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EXPERIMENTAL INVESTIGATION ON EMISSION AND COMBUSTION CHARACTERISTICS OF A DIESEL ENGINE FUELED WITH DEE BLENDED COTTONSEED BIODIESEL

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Abstract

The usage of biodiesel has offered the planet a reassuring substitute. In addition to being a renewable energy source, it also has the potential to lessen reliance on traditional diesel fuel. Furthermore, the use of additives can help with some technical issues brought on by the use of biodiesel fuel. The variety of advantages gasoline additives provide is enormous. The combustion quality and cetane rating are improved by oxygenated additions. The most popular oxygenate additives include ethers, alcohols (including butanol, methanol, and propanol, etc.), and alcohols (such as ethyl tert-butyl ether, methyl tert-butyl ether, diisopropyl ether, dimethyl ether, diethyl ether, etc.). Among the various alcohols, ethanol and diethyl ether (DEE) are a good substitute for diesel or a way to lessen reliance on it. The outcomes demonstrated that the DEE additions improved the biodiesel's oxidation stability and cetane number while reducing its viscosity. The experiment has been carried out using a Kirloskar diesel engine under various loads. Diesel has been used as the baseline reading in this investigation. For testing, Cottonseed Methyl Ether 20% blend (B20CSME) and B20CSME + DEE with various fuel percentages (5%, 10%, and 15%) are employed. From 0% to 100% of a load was applied to the engine, and the results were evaluated, totaled, and plotted on graphs for discussion. Therefore, using this additive reduces emissions without compromising combustion characteristics.

The B20CSME + DEE15% displayed improvement in all the investigated parameters with reduction of unburnt hydrocarbons by 18.75%, NOx by 8.52%, CO emissions by 0.0353Vol% and Improvement in HRR by 12.68% and Peak pressure, 6.37% at full load. This effort addressed global challenges including air pollution and the fossil fuel crises at the same time, which came close to making an economic contribution.

Fuel blends description:

B20CSME- 20% CSME and 80% diesel

B20CSME+DEE5% - 20% CSME and 80% diesel + 5% diethyl ether

B20CSME+DEE10% - 20% CSME and 80% diesel + 10% diethyl ether

B20CSME+DEE15% - 20% CSME and 80% diesel + 15% diethyl ether

Keywords: Cottonseed biodiesel, DEE, HRR, Peak Pressure, Emission characteristics.

1. Introduction

The International Energy Agency (IEA) estimated that the oil market anticipated an increase in oil demand of roughly 1.3% in 2019 [1]. Fuels made from petroleum will cost more and release hazardous byproducts like CO, NOx, CO2, and PM, which raises greenhouse gas levels. These reasons encourage scientists and researchers to explore for an alternate source since they believe that biodiesel will have notable benefits. Long chain fatty acids from vegetable or animal fats are used to make biodiesel. Although biodiesel will be the greatest alternative for CI engines and have properties similar to those of diesel, it cannot be used directly since it contains triglycerides, necessitating the transesterification process in order to produce biodiesel that meets ASTM criteria. Biodiesel has various unfavorable characteristics, like greater density, greater viscosity, and lower heating values, among others. In order to change these unfavorable conditions, chemicals are used. These additives will improve the biodiesel's quality so that it complies with global pollution standards [1]. Due to an increase in O2, DEE blends will produce less NOx, emit less CO2, and minimise smoke than pure diesel [2].

Dominic Okechukwu Onukwuli [3], investigation has shown that biodiesel production from refined cotton seed oil and its characterization. It was made in a batch fashion by the process was successful refined cottonseed oil using ethanol and potassium hydroxide (KOH) as a reagent. ASTM fuels test criteria were used to describe the physico-chemical parameters of plant oils or biodiesel like a renewable fuel for a diesel fuel. System characteristics for the transesterification process were examined, including the alcohol, oil molar, the KOH catalytic effect, temp, and reaction time. The analysis of variances (ANOVA) revealed that a good result was achieved. Similarly, raising both temperatures and KOH content resulted in a greater conversion rate, with time having no discernible influence. This measurement technique for foretelling yield had a good agreement (P0.96) between obtained from the experiment principles, proving the utility of correlational analysis is a technique for optimizing. The following are the results that imply the ideal condition: 6:1 methanol/oil molar proportion; 55 degrees Fahrenheit; 60 minutes; 0.6 percent catalyst concentration The real conversion efficiency of 96 percent was used to validate this adjusted condition.

