International Journal of Engineering Trends and Technology
ISSN: 2231–5381 / https://doi.org/10.14445/22315381/IJETT-V71I6P213

Volume 71 Issue 6, 115-121, June 2023

Original Article

Experimental Investigation using Diethyl Ether as Additive with Pumpkin Seed Methyl Ester Fueled in DI Diesel Engine

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Received: 03 May 2023 Revised: 16 June 2023 Accepted: 21 June 2023 Published: 25 June 2023

Abstract *- Petroleum fuels emit hazardous pollutants into the atmosphere when used in Internal Combustion engines, endangering people, plants, and agriculture. There is currently a lot of study being done to develop a fuel substitute for petroleum and to raise the caliber of that fuel. DiEthyl Ethers (DEE) is a commonly used substance that can be used to enhance fuel characteristics and decrease nitrogen oxide poison gas. Engine testing was carried out on predictable Direct Injection (DI) engines with a diesel and biodiesel blend under various operating circumstances. In this work, the performance and emissions characteristics of a diesel engine running on a Pumpkin Seed Oil Methyl Ester Mixture (PSOME20) are being examined. Different DEE concentrations (10%, 15%, and 20%) were incorporated into the PSOME20 fuel. According to the results, the Brake Thermal Efficiency (BTE) of the PSOME20 fuel is 2.3 percent higher than that of the diesel, but the Brake Specific Fuel Consumption (BSFC) is reduced by 6.4 percent. When diethyl ether was combined with PSOME20, engine emissions of Hydrocarbon (HC), Carbon monoxide (CO), and smoke increased dramatically, while Nitrogen Oxide (NOx) emission was minimal in comparison to the other emission characteristics*.

Keywords *- Diethyl Ether, Di Diesel Engine, Pumpkin methyl ester, Performance, Emission*.

1. Introduction

The availability and widespread use of fossil fuels, particularly in industries and automobiles, have proven to be divine blessings and boons to human life. Almost all industries rely on fossil fuels such as coal, natural gas, and other oil products such as gasoline and diesel to generate power for their daily operations and machinery. The Industrial Revolution provided countries with a clear path to rapid economic growth. Humans' job problems have been greatly alleviated as a result of the introduction of a wider range of industries [1]. Environmental damage was not considered during the industrialisation process, resulting in widespread deforestation. The diesel engine has made a name for itself by contributing to society in various ways. Its robustness in build, simplicity in operation, and ease of support are its primary selling factors [2]. Its improved brake thermal efficiency and minimized fuel consumption have made it popular in the transportation and agriculture industries. Great compression ratios, leaner fuel-air mixes, and minimal pumping losses due to the lack of throttle all help to achieve high thermal efficiency [3]. Methanol is a fuel that is both ecologically benign and energy efficient. It is easy to create, contains a lot of oxygen, and burns cleanly. It can be used in place of gasoline and diesel, lowering engine temperatures, increasing efficiency and managing emissions; biodiesel uses a variety of strategies [4]. As part of a few techniques that have been researched, High thermal efficiency can be attained through high compression ratios, leaner fuel-air mixtures, and minimum pumping losses as a result of the absence of throttle [5–6]. Methanol is a fuel that is both energy- and environmentally friendly. It burns cleanly, contains a lot of oxygen, and is simple to make [7]. Methanol's electro-fuel potential, its massive existing infrastructure, and high energy density make it an ideal fuel option that meets all three criteria [8]. Because of its poor reactivity, methanol is strongly resistant to auto-ignition, making it difficult to run a Compression Ignition (CI) engine purely on methanol [9]. However, functioning in a CI engine is achievable using the dual-fuel principle. Different injection methods for both fuels have been tested.

Table 1. ASTM D6751 characteristics of test fuels

Properties	Diesel	PSOME20
Cetane Number	48	52
Kinematic Viscosity @ 40ºC (cSt)	3.2	3.6
Oxygen content (%) by weight	-	11
Calorific value (MJ/kg)	43	41.7
Flash point (ºC)	48	70
Density (kg/m^3)	830	842
Fire point (ºC)	60	76

(a) (b)

