Experimental Investigation of Effect of Injections Parameters on Stationary Diesel Engine Fuel with the Methyl Ester of Waste Vegetable Oil

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Abstract

The research experimental work is undergone to find the substitute fuel for diesel to run the compression ignition (CI) engine at a higher performance with lower emission. The injection parameters of the engine like Injection Timing (IT) and Injection Opening Pressure (IOP) show a significant role in produce power and emission from the CI engines. This work mainly concentrates on finding out the effect of injection timings (17°, 19°, 21°, 23°, and 25° bTDC) and injection opening pressures (200, 220, and 240 bar) on engine characteristics by using methyl ester of waste vegetable oil 20% in volume blend with diesel 80% in volume. The experimental results show a improvement of marginal in the brake of thermal efficiency (BTE) and decrease in emissions at an IT of 19° bTDC and IOP of 220 bar. The NOx emission reduced by the retarded IT of 17° bTDC is 41.8% as compared with the diesel at standard IT. Hence these experimental results reveal that implementing the retarded IT with higher IOP achieves improved performance and lowered emissions.

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Keywords: Injection Timing, Injection Opening Pressure, Combustion characteristics, emission characteristics, Performance Characteristics, Compression Ignition Engine.

1 Introduction

The global energy demand, depletion of petroleum reserves, uncertainty supplies, escalation price of petroleum products, and emission regulations about environmental concerns have made it inevitable to find specific fuel to compress the ignition of engine, and are also sustainable in nature. The search for sustainable and clean energy resources have increased to unstable energy prices and environmental pollution. Primary and secondary biofuels are the main two classifications of biofuels. From the waste of animals, plants, crop residue, the fuels produced from them are called biofuels. Many researchers experimentally evaluated and concluded that biodiesel is the potential alternative fuel being considered for use in CI engines. Many advantages of biodiesel will influence to run the CI engines by replacing the diesel fuel. There are a few disadvantages associated with biodiesel like more viscosity, inferior heating value, and higher cetane number. The more viscosity of biodiesel shows resistance to flow through the fuel injector, this leads to less amount of biodiesel infuse into the combustion space. The quantity of biodiesel fuels infuse into the chamber combustion varies concerning the injection timing of CI engine. During advance IT of CI engine surplus amount of fuel infuse into the chamber combustion and produces more emissions due to the incomplete combustion of every air and fuel mixture. The retarded IT of CI engine results in lower fuel consumption and also a reduction in emission by achieving higher brake of thermal efficiencies. The IOPs plays an important role during the spray propagation of the air and fuel mixtures into the chamber of combustion through the injector nozzle. Proper atomization of the air-fuel mixture takes place at higher IOPs when matched with standard IOP, an additional increase in IOP may reason for improper propagation of air-fuel mixture. The many waste feedstock’s like dairy scum oil [1][2], chicken waste oil [3], fish fat oil [4], etc. are used to prepare biodiesel through the convenient method called transesterification. The biodiesel blends like B10 (10% biodiesel + 90 % pure diesel), B20, and B30 are prepared by adding an appropriate amount of pure diesel. These biodiesel blends are allowed to run the CI engine and results confirm that biodiesel of B10 and B20 blends shows performance results match with diesel performance values [2].
2 Related Works

The biodiesel produced may be utilized in its purified form or else could also be used in blend form upon varying the proportion of diesel as blends in compression ignition (CI) engines. The harmful engine emissions Carbon dioxide (CO2) and hydrocarbon (HC) can be significantly decreased [5]. However, the sample with blend 20 (v/v %) of biodiesel (B20) was found to be best as it shows favorable results in combustion, emission and performance characteristics amongst several other blend samples [6]. Many research work portraits that biodiesel B20 blend considered as fuel sample to evaluate CI engines responses by changing the time of injection and pressure opening of injections. The variation of IT in CI engine during the experimentation by 3° CA [7] [8] [9], 4° CA [10] [11], and 5° CA [12] from standard IT. The IOP also varied by10 bar [10] [13] and 20 bar [6] from standard IOP. The variation of injection parameters reveals that, retarded IT of biodiesel achieves an improved BTE compared to pure diesel [6], at the same time retarded IT achieves 40% lower nitrogen oxides, 25% lower in CO, and 30% lower in HC emissions compare to pure diesel nitrogen oxides emissions [14]. The Advance IT achieves higher nitrogen oxide emissions [15]. The variation of IOP up to some limit output in achieving the enhanced BTE and reduction in CO and HC emission [16], further increase in IOP results in reduced BTE due to incomplete combustion [17] [18].

