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Analyze diesel engines' emissions, performance, combustion, and green fuel design

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Abstract

Diesel fuels might be partially or entirely replaced by vegetable oils. The effects of blending biodiesel and diesel and employing ethanol and diethyl ether as additives on the engine's emissions and performance are tested experimentally. The pyrolysis process produced biodiesel. It was decided to make biodiesel from cashew nut shell liquid (CNSL). Here, we refer to B20 as fuel composed of 20% biodiesel and 80% Number 2 diesel fuel, B20+E10 as fuel composed of 90% B20 and 10% ethanol by volume, and B20+D10 as fuel composed of 90% B20 and 10% diethyl ether by volume. Torque, power, specific fuel consumption, braking thermal efficiency, and exhaust gas temperature were all measured after being exposed to various test fuels to determine their impact on the engine. Emission experiments looked at the effects of mixtures on levels of CO, CO2, HC, NO, and smoke opacity.

Introduction

Biodiesel is a sustainable and home-grown alternative fuel that burns reasonably cleanly. There are no petroleum by-products in biodiesel, but it may be mixed in any percentage with petroleum fuel to make a biodiesel blend. It requires little adjustment before it may be utilized in compression-ignition (diesel) engines. Biodiesel has little if any sulphur or aromatic components and is readily biodegradable and harmless [1]. Transesterification is the chemical process used to create biodiesel. Process of extracting glycerine from vegetable oil or animal fat. By adding an appropriate catalyst, triglycerides may be transesterified into alcohols. Methyl esters, the chemical term for biodiesel and glycerine are the two by-products left behind after the process [2]. Several issues, including poor fuel atomization and low volatility, stem from the high viscosity, high molecular weight, and density of vegetable oils, as reported in the literature [3]. Vegetable oils used in a CI engine as a fuel source for an extended length of time may create serious problems, such as injector and valve damage [4].Biodiesel is preferable to petroleum diesel due to its reduced emissions and renewable resource production. Monohydric alcohols, such as methanol and ethanol, in the presence of an alkaline catalyst, undergo transesterification. The use of biodiesel or a combination of biodiesel and petroleum-based diesel fuel in diesel engines does not need any major engine changes [5]. Biodiesel's benefits Include mitigating the risks associated with using petroleum products as fuel, such as greenhouse gas emissions, tailpipe particulate matter, hydrocarbons, carbon monoxide, and other air toxics [6]. Fuel pumps are less likely to wear down quickly when using biodiesel [7].
The Food and Agriculture Organization (FAO) reported that annual global cashew output was roughly 2.7 million tons. Vietnam (960,800 tons), Nigeria (594,000 tons), India (460,000 tons), Brazil (147,629 tons), and Indonesia (122,000 tons) are the top five nations in terms of raw cashew output in 2005 (according to the UN's FAO). India has more cashew-growing land than any other country, but its yields are poor. More than ninety percent of the world's cashew kernels are shipped out of Vietnam, India, and Brazil. Cashews (AnacardiumoccidentaleLinn.) are mostly grown and shipped out of India. Over 0.40 million metric tons of raw cashew nuts are harvested annually from India's 0.70 million hectares of land dedicated to cashew production. The cashew nut has a thin, hard inner layer and a softer, feathery outer skin. Cashew nut shell liquid (CNSL) is a phenolic substance found in the honeycomb structure between the skins. The test, a thin skin, encloses the kernel within the shell. According to their findings Twenty-five percent to thirty-five percent of a cashew nut is made up of the kernel, kernel liquid, test, and shell [8]. Cashew nut shells are the primary input used to produce CNSL. These days, the term "pyrolysis" is often used to describe procedures where liquid oil is the desired end result. When air or oxygen is scarce, one of the thermochemical transformations that might occur is called pyrolysis [9]. Anacardic acid makes up over 90% of the liquid in a cashew nut shell, while cardol accounts for the remaining 10% or so. The pyrolysis of CNSL, as described by Risfaheri et al. [10], takes place in a reactor at a vacuum pressure of 5kPa and at maximum temperatures ranging from 400 to 600 °C, with an incremental rise of 50 °C between each experiment. Condensation of the volatiles released during pyrolysis occurs in stages, beginning with air condensation and ending with condensation in an ice bath at temperatures between five and seven degrees Celsius [11]. Cardanol

that has been decarboxylated is often referred to as CNSL biodiesel. Unlike other biodiesels, CNSL biodiesel doesn't need further processing like transesterification because of its low volatility, high combustibility, and low solubility in diesel.

