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Azolla Biodiesel's Combustion and Emission Characteristics at Different Injection Timings in a CI Engine

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Abstract - The research goal is to investigate the possibility of Biodiesel generated from Azolla oil and its mixes will be tested in a diesel engine at various injection timings to see how they affect performance and emissions. Engine performance and exhaust emissions of a naturally aspirated, direct injection diesel engine were studied utilizing diesel, AZOME blends at three different injection times (20°, 23° and 26° CA b TDC) by varying the thickness of the advance shim. 'The brake thermal efficiency (BTE) improved when AZOME and its blends were injected later. The average BTE of AZ20 fuel at retarded injection time (IT) of 20°b TDC is raised by 3.78 percent and lowered by 0.89 percent when compared to diesel fuel at regular IT of 23°b TDC. Emissions testing on engine mixes AZ20 and AZ100 shows reduced nitrogen oxides, carbon monoxide, smoke opacity, and unburned hydrocarbon emissions when compared to standard IT of 23°b TDC. NOx emissions were greater with the gasoline engine, whereas CO, HC, and smoke emissions were lower with the diesel engine at IT 23°b TDC. At various injection times, the performance and emission characteristics of biodiesel generated from Azolla oil and its blends are evaluated. Varying injection timings had a significant impact on the performance and exhaust emissions of a normally aspirated and direct injection diesel engine employing diesel, AZOME blends that were injected at different injection timings (20°, 23, and 26° CA b TDC). Brake thermal efficiency (BTE) improved when AZOME and its blends were injected later in the process. The average BTE of AZ20 fuel at retarded injection time (IT) of 20° b TDC is raised by 3.78 percent and lowered by 0.89 percent when compared to diesel fuel at regular IT of 23°b TDC. For the AZ20 and AZ100 blends, engine emission test findings demonstrate that the retarded IT of 20°b TDC results in fewer nitrogen oxides and carbon monoxide as well as smoke opacity and unburned hydrocarbons compared to that of the conventional IT of 23°b TDC. NOx emissions were greater with the gasoline engine, whereas CO, HC, and smoke emissions were lower with the diesel engine at 23°b TDC.

Keywords - Emission, Injection timing, Performance, Salviniaceae filiculoides (Azolla) oil methyl ester.

INTRODUCTION

Despite the availability of alternative energy sources such as nuclear, hydroelectric, and wind, the world's fossil fuel reserves are fast decreasing. As long as this trend continues, fossil fuels will be depleted before the end of the century and economically prohibitive to get at any time. Uncertainty about residual oil reserves necessitates expensive and time-consuming extraction methods that offer larger environmental risks than those employed for the majority of the world's oil production to date [1]. Develop an alternative fuel source similar to conventional diesel fuels to safeguard the global environment and assure long-term supply of traditional diesel fuels. Research into locally affordable, environmentally acceptable, technically practicable, and able to meet global energy demand for alternative fuels is therefore sparked. By 2035, renewables are predicted to surpass fossil fuels as the world's second-largest generator of electricity [2].

Alternative fuels like biodiesel are becoming increasingly popular among scientists due to the depletion of traditional fossil fuels like oil and gas. Operational and durability concerns such injector choking, ring sticking, gum development, thickening of lubricating oil, and carbon deposits in engine cylinders can be caused by direct usage of animal fat oil. Transesterification, pyrolysis, emulsification, preheating, and blending with diesel can greatly lower the high viscosity and volatility that were mostly responsible for these difficulties. Glycerol and ester are formed by the interaction of triglyceride and alcohol in the presence of a catalyst [7, 8].

To make biodiesel, raw materials such as canola and soybean oil, peanut and sunflower oil and palm and coconut oil are used. Non-edible oil sources include Jatropha curcas, Pongamia pinnata and Polanga Calophyllum inophyllum, as well as the seeds of Azadirachta indica, Hevea brasiliensis and Madhuca indica, and waste cooking oil from food processing facilities, restaurants and homes. Using edible oil as a fuel for biodiesel production is not possible in India because of a wide disparity between demand and supply [9]. Biodiesel's commercial application is hampered by the high cost of raw material inputs [10]. There have been numerous initiatives to minimise the cost of oil feedstock, and so the cost of biodiesel in particular has become a major focus of current research [11-16]. The ability of some aquatic species, such as Salviniaceae filiculoides (Azolla), to regulate oxygen balance by significantly collecting nutrients and heavy metals, has led to their recent recommendation as agents of wastewater bioremediation. Biodiesel feedstock can be made from the aquatic Salviniaceae filiculoides (Azolla) species, which is low-cost and reliable.

Conventional diesel fuel's physiochemical qualities are taken into account when designing and operating existing engines [17]. When it comes to improving the performance and emissions of a diesel engine, fuel injection timing is the most important factor [18]. A diesel engine's combustion efficiency and exhaust emissions are heavily influenced by the time of fuel injection. Fuel injection time affects the amount of air and gas delivered into the fuel injector, which affects the ignition delay. The ignition delay will grow if the injection timing is delayed because of the low starting air temperature and pressure. Because of the high temperature and pressure, advancing the injection time reduces the delay (i.e. closer to TDC). To put it another way, engine performance and exhaust emissions, particularly BSFC and BTE emissions, are significantly impacted by adjusting the injection time because of changes in maximum pressure and temperature in the engine cylinder. There have been a slew of laboratory investigations into combustion, performance, and emission characteristics [19-22]. However, there hasn't been much investigation on the combustion and exhaust characteristics of a CI engine running on Azolla oil biodiesel at varied injection timings.

Azolla oil biodiesel biodiesel CI engine combustion performance and emission characteristics are the primary objectives of this study. The standard injection pressure of 220bar was maintained throughout the experiment. The advance shim thickness was varied to test three different injection timings (20°, 23°, and 26° CA b TDC). Variations in injection timing were examined in terms of their impact on brake thermal efficiency, specific fuel consumption, specific energy consumption, exhaust temperature, and NOx emissions, among other things.

EXPERIMENTAL METHODS

1. Fuel Preparation

On India's southwest coast, Salviniaceae filiculoideswere (Azolla) gathered at random from wetland locations. All the Azolla cultures were collected in plastic bags and taken to the laboratory immediately. Two times with water, the cultures were rinsed to eliminate sand particles. Using the equation below, the oil yield from dried Azolla was calculated gravimetrically using the Soxhlet method.

$$\text{(\%) The yield of Azolla oil} = \frac{Weight\ of\ the\ extracted\ Azolla\ oil\ (g)}{Weight\ of\ Azolla\ (g)} \text{ X } 100$$

Afterwards, the oils were separated and kept separately until they were needed. Saponification value, acid value, and molecular weight are all listed in Table 1 for the Azolla oil that was extracted. To further understand how biodiesel fuels and blends compare, take a look at Table 2.

TABLE 1

PHSICO-CHEMICAL PROPERTIES OF THE EXTRACTED SALVINIACEAE FILICULOIDES OIL

Property	Values
Density @15(°C) (kg/m³)	878.3
Kinematic Viscosity@40c in Cst	11.39
Flash Point (°C)	145
Acid value (mgKOH/goil)	14.84
Saponification value	190.2
Molecular weight (g/mol)	959.73

TABLE 2

FUEL PROPERTIES OF BIODIESEL AND ITS BLENDS

Property	ASTM D975 Petro-Diesel	ASTM D 6751 Diesel	AZOME and its blends with diesel				
			AZ20	AZ40	AZ60	AZ80	AZ100
Density(kg/m^3 @ 15°C)	834	860-900	833.4	843.6	855.1	866.3	878.3
Specific gravity @ 15°C	0.852	0.884	0.834	0.815	0.847	0.868	0.874
Kinematic Viscosity (Cst @ 40°C)	1.9-4.1	1.9-6.0	3.10	3.64	3.92	4.27	4.75
Flash Point° C	60-80	100-170	65	74	87	126	165
Fire Point° C			71	83	94	135	165
Cloud Point °C			Below2°C	4	7	9	10
Pour Point° C			Below-6°C	Below-4°C	Below-2°C	-1	+4
Calorific Value (KJ/Kg)	43,000	46,165	44,243	43,700	43,340	42,975	42,568

2. Transesterification and Chemical Analysis

The transesterification reaction was carried out in an ultrasonic cleaning bath and a 250 ml three-neck glass flask with a condenser and stirring mechanism. The temperature of the water bath was maintained at 65° C. The reaction was carried out at a constant speed of 350 rpm. It was shown that transesterification of Salviniaceae filiculoides (Azolla) oil could be achieved by adding the extracted oil to 9:1 molar methanol and using sonication for 30 minutes to aid in the reaction [30]. In the catalyst, a molar ratio of 3:1 to 12:1 was used for KOH concentrations ranging from 1.0 to 2.0 percent of Azolla oil. It took 30 minutes to complete all of the reactions. Afterwards, the mixture was allowed to settle in the funnel for 60 minutes to split into two layers. The upper layer contained methyl esters of Salviniaceae filiculoides (Azolla) oil, whereas the lower layer contained glycerol and other contaminants. This layer is cleaned by gently washing it in hot distilled water, which is adjusted to have a pH close to that of distilled water. Magnesium oxide (1gm MgO/200 ml biodiesel) is then used to dehydrate the methyl ester layer. An additional 20 minutes of gentle stirring with MgO are required to provide good contact between the solid and liquid phases, which is essential for completely dehumidifying the biodiesel. A separating funnel is used to extract MgO from biodiesel. For the engine tests, different concentrations of the methyl ester of Salviniaceae filiculoides (Azolla) oil were combined with varying ratios of diesel fuel. ASTM D6751 standards were used to analyse the physiochemical parameters that affect the performance and emissions of different test fuel mixes.

