EFFECT OF INJECTION TIMING ON PERFORMANCE, COMBUSTION AND EMISSION CHARACTERISTICS OF DIESEL ENGINE USING CANOLA OIL AS FUEL

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ABSTRACT

Due to the increasing demand for fossil fuels and environmental threat, a number of renewable sources of energy has been studied worldwide. An attempt is made to assess the suitability of vegetable oil for diesel engine operation. In Diesel engines quality of combustion is depending on the formation fuel-air mixture. A high-quality of formation for combustion is achieved by addition of pulverized fuel drops and the air inside the cylinder. In this issue, injection parameters such as timing and period of injection, injection pressure and the number of the injection beams affect quality of combustion and mixture formation. The present paper is focused on the effect of injection timing on performance, combustion and emission characteristics of canola biodiesel and its blends with pure diesel on a 4 stroke direct injection diesel engine without any modification in the existing experimental setup. Standard injection pressure (220 bar) is maintained during the experiment. Injection timings (21°, 24° and 27° bTDC) were considered under steady state conditions at maximum load condition of the engine. The effect of varying injection timing was evaluated in terms of thermal efficiency, specific fuel consumption, carbon monoxide, hydrocarbons and oxides of nitrogen were presented graphically and concluded that the advanced injection timing increases the brake thermal efficiency and reduces unburned hydrocarbon and Nox emissions significantly.

KEYWORDS: Diesel Engine, Injection Timing, Canola Oil, Performance, Emission, Combustion Characteristics

INTRODUCTION

Non-edible vegetable oils are chosen for engine applications in India. Use of bio fuels (such as biodiesel) as an alternative to diesel might reduce the dependency on petroleum products and the pollution intensity, since it is renewable and can be derived from plant species. The engine performance depends on some factors like fuel properties, the combustion chamber geometry and the injection parameters like injector opening pressure (IOP), fuel injection timing (FIT), etc. Variation of FIT results in deviation in air temperature and pressure at the time of fuel injection, the delay period, fuel evaporation rate, rate of combustion etc., affecting engine performance, combustion and emission characteristics. For a diesel engine, fuel injection timing is a main consideration that affects the performance and exhaust emissions. The condition of air into which the fuel injected changes as the injection timing is varied, and thus ignition delay will vary. If injection starts prior, the initial air temperature and pressure will be lower, so that the ignition delay will increase. If injection starts later (when piston is closer to TDC), the temperature and pressure will be slightly higher, a decrease in ignition delay will proceed. Hence, injection timing variation has a strong effect on the engine performance and exhaust emissions, particularly on the brake specific fuel consumption (Bsfc), brake thermal efficiency (BTE) and NOx emissions, because of altering maximum pressure and temperature in the cylinder [1][2].
Clark et al[3] concluded that soybean biodiesel gives higher specific fuel consumption and lesser emissions excluding NOx than diesel. Kyle et al [4] found that as compared to diesel fuel, soybean methyl ester gives lower emissions of CO, HC, smoke density and NOx. Puhan et al [5] observed considerable enhancement in engine performance and emission of DI engine with mahua oil methyl ester (MOME), mahua oil methyl ester, mahua oil methyl ester and diesel fuel. Subramanian et al [6 ]completed that 10% diesel, 80% of pongamia oil methyl ester and 10% ethanol gives better performance of diesel engine without any modification. Puhan et al[7] concluded that MOME gives better results as compared with ethyl ester of mahua oil. Puhan & Nagarajan[8] found that MOME gives lowest NOx as compared with diesel fuel. K Muralidharan and P Govindrajan, [9] investigated the effect of injection timing on performance and emissions characteristics of a single cylinder direct injection diesel engine fuelled by means of pongamia pinnata methyl ester. The tests were conducted at three different injection timings (19°, 23° and 27° btdc). The experimental work reveled that at advanced timing of 27° btcd the engine performance was better than standard timing of 23° btcd with considerable reduction in emissions of HC and CO at all loading conditions. Retardation of injection timing indicated developed over NOx and CO2 emissions for blend B10 over entire range of engine operation. Most investigate works were reported on the performance and emission experiment of diesel engine employing pongamia biodiesel as fuel in different proportions without any engine modifications and reported that smoke, HC, CO emissions were found to be lower with higher BTE for B10, B20 and B40 biodiesel blends [10] - [14]. on the other hand in almost all the literature it was reported that NOx emission was higher for biodiesel than diesel due to higher oxygen content of the fuel [11] – [14]. However, to improve the performance of the engine researchers also employ engine modifications such as modification in fuel injection timing, injection pressure, nozzle specification. Lot of work had been done on modification of injection timing for straight vegetable oils and other fuels, few work has been reported for biodiesel [15] – [20]. This study analyses injection timings (IT) of 21°, 24° and 27° bTDC and injection pressure of 220 bar at maximum load of diesel engine with canola biodiesel (B0, B20, B40, B60 and B100) as fuel.

