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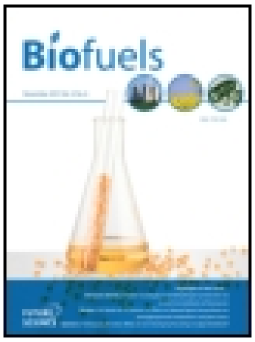

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Effects of ethyl proxitol (1-ethoxy-2-propanol) additive on combustion and emission characteristics of biodiesel blends

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ABSTRACT
The cold filter plugging point (CFPP) value of biodiesel fuel blends need to be improved because of it has been reported that utilizing high concentrations of biodiesel blends in cold climates can cause major issues. Therefore, the main objective of the study is to improve CFPP value of biodiesel blends using ethyl proxitol additive. It is also to examine combustion and emission of the blends behavior. Biodiesel blends were prepared as; 5% ethyl proxitol-10% biodiesel-85% ultra-low sulfur diesel (ULSD) named as E5B10 and 5% ethyl proxitol-20% biodiesel-75% ULSD named as E5B20 fuel. These fuel blends were compared with ULSD fuel in a compression ignition engine at a constant engine speed of 1500 rev/min and four different loads (idle, 1, 2, and 3 bar BMEP) of eddy current dynamometer. The addition of ethyl proxitol led to a decrease in in-cylinder pressure and temperature due to an about 1° later SOC and 2° earlier EOC compared to ULSD. The pressure rise rate was slightly higher compared to ULSD at both low and high loads, with a difference of about 1 bar per degree. As a result, these blends with improved CFPP value can be used in cold climates.

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KEYWORDS
Ethyl proxitol; biodiesel; cold filter plugging point; combustion; emission

1. Introduction

Compression ignition engines or diesel engines are commonly used for power generation [1]. However, harmful exhaust gases resulting from the combustion of petroleum products in diesel engines seriously affect both the environment and human health. recently, it has been subject to public scrutiny [2]. Legislations have been pushed diesel engines and their fuels to a continuous improvement in all areas [3]. In order to eliminate or at least minimize these negative impacts, the engine combustion chamber and operating parameters are optimized using numerical and experimental methods [4]. On the other hand, researches are carried out to use cleaner and renewable fuels to minimize exhaust emissions [5,6]. Many promising alternative fuels have been proposed in previous studies. Alternative fuels such as safflower methyl ester [7], polyoxymethylene dimethyl ether [8], glycerol tert-butyl ether [9], canola oil biodiesel [9], waste frying oil [10], sunflower oil [11], soybean oil [12], palm oil [13], opium poppy oil [13] biodiesel methyl esters, iso-propanol [10], ethanol [14], methanol [15], n-butanol [14], and toluene [16] were successfully used as a fuel in a compression ignition engine. In the studies, it was understood that it is possible to use biodiesel obtained from vegetable oils or animal fats in a diesel engine [17].

Biodiesel production costs are higher than fossil-based diesel fuel when biodiesel is produced from edible vegetable oil sources. About 80% of the total biodiesel production cost consists of the direct materials cost [18]. Moreover, edible oils are a nutrient source. Biodiesel production from edible oils will increase the need for agricultural land and hence the risk of deforestation [19]. However, biodiesel production from waste oils is very low-priced. Moreover, the usage of households and industrial waste oil as biodiesel helps in solving the disposal problem.

Dumped cooking oil into water sources and therefore pollution of drinking water and clog drainage may be prevented by converting waste vegetable oils into liquid fuel. Biodiesels derived from waste vegetable oils have dual benefits for both the environment and industries [20].

CFPP is the point where the existing crystals agglomerate as the temperature of the crystals formed at the cloud point decreases further in the fuel. When this temperature value is reached, the fuel filter becomes clogged. The critical weakness of biodiesel is its low-temperature flow properties, limiting its use in cold weather. Biodiesel tends to solidify or gel at low temperatures. Solidified biodiesel causes problems in the fuel line, filter, and injectors of the engine system. Biodiesel has a higher cold filter plugging point (CFPP) value compared to diesel fuel [21]. CFPP is the lowest temperature at which 20 ml of fuel can pass through a standard fuel filter in 60 s without being gelled or solidified [22]. The higher CFPP of fuel limits the operation in cold regions. There are international standards for the CFPP. According to one of these standards, DIN EN 14214, the CFPP value for biodiesel is 0 °C for summer, −10 °C for spring and autumn, and −20 °C for winter [23].

1.1. Literature review

In previous studies, it was aimed to improve the cold flow properties of biodiesel by using some methods. Adding fuel additives, using biodiesel as a blend, and winterization are some of these methods. Giraldo et al. investigated the effects of cold flow properties using additives to palm oil

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biodiesel [24]. By adding a 2-Butyl ester (5%) to biodiesel, cloud and pour points of the fuel were reduced by 6 °C. They found by using particle size analysis that the crystal size and crystallization point of esters decreased by using additives. Wang et al. studied the influence of polymaleic anhydride, polymethyl acrylate, poly-α-olefin, and ethylene vinyl acetate copolymer additives on cold flow properties and viscosity of waste cooking oil biodiesel [25]. Polymethyl acrylate was found to be the most effective additive in improving the cold flow properties of biodiesel. It was found that the addition of 0.04% polymethyl acrylate to biodiesel reduced the CFPP value by 6 °C.