3. Experimental Setup

Four-stroke, naturally aspirated, single-cylinder water-cooled DI diesel engine trials were carried out. Figure 1 shows a schematic representation of the experimental test setup. According to Table 3, these are some of the engine's technical details. An electrical dynamometer was used to load the engine. Crank angle, injection pressure, and cylinder pressure can all be monitored in real time with this configuration. A digital data acquisition system and a piezoelectric pressure transducer were used to measure the engine cylinder pressure at each 1° crank angle.

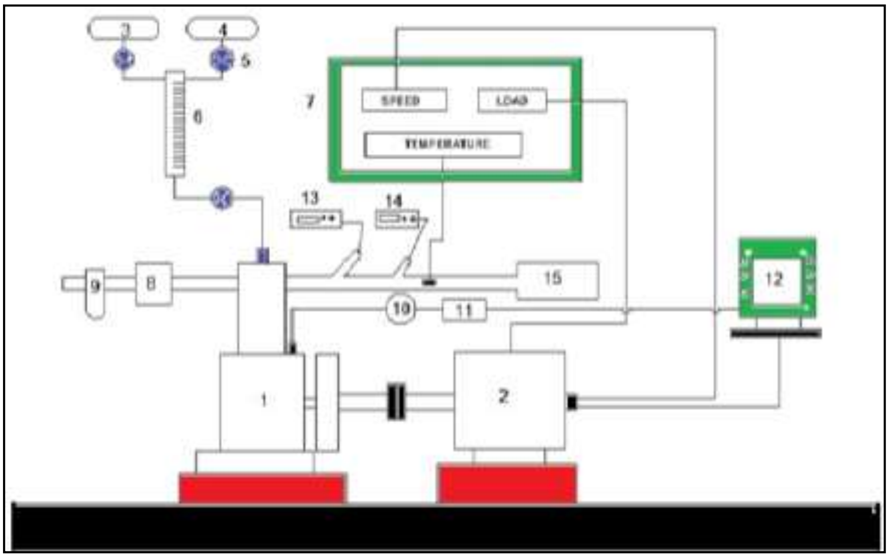

FIG. 1

EXPERIMENTAL SETUP OF DIESEL ENGINE

1. KIRLOSKAR SV-1 DIESEL ENGINE, 2. EDDY CURRENT DYNAMOMETER, 3. DIESEL TANK, 4. BIODIESEL BLEND TANK, 5. CONTROL VALVE, 6. FUEL MEASURING BURETTE, 7. CONTROL PANEL, 8. AIR STABILIZING TANK, 9. AIR FILTER, 10. CHARGE AMPLIFIER, 11. INDIMETER, 12. DATA ACQUISITION SYSTEM, 13. AVL DI GAS ANALYZER, 14. AVL SMOKE METER, 15. SILENCER

An exhaust gas analyser and a smoke metre are also part of the experimental set-up. Exhaust gas analyzers and AVL smoke metres were used in Bosch Smoke Units to monitor NOx, HC, and CO emissions in the exhaust, respectively (BSU). Exhaust gas analyzers were used to measure NOx, HC, and CO emissions in the exhaust. The initial step in the experiment was to run the engine at its rated speed of 1800 rpm on neat diesel fuel. Each time the engine was permitted to run, the load increased by 20%. After the engine had stabilised at a given operating point, performance measures such as fuel consumption, brake power, and exhaust emissions characteristics such as CO, NOx, smoke opacity, and HC were measured. Azole mixes and neat diesel fuel were employed for the engine's trial and error testing. Experiments were done out with a decreasing or rising advance shim at three distinct injection timings (20°, 23°, and 26° CA b TDC). Reducing the injection timing by 3° CA was achieved by adding an additional shim, while increasing the conventional injection timing by 3° CA was achieved by eliminating a shim.

TABLE 3

TEST ENGINE SPECIFICATION

Parameters	Specifications
Make and Model	Kirloskar SV1
General Details	Direct Injection, single-cylinder, Four Stroke, Water Cooled,
Rated Power	5.9 Kw
Rated Speed	1800 rpm
Loading Type	Eddy Current Loading
Bore x stroke	87.5 x 110 mm
Compression Ratio	17.5 : 1
Injection timing	23° b TDC
Smoke measurement	AVL 437 smoke meter (HSU)
CO, HC and NOX Measurement	AVL di-gas analyzer

4. Error Analysis

TABLE 4

UNCERTAINTY ANALYSIS

Parameters	Values
Speed	± 0.10 %
Load	± 0.42 %
Mass flow rate of diesel	± 0.74 %
Brake power	± 0.20 %
Brake thermal efficiency	± 0.21 %
NO_X	± 1.2 %
Hydrocarbon	± 0.01 %
CO	± 0.8 %
Smoke	± 1.4%

Uncertainty analysis is a technique for observing, quantifying, and combining errors. Calibration, instrument selection, condition, test planning environment, observation, and reading all contribute to errors and uncertainty in experiments. Errors must be avoided and experiment correctness must be demonstrated by uncertainty analysis. As can be seen in Table 4, results of the uncertainty analysis and the estimated uncertainty levels under typical operating conditions are shown. Experimental measurements have a level of uncertainty ranging from 0.01 to 1.4%.

RESULTS AND DISCUSSION

Fuel injection timing has a considerable impact on CI engine combustion and emissions performance. When employing AZOME and its blends, this study examined the impact of retarding or advancing injection timing on engine performance and exhaust emissions. AZOME and its Diesel blends have been used to test the effect of injection time on the combustion, performance, and emission characteristics of the engine. The standard injection pressure of 220bar was maintained throughout the investigations. There were three distinct injection times tested, each with a different thickness of the advance shim. Variations in injection time were examined for their effect on the parameters of brake thermal efficiency, specific fuel consumption, exhaust temperature, and exhaust emissions such as CO, smoke, HC, and NOx. These emissions were all taken into account.

1. Combustion Characteristics

Rate of Pressure Rise

In order for fuel to mix with air and burn, cylinder pressure is a good indicator of the fuel's aptitude. Fuel burned during the pre-mixed combustion period affects the cylinder pressure of CI engines. At full load, Figure.2 shows the effect of injection timing on the rate of pressure rise with the biodiesel blend ratio.

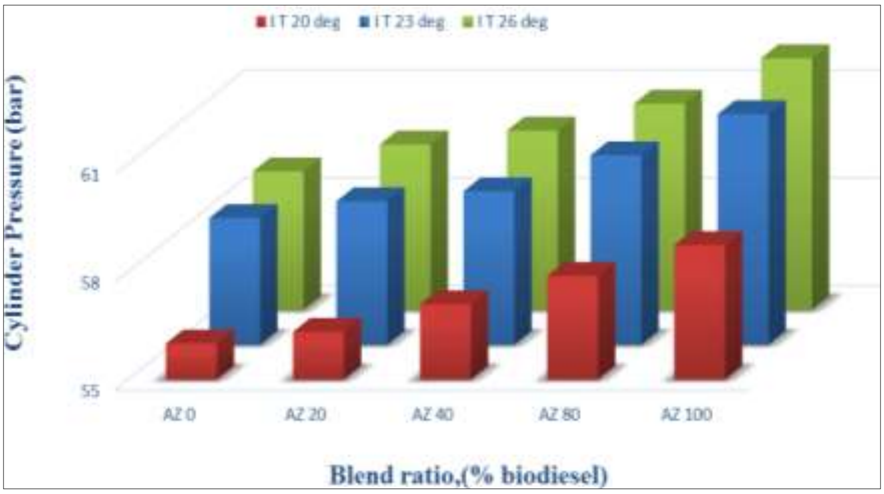

FIGURE 2

VARIATION OF CYLINDER PRESSURE WITH A BIODIESEL BLEND RATIO

Figure 2 shows that the cylinder pressure increases as the biodiesel content in the gasoline increases for all three injection times. A movement away from TDC reduces the rate of pressure rise when the injection timing is retarded. It's mostly because delaying injection time results in more fuel being injected earlier and later, which is why delaying injection causes this effect. Due to a longer ignition delay, the cylinder pressure rises when the injection timing is advanced, compared to when the timing is retarded (Sayin et al 2009; Liu et al 2014). Compared to normal peak pressure, injection time 20° b TDC results in the lowest cylinder pressure at maximum load. There was a 4.37 percent loss in peak pressure for diesel, a 4.45 percent drop for AZ20, 3.61 percent drop for AZ40, 3.90 percent decline for AZ80, and a 4.28% drop for AZ100 when compared to conventional injection timing of 23° b TDC. As with conventional injection timing, the rise in peak pressure was determined to be as follows for advanced injection timing: As a percentage of diesel, it is 0.421 percent; AZ20 is 1.02 percent; AZ40 is 1.19 percent; AZ80 is 0.78%; and the AZ100 is 2.1%. At varied loads, injection timing has a significant impact on cylinder pressure in AZ20 and AZ100 cylinders, as demonstrated in Figure 3. Figure 3 shows that the cylinder peak pressure is lower when the injection timing is retarded compared to the standard injection timing of the corresponding blends.