From the literature survey, it is observed that B20 of biodiesel shows good performance among all the other blends. Many researchers have carried out the work on injection timing alone for different biodiesel whereas no significant works have been done on injection time and injection opening pressure together. With this novel conception this research work purpose on a complete study of the combustion, emission, and performance characteristic of methyl ester of unwanted vegetable oil B20 (MEWVO-B20). The experiment carried out by considering the effect of injection timing (17°, 19°, 21°, 23°, and 25° bTDC) and injections opening pressures (200, 220, and 240 bar) simultaneously.

3 Materials and Methods

Collected waste vegetable oil (WVO) from the local hotels in Bangalore city, India. The taken oil is subjected to a filter through a 10-micron filter paper to separate any solid particles in it. Transesterification is a process which converts any free fatty oil into biodiesel with the help of alcohol reactant and catalyst. The reagents (research-grade) such as methanol and Sodium Hydroxide (NaOH) is taken from the market. Here methanol acts as a reactant with WVO and NaOH acts as a catalyst to speed up the Transesterification. The prepared pure biodiesel is called methyl ester of waste vegetable oil (MEWVO). Biodiesel blends are prepared by adding an
appropriate amount of pure diesel and MEWVO. From the previous literature [2], B20 of biodiesel blend achieved good results among the different biodiesel blends. The MEWVO-B20 (MEWVO 20% + Pure Diesel 80%) was considered to run the CI engine on speed of 1500 rpm which is constant and compress ratio is 17.5:1. This research work concentrates on improvising the performance of the CI engine by considering its modification such as injection timings and injection opening pressures. The test data were documented at a steady state of the engine at different injection timings of 17°, 19°, 21°, 23°, and 25° bTDC. Further experiments are carried out by using the best time of injection and opening pressure of injection such as 200, 220, 240 bar. The optimization of injection timing and injection opening pressure was carried out through experimental results.

3.1 Biodiesel Preparation

Table 1. The Properties of test fuel

<table>
<thead>
<tr>
<th>Fuel Property</th>
<th>Waste Vegetable Oil</th>
<th>Diesel</th>
<th>MEWVO-B20</th>
<th>Test method</th>
<th>Test limit ASTM D6751-15C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>0.886</td>
<td>0.830</td>
<td>0.841</td>
<td>ASTM D891</td>
<td>0.87-0.89</td>
</tr>
<tr>
<td>Viscosity during 40°C (cst)</td>
<td>3.72</td>
<td>2.9</td>
<td>3.06</td>
<td>ASTM D445</td>
<td>1.9-6.0</td>
</tr>
<tr>
<td>Flash Points (°C)</td>
<td>204</td>
<td>52</td>
<td>120</td>
<td>ASTM D93</td>
<td>Min.93</td>
</tr>
<tr>
<td>Calorific Value (kJ/kg)</td>
<td>36057</td>
<td>42500</td>
<td>41211</td>
<td>EN 14214</td>
<td>Min.35000</td>
</tr>
<tr>
<td>Cetane Number</td>
<td>64</td>
<td>49</td>
<td>55</td>
<td>-</td>
<td>48-65</td>
</tr>
<tr>
<td>Cloud point (°C)</td>
<td>17</td>
<td>2</td>
<td>9</td>
<td>ASTM D2500-11</td>
<td>-13 to 12</td>
</tr>
<tr>
<td>Acid value (mgNaOH/g)</td>
<td>16</td>
<td>-</td>
<td>0.4</td>
<td>ASTM D1980-87</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Biodiesel was prepared using a single-stage transesterification process. Initially prepare a methoxide mixture using 300 ml of methanol and 5 grams of NaOH. The waste vegetable oil of 1000 ml collected and heated at 60° C in 3 necks round bottom flask. Methoxide mixture transfer into the round bottom flask and stir the whole mixture for 2 hours using magnetic stirrer also maintain the temperature of the mixture at 60° C. The mixture is shifted to separate funnels and which are allowed to settled down for about 2 hours. The resulted mixture bifurcates two phases, lighter methyl ester followed by
denser glycerol later settled at the bottom. With the help of separating funnel remove all bottom glycerol layers in a beaker. The left layer in the separating funnel comprising MEWVO was treated to hot water to separate undissolved methanol and NaOH. The MEWVO obtained was dried to get pure biodiesel. The fuel properties of biodiesel obtained are explained in the Table 1.