Ranjan et al. investigated the effect of MgO nanoparticles on combustion, emission, and cold flow characteristics of biodiesel. They found that MgO nanoparticles at 30 ppm concentration improved the CFPP value of the blend without changing other fuel properties considerably [26]. Okoye et al. used triacetin and diacetin as oxygenated fuel additives in order to improve the cold flow properties of biodiesel [27]. Örs et al. studied the addition of TiO_2 nanoparticles in biodiesel fuel blends for combustion, performance, and emission of compression ignition engines. The addition of TiO_2 nanoparticles increases the torque and power, but, this additive has not much effect on kinematic viscosity, density, and cold flow properties of the fuel blend [28]. Wang et al. determined that low-temperature properties of biodiesel were improved during biodiesel production from waste cooking oil and fusel alcohols using the biocatalyst method [29]. Lv et al. used DEP, polyglycerol ester, and PA additives to improve the low-temperature properties of palm oil biodiesel and reduced the CFPP of biodiesel by 7 °C [30]. Park et al. compared the CFPP specifications by blending palm, soybean, and rapeseed biodiesels in certain ratios [31].

Palm, rapeseed, and soybean biodiesels have CFPP values of 10.0, −20.0, and −3.0 °C, respectively. The low CFPP of Soybean biodiesel decreased the CFPP of the blend. Moser and Erhan achieved the best cold flow performance with 2-ethylhexyl ether which has a cloud point and pour point of −26 °C and −29 °C, respectively [32]. Monirul et al. examined the cold temperature behavior of coconut biodiesel blends using poly(methyl acrylate) additive [33]. They improved the CFPP by adding poly(methyl acrylate) of 0.03%. On the other hand, the additive decreased the BSFC by 3.25%, while it increased the thermal efficiency by 2.16%. Cao et al. investigated the effects on cold flow properties by adding ethyl acetoacetate to waste cooking oil biodiesel [34]. With a 20% additive of ethyl acetoacetate to the biodiesel, the CFPP value decreased by 4 °C. The aforementioned studies were carried out to improve the CFPP characteristics of biodiesel so that the fuel can be utilized in cold regions.

The use of biodiesel blends, up to 20%, has been approved by some engine manufacturers and the European Union's Renewable Energy Directive requires at least 10% of transportation energy to come from renewable sources [36–38]. Within this framework, 10% and 20% of biodiesel as a test fuel were used in this study. Because of the higher CFPP value of biodiesel, it is limited the usage in cold regions. Since the CFPP value of ethyl proxitol (1-ethoxy-2-propanol) is very lower, it also decreases the CFPP value of biodiesel-diesel blends [35]. Ethyl proxitol additive improves the cold flow characteristics of biodiesel. Therefore, the blends can be used in a compression ignition engine under a wide range of weather conditions. Low level of ethyl proxitol that has a lower calorific value was used to maintain combustion parameters while improving the cold flow characteristics of the blends. Combustion and emission characteristics of the engine fueled with diesel, biodiesel, and 1-ethoxy-2-propanol (ethyl proxitol) were examined and compared with an ultra-low-sulfur diesel (ULSD). The aim of this study is to use of ethyl proxitol additive is intended to explore the viability of using biodiesel at high concentrations in diesel engines. In the literature review, no low-rate ethyl proxitol added to biodiesel blended fuel studies were found. In the present study, the combustion and emission changes of the ethyl proxitol additive, which has good cold flow properties, with biodiesel-diesel fuel were particularly investigated. The experiments were conducted with the E5B10, E5B20, and ULSD fuels in a compression ignition single-cylinder engine at idle, 1, 2, and 3 bar BMEP. A comprehensive analysis was done to find suitable fuel alternatives for compression ignition engines.

2. Material and methods

2.1. Test fuels

1-ethoxy-2-propanol (ethyl proxitol) is colorless to faint yellow liquid form. It is a solvent of glycol ethers. Ethyl proxitol was used to improve the cold flow properties of the biodiesel blends. Diesel was blended with 5% of 1-ethoxy-2-propanol + 10% of biodiesel (E5B10) and 5% of 1-ethoxy-2-propanol + 20% of biodiesel (E5B20) using the mixing method until a homogeneous mixture is achieved for the experimental work. The characteristics of test fuels used in this study are listed in Table 1.

The characterization of test fuels (ULSD, E5B10, and E5B20) is listed in Table 2. 20% sunflower oil, 40% soybean oil, and 40% vegetable waste oil biodiesel and ethyl proxitol addition to diesel fuel increase the viscosity and density whereas decreasing the cetane index. Distillation temperatures of the test fuels were examined for T10, T50, and T90 i.e. 10%, 50%, and 90% distillation temperatures respectively. It can be seen that ethyl proxitol significantly reduces the CFPP value of the fuel blend compered the neat biodiesel.