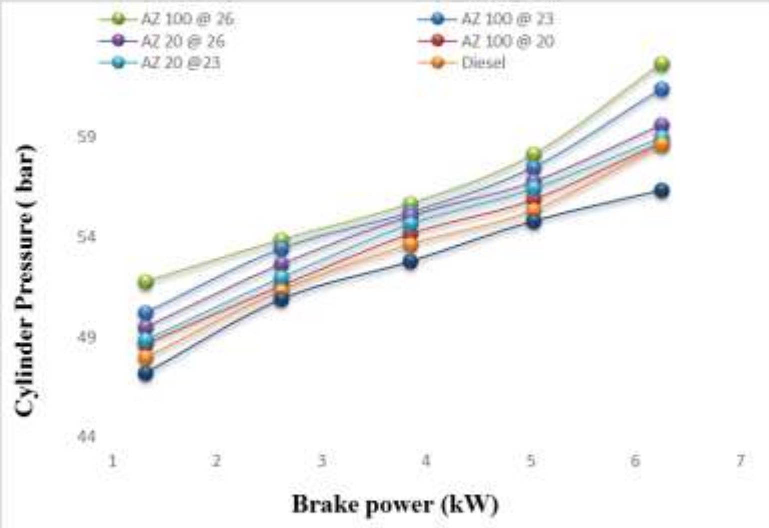

FIGURE 3

EFFECT OF INJECTION TIMING ON CYLINDER PRESSURE OF AZOME AND ITS BLENDS

Standard injection timing IT 23° b TDC results in an increase from 44.163 bar at no load to 61.415 bar at full load for the blend AZ100, whereas retarded injection timing results in a decrease from 42.88 bar at no load to a gain of 58.71 bar at full load. The cylinder peak pressure rises from 45.77 bar at no load to 62.47 bar at full load in the case of advanced injection timing. There are a number of factors that affect peak pressure in a CI engine, including how fast the combustion begins, how much fuel is burned, and how long it takes for the fuel to burn out. During the delay, fuel mixture preparation has an impact on it as well [23]. While the average rise in peak pressure for the blend AZ100 at delayed injection timing is 0.91 percent, the average drop in peak pressure for the blend AZ20 is 1.58 percent. At maximum load, Figure 4 shows the in-cylinder pressure fluctuation as a function of crank angle for each of the three injection timings. The blend AZ100 achieves its greatest peak pressure at an advanced injection timing of 26° b TDC, whereas the blend AZ20 achieves its minimum peak pressure with a delayed injection timing of 20° b TDC, with a 6.55 bar difference in cylinder pressure between the two.

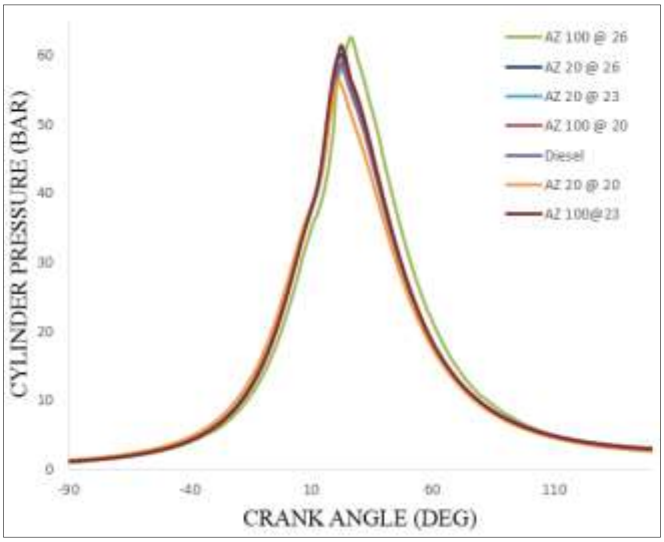

FIGURE 4

VARIATIONS IN-CYLINDER PRESSURE WITH CRANK ANGLE

Heat Release Rate

Figure 5 depicts the variation in the biodiesel heat release rate for the three injection times. As the percentage of biodiesel in the test fuel rises, so does the rate at which heat is released. Retarded injection timing results in a lower heat release rate as compared to regular injection timing, as seen in Figure 1. With the standard injection timing IT 23° b TDC, heat release rates were observed to decrease by 5.58 percent for diesel; 4.7% for gasoline; 3.7% for gasoline; 2.8% for gasoline; and 2.4% for gasoline. It was determined that the advanced injection timing increased peak heat release rate by the following percentages: Diesel, AZ20, AZ40, AZ80, and AZ100 are each 0.81 percent, 0.63 percent, 1.29 percent, 2.12 percent, and 2.63 percent.

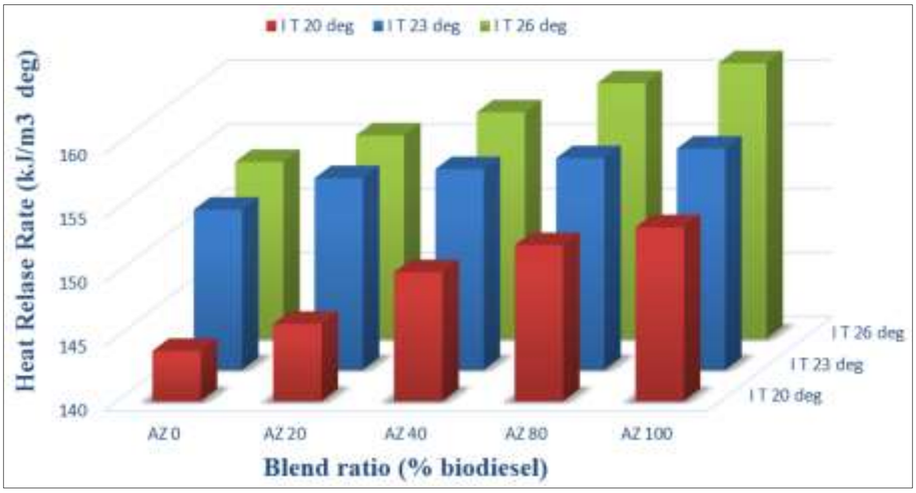

FIGURE 5

VARIATIONS IN HEAT RELEASE RATE WITH BIODIESEL BLENDS

Figure 6 shows the heat release rate with crank angle for the AZ20, AZ100, and diesel fuel blends at three different injection timings. The heat release rate for all mixes increases as the load increases, as seen in the figure. At all loads, AZ100 at advanced injection timing has the maximum heat release rate, whereas AZ20 at retarded injection timing 20° b TDC has the lowest heat release rate when compared to diesel and another blend ratio. Heat release rate for AZ20 at 20° b TDC retarded injection timing increases from 108.4kJ/m3 deg at no load to 147.48kJ/m3 deg at full load, whereas for AZ100 at 20° b TDC retarded injection timing, it increases from 113.38kJ/m3 deg at no load to 153.48kJ/m3 at full load. For the mix AZ20 at 20° b TDC, an average heat release drop of 1.95 percent compared to diesel fuel is seen while the average heat release rise of 1.47 percent for the blend AZ100 at 20° b TDC is observed.

