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Ignition Investigation of Pure Biodiesel in A Research Engine with Dual Fuels

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ABSTRACT

Under the effect of acetylene (C_2H_2) as a secondary energy in diesel engines powered by Acacia methyl ester (ABD) is investigated in this study. This experimental work is carried out on single cylinder, water cooled, direct injection diesel engine. At the intake manifold air and C_2H_2 was combined and mixture will have specific stream rate (2 and 4 lpm). In a diesel engine, the ignition analysis of changed fuels under varied Mean Effective Brake Pressure (BMEP) is assessed and contrasted with diesel by adjusting the apparatus load between 01 and 05 BMEP. This research looks at C_2H_2 as a sustainable twin fuel with the goal of lowering diesel apparatus emissions while improving performance. Experiments demonstrated that supplying C_2H_2 at 2 and 4 Litres per minute (lpm) results in faster flame velocity and greater flammability for ABD, resulting in enhanced efficacy and improved combustion patterns. Because of its higher flammability and longer C-H chain, acacia methyl ester with acetylene (ABD-C_2H_2) at 2 lpm and ABD-C_2H_2 at 4 lpm reduced hazardous diesel motor exhaust compared to biodiesel alone. According to the findings of this investigation, adding acetylene at varied flow rates improves biodiesel's ignition patterns in a diesel engine with no changes.

1. Introduction

By combining fossil fuels with biofuels, fossil fuel consumption and greenhouse gas emissions will be drastically reduced [1]. High cetane index and plentiful availability of oxygen in biofuels cut pollutants and improve diesel engine combustion [2]. Many works have made use of biofuels such as oil from sapota seed, palm, mustard seed oil, Karanja, tamarind seed oil, neem, Jatropha, and mahua biodiesel. Jayapal *et al.,* [3] investigated the emission profile of a engine with compression ignition (CI) utilising fuel mixtures containing varied amounts of sapota biodiesel and diesel. Sapota biodiesel/diesel mixes with a higher sapota biodiesel proportion produced less Hydrocarbons (HC) and carbon monoxide (CO). Furthermore, Ganesan *et al.,* [4] researched the emissions patterns referring to a CI motor using mustard biodiesel in varied amounts. At maximum load, the greater percentage of biodiesel made from mustard reduced net CO emissions by 7.30%. Nagappan *et al.,* [5]

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inspected the emissions design of a (CI) machine using biodiesel generated from tallow oil in addition diesel fuel at varying meditations. The addition of a higher proportion of beef-tallow biodiesel reduces the smoke, CO, HC, and Nitrogen Oxide (NO) discharges of biodiesel/diesel combinations substantially. Devarajan *et al.,* [6] investigated a CI engine's exhaust pattern powered by grape seed biodiesel. It was feasible to cut NO emissions by 4.2% by adding 20% grapeseed biodiesel to fuel. Rangabashiam *et al.,* [7] studied the ignition pattern pertaining to a (CI) engine using varied percentages of neem biodiesel and diesel. Mixing The addition of 30% neem biodiesel towards fuel occasioned in decreased NOx, CO, and HC discharges from neem biodiesel/diesel blends. Rangabashiam *et al.,* [8] looked into the ignition behaviour of CI apparatus's utilising Pongamia biodiesel in another study Pongamia biodiesel (20% by volume) in biodiesel/diesel combinations cut the smoke productions by 02.20% than Pongamia biodiesel. Kavitha *et al.,* [9] investigated the discharges of a CI engine layout utilising different Jatropha biodiesel and diesel combinations. The higher the content of biodiesel from Jatropha in diesel/Jatropha biodiesel combinations, the inferior the CO, smoke, and HC emissions.