### 3.2 Experimental Setup

The layout and the detailed specification of the diesel engines setup is shown in Figure 1 and Table 2. The engines is fitted with essential instruments required to fulfill the experimentation. Each integral part of the experimental setup is computerized to evaluate the engine characteristics, such as pressure-volume and pressure-crank angle (CA) graphs, temperatures, airflow, fuel flow, and load. To evaluate performance parameters a CI engine was selected. The engine is accommodated with an eddy current type of dynamometer comprising of loaded cell of strained gauge to quantify load. The U-tube manometer and burette are utilized to calculate the rate of air flow and flow rate of fuel. The “Engine soft” engine characteristics examination software was used to record cylinder pressure. The analyzer consists of an ADC with sixteen ports computer interface. The piezoelectric transducer is used to measure inline-cylinder pressure. The injection time is varied by adding and deleting the shims, these crank angle signals encoded and are transferred into a computer to get the required engine characteristics. The injection opening pressure can be changed by replacing the corresponding fuel injectors.

The AVL 437C smoke meter and AVL DIGAS 444 N gas analyzers were helped to record the opaqueness and basic harmful emissions of exhaust gas under steady-state situations. Table 2 describes the specification of test engine utilized for the experimentation and Table 3 indicates the accuracies and uncertainty of measured and calculated parameters of the engine, exhausted gas analyzer, and smoker meter used in the experimentation. All the experimental values considered for the study were recorded for an average of 3 trials. The evaluation is carried out at engine speed of 1500 rpm which is constant and a 17.5:1 compression ratio. The test data were documented at a steady state of the engine at different injection timings of 17°, 19°, 21°, 23°, and 25° bTDC. Further experiments are carried out by the best injections timing and injection openings pressures of 200, 220, 240 bar.
Table 2. Specification of the Engine Test System

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine company, Model</td>
<td>Kirloskar, Model TV1</td>
</tr>
<tr>
<td>Cylinder</td>
<td>Single cylinder</td>
</tr>
<tr>
<td>Number of Strokes</td>
<td>4 strokes</td>
</tr>
<tr>
<td>Dynamometer</td>
<td>Eddy current type with water cool</td>
</tr>
<tr>
<td>Power</td>
<td>5.2 kW at 1500 rpm</td>
</tr>
<tr>
<td>Bore</td>
<td>87.5 mm</td>
</tr>
<tr>
<td>Strokes</td>
<td>110 mm</td>
</tr>
<tr>
<td>Displacement</td>
<td>661 cc</td>
</tr>
<tr>
<td>Ratio of Compression</td>
<td>17.5:1</td>
</tr>
</tbody>
</table>