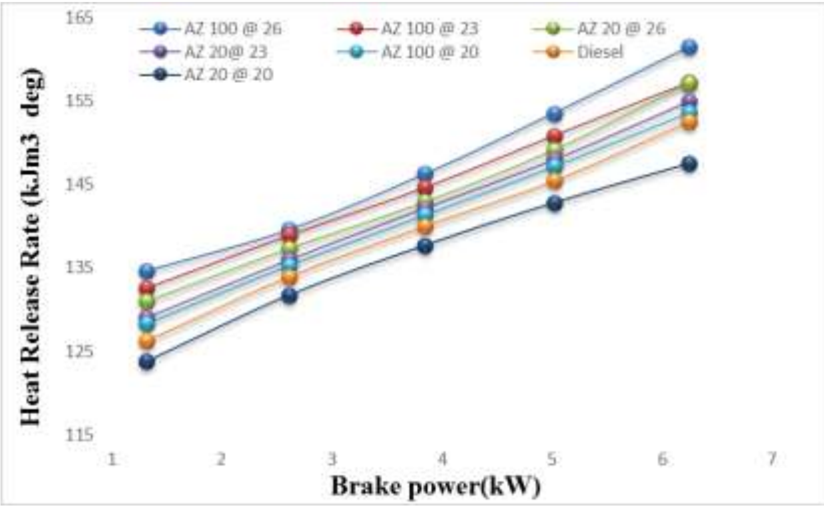

FIGURE 6

EFFECT OF INJECTION TIMING ON THE HEAT RELEASE RATE OF AZOME AND ITS BLENDS

Figure 7 depicts the full-load heat release for the AZ20, AZ100, and diesel blends with a crank angle for the three injection timings. To see this in action in Figure 7, it is clear that the heat release rate drops immediately after the fuel-air mixture is ignited. When compared to advanced injection timing, retarded injection timing results in lower heat release rates for all mixes. At advanced injection timing, the minimum heat release rate for the AZ100 blend is 161.38 kJ/m3 deg; at delayed injection timing, the minimum heat release rate for the AZ20 blend is 174.4 kJ/m3 deg. At delayed injection timing, the AZ100 blend has a higher heat release rate than diesel fuel, increasing by 1.08 kJ/m3 deg.

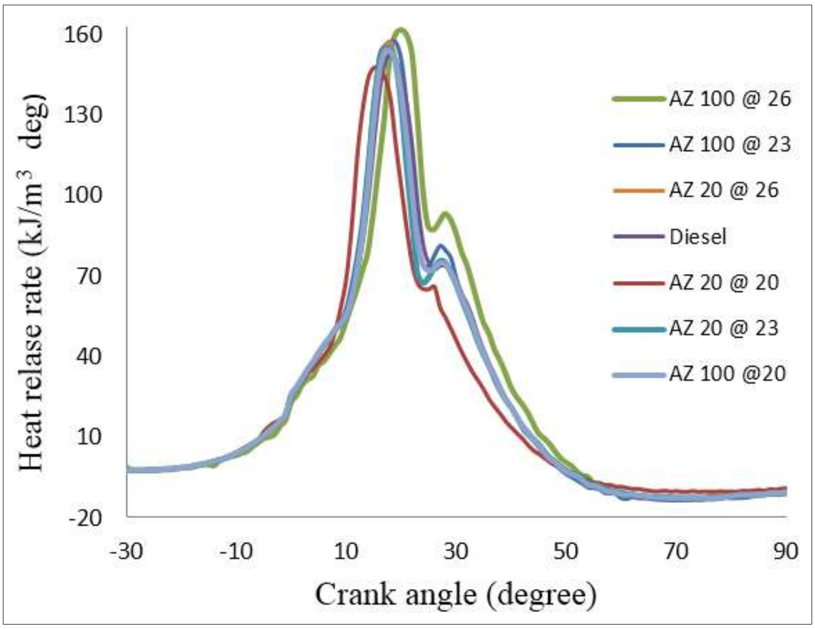

FIGURE 7

VARIATIONS IN HEAT RELEASE RATE WITH CRANK ANGLE

2. Performance Characteristics

Brake Thermal Efficiency (BTE)

Figure. 8 shows the effect of varying injection timings on brake thermal efficiency as a function of biodiesel mix percentage under full load. Increases in test-fuel biodiesel content lower BTE across the board for all injection timings, as seen in the figure. Compared to the other injection timings of all biodiesel mix ratios, 20° b TDC has the highest BTE (percent). For Diesel, AZ20, AZ40, AZ80, and AZ100, BTE for IT 20°b TDC at maximum load is 5.01 percent, 6.47 percent, 5.54 percent, and 6.42 percent more than the usual IT of 23°b TDC at maximum load. Among all fuel blends and injection timings, diesel had the greatest BTE, measuring 33.18 percent of maximum load. Fuel injection may have started sooner in the cycle, resulting in more fuel being injected and earlier pressure rise before the piston reaches the TDC position, resulting in a higher BTE.

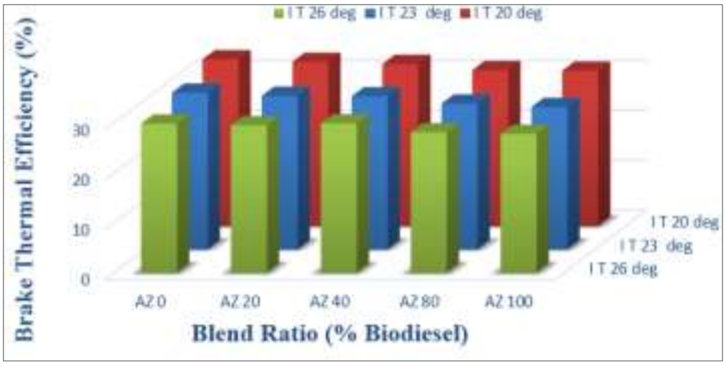

FIGURE 8

VARIATIONS IN BRAKE THERMAL EFFICIENCY (BTE) WITH THE BIODIESEL BLEND RATIO

There is a strong correlation between engine performance and the time of the injections. Figure.9 shows that by retarding the injection timing by 3° b TDC, the thermal efficiency is significantly increased. If you're going to slow down the combustion process, you might as well slow it down a bit more than you already are. Based on experiments, it was shown that the percentage of BTE in the blended oil at 20° BTC ranges from 16.16% to 33.18% for the AZ20 blend at low load and from 15.17% to 31.11% for AZ100 at maximum load. Diesel fuel's BTE ranges from 15.44 percent at low load to 31.46 percent at full load when using conventional injection timing. There is a noticeable difference in BTE between the diesel fuel and the mix AZ20 when the timing of injection is retarded by 20° b TDC for all loading circumstances. At 20° b TDC, the AZ20 fuel's maximum thermal efficiency of 33.18 percent was achieved. Relative to conventional injection timing, the average BTE for AZ20 fuel is 3.77 percent higher and for AZ100 gasoline it is 4.78 percent lower when using retarded injection timing of 20°b TDC. When AZ100 was used at a retarded injection time of 0.87 percent, the BTE reduction was not considerably greater than that of diesel fuel at full load. Increased brake heat efficiency can clearly be seen when inject timing is delayed by 3°b TDC. However, when injection time improves, BTE decreases.

Reducing the injection timing causes the combustion process to begin earlier than expected, resulting in lower peak heat release rates and an increase in effective combustion pressure that can be used to perform work. Retarded injection timing leads in a higher brake thermal efficiency because of the increased work output. A higher BTE is the outcome of this complete combustion. Previous studies have found the same thing [24].

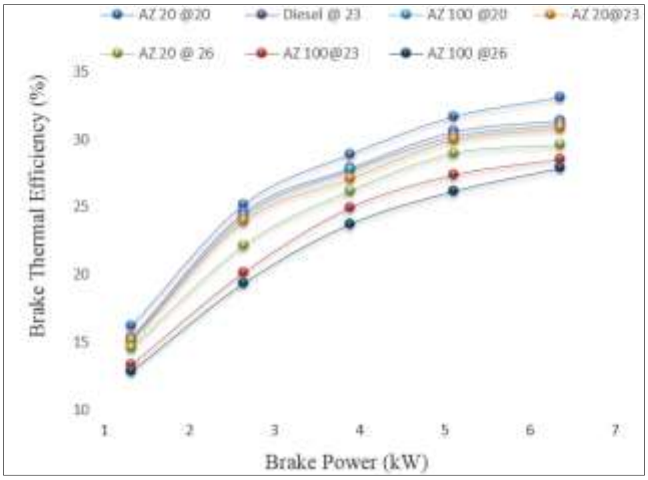

FIGURE 9

EFFECT OF INJECTION TIMING ON BRAKE THERMAL EFFICIENCY OF AZOME AND ITS BLENDS WITH DIESEL

Brake Specific Fuel Consumption (BSFC)

Variations in injection timing have an effect on both brake thermal efficiency and brake specific fuel consumption (BSFC). While the fuel injection timing is advanced, the brake specific fuel consumption rises, but retarding results in an improvement. Figure. 10 depicts the BSFC fluctuations due to the blend ratio for all injection times. The lowest BSFC may be achieved with a 20° b TDC injection timing, compared to all other injection timings. When it comes to Diesel and AZ20 fuel, 20° b TDC injection timing yields the lowest BSFC among all other ITs. Diesel, AZ20, AZ40, AZ80, and AZ100 had BSFC reductions of 5.78 percent, 6.95 percent, 5.55 percent, 3.93 percent, and 8.32 percent as compared to normal IT (23° b TDC). It was quite close to the AZ20 in terms of BSFC reduction percentage when using diesel as a fuel source. Diesel and AZ20 perform better in BSFC than all other blends at 20°b TDC because of their higher viscosity, lower calorific value, and greater fuel quantity at maximum load, which improves air usage and resulting in a more efficient combustion process.