Table 1. Characteristics of ULSD, ethyl proxitol and pure biodiesel fuels.

Parameter	ULSD	Ethyl proxitol	Biodiesel	EN 14214	ASTM D6751
Density [kg/m^3]	832	[a]896	[b]888	860–900	—
Heating value [kJ/kg]	[a]43490	[b]28500	[c]38122	—	—
Kinematic viscosity, 40 °C [mm^2/s]	2.855	[a]2.34	[b]5.8	3.5–5	—
Cetane index	52.78	—	[b]56.82	51 min.	47 min.
CFPP [°C]	−15	−55	−3	−20	−12
Flash point [°C]	74	[a]42	[b]148	120 min.	130 min.

a: [39] b: [35], c: [40]

Table 2. Characterization of test fuels.

Test fuels	Viscosity [mm^2/s]	Density [g/cm^3]	Cetane index	Calorific value	CFPP [°C]	IDP, [°C]	Distillation, T10 [°C]	Distillation, T50 [°C]	Distillation, T90 [°C]	FDP, [°C]
ULSD	2.8553	0.8320	52.78	43,490	−15	164.0	205.8	264.6	325.9	355.8
E5B10	3.1092	0.8390	52.70	43,048	−13	125.9	201.6	282.0	345.0	358.8
E5B20	3.5273	0.8470	51.11	42,414	−11	87.1	213.5	290.7	337.8	348

Table 3. The test engine specifications.

Engine Specifications	Kirloskar TV1 (naturally aspirated, four-stroke, compression ignition)
Total displacement	0.661 liter
Compression ratio	17.5:1
Bore/Stroke	87 / 110 mm
Connecting rod length	234 mm
Start of injection	0–25° bTDC
Maximum power	5.2 kW @ 1500 rev/min

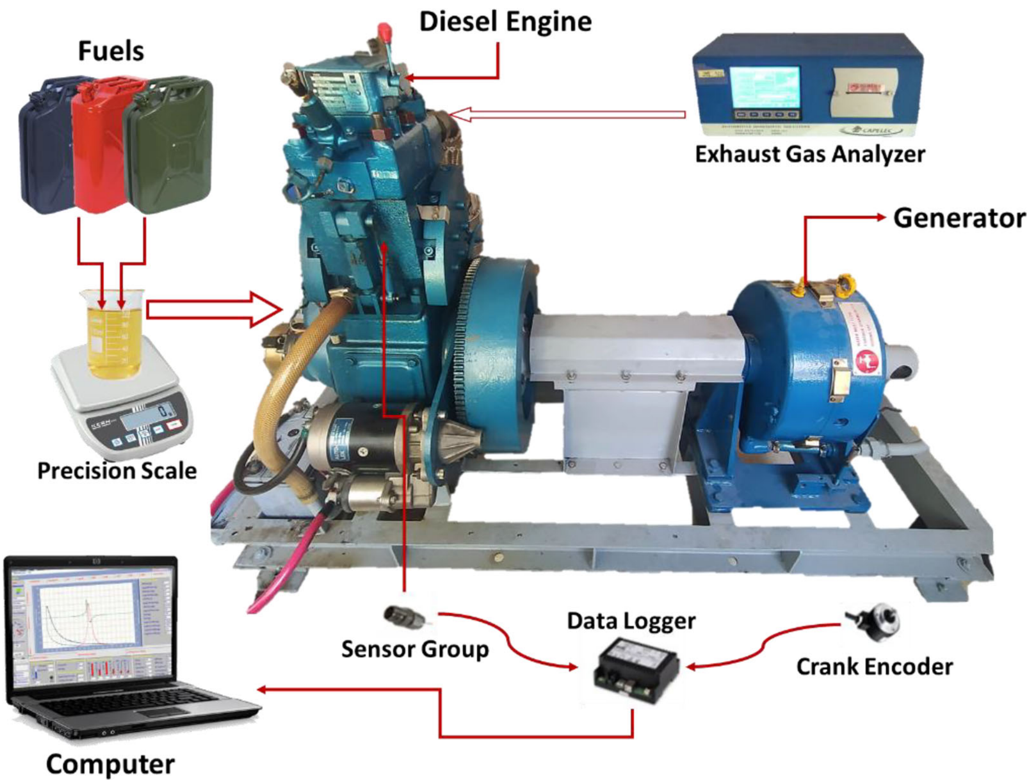

Figure 1. Schematic diagram of the experimental set-up.

2.2. Test methods

The experimental work was carried out with a naturally aspirated, four-stroke, variable compression ratio, and compression ignition engine (Kirloskar TV1) at Batman University, Automotive Engineering Department, Engine Laboratory. The main characteristics of the test engine are presented in Table 3. The experiments were performed at a constant speed of 1500 rev/min and different loads namely idle, low (BMEP of 1 bar), medium (BMEP of 2 bar), and high (BMEP of 3 bar) using a directly coupled eddy current dynamometer. The test engine was controlled using the dynamometer control software and data were collected for each crank angle.

