

Impact Of Injection Timing On The Emissions And Production Of A CI Engine Utilizing B30 Biodiesel Fuel

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Abstract: In order to assess the effects of injection duration (10, 8, 6, 4, 2 before TDC) on emissions, combustion parameters, and CI engine performance once utilizing biodiesel and diesel mixture (B30) at engine speeds of 3000 rpm with a full load, we prepared the AVL Boost model with combustion models Vibe 2 and Woschni 1990 as sub-models and applied numerical analysis. The utilization of various fuel types in compression ignition engines to enhance performance of engine with decreasing exhaust releases was the main emphasis of this study. In this effort, a 4-strokes and 4-cylinders, engine has been utilized. The findings demonstrated that once the time of injection was rated, the effective torque and the braking power both dropped. Biodiesel blends produced less effective power and torque than diesel fuel at all selected time of injection. Biodiesel blends produced less effective power and torque than diesel fuel at all chosen time of injection. Under all operating conditions, biodiesel fuels emit much less soot but more NO_x than traditional diesel fuels. For all selected fuels, NO_x releases reduced with increasing the soot releases once durations of injection were switched from advanced to rated.

Keywords: Biodiesel fuel, Compression ignition engines, Direct Injection, Engine performance, Time of injection.

1. Introduction

Demand for energy has risen sharply in recent years [1,2], while environmental pollution has gotten worse [3]. Finding new energy sources to replace conventional energy sources is required to address these issues [4]. Biodiesel is viewed as a possible renewable energy source [5] once compared to other alternative energy sources like geothermal, solar, wind, and biomass energy because it can be produced efficiently [6] and offers sustainable development to address these issues [7].

Owing to its physicochemical qualities being similar to those of fossil diesel, biodiesel is now seen to be the most potential replacement for it in diesel engines [8]. Bio-diesel is a potential fuel from a sustainability perspective because it is made from microbes, animal fats, and vegetable oils. In comparison to ordinary diesel, bio-diesel is thought to be less effect on the surrounding environment [9].

According to the manufacturer's recommendations for engine production, biodiesel is often mixed with up to 20% of commercial fossil diesel oil and utilized in already-existing internal combustion engines (ICE) without modification. Furthermore, blends with a 5–20% biodiesel amount are well-liked since they strike a fair compromise between cost and fuel efficiency and are subject to regulations like ASTM D7467 [10].

The use of biodiesel and its combinations in diesel engines has been showed in a large body of literature, and research on their characterizations related to releases and performance has been conducted [11]. For example, Lu et al [12]. experimental study examined the impact of biodiesel made from utilized cooking oil on the diesel engines performance. The authors tested various biodiesel blends, including B5, B20, and B30, in a 4-cylinder diesel engine. These biodiesel blends did not enhance engine

performance once compared with the usage of pure diesel fuel, but their emission characteristics were significantly enhanced, according to the study's findings.

Lenik et al. [13] employed the numerical and experimental technique to study the emission, performance, and combustion features of biodiesel, diesel, and their mixtures in a heavy-duty DI diesel engine as well as the biodiesel fuel effect on emission formation, diesel engine performance, and injection characteristics. Moreover, the findings demonstrated that a heavy-duty diesel engine could be fed pure biodiesel or mixtures of biodiesel-diesel once the mechanically controlled injection system's static fuel delivery angle was modified. The evaluation of an one-cylinder direct-injected compression ignition engine operating on biofuels was conducted by Iclodean and Burnete [14]. Findings indicated that NO_x amount in exhaust gases could be decreased by combustion gas recirculation, load, and optimizing engine speed.

Vilela et al [15] analysis of the acidity of fish oil examined the viability of using it as biodiesel. In the current study, fish oil produced a biodiesel yield that varied from 68% to 90%. The emission features and performance of diesel engines running on methyl ester of fish oil and its mixtures with diesel were studied by Godiganur et al. [16]. The test findings revealed no significant changes in diesel engine performance or combustion, although there was a decrease in the primary noxious pollutants, notably HC and CO, except for No_x. The aim of this research is to explore numerically by using AVL model the influence of time of injection (10, 8, 6, 4, 2 before TDC) on CI engine performance (cylinder pressure, effective torque, effective pressure, excess air, fuel consumption and others) and exhaust emissions fuelled with biodiesel B30 and diesel at constant engine speed 3000 rpm.

2. Selection of Materials

In this investigation, environmentally friendly biodiesel fuel made from utilized vegetable cooking oil and its mixtures with diesel were utilized. The ASTM standards and methodologies were utilized to establish some of the significant fuel attributes of waste vegetable cooking oil biodiesel (B100) and diesel fuel, which are summarized in Table 1. In order to fuel the diesel engine under test, waste vegetable oil biodiesel was mixed with diesel fuel at 30 percent proportion.