S. Srihari et al [4], studied the possibility of alternative fuels the potential of resources has motivated engine makers. Emissions regulations have necessitated the use of reduced engines. In One main goal of this research is to see how diethyl ether with biodiesel and its blends affects performance and emission characteristics in a PCCI-DI (Premixed Charged Compressor Ignite Directed Injections) engine. The inclusion of DEE improves physical qualities such as porosity, certain number, or self - ignition temp. The DBD-3 mix has a significant reduction in NOx, CO, and HC emissions. When comparing DBD-3 to certain other mixes, the emissions are determined to be lower. As comparing to 80D-20BD and D-D blends, it is greater for DEE mix. Additionally, it was found that for all loads, BTE of DBD-3 mix is higher than D-D, DBD-1, and DBD-2. DBD-3, on the other hand, is more efficient than 80D-20BD with the exception of medium workloads.

2. Materials used and methodology

The process for making biodiesel, the characteristics of the tested fuels, and the experimental setup are all described in this section.

2.1 Biodiesel Used

Cottonseed oil is the biodiesel that was employed in this study. Figure 1 depicts the two steps of oil transesterification, known as acid transesterification and base transesterification. Cottonseed oil (CSO), which undergoes acid transesterification, is heated to 50°C. Methanol is then used to heat the CSO. Following this Base Transesterification process, the bottom deposit is separated from the reaction. The resultant mixture is heated for 45–55 minutes while being mixed with methanol and KOH (potassium hydroxide). The finished products are allowed to separate into two deposits after the reaction is complete. The glycerol-containing bottom deposit is eliminated. Residual ester (CSME) in the top deposit [5]. The full functionality of the transesterification process is shown in Figure 1. Diesel, CSME along with and without DEE fuel characteristics were identified and judged to satisfy the ASTM standard criteria. Table 1 lists all the characteristics of the tested biofuels.

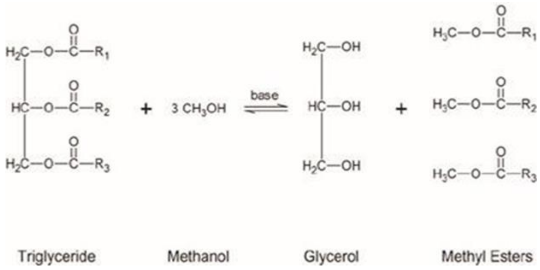


Fig.1 Chemical process of transesterification of oil

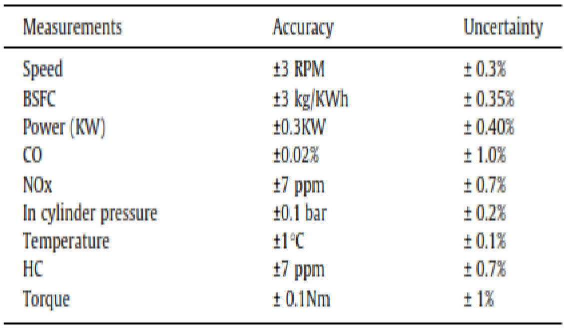
2.2 Oxygenated additives

Oxygen is present in oxygenated additives, which makes them no more than fuel. Oxygenated additives were used to enhance the combustion characteristics and octane number. A few examples of oxygenate additives are ethanol (methanol, ethanol, propanol, butanol, etc.), esters (acetoacetic ester and dicarboxylic acid esters), and ether (methyl tert-butyl ether, ethyl tertiary butyl ether, diethyl ether, dimethyl ether, etc.). It is believed that oxygenated additions lower the temperature at which biofuel ignites. However, the oxygen level and fuel molecular structures affect how much smoke oxygenated additives reduce from combustion. The composition of biodiesel, including the use of additives, affects a variety of properties, including viscosity, density, volatility, low-temperature behaviors, and cetane number. With oxygenated components, oil may react more effectively, which minimises gases released into the atmosphere. Oxygenated diesel enables the engine to burn fuel more thoroughly [6, 7 & 8].