A schematic diagram of the experimental setup is shown in Figure 1. The exhaust emissions of the engine were measured using an exhaust gas analyzer (Capalec CAP3200) during the experiments. In-cylinder pressure measurements were conducted with Optrand D33294-Q pressure transducer with a sensitivity of 1.35 mV/psi. Temperatures of ambient air, engine coolant, engine oil, and exhaust were measured with thermocouples. In-cylinder pressure, temperature, heat release rate, cumulative heat release and fuel line pressure values against the crank angle were collected with the combustion analysis software [41]. Accuracy, uncertainty, and measurement range of the test devices are listed Table 4.

Engine oil, lubricant, and air filtration were checked before starting the experiments. All engine data were collected when the exhaust temperature reached a steady state. The test engine is operated at constant-speed of 1500 rev/min which is the maximum brake torque speed. Thus, experimental conditions were defined to determine the emission and combustion characteristics of the test fuels used in this engine. All measurements were repeated three times and results were averaged.

2.3. Calculation methods

The ICEngine Software (version 9.0) collects the in-cylinder pressure and crank position data for each crank angle degree using the cycle averaged (10 cycles) values [41]. This code executes the combustion calculations by processing the pressure measurements and by using the test engine specifications. A simplified first law analysis of thermodynamics was

Table 4. Accuracy, uncertainty, and measurement range of the test device.

Parameter	Measurement range	Accuracy	Uncertainty
Engine speed	0–12,000 rev/min	±0.1%	±1.0%
Pressure sensor	0–200 bar	±0.5%	±0.2%
Precision scale	0.5–30,000 g	±0.1 g	±0.1%
CO_2	0–21.0%	±0.1%	±0.5%
NO_X	0–10,000 ppm	±1.0 ppm	±1.0%
HC	0–20,000 ppm	±1.0 ppm	±1.0%
BMEP	—	—	±1.0%
Heat release rate	—	—	±0.2%

used to calculate these parameters. Heat release rate was calculated as given below:

$$\frac{dQ}{d\theta} = \frac{\gamma}{\gamma - 1} P \frac{dV}{d\theta} + \frac{1}{\gamma - 1} V \frac{dP}{d\theta} \quad (1)$$

The total or cumulative heat release can be calculated using the integral of the heat release rate with the following equation:

$$\int dQ = \int \left(\frac{\gamma}{\gamma - 1}\right) p(dV) + \int \left(\frac{1}{(\gamma - 1)}\right) V(dP) \quad (2)$$

The specific heat ratio is calculated using the average gas temperature with the equation below [42,43].

$$\gamma = -60 \cdot 10^{-5} \cdot T + 10^{-8} \cdot T^2 + 1.338 \quad (3)$$

The Hohenberg heat transfer coefficient is calculated with the combustion parameters in the equation below [44].

$$h = c_0 V^{-0.06} \cdot p^{0.8} \cdot T^{-0.4} [c_m + 1.4]^{0.8} \quad (4)$$

In-cylinder pressure values are used to calculate the knock density and the parameters are given in the following equation [45].

$$dp(\theta) = \frac{[86(p_{i-4} - p_{i+4}) + 142(p_{i+3} - p_{i-3}) + 193(p_{i+2} - p_{i-2}) + 126(p_{i+1} - p_{i-1})]}{1118 d\theta} \quad (5)$$

The knock density is filtered to decrease the signal noise using the equation below [42].

$$F(\theta) = \frac{[2(p_{i-4} - p_{i+4}) + 3(p_{i+3} + p_{i-3}) + 4(p_{i+2} + p_{i-2}) + 5(p_{i+1} + p_i + p_{i-1})]}{33} \quad (6)$$

All experiments were carried out very precisely under the same conditions. The data were obtained at different loads and fuel blends. And also, all obtained data were processed with ICEngine software, then the comparative figures were prepared in MS Excel.

3. Results and discussion

Biodiesel is a renewable energy source and a biodegradable. Biodiesel usage is a way of reducing the carbon footprint as the plants absorbed, which is used for its production. Low-concentration biodiesel blends can be used on modern engines without the need for any modification. Due to poor cold flow characteristics of biodiesel, ethyl proxitol additive can be utilized.

3.1. Combustion analysis

The important combustion parameters such as pressure, temperature, rate of heat release rate, knock density, cumulative heat release, and pressure rise rate variation according to crank angle were examined for test fuels. In order to eliminate