For this study, an AVL Boost model (AVL BOOST is engine cycle and gas exchange simulation software that enables you to build a model of the entire engine by selecting elements from a toolbox and connecting them by pipe elements) was developed to forecast engine efficiency, combustion properties, and exhaust releases. A direct-injected diesel engine with four cylinders was employed. As sub-models, the combustion models Vibe 2 and Woschni 1990 have been selected. The experiments were run using biodiesel mixtures at various time of injection (10, 8, 6, 4, and 2 before TDC) with an engine speed of 3000 revolutions per minute (B30) with full load engine. The test engine components involving the catalyst, unit boundaries, filter of air, output and input manifold, and cylinder configurations, were extracted in line with real dimensions. All components are interconnected via pipes inside the program interface, as seen in Figure 1. Table 2 presents the fundamental engine specs.

Table 1. Properties of Utilized Fuels

Property	Diesel	Biodiesel
Chemical formula	C8 to C25	C12 to C22
Density at NTP (kg/L)	0.81	0.911

Oxygen amount by mass	0	11
Lower Heating Magnitude (MJ/kg)	44.22	38.8
Stoichiometric air fuel proportion	14.7	13.8
Boiling point at 1 Bar (C)	244-380	230
Heat of vaporization (KJ/kg)	233	-
Adiabatic flame temperature (Temp) (C)	2100	
Kinematical viscosity, 40 °C	4.03	4.15
Cloud point	2	0
Pour point	0	3

Table 2: Engine Specifications.

Variables	Requirements
Engine	Tractor diesel
Category	Natural aspirated
Combustion	Injection directly
Cylinders Number	4-cylinders, 4-strokes
Bore x stroke (mm)	105 mm x 112 mm
Compression proportion	16.8:1

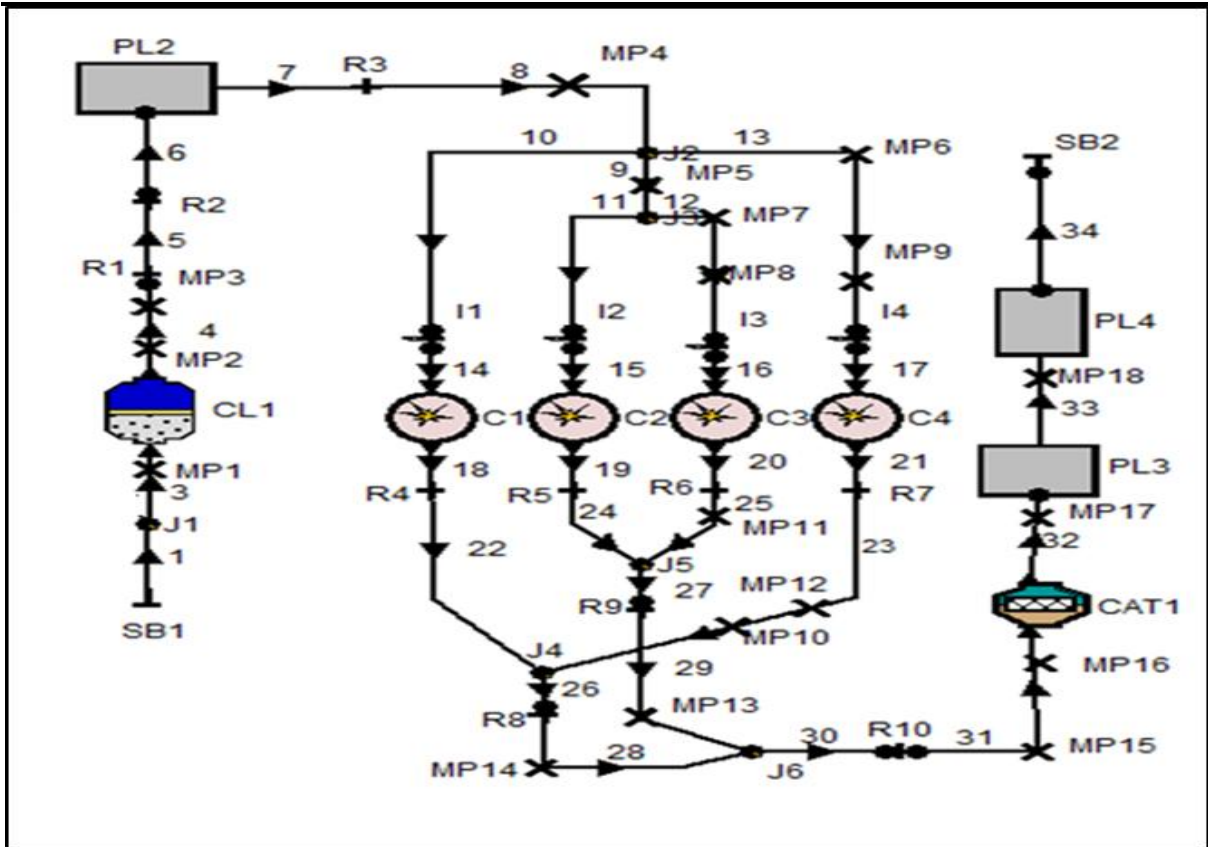


Figure 1 Schematic of the Engine Symbolic Model (AVL BOOST)

3- Results and Discussions

3.1 Cylinder Pressure

Figure (2) displays the real and simulated CIE engine outputs at 3000 rpm with the accelerator placed at a constant location together with variations in cylinder pressure (bar) based on the crank angle position [CA deg]. There is clear evidence of a link between the experimental trace and the simulation.