2.3. Error analysis and uncertainty

There will surely be inaccuracies and uncertainties in the experimental data, which may result from ambient conditions, experimental test settings, excessive or incorrect handling of the instruments that affect their calibration, as well as from planning, monitoring, and reading. Accurate findings cannot be obtained due to the inaccuracies that are made. Thus, techniques and tools from mathematics and statistics are employed to cancel out these inaccuracies. In order to reduce any potential inaccuracy, the procedure often involves taking the experimentation's data repeatedly (at least three times) and calculating the mean. Uncertainty measurements were computed, and the outcomes are displayed in Table 1. The experiment's level of uncertainty was 1.85%.

Table 1: Error analysis and uncertainty.



Measurements	Accuracy	Uncertainty
Speed	±3 RPM	± 0.3%
BSFC	±3 kg/KWh	± 0.35%
Power (KW)	±0.3KW	± 0.40%
CO	±0.02%	± 1.0%
NOx	±7 ppm	± 0.7%
In cylinder pressure	±0.1 bar	± 0.2%
Temperature	±1°C	± 0.1%
HC	±7 ppm	± 0.7%
Torque	± 0.1Nm	± 1%

3. Set-up for an experiment

The experiment has been executed out using a 3.5kW Kirloskar diesel engine under various loads. Diesel and four additional fuels were used in this experiment as baseline readings. The engine was run on each of the five fuels at varying loads and the findings were assessed, gathered, and presented on graphs for debate. Table 2 presents the test fuels' characteristics.

Fig. 2: Computerized Diesel Engine Test Rig

Table 2: Diesel and biodiesel mixtures' physical and chemical characteristics

Particular	**Diesel**	**B20CSME**	**B20CSME+ DEE5%**	**B20CSME+ DEE10%**	**B20CSME+ DEE15%**
Kinematic Viscosity (40°C, CST)	3.05	4.01	3.97	3.84	3.76
Heat Value (MJ/Kg)	42.6	39.2	39.41	39.65	39.84
Density (Kg/m^3)	828	830	830	828	826
Flash point °C	60	95	91	88	86
Cetane Number	40	48	49	51	53

4. Results and discussion

Multiple tests have been conducted under various loads, and the results have been compiled and graphically represented.

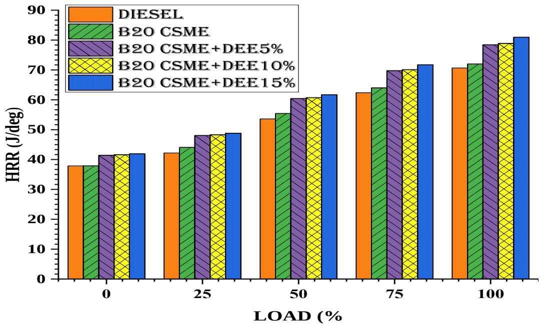


Fig 3: Variation of HRR with Load for diesel, B20CSME and B20CSME+ DEE

Figure 3 shows the deviation of HRR with load for diesel, B20CSME, B20CSME+DEE5%, B20CSME+DEE10% and B20CSME+DEE15% samples, among all the blends B20CSME+DEE15% shows the improved HRR of 12.68% compare to diesel and other concentration. [9,10]. Due to the fact that larger loads burn more fuel, which results in a higher heat release rate, it is also noticeable that the values of HRR significantly increase with rising loads. The maximum HRR is observed in B20CSME+DEE15% at full load and minimum is observed in Diesel. This is due to the molecular composition of the biodiesel blend contains more oxygen molecules with DEE gives higher HRR than the all-tested blends. Higher HRR of Blend is also attributed to premixed combustion.