Fig. 1 (a) Pumpkin fruit (b). Pumpkin seeds

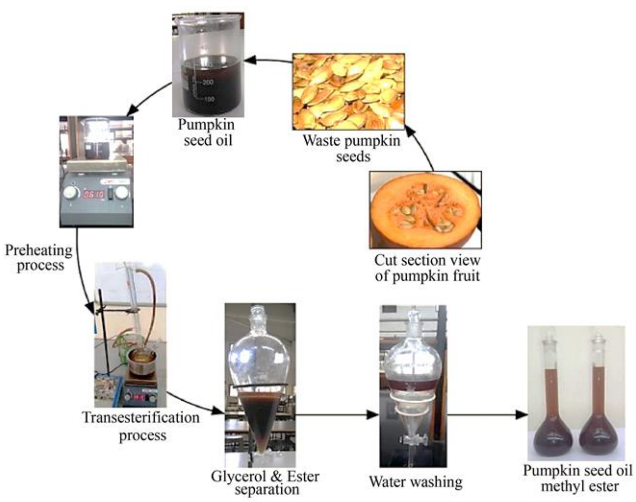

Fig. 2 Production process of pumpkin seed oil Methyl Ester

Methanol fuel has a high latent heat of vaporisation, which makes it perform badly during startup at low temperatures [10]. There are various restrictions on the direct use of methanol in engines and the reduction in the initial combustion temperature. Methanol is a perfect fuel alternative because it can be used as an electrical fuel, has a large existing infrastructure, and has a high energy density [11]. Methanol has a low reactivity and a high auto-ignition resistance, making it challenging to run a CI engine only on methanol. However, the dual-fuel idea can be used to operate in a CI engine. For both fuels, various injection techniques have been investigated [12]. Figures 1(a) and 1(b) show the pumpkin fruit and seed.

From the literature review, several notable works have been done on different biodiesel with different proportions of diethyl ether as an additive with biodiesel blends. Only very basic research is available on pumpkin seed oil blended biodiesel in diesel engines as it is a novel biodiesel. However, the study of diesel engines using novel Pumpkin seed oil biodiesel with different DEE blends is not investigated and published in any journal. By keeping this in mind, the author aims to study the influence of different proportions of DEE with biodiesel in a CI engine.

Thus, the aim of this research work is to study the impact of DEE on diesel engine performance and emissions behaviors by using 10%, 15%, and 20% DEE mixed with biodiesel (PSOBD20) made from pumpkin seed biodiesel and diesel and the values are analyzed and compared to the diesel and biodiesel blend.

2. Materials and Methods

2.1. Pumpkin Seed Oil Extraction

Pumpkin's botanical name is Cucurbita pepe L. Pumpkin seeds are vibrant green and fragrant. Raw pumpkin seeds are heated to a consistent temperature to produce pumpkin oil. It is created by attempting to squeeze buttery cowling pumpkin seeds derived directly grown different pumpkin varieties [13]. The viscosity content of pumpkin seeds ranges from 39% to 55%. The two processes of pre-expelling and hexane removal are used to make pumpkin oil. The colour of pumpkin oil is green on the outside and red on the interior. It has an acid value of 1.2 and a molar mass of 4.62. The oil must be kept cool and dehydrated due to its delicate nature. The creation of pumpkin seed methyl ester is depicted in Figure 2 [14]. There was pure B-100 fuel available. PSOME fuel was also blended with diesel at a 30% by capacity range to create PSOME20 fuel. Table 1 displays the determined ASTM D6751 characteristics of test fuel.

3. Experimental Method

PSOME20 biodiesel is mixed thoroughly before it can be used in an engine with 10 %, 20 %, and 30 % diethyl ether (DEE). For example, for 900 ml of PSOME20, 100 ml DEE is added at 10 %; for 800 ml of PSOME20, 200 ml is added at 20 %; and for 700 ml of PSOME20, 300 ml is added at 30 %. PSOME20 is completely drained from the gasoline tank, and PSOME20 + DEE is added. Due to DEE's strong volatility and flammability, it gives biodiesel better performance by introducing desired qualities. Its inclusion in biodiesel decreases density and even raises the mixture's calorific value. Compared to PSOME20 biodiesel alone, reduced density and kinematic viscosity improve atomization and combustion. The calorific value of the mixture, including DEE and biofuel, is simultaneously increased by adding DEE. PSOME20 + 10%, PSOME20 + 20%, and PSOME20 + 30% DEE are used to drive the engine, and the combustion and emission parameters are noted. The recorded parameters are contrasted with the comparable features discovered using the D100.