MATERIALS AND METHODS

Preparation of Biodiesel

Canola oil was converted into its methyl ester by the transesterification process. This involves making the triglycerides of Canola oil to react with methyl alcohol in the presence of a NaOH catalyst to produce glycerol and fatty acid ester. Transesterification is a process of producing a reaction of triglyceride and alcohol in presence of catalyst to produce glycerol and ester. Molecular weight of a typical ester molecule is roughly one third that of typical oil molecule and therefore has a lower viscosity [21]. Methanol is extensively used because of its low cost and its physicochemical advantages with triglycerides and alkalis are easily dissolved in it.

Alkali catalyzed transesterification is faster than acid catalyzed transesterification and is most often used commercially. Specified amount (800ml) of Canola oil (200 ml) methanol and (1.5 g) sodium hydroxide were taken in a round bottom flask. The contents were stirred till ester formation began and the mixture was heated to 70°c. Then it was allowed to cool overnight without stirring. Two layers are formed. The bottom layer consists of glycerol and top layer was the ester.

Experimental Setup and Procedure

The performance tests for the stable Diesel-biodiesel are carried out on a computerized single cylinder four stroke direct injection variable compression ratio engine. The Table shows the specification of the engine. No modification or alteration has been made in the engine. The experimental setup consists of a variable compression ratio engine is coupled
to an eddy current dynamometer. The specification of the engine is shown in Table 1. A computerized data acquisition system is used to collect, store and analyze the data during the engine testing. A Kistler piezoelectric pressure transducer and a crank angle encoder is used to measure the in-cylinder gas pressure and the corresponding crank angle. The load applied on the engine is measured by the load cell connected to the eddy current dynamometer. A burette with two infrared optical sensors measures the fuel flow rate, an air flow sensor measure the inlet air flow rate, K type thermocouples measure the inlet air and exhaust gas temperatures. AVL DIGAS analyzer is used to measure the exhaust gas constituents such as CO, HC, NO and the smoke is measured using the AVL smoke meter. All the experiments are conducted at the compression ratio of 17.5 and the results are recorded under steady state conditions.

**Table 1: Specification of the Engine**

<table>
<thead>
<tr>
<th>Specification</th>
<th>3.7 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>1500 rpm</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>17.5 (Variable)</td>
</tr>
<tr>
<td>Bore</td>
<td>80 mm</td>
</tr>
<tr>
<td>Stroke</td>
<td>110 mm</td>
</tr>
<tr>
<td>Ignition</td>
<td>Compression ignition</td>
</tr>
<tr>
<td>Cooling</td>
<td>Water cooled</td>
</tr>
<tr>
<td>Loading System</td>
<td>Eddy current dynamometer</td>
</tr>
</tbody>
</table>

The fuels which have been used in this study are: Commercial diesel (D) and a blend of 20% biodiesel (B20), 40% biodiesel (B40), 60% biodiesel (B60) and 100% biodiesel (B100). The main properties of the test fuels are given in Table 2.

**Table 2: Properties of Canola Biodiesel**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acidity as Mg Of KOH/Gm</td>
<td>0.01</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>886.5</td>
</tr>
<tr>
<td>Viscosity at 40 °C in cst</td>
<td>5.38</td>
</tr>
<tr>
<td>Gross calorific value (KJ/kg)</td>
<td>38758</td>
</tr>
<tr>
<td>Cetane number</td>
<td>48</td>
</tr>
<tr>
<td>Sulfur content (mg/L)</td>
<td>&lt; 50ppm</td>
</tr>
<tr>
<td>Flash point</td>
<td>172°C</td>
</tr>
<tr>
<td>Fire point</td>
<td>186°C</td>
</tr>
</tbody>
</table>

The experiments were performed at constant speed of 1500 rpm. The engine was loaded by eddy current dynamometer and the load was measured using a strain gauge. The fuel injection timings was set to 21°, 24° and 27° bTDC. Injection pressure was changed by means of adjusting the injector spring tension. The air consumption was measured with an air manometer surge tank set which has orifice diameter of 20 mm. A blend of 20% biodiesel and 80% diesel (by volume) is denoted by B20. The performance parameters, efficiency and brake specific fuel consumption (BSFC) are compared.

**RESULTS AND DISCUSSIONS**

**Performance Characteristics**

**Brake Thermal Efficiency (BTE)**

Thermal efficiency is the ratio between the power output and the energy introduced through fuel injection. The variation of brake thermal efficiency with load is given in Figure 1. It was found that there was 2.88% increase in brake thermal efficiency while injection timing was advanced to 27°CA bTDC but about 5.3% decrease whereas retarded
to 21°CA bTDC. This was also due to improved combustion when advancing the injection timing and poor combustion while retarding.