2. Experimental Procedure and Equipment

Direct injection diesel engines using CNSL biodiesel have been the subject of published papers examining combustion and performance. They come to the conclusion that a 20% mix won't have any detrimental effects, therefore that's the one that's analyzed [19]. The mix percentage can't go over 20% because of the decreased calorific value and increased viscosity. Alcoholic beverage (ethanol) and C.I. engine performance and emissions were monitored when diethyl ether was used as an additive. Due to the cooling impact on the combustion chamber at higher percentages, the addition of ethanol and diethyl ether was capped at 10% [20, 21]. Additives, according to some writers, may mitigate biodiesel's drawbacks [22]. By-product of the cashew industry, CNSL finds widespread use in the pharmaceutical and rubber manufacturing sectors. CNSL has a high calorific value, thus we attempt to utilize it as engine fuel by mixing it with additives to make it more like regular diesel fuel. The primary goal of this research is to enhance the fuel properties of biodiesel via the use of additives and to increase the amount of biodiesel used in a conventional diesel engine.

These blends are prepared using CNSL biodiesel; B20 refers to a blend with a volume ratio of 20:80 CNSL biodiesel to diesel; B20E10 refers to a mix with 10% ethanol; and B20D10 refers to a blend with 10% diethyl ether. Table 1 lists several fuel and additive characteristics.

The characteristics of No. 2 Diesel, ethanol, and diethyl ether are summarized in Table 1.

Properties		Diesel	Ethanol	Diethyl ether
Kinematic Viscosity (40℃) cSt		2.82	1.32	-
Density	kg/m^3	840	792	710
Calorific Value	MJ/kg	43.3	26.8	36.8
Flash Point	℃	74	16	- 42
Cetane Number		46	7	-

The engine is a direct injection diesel unit with a single cylinder, naturally aspirated, four stroke, water cooled, 16.5:1 compression ratio, with a maximum power output of 3.7 kW at 1500 rpm (kilowatts). All tests were performed under ambient conditions. The RPM sensor located near the engine's flywheel was used to get accurate readings of engine speed. A Kirloskar alternating current (A.C.) generator that loads itself through a resistance bank is also included. Piezo electric sensor and shaft encoder for measuring combustion pressure and volume; fuel flow sensor unit; electrical loading arrangement; voltmeter; ammeter; rpm meter; cooling water sensor unit; air flow sensor unit; are the primary components of the experimental set up. The thermocouples (Cr Al) fitted to the cooling water and exhaust gas outlets allowed for precise temperature readings. All the information is sent to the computer through a software interface.

The AVL-444 Di gas analyzer (Table 2 shows its specifications) was used to test the levels of NO, CO, HC, and CO2 in the engine exhaust. At a distance of 200 mm from the exhaust valve, the exhaust emissions were measured. After lowering the pressure and temperature in the expansion chamber, the AVL-437C smoke meter was used to measure the opacity of the smoke. The engine was set up to reach its rated speed and steady state conditions with a no-load start and by carefully adjusting the feed control. The monitor showed data on fuel use, engine speed, the temperature of the exhaust gases, and horsepower. The engine was progressively loaded to maintain a safe speed. To compare the performance and emission characteristics of diesel and fuel blends, the pressure and crank angle diagram of the test engine was obtained at full load for both fuel types. The average of three separate readings for each variable in the experiment was used.

The features of gas analyzers are shown in Table 2.

*Corresponding Author

Measured quantity	Measuring Range / Resolution	Accuracy
CO	0…10 % Volume / 0.01 % Volume	±0.03% Volume
CO_2	0…20 % Volume / 0.1 % Volume	±0.4% Volume
HC	0…20000 PPM/1 PPM /10 PPM	±10 PPM
O_2	0…22 % Volume / 0.01 % Volume	±0.1% Volume
NO	0…5000 PPM/1 PPM	±50 PPM