Table 3. Accuracy and uncertainty measures and estimated parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Accuracy</th>
<th>Uncertainty (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoke Opacity</td>
<td>± 1% of a full scale</td>
<td>± 0.5</td>
</tr>
<tr>
<td>CO</td>
<td>0.0001 % Vol</td>
<td>± 0.03</td>
</tr>
<tr>
<td>HC</td>
<td>± 1 ppmVol</td>
<td>± 1.3</td>
</tr>
<tr>
<td>NOx</td>
<td>± 1 ppm</td>
<td>± 0.05</td>
</tr>
<tr>
<td>Time</td>
<td>± 0.2 Seconds</td>
<td>± 1</td>
</tr>
<tr>
<td>Flow</td>
<td>± 0.2 CC</td>
<td>± 0.75</td>
</tr>
<tr>
<td>Load</td>
<td>± 0.1 kg</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Temperature</td>
<td>± 1º C</td>
<td>± 0.2</td>
</tr>
<tr>
<td>Speed</td>
<td>± 30 rpm</td>
<td>± 1.9</td>
</tr>
<tr>
<td>Calculated parameters</td>
<td>-</td>
<td>Uncertainty (%)</td>
</tr>
<tr>
<td>BSFC</td>
<td>--</td>
<td>± 1.7</td>
</tr>
<tr>
<td>BTE</td>
<td>--</td>
<td>± 1.8</td>
</tr>
<tr>
<td>HRR</td>
<td>--</td>
<td>± 0.15</td>
</tr>
</tbody>
</table>
The experimental study was conducted for finding the characteristics of engine (combustion, emissions, and performance) by considering various injection timing of fuel and injection opening pressures of fuel. Initially, baseline data were recorded by running the engine at standard IT (23° bTDC) and IOP was 200 bar, this standard IT and IOP are well-defined by the engine manufacturer. The MEWVO-B20 is considered as a fuel to run the diesel engines and record the engine characteristics data via keeping constant engine speed (1500rpm), constant compression ratio (17.5:1), varying ITs (17°, 19°, 21°, 23°, and 25° bTDC) and varying the IOPs (200, 220, and 240 bar) to all loads (from 0 to 100%). The pure diesel and MEWVO-B20 test results are compared and discussed as follows.

4.1 Brake Thermal Efficiency

The BTE shows where and how better the engine will transfers the heat from the fuel into mechanical works. Figure 2 depicts the BTE for load from 0% to 100% for the pure diesel and different injection parameters of MEWVO-B20. The BTE of diesel, MEWVO-B20 fuel at CA 17°, 19°, 21°, 23°, and 25° bTDC at a full load and constant IOP (200bar) are 34.33%, 31.1%, 32.3%, 30.8%, 30.5%, and 29.87% respectively. Figure 2 shows that retardation IT increases the BTE of MEWVO-B20 up to CA of 19° bTDC. Further retardation or advance in IT achieves lower BTE. At the retardation of IT, the quick start of combustion takes place and prolongs the power stroke to attain higher efficiency [19]. Further retardation of injection timing cause lesser quantity of fuels to infuse among the chamber of combustion, this leads to improper combustion as well as attainment of less BTE [8] [9]. Advanced IT causes more fuel injections to the chamber of combustion before actual IT, this leads to the collection of surplus fuel and prior increase in pressure before the piston reaches TDC, so incomplete combustion takes place [13]. The higher BTE among different ITs of MEWVO-B20 is observed to be 32.33%, which is a 5% lower BTE of pure diesel. Therefore optimum IT (19° bTDC) consider for further study on the effect of IOPs (200bar, 220bar, and 240bar) on BTE. Figure 2 shows amongst all IOPs experimented the highest BTE (32.93%) is achieved at 220 bar for optimized IT 19° bTDC, which is 4% lower in BTE of pure diesel. This is because higher IOPs result in good atomization of the fuel with air and spray characteristics that influence the improvement in combustion. Further increase in IOP of 240 bar will lead to achieving lower BTE. In observation of all these, the experiment result showed that the BTE is achieved better with IT of 190 bTDC and IOP of 220bar.
4.2 Brake Specific Fuel Consumption

The deviation of Brake Specific Fuel Consumption (BSFC) with the load for every sample of fuel is portrayed in the Figure 3. From the graph, it shows that when the load gets increased BSFC decreased, due to the lower loads there is a rich mixture and incomplete combustion, but this will be enough to achieve the required power. Whereas at higher loads the mixture becomes lean and combustion is complete this ensures that the required power is achieved. At a full load, thermal efficiency will be higher, cylinder wall temperature reaches combustion temperature that will be helpful to burn all particles completely [20]. From Figure 3, it is evident that fossil diesel exhibits lesser BSFC compared to MESO-B20 blend for different ITs, due to the lesser value of heating like MESO-B20 which blended comparing to pure diesels [21] [22] [23]. Therefore, excessive biodiesel has to introduced to the chamber of combustion to achieve power output the same as that of fossil diesel [17] [24]. For full load conditions, the diesel shows lower BSFC is 0.25 kg/kWh at IT of 23° bTDC and MESO B20 fuel BSFC at IT of 17°, 19°, 21°, 23° and 25° bTDC are 0.3, 0.28, 0.31, 0.32, and 0.33 kg/kWh sequentially.
Figure 3. The effect of Injection Parameters on BSFC.