3.1. Diethyl Ether

Diethyl ether, usually referred to as Et2O, is an ether-class chemical molecule with the formula (C2H5)2O. (shown in Figure 3). It is a colourless liquid that is very combustible, highly volatile, and has an ethereal odour. It is frequently utilised as a solvent in lab settings and as a starting fluid for some engines. It was employed as a general anaesthetic prior to the invention of combustible medications like halothane.

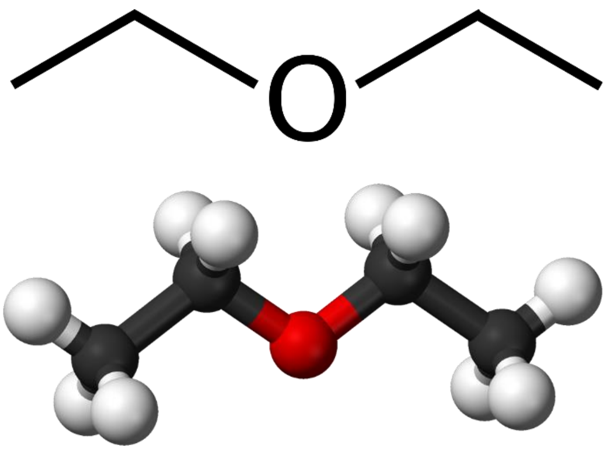

Fig. 3 Diethyl ether

Diethyl ether, which has a high cetane number of 86-95 and a low flash point, is used as a starting fluid in gasoline and diesel engines due to its low flash point and moderate volatility [15]. Because it can aid in cold starting an engine in temperatures below freezing, ether starting fluid is available and used in extremely cold countries. It also serves a similar purpose in blended fuels used in carbureted engines. In this regard, one of its precursors, diethyl ether and ethanol, are very similar.

3.2. Experimental Test Engine

In order to simulate brake load, throughout this experiment, a dynamometer was connected to a single-cylinder Kirloskar diesel engine. A test engine is schematically depicted in Figure 4.

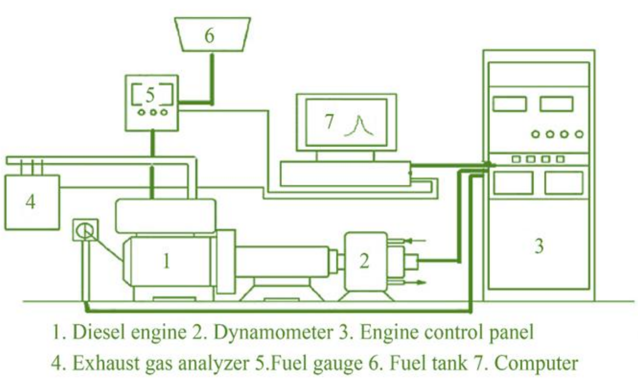

Fig. 4 Test engine is depicted schematically

4. Results and Discussion

4.1. Combustion - Diesel/PSOME20/DEE

Figure 5 illustrates the relation between Cylinder Pressure (CP) with Crank Angle (CA) for diesel and PSOME with DEE mixtures. PSOME20's higher viscosity and lower peak load heating value cause it to have a lower cylinder pressure than diesel. Peak cylinder pressures for diesel and PSOME20 mix are 67 bar and 66 bar, where between, at full load, however for PSOME20 -10% DEE, PSOME20 - 15% DEE, and PSOME20 - 20% DEE, they are 65 bar, 67 bar, and 64.5 bar, respectively. Peak pressure for PSOME 20 with 15% DEE blends is seen to be elevated by 1 bar when compared to PSOME 20 mix at peak load, and it is decreased by 1 bar and 1.5 bar for 10% DEE blend and 20% DEE blend, respectively. A decline in-cylinder pressure may be due to butanol's high latent heat, which cools the charge at a high load and lowers peak pressure for higher DEE blends.