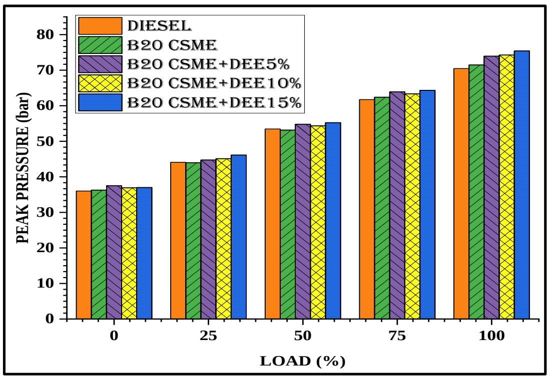


Fig 4: Variation of peak pressure with Load for diesel, B20CSME and B20CSME+ DEE.

Figures 4 show deviation peak pressure is a function of engine load for diesel, B20CSME, B20CSME+DEE5%, B20CSME+DEE10% and B20CSME+DEE15% samples. B20CSME+DEE15% is enhanced by peak pressure 6.37% compared to diesel and all other blends. This evidence shows that increasing the percentage of DEE in blending biodiesel exhibits cylinder pressure rises. The oxygen content of biodiesel has been found abundant, which causes the enhancement in-cylinder pressure by greater surface area contact. Additional air and fuel combination encourage quicker burns the fuel inside the cylinder. B20CSME+DEE15% displayed the highest Peak Pressure at 78.87 bars, while B20CSME and diesel displayed 71.89 bar and 70.67 bar, respectively. Because of its shorter ignition delay and higher viscosity, it causes an increase in peak pressure. [11, 12].

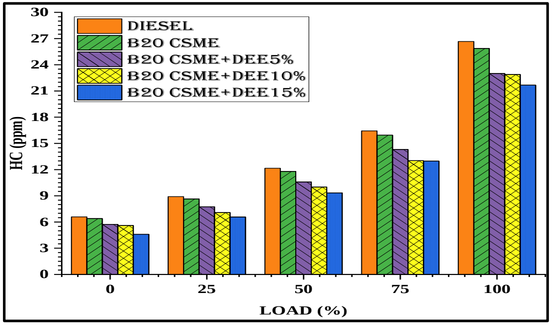


Fig 5: Variation of UBHC with Load for diesel, B20CSME and B20CSME+ DEE.

Figures 5 shows the graph for HC in terms of PPM against varying load in terms of percentage. The variation of HC emission with brake power at different loads for diesel, B20CSME, B20CSME+DEE5%, B20CSME+DEE10% and B20CSME+DEE15% samples. The figure shows that, under all loading situations, the engine generates more HC when running on diesel than when running on esterified oils. The biodiesel is made up of methyl esters, which are hydrocarbon chains with an oxygenated end at one end. The oxygen in the biodiesel that has been combined with DEE encourages a rise in the rate of combustion, which lowers the hydrocarbon emissions. As the air-fuel ratio exceeds the stoichiometric value, the HC emission rises. B20CSME+DEE15% shows reduction of the HC compare to B20CSME was 16.22% and 18.75% compares to diesel because these denser alcoholic esters and alcohols with hydrocarbons in their structure exhibit prolonged combustion, the amount of HC is reduced [13, 14].

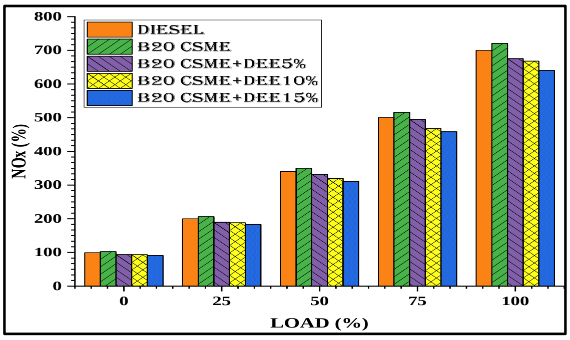


Fig 6: Variation of NOx with Load for diesel, B20CSME and B20CSME+ DEE.