3. Results and discussions

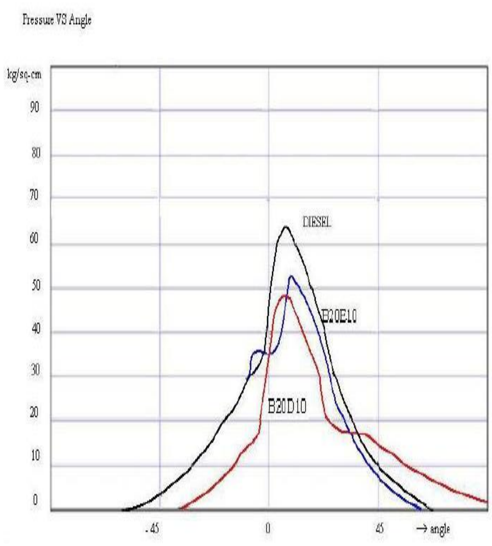
3.1. Combustion Pressure and Crank Angle

Cylinder pressure vs. crank angle at full throttle for diesel, B20E10, and B20 D10 mixes is shown in Fig. 1. There was no mistaking that diesel had a greater peak cylinder pressure. The ignition delay is a crucial factor in the combustion process. Biodiesel's combustion begins sooner than diesel's. This is because of a deficit in Improve biodiesel performance with a delayed ignition and improved injection timing [23]. The ignition delay seems to be less for biodiesel than for diesel [24], despite biodiesel's somewhat greater viscosity and lower volatility. The crank angle between the beginning of fuel injection and the beginning of combustion was used to determine the ignition delay in this analysis. Diesel, B20E10, and B20D10 all reached their maximum pressures of 64 bar, 52.9 bar, and 48.2 bar, respectively, at full loads. However, regardless of fuel type, peak cylinder pressure was achieved at crank angles ranging from 6 to 9 degrees after top dead centre. The greater ignition time lowered peak cylinder pressure [25].

3.2. Engine Performances

Figure 2 depicts the shift in Break Thermal Efficiency (BTE) as a function of load for each of the four fuels. Both diesel and bio diesel blends have a higher BTE at higher loads. Increases in power generated with an increase in load have been attributed to the rise in BTE. For B20D10, the range of BTE when running at full capacity is 25.48, 23.6, 24.1, and 24.3. Diesel, B20, and the B20E10 blend. In comparison to diesel, B20D10 fuel BTE is 5% higher at maximum throttle, while B20E10 fuel BTE is 7.38% higher and B20 fuel BTE is 4.63% higher. According to the experimental results, the blend B20D10 performed marginally better than the other blend ratios. Brake Specific Fuel Consumption (BSFC) was shown to vary less across biodiesel blends than among diesel, and BSFC dropped precipitously as load increased across the board.

One possible explanation is that at greater loads, more energy is needed per kilowatt than at lower loads. As can be seen in Fig. 3, the BSFC of B20D10 was somewhat lower, while that of B20E10 is almost identical to that of B20.



Diesel, B20E10, and B20D10 cylinder pressure vs. crank angle at 0.57 9MPa load is shown in Fig. 1.

The temperature of the exhaust gas is influenced by the ignition delay. Combustion is slowed and exhaust temperatures are raised when ignition delays are increased [26]. However, unlike diesel, the igniting delay was shorter in this case. Consequently, there may be an increase in afterburning combustion if the ignition delay is shortened. As may be seen in Fig. 4, the temperature of the exhaust gas is greater than that of diesel l.

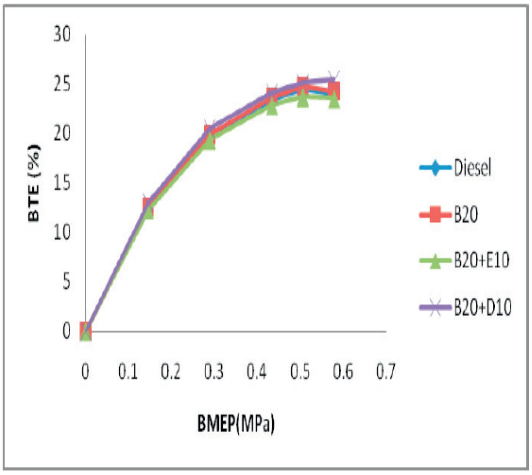


Fig. 2. Comparison of BTE variation with load and fuel blends.