Increasing the efficiency of biodiesel usage, a variety of approaches such as fuel preheating, water inclusion, metal-based additives, oxygenated additives, and gaseous fuel induction are commonly utilised [10]. Modassir Khan *et al.,* [11] observed the emissions pattern of a single-cylinder, light-duty diesel appliance using quaternary mixtures of neem oil methyl ester, diesel, pure neem oil and decanol at numerous volumetric proportions. The increased concentration of decanol improved the brake specific fuel consumption among the quaternary blend. Furthermore, Arun Kumar *et al.,* [12] investigated emissions and performance from a CRDI engine running on ternary blends of diesel, jatropha biodiesel and heptanol. The ternary blends resulted in higher BTE and lower BSFC with increased volumetric proportion of heptanol. The CO and UHC emissions were reduced for ternary blends than diesel, however NOx emission got increased. The use of heptanol up to 40% as additives in biodiesel-diesel blends showed huge potential as alternate and sustainable fuel. Swamy *et al.,* [13] four fuels were utilized mixes with varied proportions of diesel, 1-butanol, and tamarind biodiesel to evaluate the CI engine emissions behaviour. The addition of 1-butanol to BD/diesel combinations significantly enhanced the BTE of tamarind biodiesel/diesel mixtures. Mozammil Hasnain *et al.,* [14] examined the performance and emissions of a common rail direct injection (CRDI) engine power-driven by soy methyl ester (SME) and its combination with methyl oleate (MO). A remarkable reduction in the BSFC and an increase in the BTE were found in the blended biodiesel (S80-MO20, S70-M30, and S50-M50) as compared to the case of SME. In a further investigation, Lata *et al.,* [15] used hydrogen with altered flow rates in biodiesel-fueled diesel engines along with Exhaust gas recirculation (EGR). The formation of NOx gets decreased by 37.82, 48.29 and 75.95% by using 5%, 10% and 15% EGR, respectively, at 40% load conditions as compared with pure diesel operation. Justin *et al.,* [16] used Biogas as a secondary fuel in a mustard biodiesel and biogas-powered diesel engine. The increasing supply concentration of biogas generates a large rise (04.40%) in BTE. Sivamurugan and Devarajan [17] thoroughly investigated the influence of ethylene gas on biodiesel-fueled CI engines was investigated, besides it was revealed that the BSFC was lowered by 03.70%. Mozammil Hasnain *et al.,* [18] ternary-blends (diesel, soy biodiesel, and Methyl oleate) was utilised by way of energy in CRDI biodiesel-powered diesel machines. The addition of methyl oleate improved brake specific fuel consumption of blended biodiesel almost near to diesel [11-18], dual delivery of gaseous fuel is an effective strategy for decreasing Specific Fuel Consumption (SFC) with a significant rise in biodiesel BTE and no significant adjustments to the CI engine. Nevertheless, no extensive research on the utilization of acetylene gas as a dual fuel in Acacia methyl ester has been done. As a result, this research paves the path for the use of ABD as a biodiesel. The consequence of introducing acetylene (C2H2) as a secondary energy to an Acacia methyl ester-fueled diesel engine is investigated in this study. At the intake manifold, C2H2 was combined with air at a specific stream rate (2 and 4 lpm). In a diesel engine, the detonation analysis of different fuels at altered BMEP is examined by varying the device load from 01 to 05 BMEP and comparing it to diesel.

2. Ingredients and Procedures

2.1 ABD Groundwork

In the transesterification, methanol and the base-catalyst potassium hydroxide (KOH) were utilised. Acacia seed oil's (ASO) Free Fatty Acid (FFA) composition is shown in Table 1. A 5-liter batch reactor was constructed with a magnetic agitator, tachometer, and stopper to create biodiesel from Acacia seed oil. In a batch reactor, 500 cc of Acacia seed oil was boiled with KOH (3.0 wt%) then methanol (6:1 ratio). The combination was kept unchanging after heating in order to separate glycerol from biodiesel. Table 2 summarises the key features of diesel and base fuel.

Table 1
Displays the FFA content of acacia seed oil

Fatty Acids	ASO (% by weight)
C18:1 (Oleic)	21.00
C18:0 (Stearic)	07.30
C18:3 (Linolenic)	15.50
C16:0 (Palmitic)	12.80
C18:2 (Linoleic)	41.60

Table 2
Tested fuel properties

Properties	DIESEL	ABD	ASTM (D6751 – 08)
Density@30°C (gm/ml)	00.85	00.88	00.860-00.890
Kinematic Viscosity @ 40°C (cst)	02.60	04.15	01.90-06.10
Gross Calorific Value (Kcals/Kg)	10800	8534	8500-8700
Flashpoint (°C)	60	80	50-90
Cetane Index	48.50	44.60	47(min)

2.2 Experimental Arrangement

To conduct tests a water-cooled, direct-injection, four-stroke, single-cylinder diesel engine at room temperature is fed with modified and base fuels (Figure 1). The experimentation was conducted on a diesel apparatus equipped by a compression ratio of 17.5:1, an 17°bTDC injection time and 1,500 rpm constant speed. The engine has the essential instruments to monitor burning pressure, air and fuel stream, temperatures, and load. Engine Soft, a Lab view-based application, is incorporated into the engine test setup to monitor and assess engine performance and combustion parameters. Table 3 contains detailed information regarding the device. A di-gas analyzer was used to calculate nitrogen oxides, carbon monoxide, and hydrocarbon discharges. To calculate Emissions of tailpipe smoke, the AVL-437C smoke metre was used. To reach steady-state conditions, the engine was supplied with baseline diesel, and the required parameters were calculated. Under comparable engine settings, other test fuels, such as ABD and ABD-C_2H_2, were injected at 2 and 4 lpm. The pressure of C_2H_2 is controlled with a pressure regulator that ranges from 1 to 14 bar. A gas flow metre is built within the C_2H_2 storage cylinder to modify and quantity the C_2H_2 flow proportion. The engine's ingestion manifold is outfitted by non-return injectors to securely regulate C_2H_2 with intake air. While employing C_2H_2 as a dual fuel, safety precautions were taken.