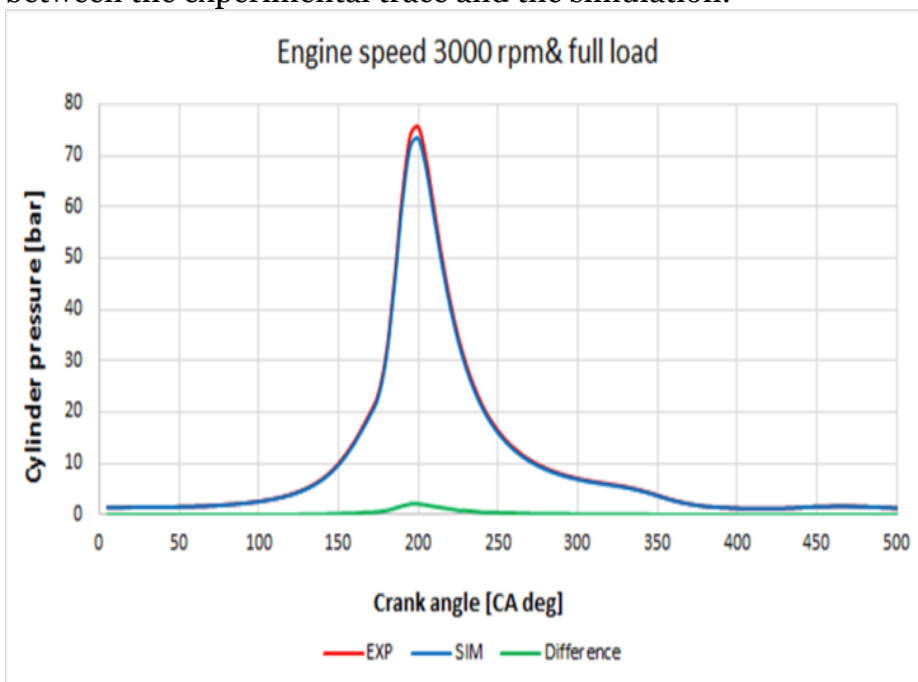


Figure 2: The differences between simulation and experimental pressure traces for 3000 rpm engine speed at full load

3.2 Effective Power

Figure 3 illustrates the impact of varying time of injections (BTDC and CA DEG) on the DI engine performance while utilizing diesel and certain biodiesel mix percentages at full load and constant speed of the engine. Despite the apparent reduction in effective power due to the increased fraction of biodiesel relative to total fuel volume, the lowest effective power magnitude for biodiesel, with same time of injection as diesel fuel, has been documented. Furthermore, effective power decreases with the nominal duration of fuel injection for engines operating on diesel or any biodiesel mix. This back to the fact that the increasing in the amount of mixed biodiesel results in a decrease in effective power, which can be attributed to longer delay times and the fact that biofuel has a lower volumetric magnitude than conventional fuel. As a result, less heat was converted because less heat was gained overall during combustion.

Once using biofuel, combustion and compression phenomena occurred, which resulted in a reduction in power since the mixture ignited more quickly due to the fuel's greater cetane number and shorter combustion delay [17].