The retarding of IT leads to a reduction in fuel infuse into the combustion chamber, thereby reducing fuel consumption [15]. Fuel consumption will be more in advancing the IT in an engine, by all these observations for fuel MEWVO-B20 at IT of 19° bTDC recorded the lowest specific fuel consumption among the different ITs, a further experimental investigation is performed on optimized IT (19° bTDC) for the fuel MEWVO-B20 by varying IOPs (200, 220, and 240bar). The results show BSFC reduces with the increase in IOPs up to 220 bar, because of better atomization and good propagation of air-fuel mixture into the combustion chamber. At higher IOP the larger area of the fuel droplets exposes to the higher temperature of air to cause good combustion of fuel. Further increase in IOP leads to incomplete combustion due to more fuel infuse into the combustion chamber [25]. All these discussions concluded that the MEWVO-B20 achieved lower BSFC at IT of 19° bTDC and IOP of 220bar is 0.27 kg/kWh and this is 7% more BSFC compared to diesel at standard injection parameters.

4.3 Carbon Monoxide

The incombustible product of the air-fuel mixture induces more Carbon monoxide (CO) emission, further lower cylinder temperatures will cause a cooling impact and leads to incomplete result of combustion for the formation of CO emissions. The extent of CO emission decreases along with
the engine load and achieves maximum at a full load [26]. Figure 4. revealed the effects of injections parameters on CO emission. For larger load condition, the emission of CO diesel at 23° bTDC and 200 bar is 0.142 %. The CO emission of MEWVO-B20 at constant IOP of 200 bar for an IT of 17°, 19°, 21°, 23°, and 25° bTDC are 0.13%, 0.133%, 0.182%, 0.234%, and 0.241 % respectively. During the retarded timing of fuel injection, the pressure and temperature of air present in the combustion chamber are high, this enhances the complete combustion of the air-fuel mixture. The presence of more amount of oxygen in the biodiesel leads to the process of oxidation among the molecules of carbon and oxygen thus reduce the formation of CO during the combustion. At advanced IT surplus fuel amount is involved in the process of combustion, which leaded to lower oxidation of carbon particles and an increase in CO emissions [27]. A decrease of 8.5% lower CO emission was achieved by 19° bTDC of MEWVO-B20 compared to diesel at standard injection parameters. This optimized IT of 19° bTDC allowed for analyzing the effect of IOPs. Figure 4 shows a decrease in CO emission along with an increase in IOPs. Due to the good fuel air mixture and the combustion of complete smaller droplets under higher fuel injection pressures [28]. At larger load emission of CO is MEWVO-B20 for 200, 220, and 240bar are 0.133%, 0.127%, and 0.121% respectively. The IOP of 240bar shows very less emission of CO, which is 14% less than diesel fuel at standard injection parameters.

![Figure 4. The Effect of Injection Parameters on Carbon monoxide](image)

**4.4 Hydrocarbon**

The unburned hydrocarbon (HC) molecules present in the fuel evaporates through exhaust gases during the combustion. Figure 5 portrays the influence of injection parameters for HC discharge of MEWVO-B20. The
HC emission increases by a rise in load and maximum at a full load. The lean mixture establishment of fuel throughout the delay period causes the HC emission, and also fuel departure with a lower velocity at the fuel injector nozzle [10]. The graph reveals that the engine fueled with MEWVO-B20, HC emissions are more than diesel fuel. The HC emission for diesel fuel, MEWVO-B20 fuel at IT of 17°, 19°, 21°, 23°, and 25° bTDC at a full load is 39 ppm, 40 ppm, 43 ppm, 49 ppm, 57 ppm, and 64 ppm respectively. The results show that the HC emission decreases with retarded IT and the trend is reversed for advance IT. Due to complete fuel combustion with air and the availability of oxygen content in the MEWVO-B20. The graph also revealed that, the effect of IOPs (200, 220, and 240 bar) on the HC emission. HC emission getting reduces while increasing the fuel IOPs along with IT of 19° bTDC. The higher IOPs caused the good air and fuel mixing for the combustion of chamber [29]. Minimum HC emission for MEWVO-B20 fuel achieved at 19° bTDC and 240 bar is 38 ppm, which is 2.5% less than the diesel fuel at standard injection parameters.