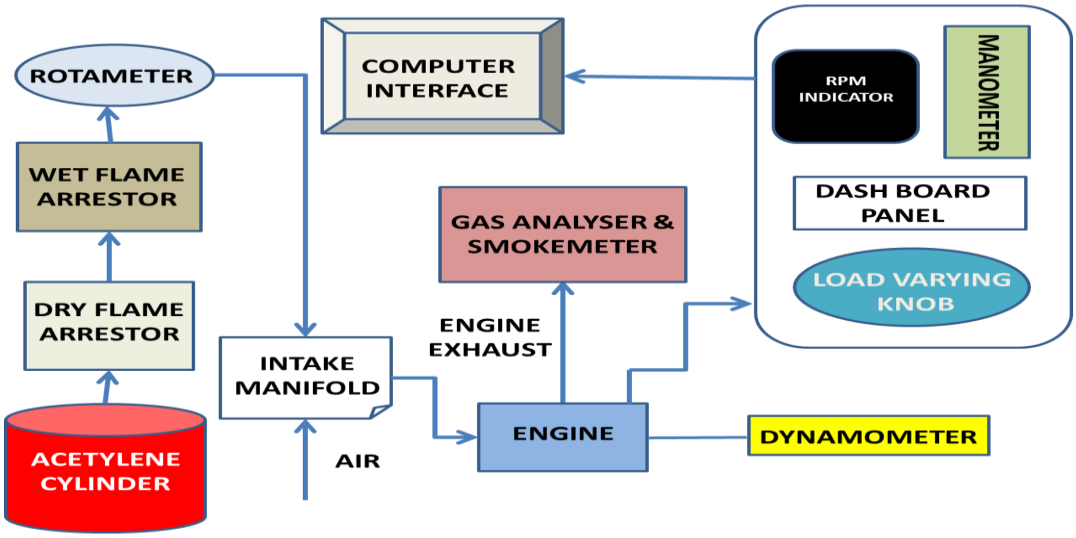

Fig. 1. Depicted the experimental setup

Table 3
Experimentation apparatus specifications

Parameter	Specifications for Engine
Engine	Product TV1, 4-stroke diesel engine, type 1 cylinder, power 5200 W at 1500 rpm, cooled by water, stroke length 110 mm, compression ratio 17.5, bore 87 mm.
Crack angle Sensor	Speed 5500 rpm, Resolution 1 Deg.
Data acquisition gadget	16 bit, NI USB - 6210, 250 kilobytes per second
Piezoelectric Sensor	Range:5000 PSI
Dynamometer	Water Cooled, and Eddy's current
Rotameter	Calorimeter Range: 25-250 LPH, Engine Cooling: 40-400 LPH
Temperature Sensor	Thermocouple

2.3 Uncertainty Evaluation

Experimental uncertainty is influenced by a number of variables, including machine calibration, data collection, operating and environmental conditions [19]. In order to achieve the accuracy of obtained measurements, it is imperative to investigate the exact uncertainty. This study used J.P. Holman's uncertainty approach [19]. The entire uncertainty of observed and estimated parameters is calculated via backward propagation as ±1.44%.

Overall uncertainty

$$\sqrt{\text{uncertainty of } (P^2 + W^2 + N^2 + \text{BSFC}^2 + \text{BSEC}^2 + \text{BTE}^2 + \text{CO}^2 + \text{smoke} + \text{HC}^2 + \text{NOx}^2)} \quad (1)$$

3. Findings and Analysis

3.1 Brake Thermal Efficiency (BTE)

Figure 2 displays the BTE deviation of ABD, ABD-C_2H_2 on 2 lpm, diesel, besides ABD-C_2H_2 at 4 lpm with BMEP. BTE varies between 12% (2 BMEP) and 23.8% (5 BMEP) for ABD, while diesel varies between 14% and 28%, ABD-C_2H_2 at 2 lpm varies between 12.5% and 24.6%, and ABD-C_2H_2 at 4 lpm varies between 13.5% and 25.5%. ABD BTE is 02% (02 BMEP) and 4.2% (05 BMEP) lower than diesel BTE. ABD's thickness hinders charge vaporisation and atomization, resulting in decreased BTE and incomplete combustion [19,20]. Diesel has a 2.09% greater Calorific Value (CV) than ABD, resulting in greater BTE. BTE for ABD-C_2H_2 at 2 lpm is 0.5% (2 BMEP) and 0.8% (5 BMEP) greater than that of ABD. In addition, the BTE for ABD-C_2H_2 at 4 lpm is enhanced by 1% (2 BMEP) and 1.7% (5 BMEP) compared to ABD. C_2H_2 flow rates of 2 and 4 lpm provide rapid fire speed and combustibility for ABD, resulting in a greater CV [15,16,19]. In addition, C_2H_2 improves vaporization and atomization, increases air motion change, and enhances BTE.