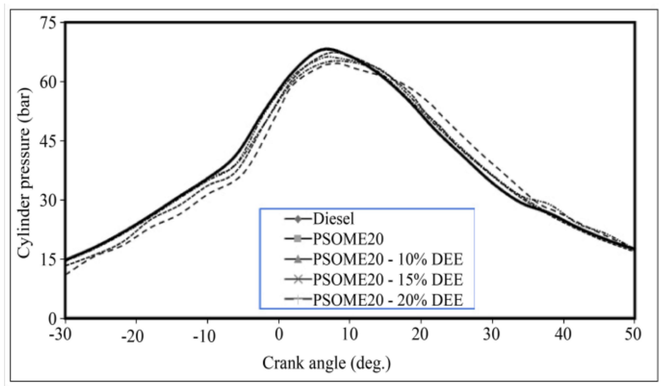

Fig. 5 Cylinder Pressure (CP) VS Crank Angle (CA) – Diesel/PSOME20/DEE

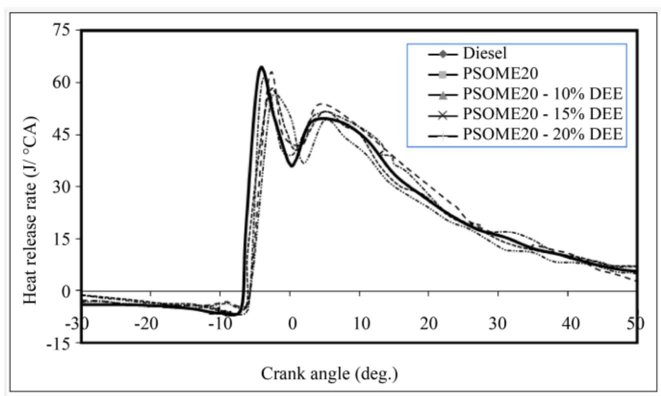

Fig. 6 Heat Release Rate (HRR) VS Crank Angle (CA) – Diesel/PSOME20/DEE

Figure 6 displays the variation in PSOME with DEE blends and HRR with CA for diesel. The premixed combustion phase is longer for PSOME20 with DME blends because the ignition delay is less than it is for PSOME20 blends at peak load. The heat release rates for PSOME20 with 10%, 15%, and 20% DEE blends are 57J/ºCA, 61J/ºCA, and 56J/ºCA, respectively, compared to 63.3J/ºCA and

60.2kJ/°CA for diesel at full load. It is possible that DEE, which works as a biodiesel ignition improver and so increases the premixed combustion phase, is to blame for the rise in heat release rate for PSOME20-DEE15 blends. The different temperatures of vaporisation of DEE at peak load may be the cause of the drop in HRR for PSOME20 - 20% DEE.

4.2. Performance - Diesel/PSOME20/DEE

Figure 7 represents the difference in BTE with BP for diesel and PSOME with DEE blends. Because of its high viscosity, PSOME20 has a significantly decreased BTE than diesel at all loads, resulting in poor atomization and poor energy combined from the biodiesel. The addition of DEE to PSOME20 significantly increases the BTE due to the enhanced combustion of the biodiesel, which acts as a cetane improver of up to 15% DEE [26]. The increase in BTE could be attributed to DEE's improved flammability, which allows it to quickly adding with fuel and different air ratios to form a homogeneous mixture, consequential in better combustion and higher brake thermal efficiency. Due to DEE20's significant evaporation rate at peak load, it was also employed to lower BTE. In comparison, the BTE generated by combining PSOME20 - 10% DEE, PSOME20 - 15% DEE, and PSOME20 - 20% DEE is 29.8%, 28.6%, and 27.6%t respectively, at complete load. The BTE obtained for diesel, and PSOME20 is relatively 30.6% and 31.4%.

Figure 8 represents the relationship between BSFC and BP for diesel, and PSOME20 blends with DEE. The BSFC for diesel and PSOME20 at full load is 0.195 kg/kWh and 0.254 kg/kWh, between the nominal value, whereas the BSFC for PSOME20 with 10%, 15%, and 20% DEE blends is 0.263 kg/kWh, 0.232 kg/kWh, and 0.271 kg/kWh, were between the nominal value. Lower BSFC for PSOME20 with 15% DME compared to PSOME20 without DEE blend could be attributed to more DEE oxygen and good DEE ignition characteristics, which improves process combustion and results in lower BSFC [26]. Because DME has a more temperature distribution of vaporisation, it reduces the BSFC in the PSOME20 blend.