![BTE Vs Load](image1.png)

**Figure 1: Load Vs Brake Thermal Efficiency for Different Injection Timing of Biodiesel**

**Brake Specific Fuel Consumption**

Specific fuel consumption is the ratio between mass of fuel consumption and brake power. The variation of specific fuel consumption with load is given in Figure 2. It is clearly seen that SFC increased by 3.8% on advancing the injection timing to 27°CA bTDC while reduced by 3.7% on retarding to 21°CA bTDC from the original injection timing of 24° CA bTDC. Because of advancing the injection of fuel to 27°CA bTDC, complete combustion would have been taken place that results in less significant SFC. Whereas retarding the injection to 21°CA bTDC, combustion is incomplete that results in higher SFC.

![SFC Vs Load](image2.png)

**Figure 2: Load Vs Brake Specific Fuel Consumption for Different Injection Timing of Biodiesel**

**Exhaust Gas Temperature**

At maximum load condition, 21° bTDC of IT gives lowest EGT in case of B20 and B60 as compared to all other ITs and all blends (Figure 3). As compared with standard IT of 24° bTDC, reduction% of EGT for IT of 21° bTDC for fuels was found as follows; B20, 3.75; B40, 1.72; B60, 1.2; and B100, 4.46%. Among all blends, B60 gives lowest EGT, and B40 is also closer to that of B60. There is an increasing trend of EGT as increase in blend ratio of biodiesel with diesel fuel, could be due to increased heat losses of higher blends, which is also evident from their lower BTEs as compared with neat diesel.
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Emissions Characteristics

CO Emissions

IT (27° bTDC) gives lowest CO as compared to all other ITs for all blends of fuel (Figure 4). As compared with standard IT (24° bTDC), reduction% in CO for IT of 27° bTDC for fuels was found as follows: B20, 0.08; B40, 0.07; B60, 0.06; and B100, 0.05%. Among all blends, B100 gives highest reduction% of CO of 0.05% at maximum load, may be due to oxygen concentration and cetane number of blend. On advancement the fuel blend had sufficient time to undergo the combustion process whereas it had lesser time on retardation.

HC Emissions

From the Figure 5, it was found that HC emission also decreased by about 9% on advancing the injection timing to 27°CA bTDC but increased about 8.3% on retarding the fuel injection to 21°CA bTDC. Advancing the injection timing caused earlier start of combustion relative to TDC. Hence the cylinder charge had relatively higher temperatures and thus lowered the HC emissions.

NO Emissions

Figure 6 showed that as load improved from 0% to 100%, the NOx emission increased at different injection timings. This is due to as the load increased to the maximum value the fuel utilization with higher oxygen content also proportionately increased which lead to the higher NOx emission. It was also found that at each load the NOx emission
increased as the injection timing was advanced to 27° CA bTDC from the original injection timing of 24° CA bTDC whereas on retarded to 21° CA bTDC the NOx emission was reduced. Since:

- As the injection timing was advanced to 27° CA bTDC, mostly all the injected fuel is burnt before TDC. i.e during the progress of the compression stroke. Hence high peak temperature resulted which led to higher NOx emission.

- When the injection timing was retarded to 21° CA bTDC, only part of the fuel burnt before TDC and the remaining fuel burnt in early expansion stroke resulting in less peak temperature. Hence NOx emission lowered

![Figure 5: Load Vs Hydro Carbon Emission for Different Injection Timing of Biodiesel](image)

![Figure 6: Load Vs Nox Emission for Different Injection Timing of Biodiesel](image)

CONCLUSIONS

The effect of injection timing on engine performance, combustion and emission has been investigated carefully with advanced (27° bTDC), rated (24° bTDC) and retarded (21° bTDC) injection timing on diesel and canola blends and found to have very significant effect on all the parameters.

Under maximum load condition of engine, IT of 27° bTDC gives better performance, combustion and lower emissions when compared with standard IT of 24° bTDC. Of all blends tested at lower IT of 27° bTDC, B100 provides best results in terms of higher BTE, low emissions of HC, CO and NOx. Hence B100 can be effectively used as an alternative biodiesel with IT of 27° bTDC in tested engine.
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Nomenclature

- bTDC – Before Top Dead Centre
- CA - Crank Angle
- IT - Injection Timing
- CO - Carbon Monoxide
- NOx - Nitric Oxide
- HC - Hydrocarbons
- SFC - Specific fuel consumption
- BTE - Brake thermal efficiency
- D100 - Commercial Diesel
- B20 - 20% Canola Emulsion in Diesel
- B40 - 40% Canola Emulsion in Diesel
- B60 - 60% Canola Emulsion in Diesel
- B100 - 100% Canola Emulsion in Diesel
- EGT - Exhaust Gas Temperature

REFERENCES