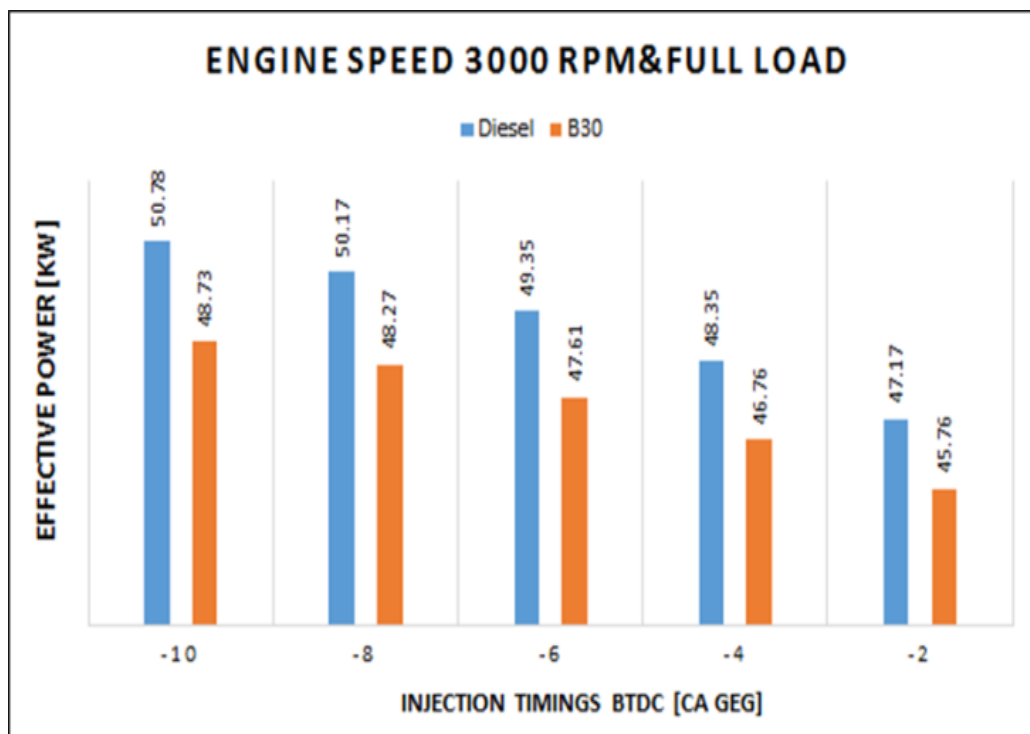


Figure 3. The changing in effective power with times of injection at 3000 rpm engine speed at full load.

3.3 Effective Torque

Using a diesel and combination of biodiesel fuel, the statistically calculated impact of different time of injection on the DI engine actual torque while preserving engine load and speed is shown in Fig. (4). Once diesel fuel was injected, the optimum magnitude of the actual torque was found; nevertheless, this figure indicated that the effective torque was falling because of the fuel combination's proportion of biodiesel to total volume. This occurs as a result of diesel fuel's higher energy amount, which enhances the diesel engine's ability to burn fuel efficiently. Also, the effective torque is

reducing with the rate of the time of injection for engines running on diesel or at combination of biodiesel.

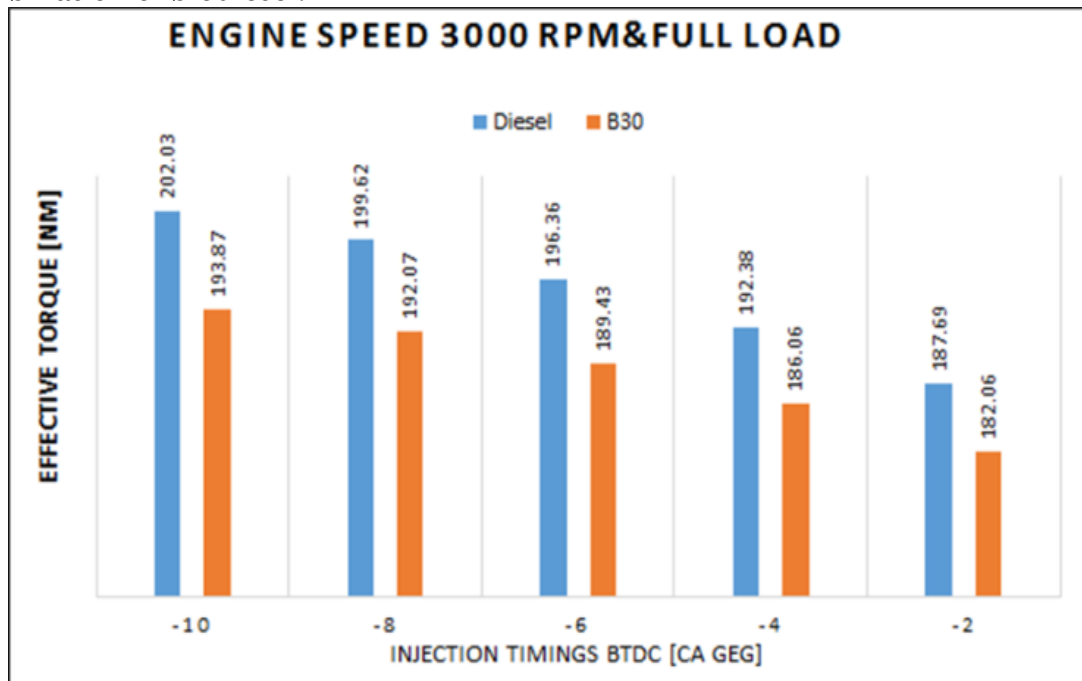


Figure 4. The changing in effective torque with times of injection at 3000 rpm engine speed at full load.

3.4 Brake specific fuel consumption (BSFC)

Figure (5) illustrates how varied time of injection BTDC affect the break-specific fuel usage with using diesel and biodiesel combination (30%). The percentage of biodiesel amount in the fuel combination as a proportion of the overall volume while, as shown in this figure, is increasing the break fuel consumption. This is because biodiesel has a lower heating magnitude. Once a CI engine runs on both diesel and biodiesel at the same time of injection, the least amount of fuel is consumed. Moreover, the consumption of various fuels rises as the time of injection approaches. Similarity to [18] that it provided the findings demonstrate a parallel between the law of changing work capacity and the law of changing fuel consumption rate once the early injection angle is altered. The highest power yields the lowest level of fuel consumption at the ideal injection angle magnitude because the amount of fuel provided remains constant [19,20].