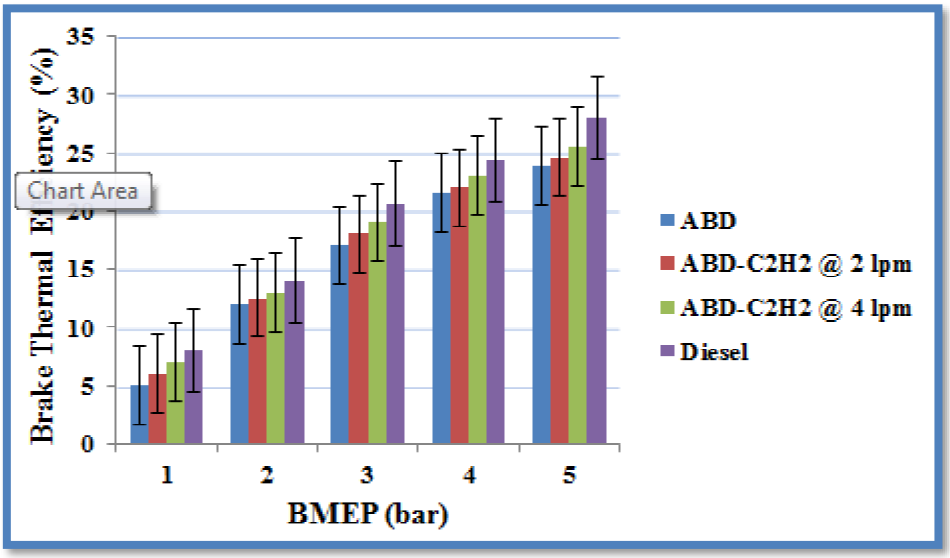

Fig. 2. BTE variation for tested fuels

3.2 Brake-Specific Fuel Depletion (BSFC)

The BSFC variation of ABD, ABD-C_2H_2 at 2 lpm, diesel, and ABD-C_2H_2 at 4 lpm with BMEP is shown in Figure 3. ABD's BSFC ranges from 00.34 (02 BMEP) to 00.21 (05 BMEP) kg/kWh, whereas diesel ranges from 00.29 to 00.14 kg/kWh, ABD-C_2H_2 at 2 lpm ranges from 00.32 to 00.18 kg/kWh, and ABD-C_2H_2 on 4 lpm ranges since 0.3 to 0.16 kg/kWh. ABD has a BSFC of 0.05 kg/kWh, which is 0.07 kg/kWh higher than petroleum diesel. Because of the higher viscosity of ABD, the charge is inefficiently vaporised and atomized, resulting in higher BSFC and incomplete combustion [19,21]. The CV of diesel is greater than ABD, resulting in a lower BSFC. When compared to ABD, the BSFC for ABD-C_2H_2 at 2 lpm is 0.020 kg/kWh lower at 02 BMEP and 00.03 kg/kWh lower at 05 BMEP. Furthermore, the BSFC aimed at ABD-C_2H_2 at 4 lpm is 0.04 kg/kWh lower at 02 BMEP and 00.05 kg/kWh lower at 05 BMEP. C_2H_2 at 2 and 4 lpm provides rapid flame speed and broader flammability for ABD, resulting in a greater CV. In addition, C_2H_2 improves vaporization and atomization, increases air motion change, and reduces BSFC [17,22,23].