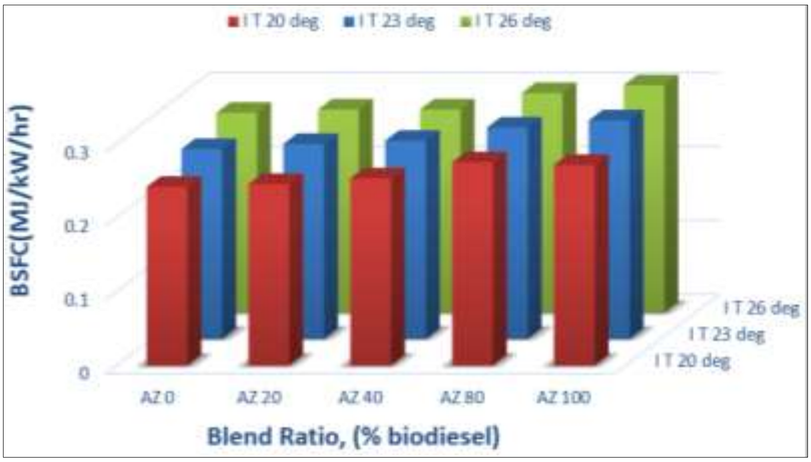

FIGURE 10

VARIATIONS IN BRAKE SPECIFIC FUEL CONSUMPTION WITH BIODIESEL BLEND RATIO

An engine's BSFC is a measurement used to assess its performance. Figure.11 shows that the BSFC falls with increasing load and is lowest at maximum load for all the blends at varying injection timings, as shown in the graph. At 20° b TDC, the BSFC of an AZ20 blend ranges from 0.501 (MJ/kW/hr) at low load to 0.245 (MJ/kW/hr) at full load, whereas the BSFC of an AZ100 blend varies from 0.556 (MJ/kW/hr) at low load to 0.271 (MJ/kW/hr) at full load, according to the results of the experiment. As with diesel fuel, the BSFC fluctuates from 0.525 (MJ.kW.hr) at low load to 0.255 (MJ.kW.hr.) at high load when using conventional injector time. At full load, the AZ100 fuel had a BSFC of 0.306 (MJ/kW/hr) and the AZ20 fuel had a BSFC of 0.245 (MJ/kW/hr) when the injection time was slowed to 20°b TDC, respectively. Retarded injection timing of 20° b TDC results in a 3.31 percent decrease in the average BSFC of AZ20 fuel and a 5.2 percent rise in the average BSFC of the AZ100 fuel.

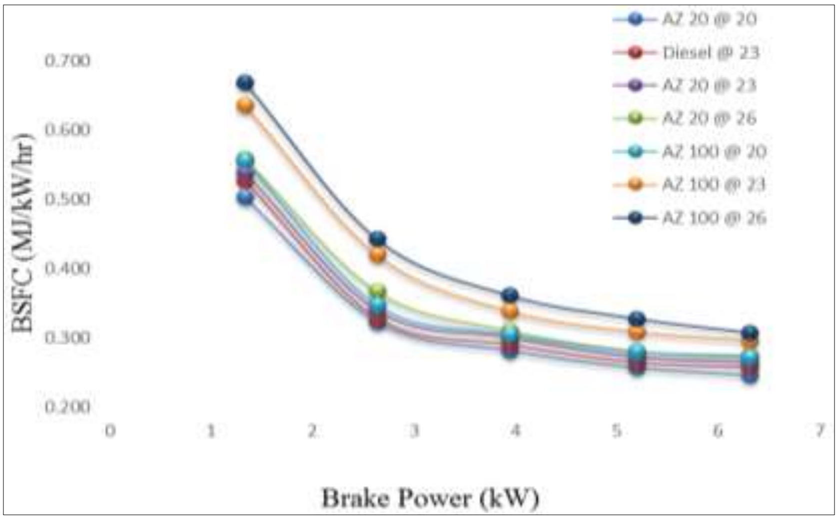

FIGURE 11

EFFECT OF INJECTION TIMING ON BSFC OF AZOME AND ITS BLENDS WITH DIESEL

Exhaust Gas Temperature (EGT)

Figure 12 depicts the relationship between the temperature of the exhaust gas and the biodiesel blend ratio at various injection times. Biodiesel mix ratios with a greater EGT trend may be attributed to the increased heat losses associated with higher blends. The EGT reduces when the injection timing is retarded, while the EGT rises when the injection timing is advanced. Diesel has the lowest EGT of any of the blends for all injection timings at maximum load, while IT 20° b TDC has the lowest EGT of any of the ITs and all blends for Diesel, AZ20, AZ40, AZ80, and AZ100. AZ20, AZ40, AZ80, and AZ100 have lower EGT for IT 20° b TDC than for IT 23° b TDC, a difference of 3.63 percent; 5.14 percent; 5.05 percent; 4.4%; and 3.9 percent.

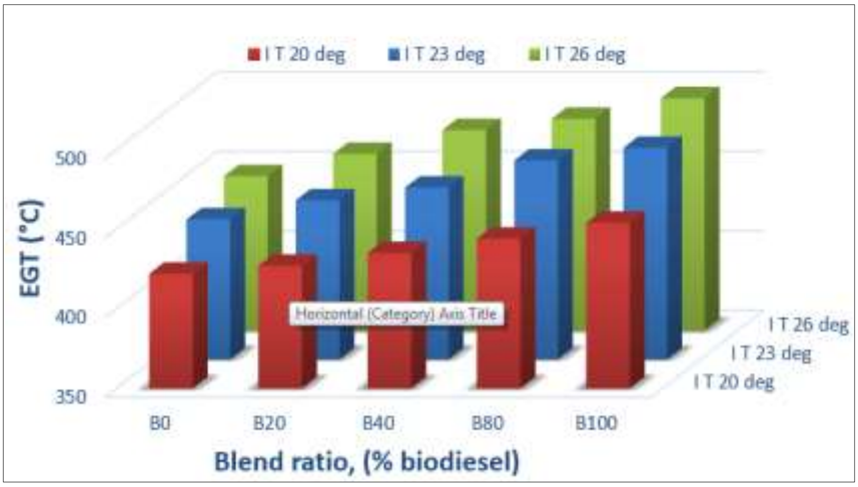

FIGURE 12

VARIATIONS IN EXHAUST GAS TEMPERATURE (EGT) WITH BIODIESEL BLEND RATIO

There is a rise in temperature in all loads illustrated in figure.13 on the trend line for exhaust temperature with varying injection timings. It's possible that the increase in EGT is attributable to the increased fuel consumption needed to supply the greater demand. With retarded injection timing of 20° b TDC, the exhaust gas temperature for the AZ20 blend is low at all loads, while it is somewhat higher for the AZ100 mix than for diesel fuel when using conventional injection. Exhaust gas temperatures range from 194°C at no load to 428°C at full load for the AZ20 mix at a retarded injection timing of 20° b TDC, whereas for the AZ100 blend they range from 189°C at no load to 455°C at full load. AZOME delayed injection timing reduces exhaust gas temperature due to reduced heat loss, as evidenced by high brake thermal efficiency. Advanced injection timing causes combustion to begin earlier, resulting in higher EGT as the piston travels toward TDC and compresses the cylinder charge.