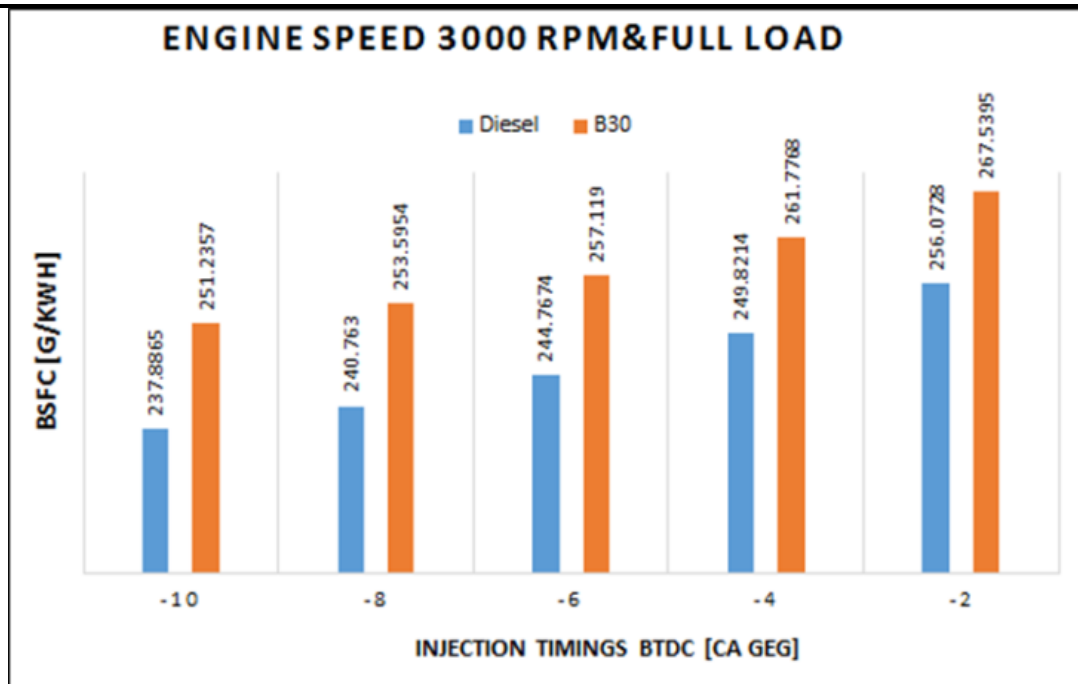


Figure 5. The changing in Brake Specific Fuel Consumption with times of injection at 3000 rpm engine speed at full load.

3.5 Excess Air Proportion

Figure (6) illustrates how the excess air proportion with certain combination of biodiesel is affected by the various time of injection BTDC. The extra air proportion grows once the volume concentration of biodiesel in the fuel combination rises as a proportion of the overall rising volume, while the diesel engine running on biodiesel combinations as opposed to diesel fuel at the same injection duration records the lowest excess air proportion magnitude. Also, as the injection duration advances for each of the chosen fuels, the extra air proportion declines. According to similar to [18] that it noted the findings demonstrated that the A/F proportion rose at all loading modes relative to Bo and increased as the biodiesel mixing proportion increased.