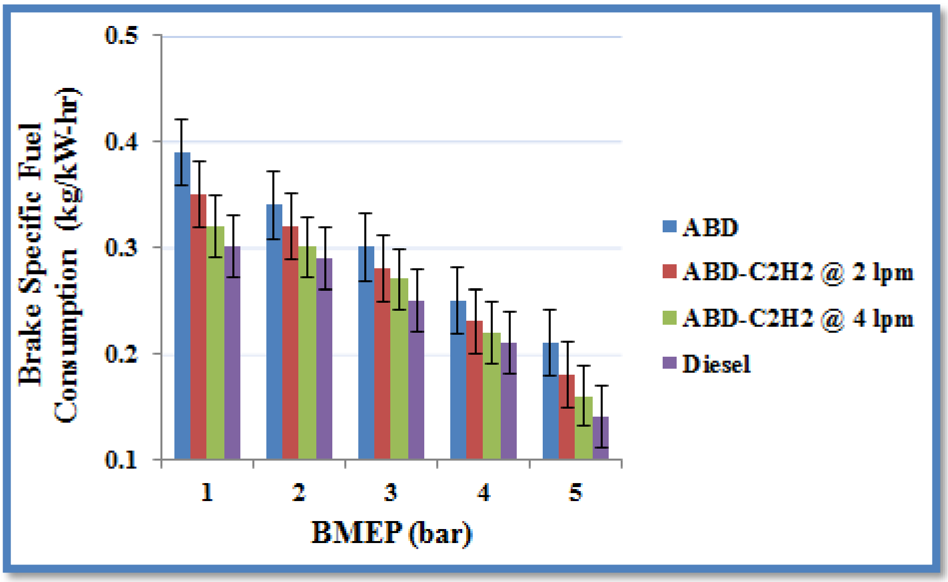

Fig. 3. BSFC variation for tested fuels

3.3 Emissions of Brake-Specific Carbon Monoxide

Figure 4 depicts the CO emissions variation of ABD, ABD-C_2H_2 on 2 lpm, diesel, besides ABD-C_2H_2 on 4 lpm with BMEP. CO emissions for ABD vary between 2.80 (1 BMEP) and 4.50 (5 BMEP) g/kWh, whereas diesel emissions vary between 3.0 and 4.90 g/kWh, ABD-C_2H_2 at 2 lpm varies between 2.4 and 4 g/kWh, and ABD-C_2H_2 at 4 lpm varies between 1.9 and 3.3 g/kWh. ABD has lower CO emissions than diesel by 0.60 g/kWh at 02 BMEP and 0.40 g/kWh at 05 BMEP. Compared to diesel, the oxygen contented of ABD produces a reduced mixture and ensures complete combustion [19,24]. At 2 lpm, ABD-C_2H_2 has lower CO emissions than ABD by 00.40 g/kWh (01 BMEP) and 0.50 g/kWh (05 BMEP). Additionally, CO aimed at ABD-C_2H_2 at 4 lpm is reduced by 00.09 g/kWh and 00.04 g/kWh compared to ABD. Dual-fueling C_2H_2 at distinct stream rates prevents carbon monoxide from being converted to carbon dioxide. The enhanced flammability and Hydrocarbon chain presence in ABD-C_2H_2 on 2 then 4 lpm were responsible for this increase [25,26].

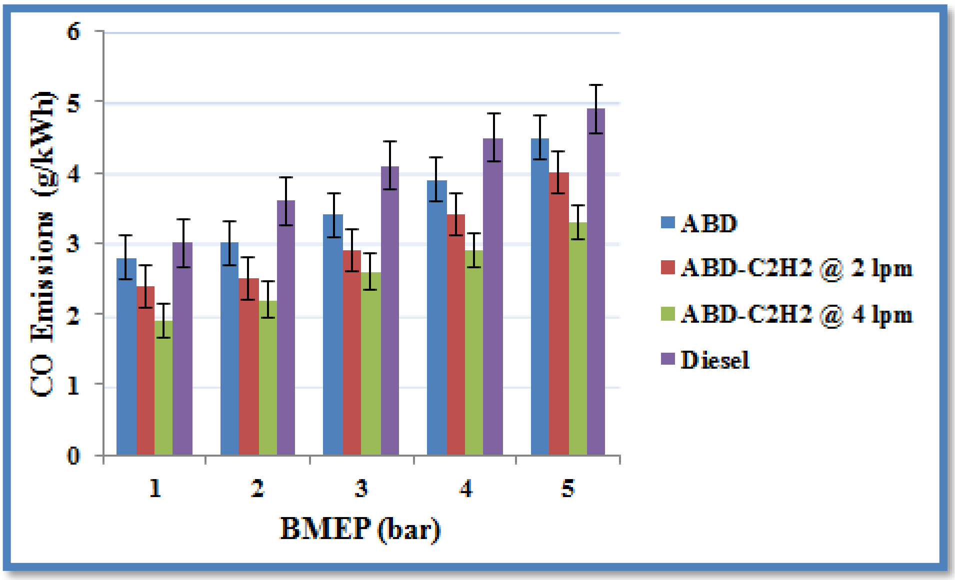

Fig. 4. CO emission variations for tested fuels

3.4 Brake Specific Unburned Hydrocarbon Emissions

Figure 5 depicts the variation in HC emissions of ABD, ABD-C_2H_2 at 2 lpm, diesel, besides ABD-C_2H_2 at 4 lpm with BMEP. HC emissions for ABD range from 0.33 (1 BMEP) to 0.5 (5 BMEP) g/kWh, while diesel emissions range from 00.35 to 00.58 g/kWh, ABD-C_2H_2 on 2 lpm ranges from 0.30 to 0.47 g/kWh, in addition ABD-C_2H_2 at 4 lpm ranges from 00.27 to 00.43 kg/kWh. ABD emits 0.02 g/kWh less HC at 01 BMEP and 0.08 g/kWh less at 05 BMEP than diesel. Increased oxygen content in ABD is the primary reason for decreased HC emissions [19,27]. ABD-C_2H_2 emits 0.03 g/kWh less HC at 01 BMEP and 00.03 g/kWh less at 05 BMEP than ABD at 2 lpm. In addition, the HC emissions for ABD-C_2H_2 at 4 lpm are 0.06 g/kWh lower at 1 BMEP and 0.07 g/kWh lower at 5 BMEP than for ABD. C_2H_2 functions as an ignitor and accelerates the rate of combustion, resulting in fewer HC emissions [17,28]. Furthermore, C_2H_2 minimises the ignition delay for ABD-C_2H_2 at 2 lpm and ABD-C_2H_2 at 4 lpm due to its improved characteristics during combustion, resulting in lower HC emissions.