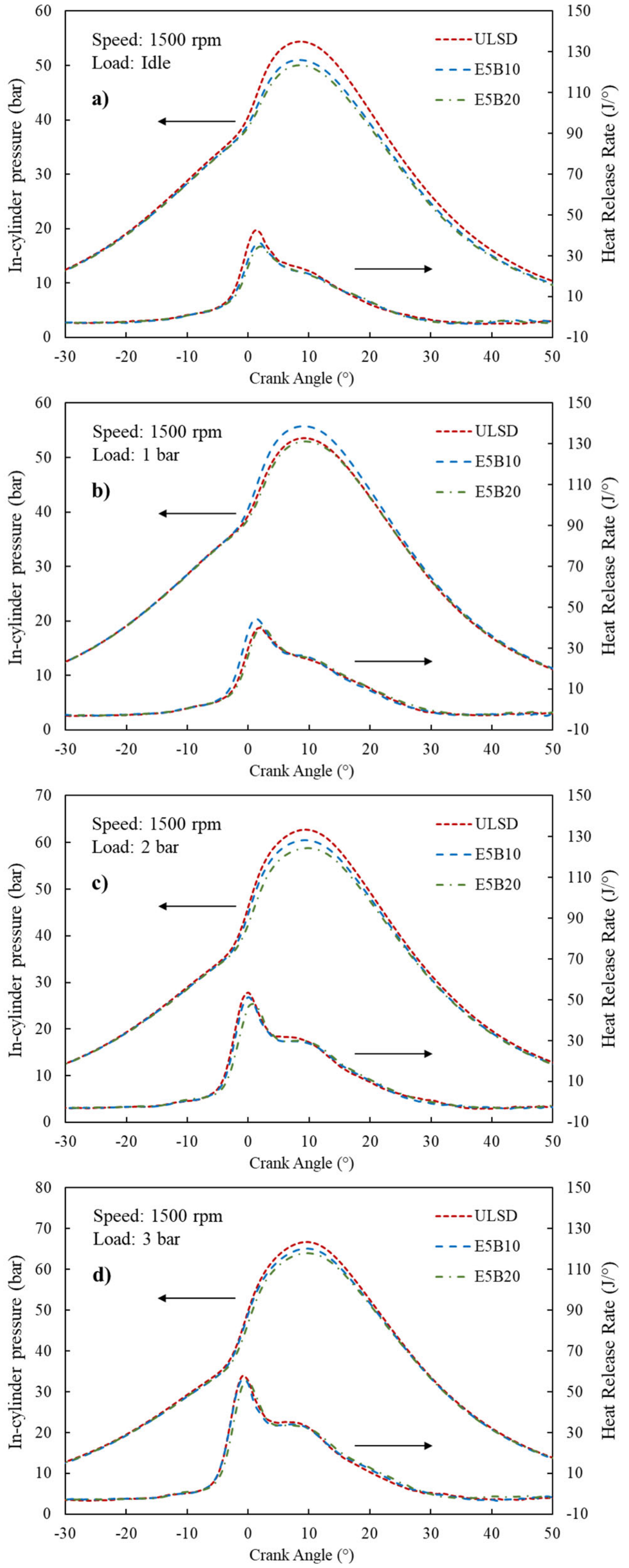

Figure 2. The pressure and heat release rate curves at varied loads for test fuels.

the cycle-to-cycle variation, all combustion parameters were used cycle averaged values in the calculations.

In-cylinder temperature and heat release rate values were illustrated in Figure 2. In-cylinder maximum pressure reached maximum value with ULSD for all loads except low load (1 bar BMEP). At a low load, maximum pressure was obtained with E5B10. ULSD reaches 54.36 bar@9° ATDC, 62.8 bar@9° ATDC, and 66.7 bar@10° ATDC, after top dead center at idle, medium, and high loads, respectively. E5B10 reaches the highest pressure at low load as 55.73 bar@9° ATDC. Heat

Table 5. SOC, EOC and combustion duration variation of test fuels.

	idle			1 bar			2 bar			3 bar		
Fuels	SOC	EOC	Duration	SOC	EOC	Duration	SOC	EOC	Duration	SOC	EOC	Duration
	(° CA)											
ULSD	−10	26	36	−10	26	36	−10	30	40	−10	31	41
E5B10	−10	25	35	−10	26	36	−10	28	38	−10	29	39
E5B20	−9	25	34	−9	28	37	−10	28	38	−9	28	39