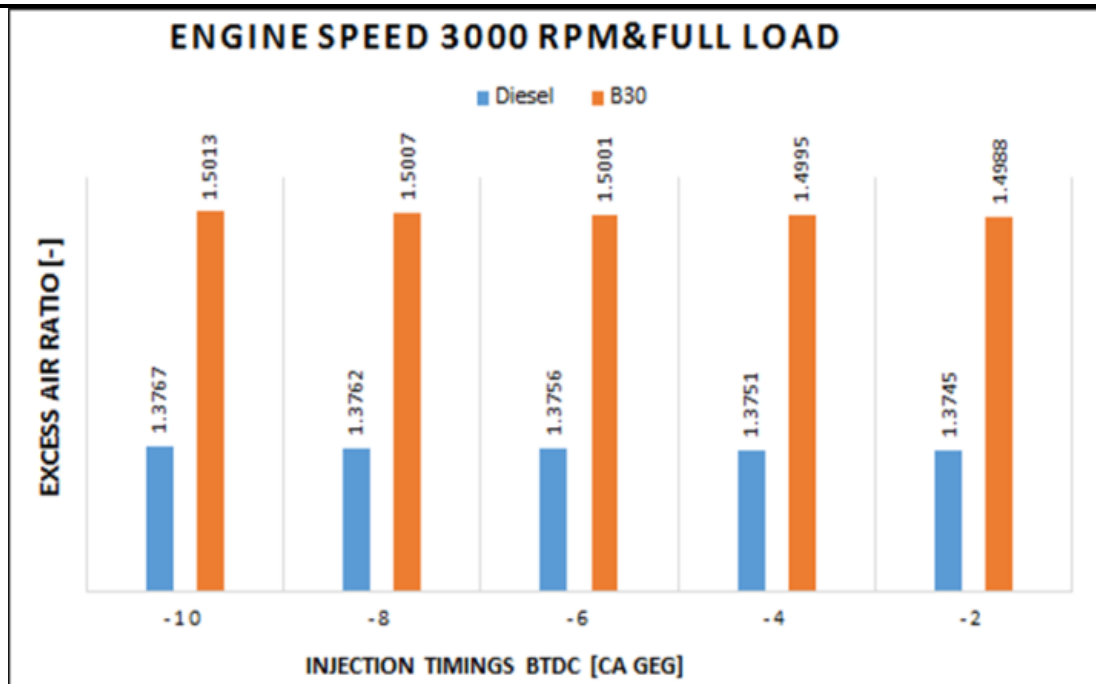


Figure 6. The changing in Excess Air proportion with times of injection at 3000 rpm engine speed at full load.

3.6 Ultimate Fire Pressure

The impact of various time of injection BTDC (CA DEG) on the DI engine ultimate fire pressure (bar) powered by percentage of biodiesel combinations is shown in Fig. 7. This graph makes it obvious that the optimum fire pressure is falling as the volume of biodiesel in the fuel combination as a proportion of the overall volume increases. The diesel engine's optimum fire pressure magnitude was for all operational circumstances. This might be because diesel fuel burns more efficiently because of its larger calorific amount. Also, for diesel-powered engines or some combination from biodiesel combination, the ultimate fire pressure is falling as the time of injection advances.

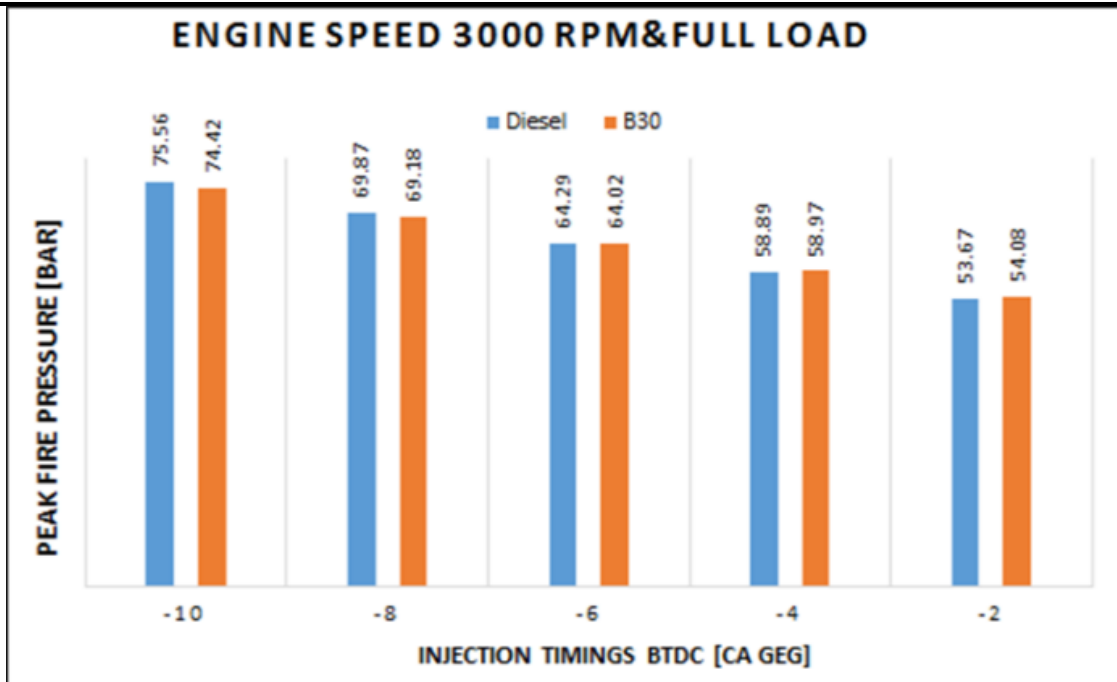


Figure 7. The changing in ultimate fire pressure (bar) with times of injection at 3000 rpm engine speed at full load.

3.6 Ultimate Fire Temperature

Figure 8 illustrates the impact of various time of injection BTDC (CA DEG) on the DI engine as an optimum fire Temp (K) with percentage of biodiesel combinations. This graph demonstrates how the optimum fire Temp drops as the volume of biodiesel in the fuel combination increases. In comparison to biodiesel blending at the same injection duration, the diesel-fueled engine's highest magnitude of fire Temp was measured. This behavior is a result of biodiesel's lower calorific magnitude than regular diesel fuel. Also, for all the chosen fuels, the optimum fire Temp falls as injection duration advances. This is brought on by a shorter ignition delay interval.