Figure 6 illustrate the distinction of NOx along with load for diesel and B20CSME with oxygenated additives diethyl ether with different proportions. It could be noted that, the blends with DEE shows the marginally lower NOx compare to diesel and biodiesel blends. At full load circumstance, a reduction of 8.52% was obtained for B20CSME + DEE15% when compared to normal diesel and B20 blends respectively, B20CSME with 15% diethyl ether additives. The lengthier ignition delay of oxygenated samples (owing to existence of high oxygen content and DEE) promotes to lower residual gas temperature and wall temperature ensures the reduced NOx.

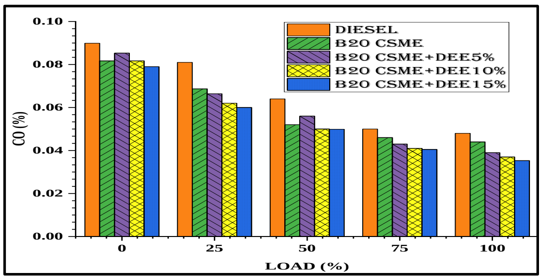


Fig 7: Variation of CO with Load for diesel, B20CSME and B20CSME+ DEE.

Figure 7 shows the deviation CO emission is a function of engine load for diesel, B20CSME, B20CSME+DEE5%, B20CSME+DEE10% and B20CSME+DEE15% samples. When compared to standard biodiesel blends, B20CSME+DEE biodiesel's had lower CO emission. This is due to oxygen enrichment in biodiesel and diethyl ether, which could increase the amount of oxygen that could contribute to further oxidising CO during the combustion process and make combustion more complete at higher loads. Diethyl ether releases an OH radical during oxidation, which is advantageous for turning carbon monoxide into carbon dioxide. At maximum loads, a sizable portion of the CO had been converted to CO2 (carbon dioxide), which led to a reduction in the CO output. Among all the tested blends B20CSME+DEE15% biodiesel shows the reduced CO by 0.035 Vol% compare to diesel [15, 16].

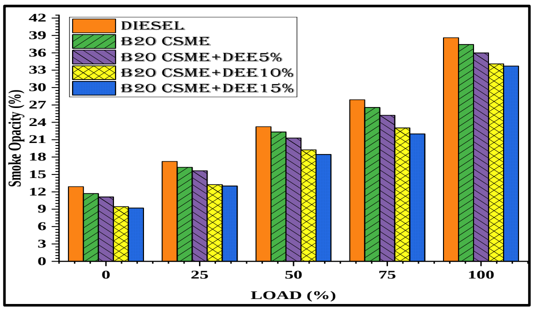


Fig 8: Variation of SO with load for Diesel, B20CSME and B20CSME+ DEE.

Figure 8 illustrates the distinction of smoke opacity along with load for diesel fuel, B20CSME, B20CSME+DEE5%, B20CSME+DEE10% and B20CSME+DEE15% samples. Blends with oxygenated additives shows the lower smoke opacity compare to diesel, The reduction of smoke for the B20CSME, B20CSME+DEE5%, B20CSME+DEE10% and B20CSME+DEE15% fuels attributed to the improved fuel air mixing and secondary atomization. B20CSME+DEE15% shows the reduced smoke opacity by 12.69% compare to diesel. By reducing ignition delay, the DEE blend improves combustion by promoting an increase in combustion time, which reduces soot production. [17, 18].

5. Conclusion

In order to evaluate the combustion characteristics, this work examines the impact of cotton seed methyl ester (CSME) with additions of diethyl ether in the proportions of 5%, 10%, and 15%. The research investigation led to the following conclusions.

- B20CSME+DEE15% shows the improved HRR of 12.68% compared to diesel and other concentration.
- B20CSME+DEE15% is enhanced by peak pressure 3.37% compared to diesel and all other blends.
- B20CSME+DEE15% shows reduction of the HC compare to B20CSME was 18.75%.
- B20CSME+DEE15% biodiesel shows the reduced CO by 0.035 Vol% compare to diesel
- B20CSME+DEE15% shows the reduced smoke opacity by 12.69% compare to diesel.

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