Figure 5: Effect of Injection Parameters on Hydro Carbon

4.5 Smoke Opacity

Smoke is a consequence of incomplete or improper combustion caused by a rich air and fuel ratio also the unavailability of oxygen contents. The opacity of Smoke values were found more for MEWVO-B20 by comparing with the diesel, it is because of the heavier molecular structure, larger viscosity, and lesser atomization which further leads to incomplete combustions [30]. The effects of injection parameters on release of smoke
for the MEWVO-B20 and diesel fuels are as shown in Figure 6. The release of smoke for diesel fuel, MEWVO-B20 fuel at ITs of 17º, 19º, 21º, 23º, and 25º bTDC at a full load are 67.2 HSU, 66.7 HSU, 69.7 HSU, 72.2 HSU, 73.2 HSU, and 75.6 HSU respectively. The graph revealed that retardation of IT influence on achieving the lower smoke level, due to the good ignition of the fuel and air mixtures [31]. Increasing the IOP from 200bar to 240bar at a step of 20bar for 19º bTDC IT shows a decrease in smoke formation because of the complete combustion of air and fuel mixtures [32]. The least smoke formation occurred at 17º bTDC and 200 bar is 66.7 HSU. which is 1% less than the diesel fuel smoke formation.

![Figure 6: Effect of Injection Parameters on Smoke Opacity](image)

### 4.6 Nitrogen Oxide

NOx emissions are consisting of Nitrous Oxide (NO) and Nitrogen Dioxide (NO2) from the exhausted gas engines. The formation of NOx is directed by exhaust gas temperature, rate of gas temperature, and oxygen molecules in the fuel. NOx emission curves are lower for which injection timings achieved a lower EGT and vice versa [19]. The retarded IT shows effective decrease in the NOx emission due to the non-availability of the required amount of EGT due to slow combustion [10] [13] [15]. Lower exhaust gas temperature will not promote a chemical reaction to form NOx.
On the other hand, advance IT showed an increase in the emission of NOx because of the availability of sufficient exhaust gas temperature for NOx emission formation [15] [18] [20]. From Figure 7, it can be noticed that NOx emission for diesel fuel, MEWVO-B20 fuel at 17º, 19º, 21º, 23º, and 25º bTDC at a full load are 1474 ppm, 858 ppm, 1032 ppm, 1228 ppm, 1424 ppm, and 1535 ppm respectively. The least NOx emission for MEWVO-B20 fuel achieved at 17º bTDC is 858 ppm. Which is 41.8 % less NOx emission compared to diesel. The effect of an increase in IOPs on NOx as shown in figure 7. NOx emission increased with the increase in IOPs because of the faster burning and higher temperature [32].

![Figure 7. Effect of Injection Parameters Nitrogen Oxides (ppm)](image)

**4.7 Cylinder Pressure**

The cylinder pressures represents the pressure of cylinder chamber at the time of engine operations, also this pressure represents the blending of fuel in air during combustion. The pressure of cylinder curves of MEWVO-B20 are considerably effected by the change in injection parameters as shown in Figure 8. The change in pressure of cylinder depends upon the quantity of fuel involved in combustion process during the delay period. Cylinder pressure also reveals combustion behavior like rapid combustion and uncontrolled combustion phase [33]. Peak cylinder pressure for diesel at 23º
bTDC is 72.24 bar at a full load condition. Peak cylinder pressure for MEWVO-B20 fuel at 17°, 19°, 21°, 23°, and 25° bTDC are 44.21 bar, 54.32 bar, 62.67 bar, 68.59, and 71.35 bar respectively at a full load condition. It is observed from the peak cylinder pressure values, the advance IT achieved greater peak cylinder pressure than the retard IT, this is due to more fuel collected during the delay period and leads to uncontrolled combustion in advance IT [34]. The MESO B20 fuel at a standard injection timing shows a lower peak cylinder pressure because of less volatility and higher density compare with diesel fuel [33]. During the controlled combustion the MEWVO-B20 fuel achieved considerably peak cylinder pressure at 19° bTDC. The peak cylinder pressures for MEWVO-B20 at 200, 220, and 240 bar at IT of 19° bTDC are 54.32 bar, 56.98 bar, and 59.29 bar respectively. Figure 8 evident that, the pressure of cylinder increases when the IOP increase up to 220 bar from 200 bar at IT 19° bTDC, further increase in IOP by 240 bar observed reverse trend. Due to the increase in HRR, the larger injected fuel and ratio of A/F ratio go to condition of stoichiometric [28].