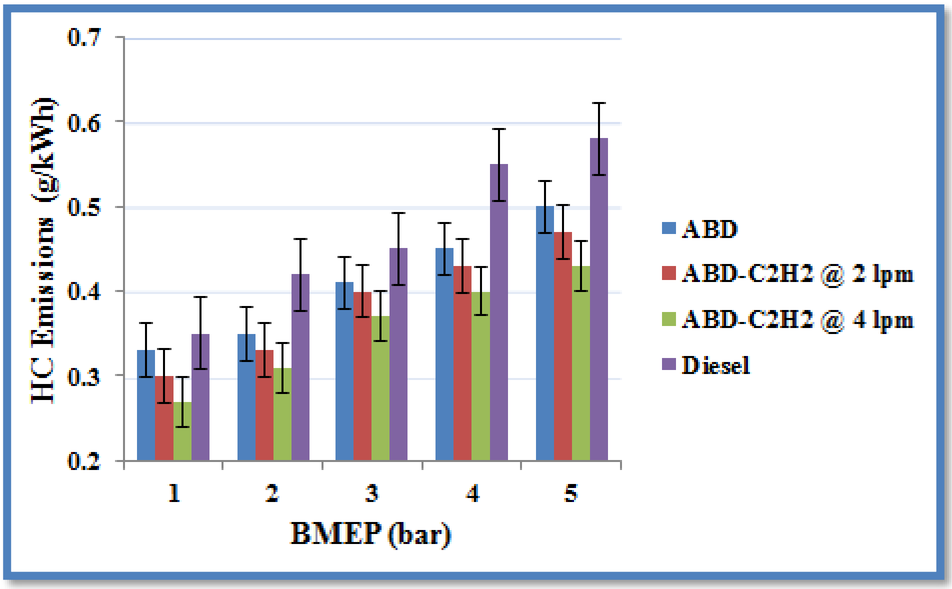

Fig.5. Variance in HC productions from tested fuels

3.5 The Opacity of Smoke

Figure 6 displays the variation in ABD, ABD-C_2H_2 on 2 lpm, diesel, and then ABD-C_2H_2 at 4 lpm with BMEP smoke discharges. ABD smoke emissions range since 0.90 (01 BMEP) to 1.80 (05 BMEP) BSU, whereas diesel smoke emissions range from 1.10 to 2 BSU, ABD-C_2H_2 emissions vary between 0.7 and 1.5 BSU at 2 lpm, and ABD-C_2H_2 emissions vary between 0.5 and 1.3 BSU at 4 lpm. ABD has lower smoke emissions than diesel by 0.20 BSU at 01 BMEP and 0.20 BSU at 05 BMEP. Because of the higher O_2 level in ABD, the mixture is lowered, resulting in a more thorough combustion than diesel. [19,29]. At 2 lpm, ABD-C_2H_2 emits 0.2 BSU and ABD emits 0.3 BSU less smoke than ABD. In addition, ABD-C_2H_2 produces 0.40 BSU (01 BMEP) and 0.50 BSU (05 BMEP) less smoke at 4 lpm than ABD. Because of its higher flammability and the incidence of a C-H chain in ABD-C_2H_2 on 2 lpm besides ABD-C_2H_2 at 4 lpm, dual-fueling C_2H_2 at varying flow rates impedes full combustion [17,29].