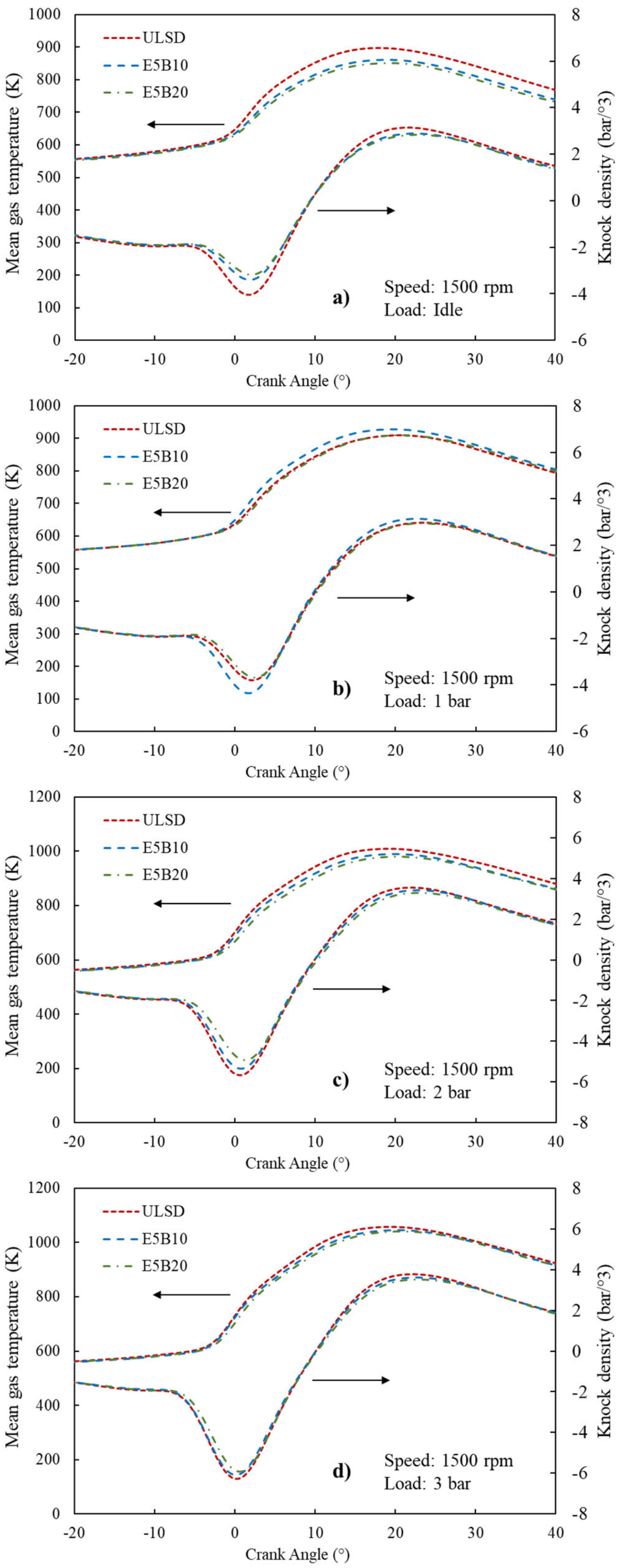

Figure 3. The MGT and knock density curves at varied loads for test fuels.

release rate (HRR) increment also occurred somewhat earlier with E5B10. The crank angle position at which in-cylinder maximum pressure occurred did not change considerably with the addition of ethyl proxitol and biodiesel in comparison with ULSD (occurred at approximately at 9-10° ATDC). The maximum cylinder gas pressure (CGP) and mean gas temperature (MGT) values were decreased with the addition of ethyl proxitol and biodiesel owing to the late start of combustion (SOC) and early end of combustion (EOC) at low and high load. The higher peak pressure of ULSD compared with E5B10 and E5B20 can be attributed to the higher cetane index [46].

SOC was slightly earlier for ULSD among all test fuels because of the poor atomization and mixing properties of biodiesel and ethyl proxitol probably due to their higher viscosity. Nevertheless, addition of ethyl proxitol to the biodiesel blends, the combustion durations of E5B10 and E5B20 were shorter that ULSD. SOC, EOC and combustion duration values of test fuels were listed in Table 5.

The MGT of ULSD, E5B10 and E5B20 reaches 897.7 K, 861.6 K and 851.1 K for idle load; 909.9 K, 928.8 K and 909.6 K for low load; 1009.9 K, 990.8 K and 980.2 K for medium load; 1058.9 K, 1046.0 K and 1041.3 K for high load, respectively (Figure 3). The addition of ethyl proxitol and biodiesel in most load conditions decrease the mean gas temperature. In addition, the ethyl proxitol and biodiesel blends reduce the knock density except for E5B10 at a low load. At this load, E5B10 started to increase earlier compared to the ULSD and E5B20 fuels. Knock density of E5B10 was between −4.34 and 3.15 bar/3° (Figure 3). Neither of the test fuels' knock density levels was found to be more than 5 bar/3°, which is typically the upper limit for the beginning of the noticeable knocking in the diesel engine combustion [47].

The rate of heat release according to crank angle for test fuels are shown in Figure 4. The heat release values provide detailed data about the combustion characteristics of test fuels. The maximum heat release values for test fuels were taken place at about 26° ATDC for idle load, 27° ATDC for low load, 28° ATDC for medium load, and 31° ATDC for high load. The highest heat release value was obtained with ULSD fuel as 584.0 J@ 31° ATDC at high load. The higher heating value and shorter ignition delay increase the released chemical energy of fuels with the combustion phase. It can be shown in Table 1 that ethyl proxitol and biodiesel have a lower heating value than ULSD reference fuel. Thus, E5B10 and E5B20 have lower heating value than ULSD. However, the heat release values did not decrease proportionally for the ethyl proxitol-based fuel blends. This is due to fuel blends based on ethyl proxitol improving the combustion properties. Therefore, the combustion efficiency was also improved. The pressure rise rate of test fuels is illustrated in Figure 4. With the increment of biodiesel ratio in the fuel blends, pressure rise rate