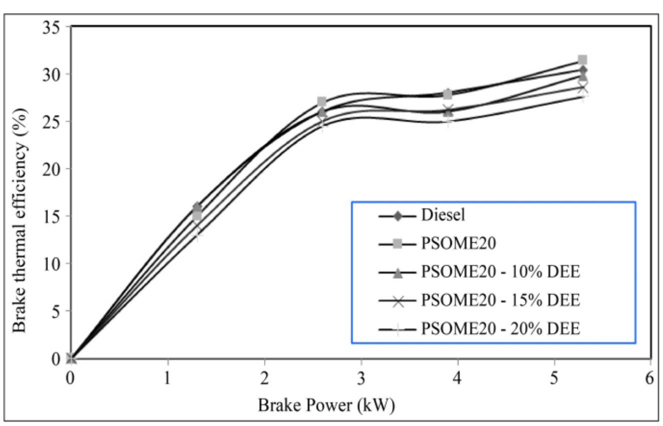

Fig. 7 BTE vs BP – Diesel/PSOME20/DEE

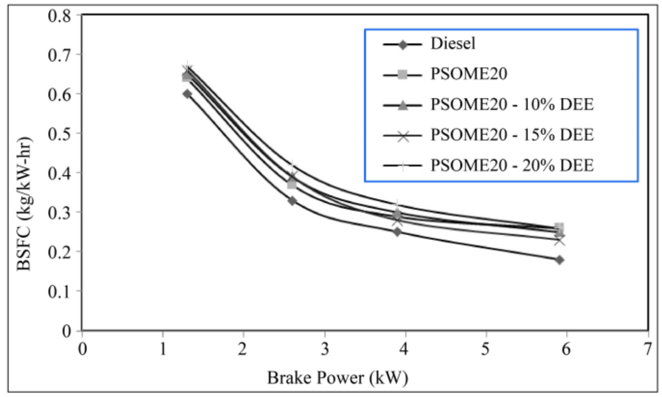

Fig. 8 BSFC vs BP – Diesel/PSOME20/DEE

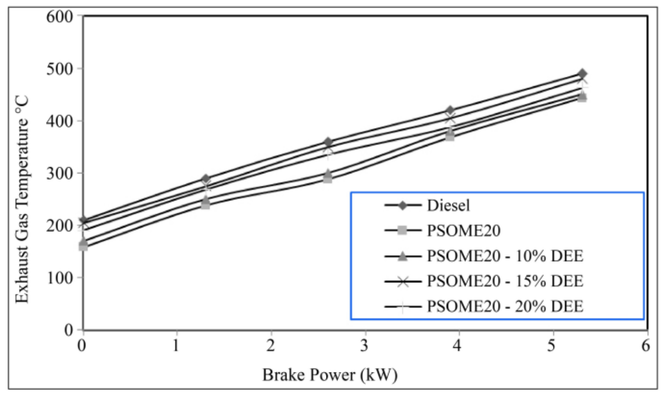

Fig. 9 EGR vs BP – Diesel/PSOME20/DEE

Figure 9 represents the temperature-varying exhaust gases with BP for diesel and PSOME20 for DEE blends. Even though more fuel was needed to satisfy the power demand, the exhaust gas temperature increased as the load increased. A decrease in the trend for DEE additives compared to diesel fuel and a decrease in outlet gas temperature for different diesel ranges and PSOME20. The exhaust gas temperatures for diesel and PSOME20 at complete load are 485°C and 442°C, and ranges are varied. At full load, the PSOME20 with 10%, 15%, and 20% DEE blends is 450°C, 480°C, and 463°C, where between the nominal value. The lower exhaust gas temperature could be attributed to DEE's faster combustion as well as its more temperature distribution of vaporisation quality, which remains cooling condition charges and thus improves the temperature of its combustion, resulting in a demised outlet gas temperature [26].

4.3. Emission - Diesel/PSOME20/DEE

Figure 10 represents the comparison in CO emissions with BP for diesel and PSOME20 with DEE blends. CO emissions are produced by the mixture of high air-fuel ratio mixture regions due to an insufficient oxygen supply. Due to the different oxygen rates of molecules present in the biodiesel's moisture, which enhances fuel oxidation and results in lower CO emissions, CO emissions for PSOME20 are lower than diesel at complete loads. Adding DEE to PSOME20 reduces CO because it has a higher cetane number, which improves the blend's combustion [26]. CO emissions for PSOME20 are 0.12 %, 0.15 % for PSOME20 - 10% DEE, 0.16 % for PSOME20 15% DEE, and 0.18 % for PSOME20 20% DEE, respectively, whereas diesel emissions are 0.14 %.