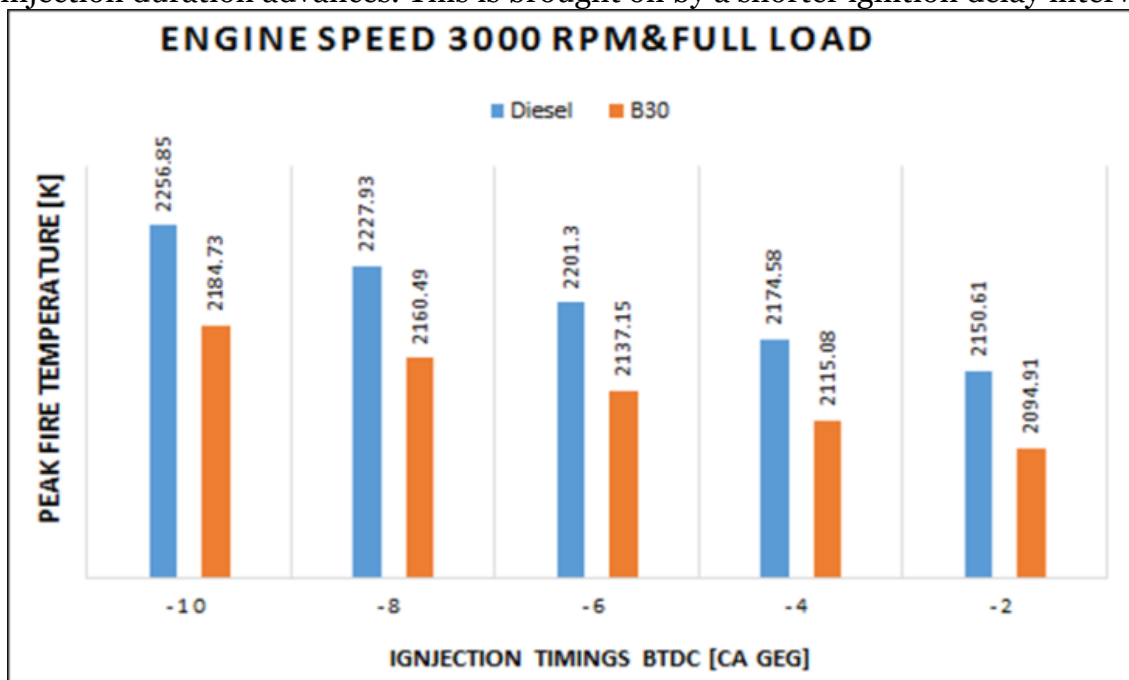


Figure 8. The changing in Ultimate Fire Temp (K) with times of injection at 3000 rpm engine speed at full load.

3.7 Soot Emission

Figure 9 depicts the soot produced by biodiesel combination as the result of multiple time of injection on the DI engine's emissions. According to this graph, soot production reduced with the fuel combination's biodiesel amount, but it ultimate once diesel fuel was utilized in a diesel engine at the same injection duration, producing the most soot. This is because biodiesel has a higher oxygen concentration, which improves combustion efficiency. Also, for all the selected fuels, soot production rises as injection duration is delayed. This is brought on by a reduction in the length of the combustion process. Moreover, Fig. (9) demonstrated that the B30 engine produced the most soot between (2) and (8) degrees CA at the time of injection because of the engine's poorer combustion efficiency. Similarity to the reference [21,22] that it proved the oxygen in the fuel composition helps to more fully oxidize the soot, which greatly reduces soot emissions, As a result, using biodiesel gasoline significantly reduces soot emissions.

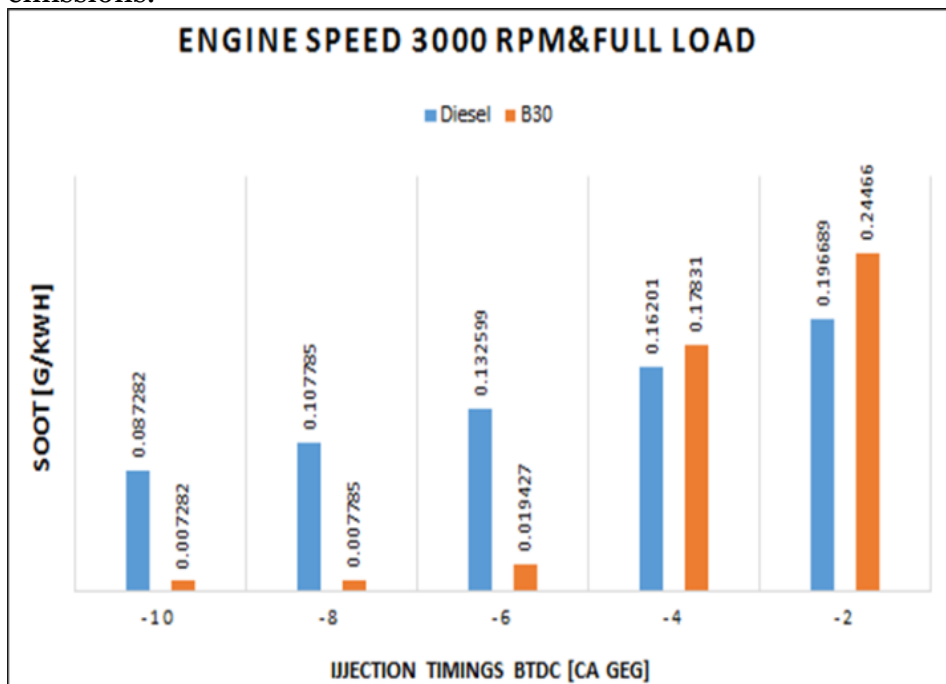


Figure 9. The changing in Soot Emissions with times of injection at 3000 rpm engine speed at full load.