Figure 8. Effect of Injection Parameters on Cylinder Pressure at 100% Load

4.8 Heat Release Rate

HRR is the rate that releases the fire energy. The HRR depends on the rate of air and fuel mixing, ignition delay, and calorific values of fuel [19]. Figure 9 depicts the effects of injections parameters on HRR. The HRR
gradually increased with advance IT at heavy loads. It is noticed that at retard IT the peaks HRR of MEWVO-B20 is marginally lesser than the diesels. The higher value of HRR for diesel at 23° bTDC is 46.44 J/degree. The peak value of HRR for MEWVO-B20 at 17°, 19°, 21°, 23°, and 25° bTDC are 30.75, 34.63, 36.1, 38.28, and 40.97 J/degree respectively. In the premixed combustion stage for advanced IT HRR is more than standard and retard IT, due to in delay period additional air-fuel mixture accumulation takes place. In retard injection timing heat release rate will be decreases [10] [15]. The extreme HRR for diesel fuel is more than MEWVO-B20 at a standard injection timing, this is because of proper air-fuel mixing [34]. The higher values of HRR for MEWVO-B20 at 200, 220, and 240 bar at an IT of 19° bTDC are 34.63 J/degree, 37.98 J/degree, and 37.61 J/degree respectively. Figure 9 also remarked that as IOP increases the peak HRR also increases. The reason behind increases in the peak HRR is that at higher IOP cause to increase of fuel injection rate because of goodvolume efficiency and atomization rates of MEWVO-B20 blending takes place [35].

![Figure 9](image)

**Figure 9.** Effect of Injection Parameters on Heat Release Rate at 100% Load

### 5 Conclusions

In this work, an experimental investigation was made on CI engine where the operating fuels are MEWVO-B20 and pure diesel. The injection parameters like fuel injection timings (17°, 19°, 21°, 23°, and 25° bTDC) and
fuel injection pressures openings (200, 220, and 240 bar) are taken to run CI engine. The results obtained for the MEWVO-B20 are compared with baseline data obtained from pure diesel and the following highlights are concluded.

(a) The BTE of diesel fuel at standard IT and IOP is 34.33% at full load. The highest BTE of MEWVO-B20 fuel at different ITs is 19° bTDC (32.33%), at different IOP is 220 bar (32.93%). The modified injection parameters for MEWVO-B20 results in 4% less in BTE compare to diesel.

(b) The lowest BSFC of MEWVO-B20 fuel at different ITs is 19° bTDC (0.28 kg/kW-h), at different IOP is 220 bar (0.27 kg/kW-h). The modified injection parameters for MEWVO-B20 consumes 8% more in fuel consumption compared to diesel.

(c) The injection parameters (19° bTDC and 240 bar) achieved lower carbon monoxide and hydrocarbon emissions are 14% and 2.5% respectively when compared with diesel.

(d) The MEWVO-B20 achieved the least emission of NOx at retarded IT (17° bTDC) is 41.8% compared to diesel.

(e) The highest pressure of cylinder and release of heat rate achieved of MEWVO-B20 during advanced timing of injection(25° bTDC). The standard injection opening pressures (200bar) is 71.35 bar and 40.97 J/degree, which are 1.2% and 11.8% less than diesel pressure of cylinder and released heat rate respectively.

Based on the combustion, emission, and performance characteristic the MEWVO-B20 is suitable substitute for the diesel in the vehicles of automotive. Where retarded timings of injection and higher injection opening pressures achieved higher brake and thermal efficiency with lower emissions, especially lower in the emission of NOx by 40% as compared with the diesel.

References


S.V. Khandal, N.R. Banapurmath, V.N. Gaitonde, “Different Injection Strategies to Enhance the Performance of Diesel Engine Powered with


Experimental Investigations of Effects of Injection Parameters on Stationary Diesel Engine Fuel with the Methyl Ester of Waste Vegetable Oil 12213


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