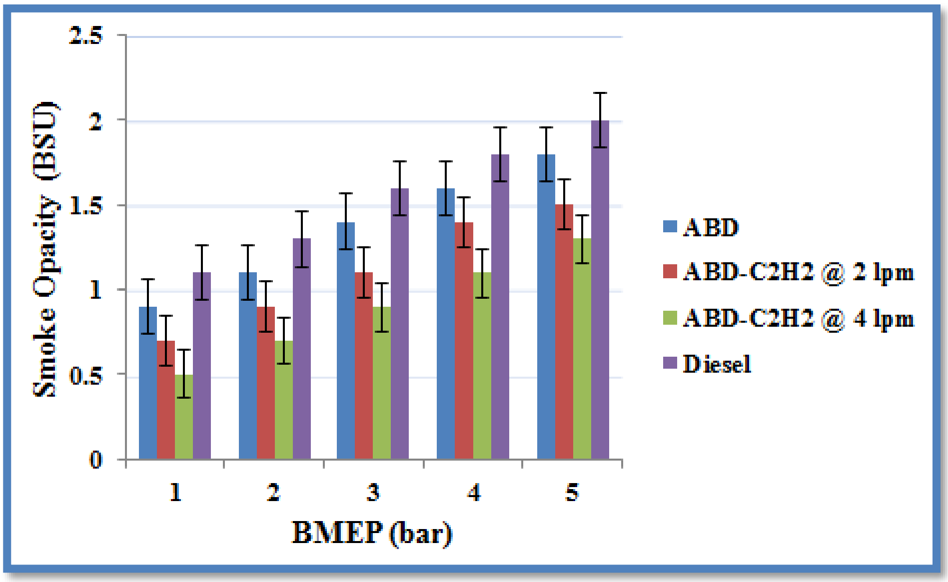

Fig. 6. Variation in smoke emission for tested fuels

3.6 Brake-Specific NOx

Figure.7 depicts the NO emissions disparity of ABD, ABD-C_2H_2 at 2 lpm, diesel, in addition ABD-C_2H_2 at 4 lpm with BMEP. NO emissions for ABD range from 8 (01 BMEP) to 17.40 (05 BMEP) g/kWh, while diesel emissions range from 06 to 14 g/kWh, ABD-C_2H_2 at 2 lpm ranges since 7.5 to 16.80 g/kWh, besides ABD-C_2H_2 at 4 lpm ranges from 7.0 to 16.10 kg/kWh. NO emissions on behalf of ABD are 2 g/kWh higher at 01 BMEP and 3.40 g/kWh higher on 5 BMEP compared to diesel. ABD's increased oxygen contented is the primaries root of its increased NO discharges. NO emissions are decreased by 0.50 g/kWh to 0.60 g/kWh for ABD-C_2H_2 on 2 lpm compared to ABD. NO for ABD-C_2H_2 at 4 lpm is 1 g/kWh lower on 1 BMEP in addition to 1.30 g/kWh lower at 05 BMEP compared to ABD. C_2H_2 functions as an ignitor and accelerates the combustion rate while reducing the temperature, resulting in complete combustion and reduced NO emissions [30,31]. Furthermore, C_2H_2 minimises the ignition delay for ABD-C_2H2 at 2 lpm and 4 lpm due to its improved characteristics during combustion, resulting in lower NO emissions. [15,17,19].

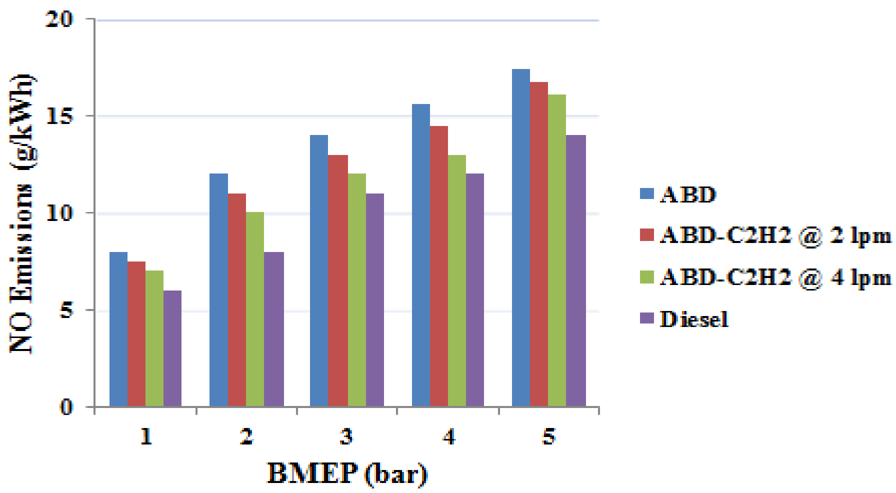

Fig. 7. Variance in NO emission for tested fuels

3.7 Pressure Discrepancy within The Cylinder (ICP)

Figure 8 depicts the ICP variation of ABD, ABD-C_2H_2 at 2 lpm, diesel, and ABD-C_2H_2 at 4 lpm with 5 BMEP. Under maximum load conditions, the ICP of ABD, ABD-C_2H_2 at 2 lpm, diesel, and ABD-C_2H_2 at 4 lpm are measured. Diesel produces the highest ICP due to its greater CV. ABD's ICP is 7.6 bar less than diesel's. Because of the increased viscosity of ABD, the charge is inefficiently vaporised and atomized, resulting in insufficient burning and a lower ICP[14,32]. ICP amplified by 1.70 bar for ABD-C_2H_2 at 2 lpm and by 3.4 bar for ABD-C_2H_2 at 4 lpm. C_2H_2 at 2 and 4 lpm produces a quick flame speed and flammability range for ABD, resulting in a greater CV and ICP. In addition, C_2H_2 enhances vaporisation and atomization, as well as air movement and ICP. C_2H_2 decreases the ignition delay as a outcome of its enhanced combustion properties for ABD-C_2H_2 at 2 lpm and ABD-C_2H_2 at 4 lpm [15,17,19].