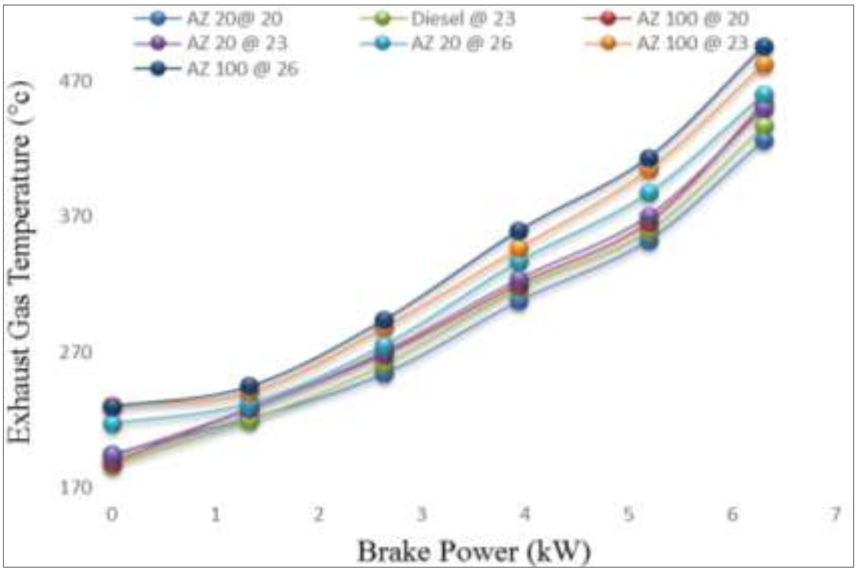

FIGURE 13

EFFECT OF INJECTION TIMING ON EGT OF AZOME AND ITS BLENDS WITH DIESEL

Carbon Monoxide Emission (CO)

For injection times of 23°, 20°, and 26°b TDC, the graph in Figure.14 shows the variation in carbon monoxide with the biodiesel mix ratio. Compared to all other injection timings, 20° b TDC has the maximum CO output for all fuel mixtures. At full load, CO emissions from IT 20°b TDC are 9.08 percent higher than the standard IT (23°b TDC) for the mixes Diesel, AZ20, AZ40, AZ80 and AZ100 respectively, when compared to the standard IT. The oxygen availability in the fuel may be the cause of the 16.650 percent volume increase in AZ40, which is the largest of any of the blends. Because AZOME fuel has a higher oxygen content, it burns more cleanly in the cylinder [25].

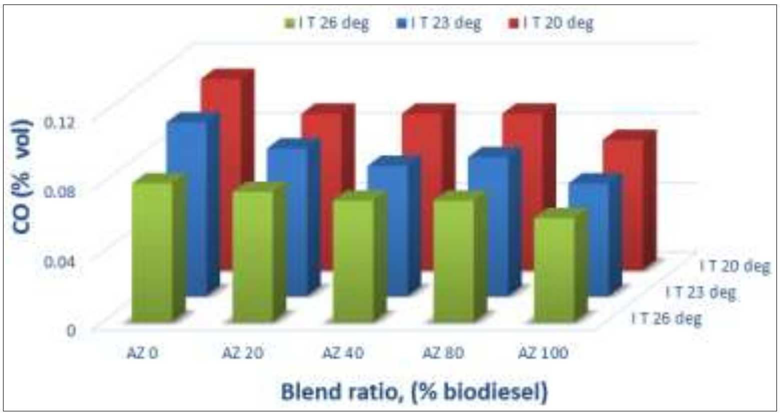

FIGURE 14

VARIATIONS IN CARBON MONOXIDE EMISSIONS WITH A BIODIESEL BLEND RATIO

AZ20 and AZ100 diesels with injection timings of 23°, 20°, and 26° b TDC at various loads are shown in Figure 15 as a function of injection time on carbon monoxide emissions. The Figure shows that CO emissions increase as engine load increases for all injection timings. In the exhaust, CO emissions are reduced when the AZOME content in the test fuel is raised. This is because the AZOME has a higher oxygen concentration, which improves the combustion process. Carbon monoxide (CO) emissions are steadily reduced as engine temperature rises at increasing loads, thanks to improved combustion. The blend AZ100 at advanced injection time 26° b TDC provides the lowest CO emission for all loads when compared to regular diesel fuel. For the AZ100 blend injected at an advanced timing of 26° b TDC, the CO concentration ranges from 0.03 percent by volume at no load to 0.06 percent by volume at full load, while for the AZ20 blend injected at an advanced timing of 20° b TDC, the CO concentration ranges from 0.05 percent by volume at no load to 0.09 percent by volume at full load. When AZ20 and AZ100 diesel fuels are run at 20°b TDC, their average CO emissions are reduced by 9.79 percent and 32.25 percent, respectively, compared to diesel fuel used at conventional injection timing. Due to a longer ignition delay, more CO emissions are produced when the injection timing is retarded, whereas advanced injection timing raises the in-cylinder temperature and enhances the oxidation process between carbon and oxygen molecules, resulting in lower CO emissions. According to past studies, the similar pattern is evident.

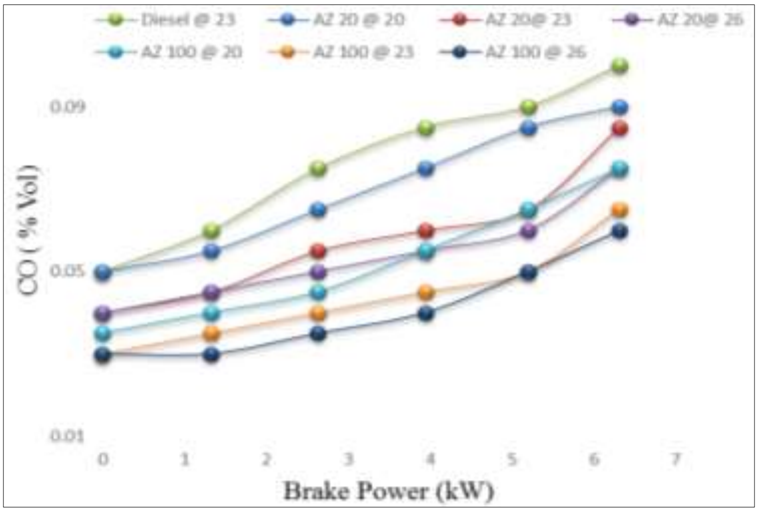

FIGURE 15

EFFECT OF INJECTION TIMING ON CARBON MONOXIDE OF AZOME AND ITS BLENDS WITH DIESEL

Carbon Dioxide Emission (CO_2)

Biodiesel's carbon dioxide content varies with injection timing (23°, 20°, 26° b TDC), as seen in Figure 16. When the amount of biodiesel in the test fuel is raised, carbon dioxide emissions are reduced. All mixes of IT 26° b TDC emit less carbon dioxide in general. In comparison to conventional IT of 23°b TDC, the carbon dioxide emissions of Diesel, AZ20, AZ40, AZ80 and AZ100 blends are raised by 3.5%, 1.87 percent, 3.86 percent, 6.97 percent and 6.19 percent when the injection timing is retarded by 20° b TDC. Diesel fuel has the highest CO2 emissions of all the mixes for all three injection timings, while AZ100 fuel has the lowest CO2 emissions.

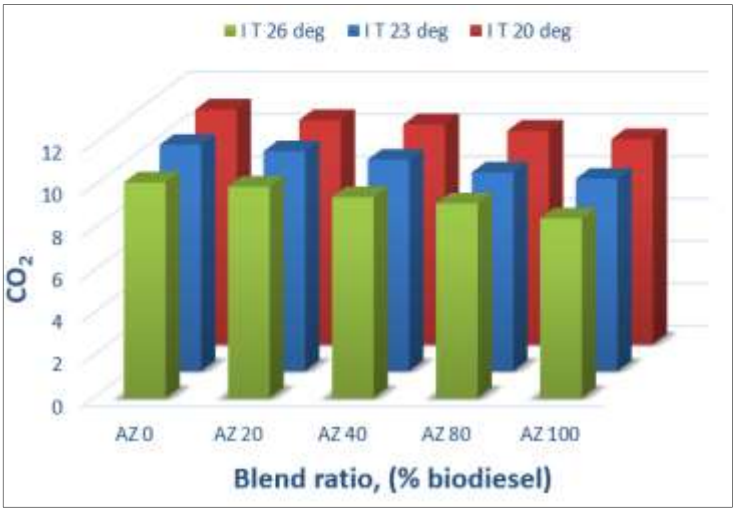

FIGURE 16

VARIATIONS IN CARBON DIOXIDE EMISSIONS WITH A BIODIESEL BLEND RATIO

For diesel, AZ20, and AZOME under varied loads with injection timings of 23, 20, and 26° b TDC, the influence on carbon dioxide emission is indicated in figure. 17. With an increase in engine load, CO2 emissions rise as the biodiesel content in the test fuel increases for all injection times. A combination of AZ20 and AZ100 with 20° b TDC retarded injection timing produces CO2 emissions that range from 3.2 to 10.7 percent by volume at no load and from 2.5 to 9.8 percent at maximum load for AZ20 and AZ100, respectively. If you use AZ20 gasoline at 20° b TDC with retarded injection timing, the average CO2 emissions are reduced by 0.65% and for AZ100 at 20° b TDC it is reduced by 11.80%.