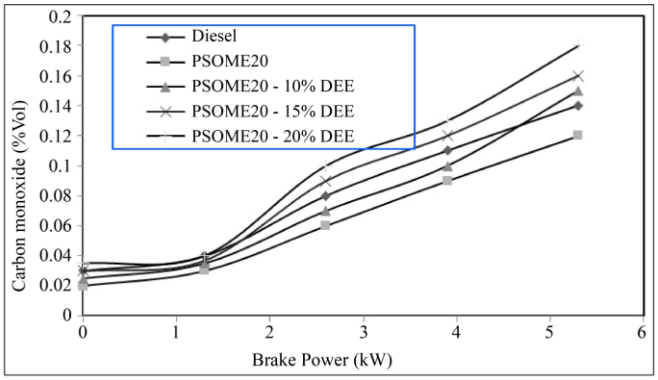

Fig. 10 CO vs BP – Diesel/PSOME20/DEE

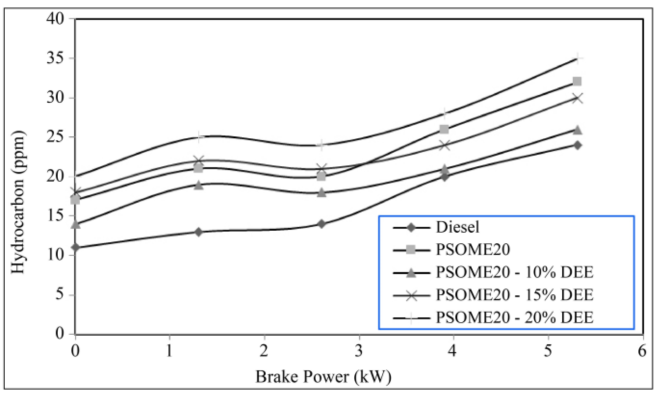

Fig. 11 HC vs BP – Diesel/PSOME20/DEE

Figure 11 represents the comparison of hydrocarbon emissions with brake power for diesel and PSOME20 fuels with DEE blends. Higher HC emission is produced as a result of combustion quenching close to the cylinder walls and crevice volume ring grooves. The PSOME20 with DEE blends, on the other hand, showed a rising HC emission pattern at all loads for all DEE blends. At full load, the hydrocarbon emissions for diesel and PSOME20 are 24ppm and 32ppm, respectively, whereas the hydrocarbon emissions for PSOME20 with 10%, 15%, and 20% DEE blends are 26ppm, 30ppm, and 35ppm, respectively. The PSOME20 fuel with DEE additive, on the other hand, showed a rising HC emission pattern at all loads for all DEE blends [26]. The cause could be a high cetane number additive that reduces the time available for combining fuel and air.

Figure 12 shows the variation of NOx emissions with BP for diesel and PSOME20 with DEE blends. Generally, the biodiesel mixture's maximum temperature, high temperature, and oxygen levels dominate NOx emission. Adding DEE to biodiesel facilitates uniform fuel distribution and reduces premixed combustion [26]. As a result, NOx emissions from DEE fuel blended with PSOME20 were reduced at peak load. Adding DEE to PSOME20, in particular, reduces NOx emissions, and the reduction decreases proportionally as the DEE blend with PSOME20 increases. At peak load, NOx emission for PSOME20 is 1040ppm, 850ppm for PSOME20-10% DEE, 800ppm for PSOME20-15% DEE, and 730ppm for PSOME20-20% DEE, whereas diesel and PSOME20 are 980ppm and 1040ppm, respectively.