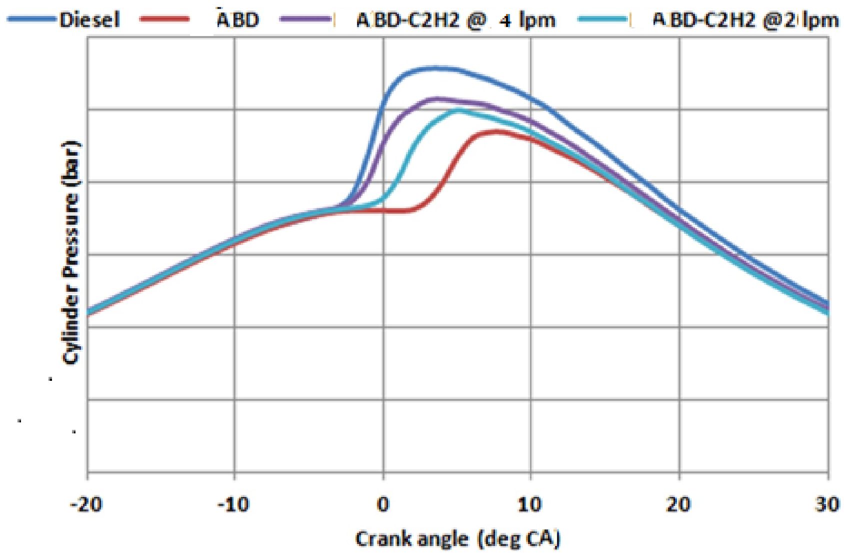

Fig. 8. Highest pressure variation per crank angle at maximum capacity

3.8 Heat Discharge Rate (HRR)

Figure 9 depicts the HRR variation of ABD, ABD-C_2H_2 at 2 lpm, diesel, and ABD-C_2H_2 at 4 lpm with 5 BMEP. Under maximum load conditions, the HRR of ABD, ABD-C_2H_2 at 2 lpm, diesel, and ABD-C_2H_2 at 4 lpm are measured. The increased viscosity of ABD results in inefficient vaporisation and atomization of the charge, resulting in insufficient combustion and increased BSFC [33,34]. Diesel's CV is 2.09% greater than ABD's, resulting in a lower BSFC. HRR increased by 1.8 J/°CA for ABD-C_2H_2 at 2 lpm and 3.6 J/°CA for ABD-C_2H_2 at 4 lpm. C_2H_2 flow rates of 2 and 4 lpm provide a faster flame speed and greater flammability for ABD, resulting in a higher CV [15]. Moreover, C_2H_2 improves vaporisation and atomization, increases air motion change, and enhances HRR [17]. ABD-C_2H_2 at 2 lpm and ABD-C_2H_2 at 4 lpm are more flammable and contain extended Hydrocarbon chain than ABD-C_2H_2 at 2 lpm [17,19], which inhibits improved combustion and higher HRR.

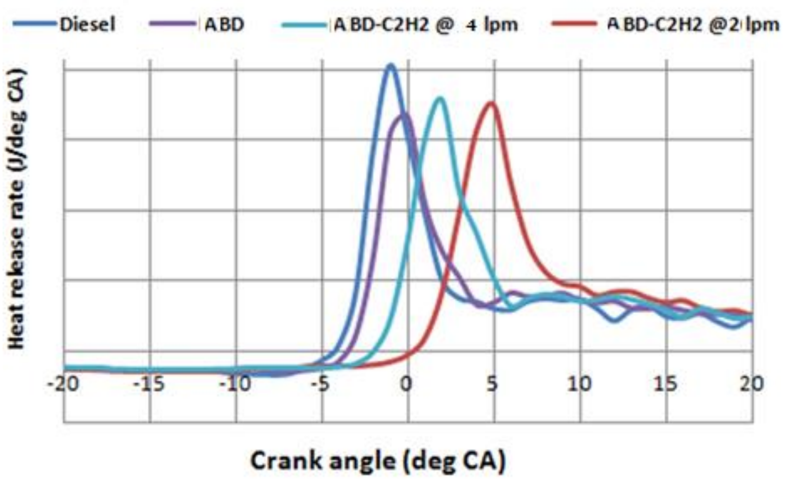

Fig. 9. HRR variation per crank angle at maximum capacity

4. Conclusion

This investigation looks at the effects of using C_2H_2 as a twin fuel. to an Acacia Methyl ester-powered diesel machine. C_2H_2 was varied with air at various flow rates at the inlet manifold. Under comparable conditions, diesel engine efficiency, combustion, and analysis of emissions, ABD, ABD-C_2H_2 at 2 lpm, and ABD- C_2H_2 at 4 lpm are evaluated. Significant results acquired throughout the course of the experiment are presented in the following section.

i. C_2H_2 at 2 and 4 lpm provides rapid flame speed and broader flammability for ABD, resulting in a greater CV. In addition, C_2H_2 improves vaporisation and atomization, increases air motion change, and reduces BSFC while increasing BTE.
ii. C_2H_2 functions as an ignitor and accelerates the combustion rate, resulting in total combustion and decreased HC and CO emissions.
iii. At 4 lpm, ABD-C_2H_2 produces 0.40 BSU (1 BMEP) and 0.50 BSU (5 BMEP) less smoke than ABD. Due to its greater flammability and the attendance of a C–H chain, dual-fueling C_2H_2 at varying flow rates inhibits complete combustion.
iv. NO emissions are reduced by 0.50 g/kWh (1 BMEP) and 0.60 g/kWh (5 BMEP) for ABD-C_2H_2 at 2 lpm compared to ABD.
v. ICP increased for both ABD-C_2H_2 at 2 lpm and 4 lpm. C_2H_2 at 2 and 4 lpm provides ABD with rapid flame speed and flammability
vi. HRR increased for ABD-C_2H_2 at 2 lpm, and ABD-C_2H_2 at 4 lpm. C_2H_2 at 2 and 4 lpm provides rapid flame speed and broader flammability for ABD, resulting in a greater CV

The combination of acacia methyl ester and C_2H_2 as a dual fuel is a promising strategy for reducing diesel engine emissions. To gain a greater understanding, it is necessary to evaluate the impact of modified fuels on working parameters of the engine such as injection-pressure, compression ratio, and injection-timing.

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