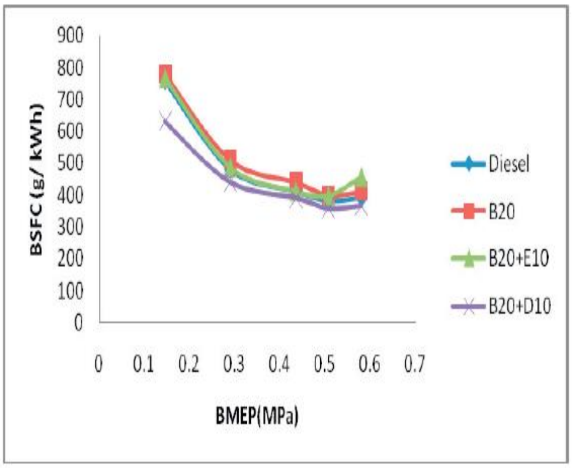


Fig. 3. Comparison of BSFC variation with load and fuel blends.

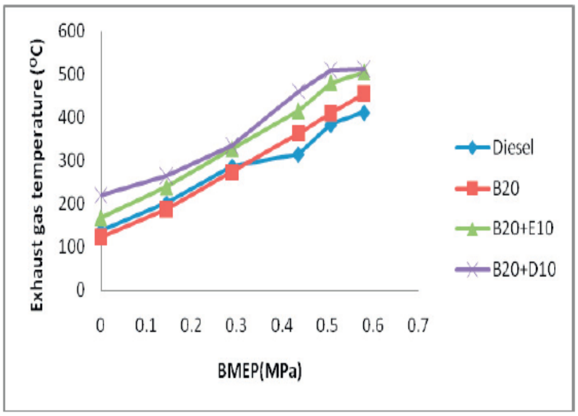


Fig. 4. Comparison of EGT variation with load and fuel blends.

3.3. Pollutant Emissions
Carbon Dioxide (CO2)

Figure 5 compares the changes in carbon monoxide (CO) emissions as a function of engine load for various fuel combinations. The lowest and highest CO Vol% yields were 0.01 and 0.31 respectively. From the diagram, we may deduce that the CO is reduction in load up to 80%, followed by a rapid increase to full capacity. When the engine is working harder, combustion may not have enough time to finish, leading to increased CO emissions. At full load, the B20D10 mix was shown to have 19% fewer CO emissions than the B20E10 blend.

Hydrocarbons, 3.3.2

Figure 6 displays the investigated fuels' HC emission variations with engine loads. In general, the biodiesel fuels' HC emission magnitude was increased because of the greater build-up of fuel in the premixed combustion phase caused by the longer ignition delay. Because of this phenomenon, biodiesel fuel may have produced more HC emissions than diesel fuel does. However, when compared to B20 at full load, the B20D10 blend's emissions were the lowest of all of the mixes tested. It's possible that the oxygen in the biodiesel fuel mix is to thank for the reduced HC emissions.

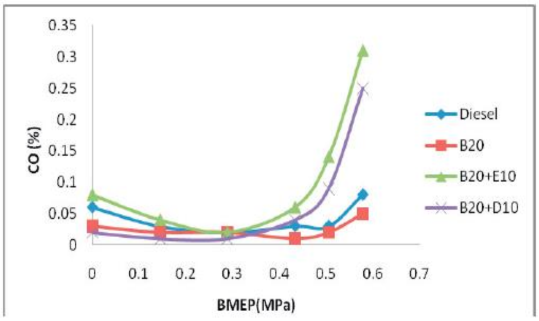


Fig. 5. Comparison of CO variation with load and fuel blends.

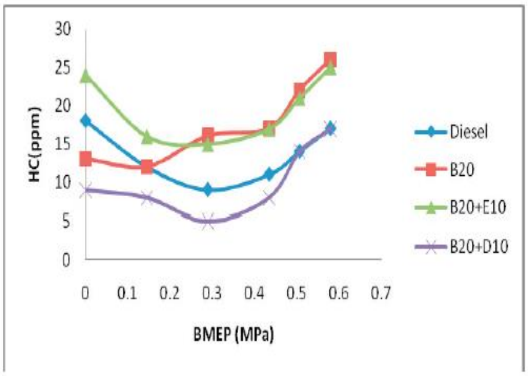


Fig. 6. Comparison of HC variation with load and fuel blends.