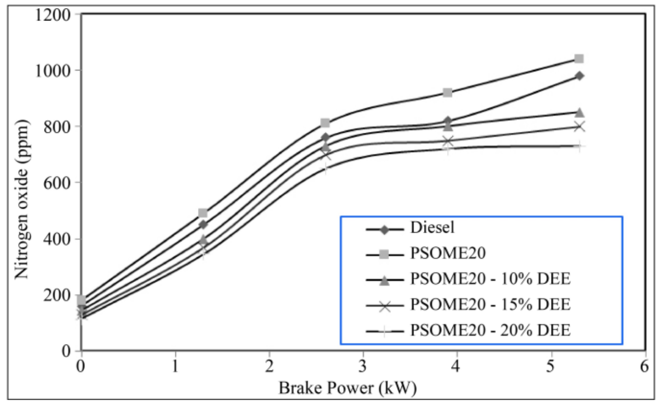

Fig. 12 NOx vs BP – Diesel/PSOME20/DEE

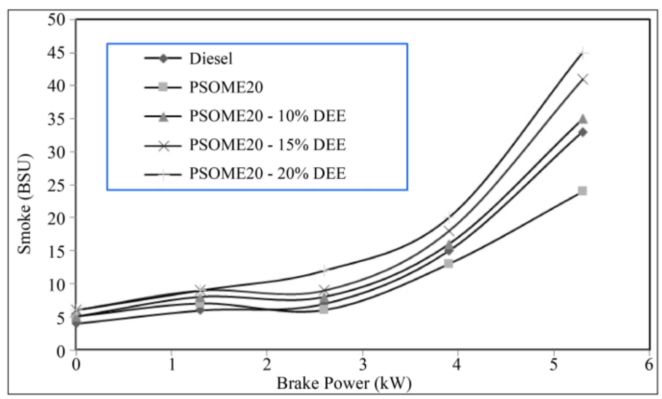

Fig. 13 Smoke vs BP – Diesel/PSOME20/DEE

Figure 13 represents the change in smoke opacity for diesel and DEE blends for diesel and PSOME20 with different proportions of DEE blends. It can be seen that diesel emits the most smoke, whereas biodiesel emits the least. It is possible that this is because PSOME has a high oxygen concentration, which helps the oxidation process and lowers the amount of smoke released. The addition of DEE to biodiesel blends, in particular, reduces opacity emissions by up to 15%.

Furthermore, it increases with an increase in DEE20 blend with PSOME20 due to the high latent heat of vaporisation of DEE, which results in poor combustion and thus increased smoke emissions [26]. At full load, the smoke opacity of PSOME20-10% DME, PSOME20-15% DME, and PSOME20-20% DEE is 35%, 41%, and 45 percent, respectively, whereas diesel and PSOME20 are 33% and 24%, respectively.

5. Conclusion

The effects of Diethyl Ether and Pumpkin seed oil methyl ester, a variation of engine emissions and performance, were investigated. The findings of this study were as follows:

- Peak cylinder pressures for diesel and PSOME20 mix are 67 bar and 66 bar, where between, at full load, however for PSOME20 -10% DEE, PSOME20 - 15% DEE, and PSOME20 - 20% DEE, they are 65 bar, 67 bar, and 64.5 bar, respectively.
- The heat release rates for PSOME20 with 10%, 15%, and 20% DEE blends are 57J/oCA, 61J/oCA, and 56J/oCA, respectively; the high latent heat of vaporisation of DEE at peak load may be the cause of the drop in HRR for PSOME20 - 20% DEE.
- The BTE obtained for diesel, and PSOME20 is 30.4 % and 31.4 %, where between the nominal value, whereas the BTE obtained with the addition of PSOME20 - 10% DEE, PSOME20 - 15% DEE, and PSOME20 - 20% DEE is 29.8 %, 28.6 %, and 27.6 %t, respectively, at complete load.
- BSFC for diesel and PSOME20 at full load is 0.195 kg/kWh and 0.254 kg/kWh, between the nominal value, whereas the BSFC for PSOME20 with 10%, 15%, and 20% DEE blends is 0.263 kg/kWh, 0.232 kg/kWh, and 0.271 kg/kWh, were between the nominal value. Lower BSFC for PSOME20 with 15% DME compared to PSOME20 without DEE blend could be attributed to more oxygen in the DEE and good ignition characteristics.
- The exhaust gas temperatures for diesel and PSOME20 at complete load are 485°C and 442°C. At the final load, the PSOME20 with 10%, 15%, and 20% DEE blends is 450°C, 480°C, and 463°C, where between the nominal value. The lower exhaust gas temperature could be attributed to DEE's faster combustion as well as its high latent heat.
- When diethyl ether was combined with PSOME20, engine emissions of HC, CO, and smoke increased dramatically, while NOx emission was minimal compared to the other emission characteristics.

6. Future Research

The diesel engine that runs on PSOME as its fuel could benefit from the following recommendations in terms of enhanced performance and reduced emissions.

- The impact of adopting a varied compression ratio to increase the performance of a diesel engine with PSOME can be investigated, and the results can be analyzed.
- The impact of various thermal barrier coatings (TiO2 and PSZ), which can be applied to the piston crown, can be investigated to boost the performance of a diesel engine that utilizes PSOME.

Conflicts of Interest

The authors of this research article neither received nor applied for any grants from any funding agency. Hence No potential conflict of interest was reported.

Acknowledgments

The authors are obliged to Aarupadai Veedu Institute of Technology, Vinayaka Mission's Research Foundation, for providing laboratory facilities.

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