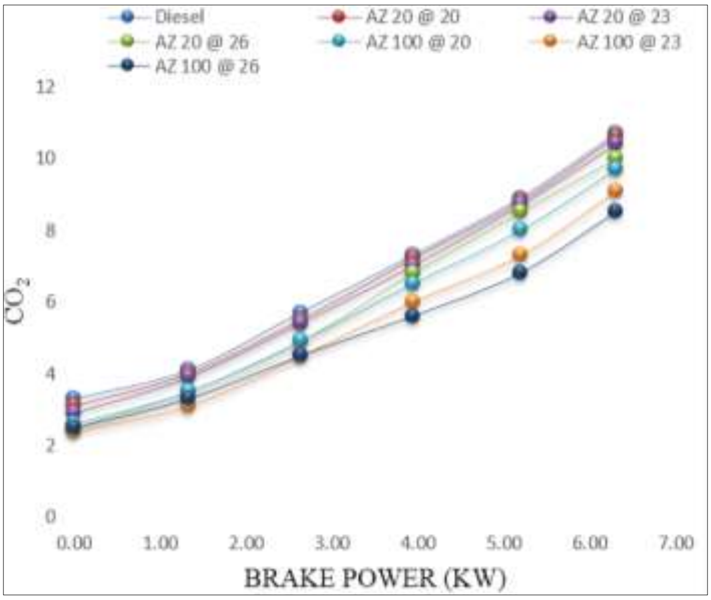

FIGURE 17

EFFECT OF INJECTION TIMING ON CARBON DIOXIDE OF AZOME AND ITS BLENDS WITH DIESEL

Hydrocarbon (HC)

Biodiesel blend ratio is shown in Figure.18 for the injection timings of 23°, 20°, and 26° b TDC. When biodiesel is added to the test fuel, hydrocarbon emissions are reduced at all injection times. IT 26° b TDC emits less hydrocarbons than any other blend. A retarded injection time of 20° b TDC results in a rise in hydrocarbon emissions of 6.52 percent, 10.51 percent, 20.57 percentage points and 20.05 percentage points for Diesel, AZ20, AZ40, AZ80, and AZ100 correspondingly.

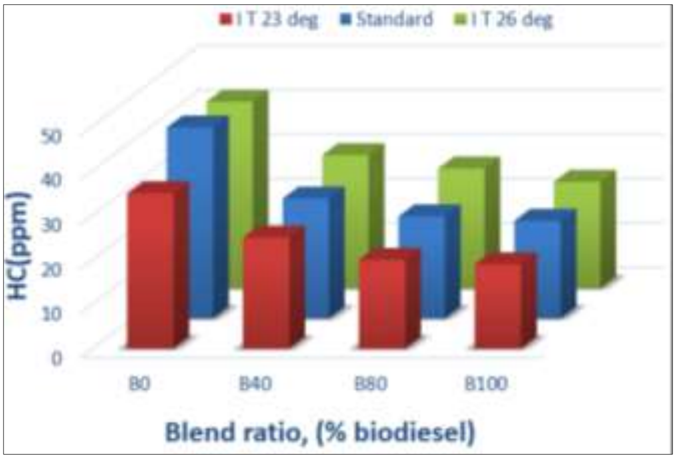

FIGURE 18

VARIATIONS IN HYDROCARBON EMISSIONS WITH A BIODIESEL BLEND RATIO

It is demonstrated in Figure.19 that different injection timings have varied effects on the hydrocarbon emission of diesel, AZ20 and AZOME at different loads. All injection timings see an increase in HC emissions as engine load increases. According to the graph, delayed injection timing has an effect on unburned hydrocarbon emission levels. For the blend AZ20 at 20° b TDC, unburned hydrocarbon emissions range from 13 ppm at no load to 37 ppm at full load; for the blend AZ100, it ranges from 12 ppm at no load to an astonishing 126 ppm at full load. Retarded injection timing of 20° b TDC for AZ20 fuel and 20° b TDC for AZ100 fuel reduces the average HC emissions by 24.38 percent and 42.74 percent, respectively, from diesel fuel at conventional injection timing. As the piston approaches the top dead centre (TDC), the cylinder charge is compressed, resulting in greater temperatures and, as a result, reduced HC emissions. This is the effect of advancing the injection time (Sayin & Canakci 2009). When compared to diesel, the unburned hydrocarbon emissions are reduced when the injection timing is delayed. The reduction in unburned hydrocarbons is due to a decrease in flame quenching thickness.

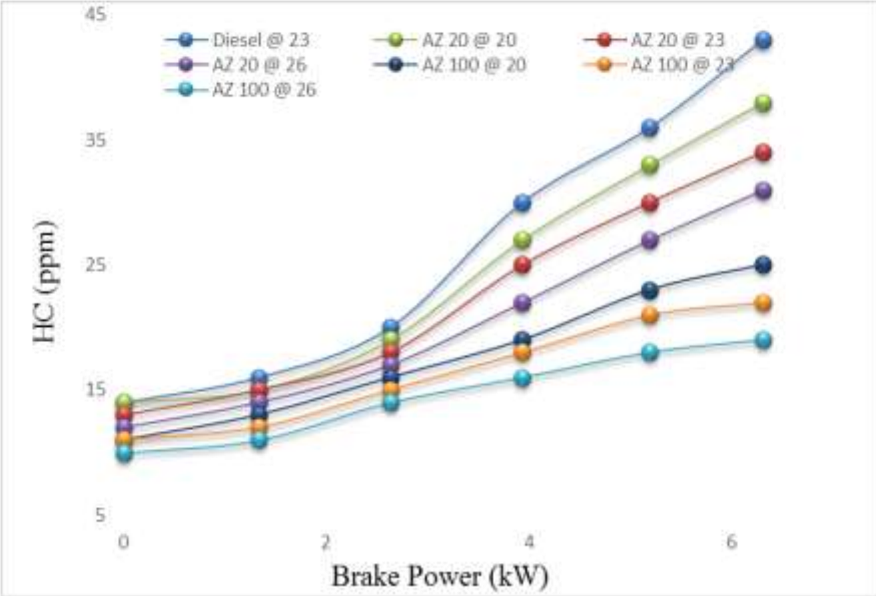

FIGURE 19

EFFECT OF INJECTION TIMING ON HC EMISSIONS OF AZOME AND ITS BLENDS WITH DIESEL

Smoke Opacity

Soot particles suspended in exhaust gas make up the bulk of smoke. A lack of air causes smoke to form. Biodiesel blend ratios and smoke opacity are shown in Figure 20 for all injection times. Compared to other injection timings, IT 26° b TDC has the lowest smoke opacity. At varied injection times, the smoke opacity of all the test fuels reduces when biodiesel content is raised in all of them. For the blends AZ0, AZ20, AZ40, AZ80, and AZ100, the smoke opacity is increased by 2.14 percent, 3.34 percent, 4.73 percent, 5.16 percent, and 4.69 percent for the retarded injection timing 20° b TDC, while it is decreased by 6.31 percent, 8.87 percent, 8.23 percent, 8.63 percent, and 7.58 percent for the advanced injection timing 26° b TDC.

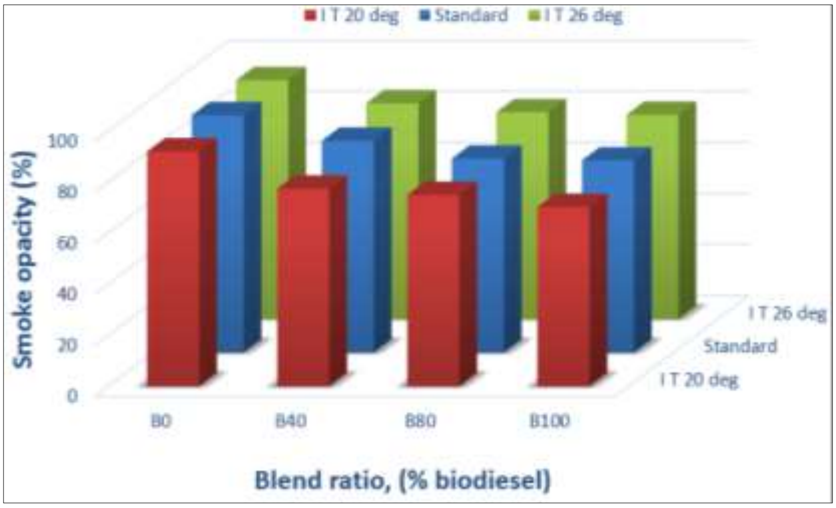

FIGURE 20

VARIATIONS OF SMOKE OPACITY WITH A BIODIESEL BLEND RATIO

AZ20 and AZOME with various loads with injection timings of 23°, 20°, and 26° b TDC are shown in the figure. 21 The opacity of the smoke increases as the engine load increases for all injection timings. When compared to conventional injection timing for the relevant mixes, the smoke production is greater with retarded injection timing. Hydrocarbons that have not yet burnt or partially reacted may be the cause of the increased smoke emissions when injecting at a later date. There isn't much of a difference between low- and high-load smoke opacity because the fuel contains oxygen, which oxidises soot into CO_2. At a retarded injection time of 20° b TDC, the blend AZ20 produces smoke ranging from 28% at no load to 91% at full load, while the AZOME (AZ100) produces smoke ranging from 25% at no load to 78% at full load. The average smoke opacity of AZ20 fuel at 20° b TDC retarded injection timing is 17.43 percent lower than that of diesel fuel at conventional injection timing, whereas AZ100 at 20° b TDC retarded injection timing is 15.61 percent lower.