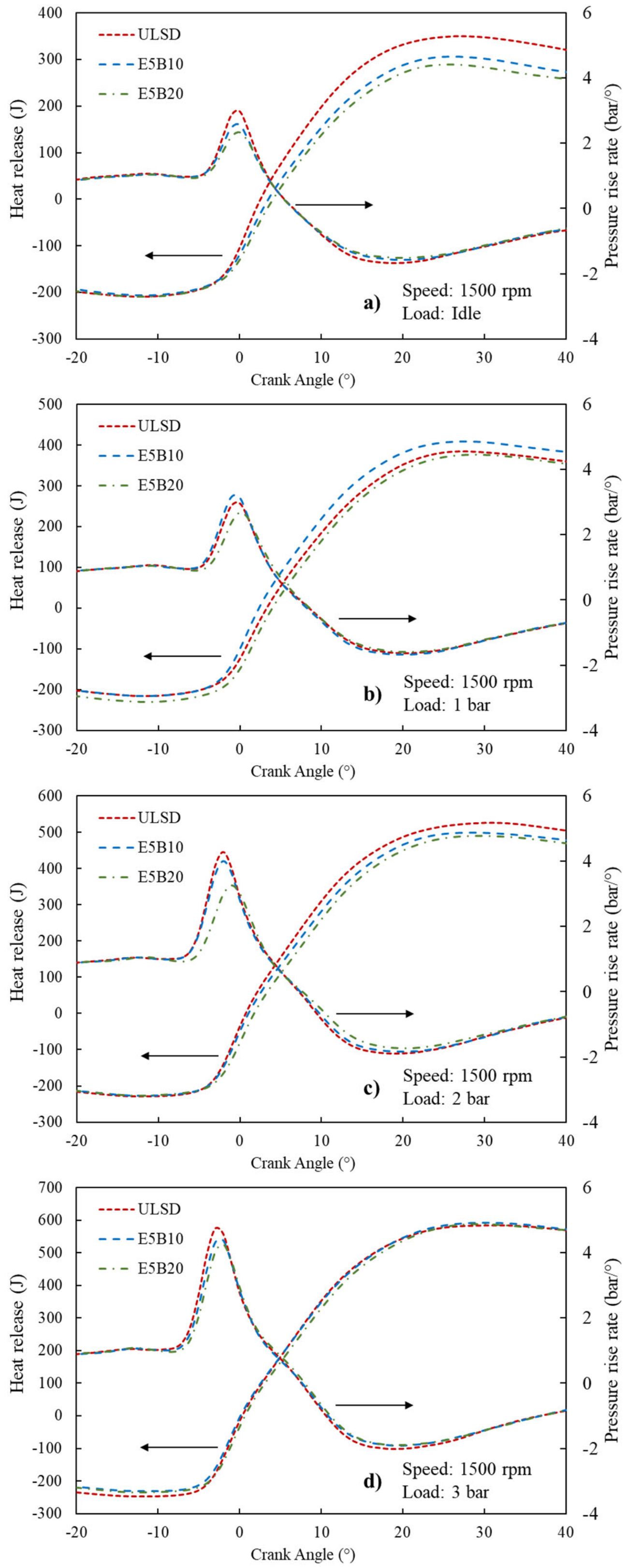

Figure 4. The HRR and pressure rise rate curves at varied loads for test fuels.

values diminish. The lowest pressure rise rate was achieved with the E5B20 blend.

3.2. Emissions analysis

The variation of CO_2, NO_X, and HC exhaust emission at different loads for test fuels used in the test engine are illustrated in Figure 5. CO_2 emission is the primary source of

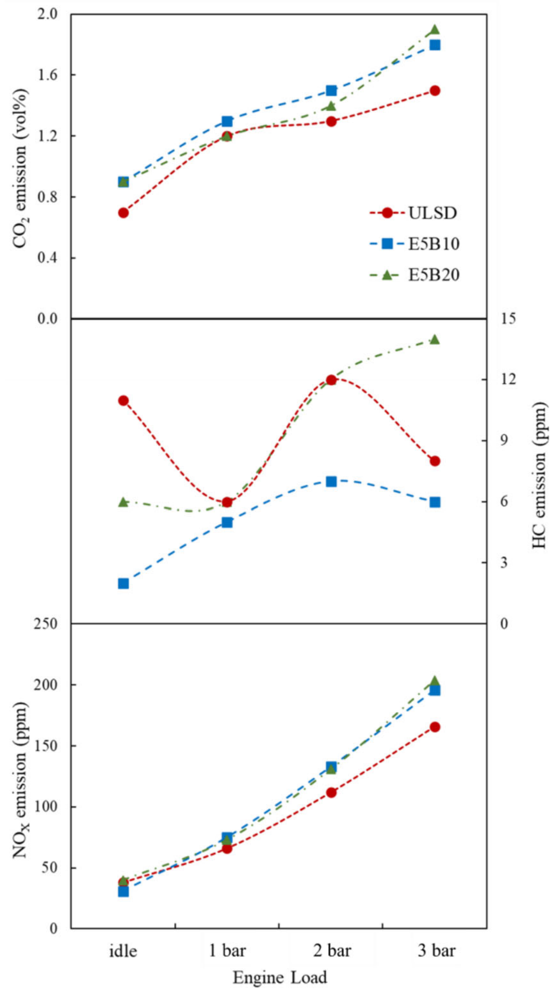

Figure 5. The variation of CO_2, HC, and NO_X emissions at varied engine loads.