Nitrogen oxide
Oxide (NO) emission level for the investigated fuels under varying load conditions is shown in Fig. 7. At low power levels, the inclusion of oxygenated components in the examined fuels has a negligible impact on NO emissions, resulting in a very little decrease. The highest levels of NO emissions were seen at medium and high engine loads. Using a B20 blend is like using 20% diesel. Increases in biodiesel combustion temperature, oxygen and nitrogen concentration, reaction time, injection timing, peak cylinder pressure, and oxygen content are all responsible for the fuel's higher NO emission level. However, it was discovered that NO emission may be lowered by blending bio diesel with ethanol and diethyl ether, with an average reduction of roughly 57% for the B20E10 mix and 69% for the B20D10 blend compared with the B20 blend. Since the behavior may result from a complicated interplay between elements like combustion temperature, response time, and oxygen concentration, a thorough investigation of the flame may reveal the precise causes of the occurrence.

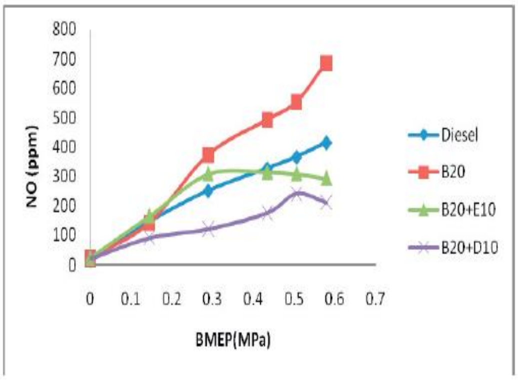


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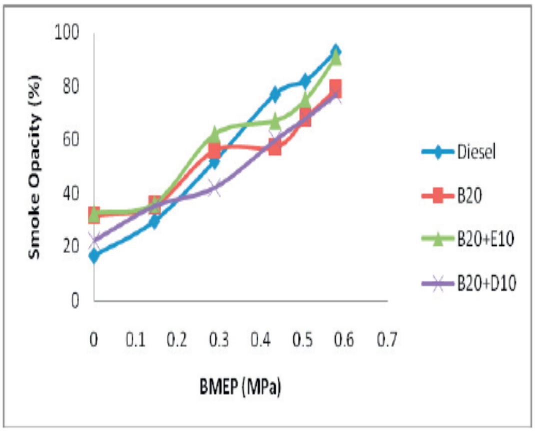
Fig. 7. Comparison of NO variation with load and fuel blends.



Smoke opacity comparison as a function of load and fuel mixtures is shown in Figure 8.

Coefficient of smoke absorption, or 3.3.4. Particulate matter may be detected by monitoring the smoke opacity of exhaust gas. A build-up of soot occurs mostly in the core area of fuel spray, where high temperatures and pressures induce breakdown of the fuel molecules. Partial oxygenation of the fuel has the potential to lessen locally over-rich areas and curb primary smoke production. Figure 8 depicts the relative smoke opacity of each tested fuel. A lower percentage of smoke was created by the B20 mix compared to 100% diesel, and the B20D10 blend performed better under medium loads. When comparing smoke densities generated by B20D10 and diesel at full load, the lowest and highest values were 77% and 93%, respectively, for a decrease percentage of 17%. More fuel is used and burnt in the diffusion mode under higher engine loads, which may be owing to the presence of oxygen molecules in the biodiesel chain, resulting in more thorough combustion.

4. Conclusions

Because of its low cost, CNSL bio oil is a significant boon to the biodiesel industry. B20 has superior qualities than diesel fuel in many ways, including its certain rating, calorific value, sulphur content, and ignition temperature. Blends' density and viscosity may also be reduced by using diethyl ether and ethanol as additions. To the BSFC of The B20 was somewhat higher than the B20D10, while the B20E10 was virtually as high as the B20. Due to the greater oxygen concentration of the B20E10 and B20D10 blends compared to B20, smoke emission was decreased, particularly under heavy engine load. Since diethyl ether is more flammable than ethanol, the smoke-cutting properties of B20D10 are more pronounced. Although B20D10's NO emissions were 28% lower than those of the B20E10 mix, it was nevertheless found to be significantly higher than those of pure B20. When comparing B20D10 to B20E10, the HC emission is lower. A viable method for utilizing biodiesel/diesel mix effectively in diesel engines without any changes is to add fuels with a greater oxygen content and high volatility, such as diethyl ether and ethanol. Consequently, mixes of Cashew nut shell liquid (CNSL) and CI engines may be employed in rural areas to satisfy energy requirements for a wide range of agricultural activities, including irrigation, harvesting, threshing, etc. Thus, diesel engines may be utilized efficiently with just a 10% diethyl ether additive and a 20% CNSL biodiesel blend.

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