3.7 Nitrogen oxides emissions

Figure 10 shows how different time of injection affect the nitrogen oxide produced by CI engines running on various biodiesel and diesel fuel combinations. This graph demonstrates how nitrogen oxide emissions rise once biodiesel concentration relative to total volume in the fuel combination rises. Optimum nitrogen oxide emissions for a diesel engine running on biodiesel versus diesel fuel injected at the same rate. This is related to biodiesel's increased oxygen amount, which lowers heat radiation because there is less soot present. Similar to the reference [23,24], which demonstrated that once the biodiesel blending proportion increased, NOx emissions increased in accordance with the faster burning of the biodiesel fuel combination, which in turn increased heat output.

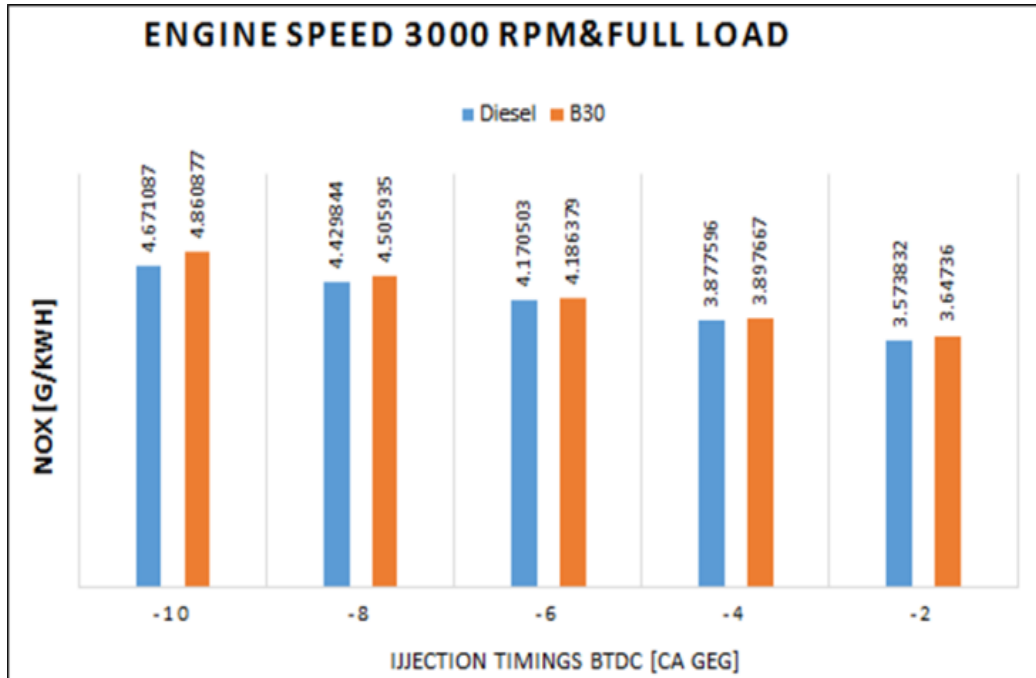


Figure 10. The changing in Nitric Oxide Emissions with times of injection at 3000 rpm engine speed at full load.

4. Conclusions

This study was concluded to some conclusion as following:

- With retarded time of injection, effective power and torque decreased. Where at time of injection (-2 CA), effective power equal 47.14 and 45.76 KW for diesel and biodiesel fuel respectively. While effective torque equal 387.6 and 382.06 N/M for diesel and biodiesel fuel respectively.
- With retarded duration of injection, break-specific fuel usage rises. Where BSFC equal 256 and 267.5 g/kW.h at (-2 CA) for diesel and biodiesel fuel respectively.
- The excess air proportion gets smaller as the duration of injection gets longer. Where 1.37 AND 1.498 at (-2 CA) for diesel and biodiesel fuel respectively.
- As the duration of injection increases, the ultimate fire pressure and ultimate fire Temp decrease. Where ultimate fire pressure equal 53.6 and 54.08 bar while ultimate fire Temp equal 2150 and 2094 k at (-2 CA) for diesel and biodiesel fuel respectively.
- Soot emission rises as the duration of injection is rated where soot regarded 0.19 and 0.24 g/kW.h at (-2 CA) for diesel and biodiesel fuel respectively.
- Once diesel fuel is utilized in CI engines with the same duration of injection as biodiesel combinations, the least amount of nitrogen oxide emissions is produced. where NOx emissions regarded 3.5 and 3.64 g/kW.h at (-2 CA) for diesel and biodiesel fuel respectively.

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