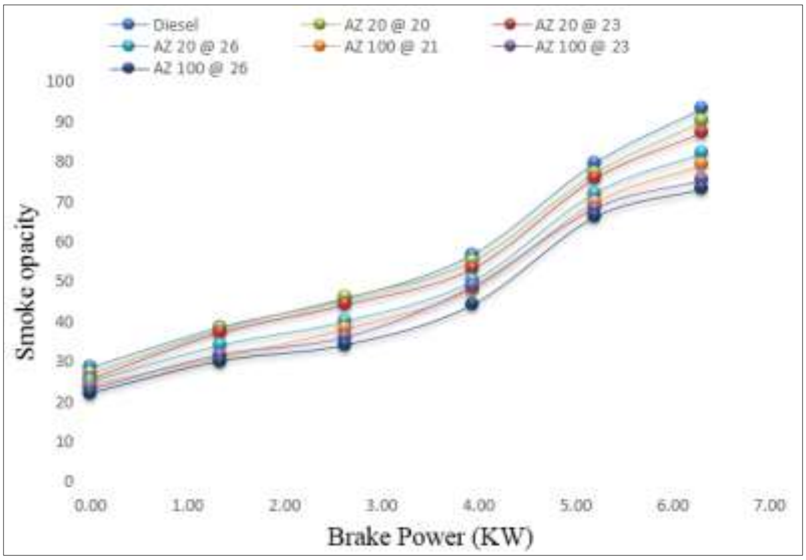

FIGURE 21

EFFECT OF INJECTION TIMING ON SMOKE OPACITY OF AZOME AND ITS BLENDS WITH DIESEL

NOx Emissions

Figure shows the variation in NOx emissions as a function of the blend ratio for the three different injection times. 22. In CI engines, the most important contaminant is NOx emissions. When it comes to NOx production, the cylinder's temperature, oxygen content, and reaction time all play an important role. For all blends, the lowest NOx is achieved by using a retarded injection timing IT 20° b TDC. Reduced NOx emissions are 5.43 percent lower for the mixes AZ20 (AZ40), AZ80 (AZ100), and AZ100 when the injection time is 20°b TDC instead of 23°b TDC. This is compared to the conventional IT at TDC of 23°b TDC.

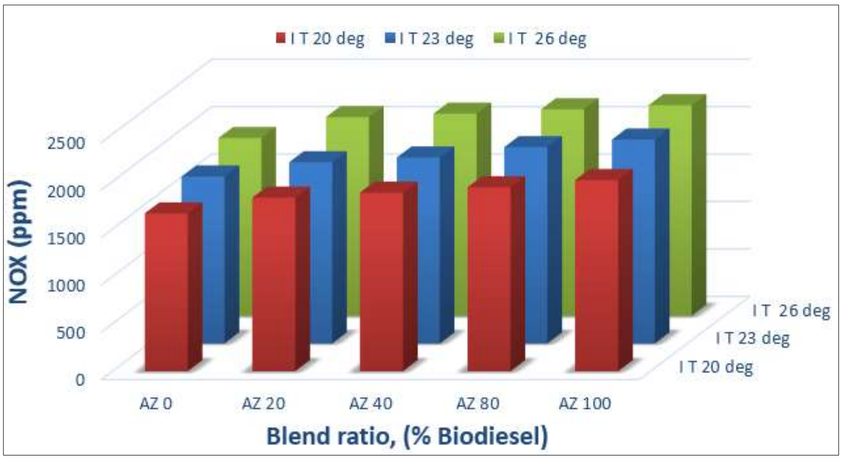

FIGURE 22

VARIATIONS OF NO_X EMISSIONS WITH A BIODIESEL BLEND RATIO

Oxygen monoxide emissions from CI engines are influenced by a variety of factors, including in-cylinder temperature, oxygen concentration, reaction time in the combustion chamber, air excess coefficient, and residual reaction time [27, 28]. Injection timing was delayed, resulting in lower in-cylinder temperatures, a shorter reaction time, and more fuel being burned after TDC, all of which reduced NOx emissions. Higher combustion temperatures and longer residence times for the oxidation of nitrogen lead to higher NOx emissions when the injection timing is advanced. Figure.23 depicts the impact of injection time on NOx emissions for AZOME at injection timings of 23°, 20°, and 26° b TDC. For all injection timings, an increase in engine load increases NOx emissions. Retarded injection timing of 20° TDC results in NOx emissions ranging from 288 ppm at no load up to 1831 ppm at full load for the mix, while the same timing results in NOx emissions ranging from 334 ppm at no load to 2015 ppm at full load for the blend AZ100 at full load. Comparing the average NOx emissions of AZ20 and AZ100 diesel fuels at 20°b TDC retarded injection timing to those of diesel fuel at standard injection timing, we find a 3.25 percent and 14.67 percent increase, respectively, in NOx.

Additionally, the average NOx emission of AZ20 fuel is reduced by 3.14 percent, and that of AZ100 fuel is reduced by 5.42 percent when injection is delayed by 20°b TDC as opposed to conventional injection.

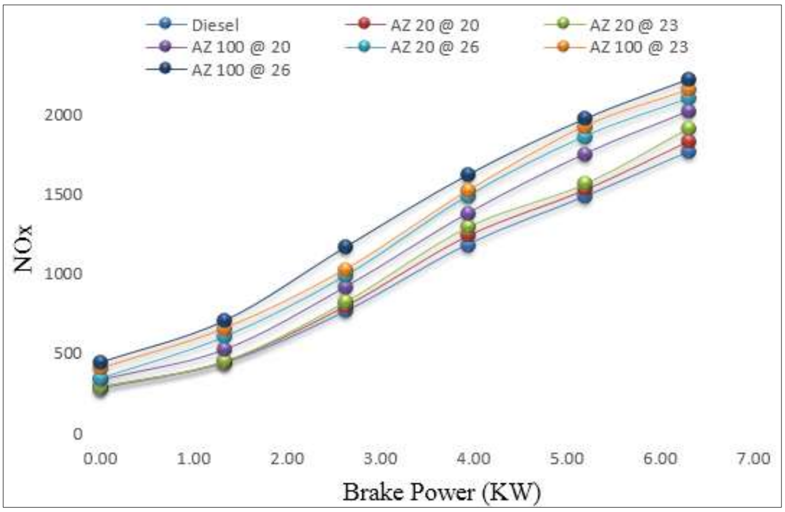

FIGURE 23

EFFECT OF INJECTION TIMING ON NO_X EMISSIONS OF AZOME AND ITS BLENDS WITH DIESEL

CONCLUSION

AZOME mixes and diesel were used in this experiment to explore the impact of injection timing on engine performance and emissions. As a result, the following findings emerged. SFOME and its blends were found to have a substantial impact on combustion, performance, and emissions when the injection timing was delayed by 3° b TDC.

- Compared to diesel fuel, the in-cylinder peak pressure for IT 20 °b TDC was lower for the mix AZ20 and higher for the blend AZ100 at all loads. When injecting at a timing of 26° b TDC, the blend AZ100 achieves its greatest peak pressure, while the blend AZ20 requires a timing of 20° b TDC to get its lowest peak pressure. The in-cylinder pressure differential between the two mixes is 6.55 bar.
- The rate of heat release followed a similar pattern. For the mix AZ20 at 20° b TDC, an average heat release drop of 1.95 percent compared to diesel fuel is seen while the average heat release rise of 1.47 percent for the blend AZ100 at 20° b TDC is observed.
- SFOME and its blends' thermal brake efficiency improves with delayed injection. Retarded injection of 20° b TDC yielded a maximum BTE of 33.18 percent, while with AZ100 the maximum BTE was reported to be 31.11%.
- As compared to diesel fuel at regular injection timing, the average BTE of AZ20 fuel at 20° b TDC is raised by 3.77 percent while for AZ100 at 20° b TDC it is lowered by 4.78 percent when retarded. At maximum load, the BTE loss for AZ100 at retarded injection timing was only 0.87 percent when compared to diesel fuel, which isn't very big.
- In comparison to AZ20, the average NOx emissions from AZ20 and AZ100 at standard injection time are reduced by 3.14 percent and 5.42 percent, respectively, when the injection timing is retarded by 20°b TDC. For example, when AZ20 gasoline is used with a delayed injection timing of 20°b TDC, the average NOx emissions rise by 3.26 percent, whereas for AZ100, they rise by 14.69 percent.
- Reductions in carbon monoxide, carbon dioxide, hydrocarbons, and smoke emissions were observed when the AZ20/AZ100 blend was tested with an injection timing retarded by 20°b TDC.

DECLARATION

The author(s) declare that there is no funding contributed in this research by any organization, available material in this manuscript is purely based on our research findings and experiments.

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