other blends. The emissions of DEE5B5, DEE7.5B7.5 and DEE10B10 are lower. The reason for lower NO_x in the blends can be attributed to the greater quantity of DEE that results in more quenching effect in the cylinder. NO_x is also based on the engine's exhaust gas temperature. Lower the temperature of the exhaust gas, lower the NO_x. Consequently, DEE helps to cool the cylinder and reduce the temperature resulting in lower thermal NO_x.

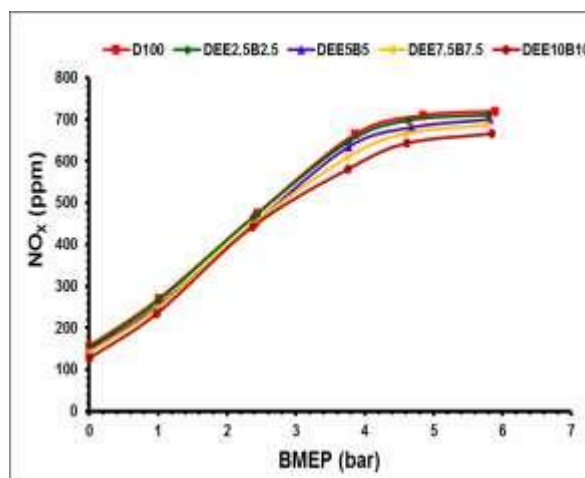


Figure 8. NO_x vs BMEP

4.5. Smoke Opacity

From figure 9, the difference in smoke opacity emissions is plotted against BMEP at different charging conditions. Opacity of smoke is almost the same for all tested fuels, but the use of biodiesel and DEE both with a higher oxygen content and a higher number of cetanes leads to proper burning and therefore to lower smoke emissions. Therefore, smoke levels from DEE2.5B2.5 and DEE5B5 are smaller than petrol. It is also observed that DEE7.5B7.5 produces the lowest smoke due to better burning than DEE10B10 due to lower viscosity and lower DEE7.5B7.5 SMD resulting in good atomization of the fuel and producing less smoke than diesel.

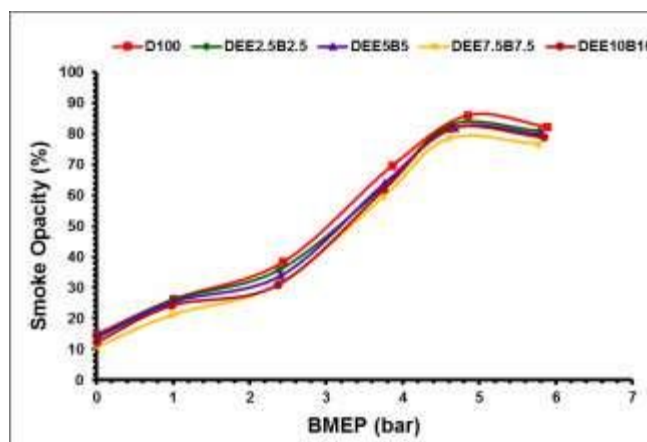


Figure 9. Smoke Opacity vs BMEP

5. Conclusions

The current study focused on the different proportions of animal fat fuel blends of diesel, JB and DEE. The results showed comparable physico-chemical and SMD properties. To determine the performance and emission characteristics, an unmodified diesel engine is used. Check fuel BTE and BSEC were very similar to petrol, showing that the introduction of DEE in diesel and biodiesel results in equivalent BTE and BSEC. Nevertheless, the ternary combination of 7.5% of DEE and JB yields the maximum efficiency of 27.9%, which is almost equal to that of diesel fuel's peak efficiency. i.e. 28.4%. Slight lower CO, HC, NO_x and smoke opacity emissions were observed for the blends. HC emissions were somewhat higher for the DEE10B10 blend, however, due to lower energy content, higher viscosity and higher DEE10B10 blend SMD. The current study revealed that due to favorable results, ternary blends of diesel, biodiesel and DEE are a viable solution for diesel replacement.

References

- [1] Ma Y, Huang R, Fu J, Huang S and Liu J 2018 Development of a diesel/biodiesel/alcohol (up to n-pentanol) combined mechanism based on reaction pathways analysis methodology *Appl. Energy* **225** 835–47
- [2] Suhaimi H, Adam A, Mrwan A G, Abdullah Z, Othman M F, Kamaruzzaman M K and Hagos F Y 2018 Analysis of combustion characteristics, engine performances and emissions of long-chain alcohol-diesel fuel blends *Fuel* **220** 682–91
- [3] Emiroğlu A O and Şen M 2018 Combustion, performance and emission characteristics of various alcohol blends in a single cylinder diesel engine *Fuel* **212** 34–40
- [4] Yilmaz N and Atmanli A 2017 Experimental evaluation of a diesel engine running on the blends of diesel and pentanol as a next generation higher alcohol *Fuel* **210** 75–82
- [5] Kaimal V K and Vijayabalan P 2016 An investigation on the effects of using DEE additive in a di diesel engine fuelled with waste plastic oil *Fuel* **180** 90–6
- [6] Agarwal A K, Gupta J G and Dhar A 2017 Potential and challenges for large-scale application of biodiesel in automotive sector *Prog. Energy Combust. Sci.* **61** 113–49
- [7] Sorate K A and Bhale P V. 2015 Biodiesel properties and automotive system compatibility issues *Renew. Sustain. Energy Rev.* **41** 777–98
- [8] Farfan-Cabrera L I, Pérez-González J and Gallardo-Hernández E A 2018 Deterioration of seals of automotive fuel systems upon exposure to straight *Jatropha* oil and diesel *Renew. Energy* **127** 125–33