global warming and causes to raise in the temperature of the earth [48]. Because high radiative forcing ability of CO_2 is the drawback that contributes to atmospheric heating. However, CO_2 levels are the representation of the complete combustion ratio and the indicator of combustion efficiency [49]. It can be understood from Figure 5, with the increase of the engine load, CO_2 emission increases. When the increase of the combustion efficiency, CO_2 emissions also increase. Besides, with an increase in the engine loads, the amount of fuel burned increases. Thus, high fuel amount burned leads the higher CO_2 emission. With the addition of the ethyl proxitol, the increased CO_2 emission values of E5B10 and E5B20 fuels can be ascribed to greater combustion efficiency and hence more complete combustion. Figure 5 shows engine NO_X emissions for fuel blends at different engine loads. The NO_X emissions increased for all fuel blends when the engine load increased. The NO_X emissions are influenced by two main factors, one is the local flame temperature and another is the duration of flame at high temperature [50]. Using diesel-oxygenate blends, increase the in-cylinder temperature and decrease the duration of flame at high temperatures. The comprehensive effect makes the NO_X tendency of the blends [49]. Therefore, in the present study, the NO_X emissions of ethyl proxitol base fuel blends were higher than ULSD.

Figure 5 presents the HC emissions produced by various fuels under different loads. HC emissions are produced when the engine cylinder is charged with a rich fuel-air mixture that fails to burn completely [51]. The source of HC emissions is the incomplete combustion of fuel, which results in an unburned mixture of fuel and air. Moreover, an excessively dilute mixture at the periphery of the fuel spray also contributes to HC emission. In addition, the combustion chamber wall surface is more prone to local flame-out, forming a quenching layer where a significant amount of HC cannot be burned.

The study found that biodiesel has the potential to reduce HC emissions, as demonstrated by the comparison between E5B10, E5B20 and ULSD fuels. The E5B10 blend, which has inborn oxygen molecules contributing to the oxidation reaction of the blends, showed lower HC emissions than ULSD fuel under rated conditions. This can be attributed to the more complete combustion facilitated by the inborn oxygen in biodiesel. Thus, E5B10 blend emits fewer HC emissions than other fuels, and its use is deemed appropriate for diesel engines. The lowest HC emissions were recorded when the engine was idling and fueled by the E5B10 blend.

4. Conclusions

The effects of ethyl proxitol additive on combustion and emission characteristics of biodiesel blends in a compression ignition engine were investigated at different loads of the eddy current dynamometer. Although E5B10 and E5B20 test fuels have a lower cetane index in the physical and chemical analysis, it can be considered positive that distillation temperatures and viscosity are very close to neat diesel. The similarity of the change characteristics of fuel types increased with the increment rate of pressure and loads. An increase in the pressure increase rate was observed with the increase in the loads. In general, the following conclusions can be drawn from this study.

- The mean gas temperature value of diesel fuel is lower than E5B10 and E5B20 fuel at low load. It can be attributed to the low flame temperature, low oxygen content, and volatility compared to diesel.
- E5B10 and E5B20 test fuels showed a slight increase in CO_2 and NO_X emissions compared to neat diesel.
- E5B10 and E5B20 test fuels show a similar characteristic to diesel fuel at almost all loads in terms of SOC, EOC, and combustion duration. Furthermore, it has been determined that the combustion and emission parameters are almost parallel to the diesel fuel curves in a way that does not have a negative impact.

Because of the harmful effects of fossil-based fuels on environment and human health, findings of cleaner and renewable energy sources have become increasingly important. In comparison to the standard diesel, E5B10 and E5B10 fuel blends fared better on combustion indicators. To summarize, ethyl proxitol has the potential to become a biodiesel additive that will improve cold flow characteristics. Considering that fossil fuel (oil, gasoline, diesel, etc.) reserves will run out one day, biodiesel is a renewable source. Biodiesel can be a replacement for fossil fuels utilized in generators and for non-road purposes, although it partially reduces the engine performance.

Nomenclature

H_u	Calorific value, kJ/kg
$\dot{m}_f$	Mass flow rate of fuel, kg/s
Q	Rate of heat release, J/°
T	Temperature of cylinder gas, °C
θ	Angle of crank, °
V	Cylinder volume, m^3
γ	Specific heat ratio, kJ/kgK

Abbreviations

ULSD	Ultra-low-sulfur diesel
E5B10	5% ethyl proxitol + 10% biodiesel + 85% ULSD (in vol.)
E5B20	5% ethyl proxitol + 20% biodiesel + 75% ULSD (in vol.)
HC	Hydrocarbon
HRR	Heat release rate, J/°
CO_2	Carbon dioxide
CGP	Cylinder gas pressure, bar
CFPP	Cold filter plugging point, °C
°CA	Crank angle degree
MGT	Mean gas temperature, K
NO_X	Nitrogen Oxides
IDP	Initial distillation point, °C
FDP	Final distillation point, °C
SOC	Start of combustion, ° CA
EOC	End of combustion, ° CA

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