# Injection timing effect on the performance of diesel engine fueled with acid oil methyl ester

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**Abstract:** Acid oil which is extracted from vegetable oil refinery operation where acid oil is cheap and readily available in enormous quantities. Acid oil consists of less amount of mineral acids (2-3%) along with long chain free fatty acid mixture, phospholipids and free moisture (4-9%) thus makes the acid oil to dark brown in colour. In this paper, the main concentration is on emission, performance and combustion characteristics using diesel and acid oil methyl ester as fuel for single cylinder diesel engine. To estimate brake thermal efficiency, HC and CO emission and combustion duration, test was conducted at different injection timings of $19^0$,$23^0$,$27^0$ and $31^0$ BTDC, keeping constant injection pressure at 205 bar and rated speed of 1500 rev/min. For each and every load, fuel flow rate, air flow rate, exhaust gas temperature, $CO_2$, CO, HC, $NO_X$ and smoke emissions were recorded. Based on the readings with the specified condition, optimum injection timing was recorded for each of the fuel tested.

*Key Word:* Acid oil methyl ester (ACOME); Injection strategies; Performance; Emission characteristics.

## 1. Introduction

Various methods of using biodiesel in CI engine could be seen in literature [1-6]. The variation in brake thermal efficiency of compression ignition engine was reported by varying the injection timing. The relationship between the process parameters and the varied input characteristics was provided by the developed mathematical model.

When engine was fueled with biofuel, combustion parameters and emissions were recorded. It was reported that fuel burning starts early and showed shorter ID [2]. The properties of Acid oil methyl ester were well within the recommended biodiesel standard ASTM D6751 and it can be an alternate source for biodiesel production. Raw materials for the production of biodiesel were more than 360 oil bearing crops around the globe [4]. Degummed jatropha of 20% with diesel yielded better results at high loads when IT was at 45˚ BTDC. Shorter ID and high cylinder pressure were recorded with JOME and its emulsions with WPO. Smoke opacity decrease was also reported when emulsions with WPO was increased by comparing it with diesel at full load [5]. A review work on the research in last decade was highlighted in the literature to get clean and efficient combustion in CI engines [6]. It was concluded that the biodiesel types have no impact on peak cylinder pressure and BSFC.

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As per the literature review, it was reported that ACOME suitability for CI engine and the subsequent effect of different Injection timing and nozzle hole combinations on this biodiesel fueled engine was scarcely reported. Hence the present work aims to study the combustion, performance and emission characteristics of diesel engine powered with ACOME with different IT, IOP and nozzle hole combinations.

## 2. Materials and Methods

### *2.1. Experimental set-up and methodology*

The experiment was conducted on diesel engine to optimize injection timing at various conditions and injection timing of 190,230,270,310 BTDC with diesel and ACOME. Diesel engine was operated at compression ratio 17.5 with a hemispherical combustion chamber of 3 holes injection and orifice size of 0.3 mm under speed of 1500 rpm. Inside cylinder gas pressure was measured by the piezo electric transducer fitted to the cylinder head. After engine attaining the stable condition, the experimental readings were recorded. Water is circulated through the engine jacket and head of the cylinder to achieve the cooling effect. The beginning of fuel injection was obtained based on the static fuel ignition time. The below figure 2.1 depicts the experimental set up of diesel engine where hatridge smoke meter is used to measure the exhaust gas composition.

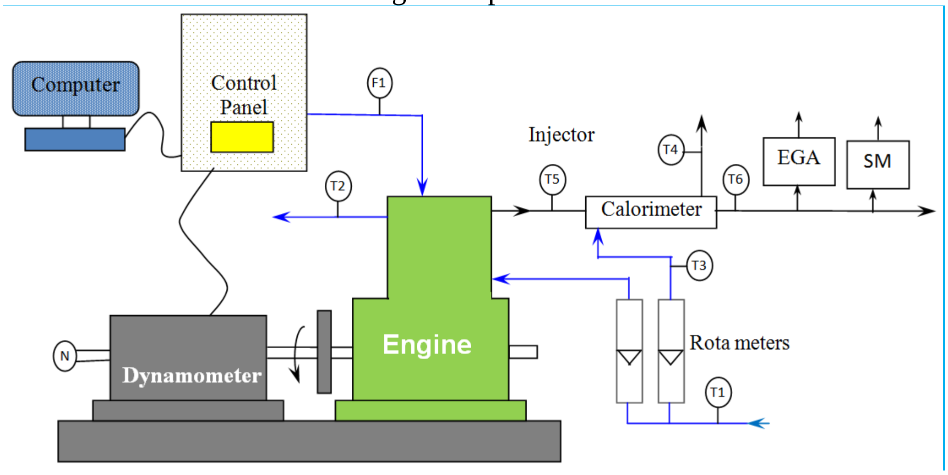


**Fig. 2.1 Experimental set up**

## 3. Results and discussions

### *3.1 Optimization of Injection Timing (IT)*

In the first part, by varying the injection timing at a constant injection operating pressure of 205 bar, performance, combustion and emission characteristics of a single cylinder CI engine using diesel and ACOME was conducted. The readings were taken at the four injection timings of $19^0$, $23^0$,$27^0$ and $31^0$ BTDC at the constant speed of 1500 rpm. From the readings obtained at each specified conditions, optimum IT was found out.

#### *3.1.1 Effect of Injection Timing on Brake Thermal Efficiency*

The injection timing effect on brake thermal efficiency for single fuel operation with diesel, and ACOME at different injection timings is shown in Fig.3. 1. At a static IT of $23^0$ BTDC with diesel, highest BTE is obtained. Due to low energy content of the fuel, BTE of ACOME is lesser than diesel. From the results, at the injection timing of $23^0$ BTDC, the brake thermal efficiency of diesel is 31.25% whereas the brake thermal efficiency of ACOME is 25.87%. In order to increase the BTE of ACOME, the injection timing was advanced by $4^0$ then the BTE of ACOME was increased to 28.5%. The optimum IT for diesel and ACOME are selected as $23^0$ BTDC and $27^0$ BTDC respectively from the obtained results. Manufacturer specified the optimum IT of $23^0$BTDC for diesel operation and accordingly the experiments confirmed the results.

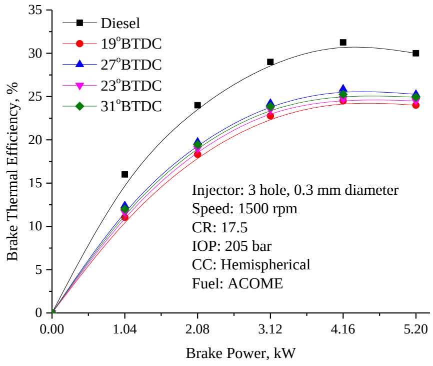


**Fig. 3.1** Injection timing effect on BTE

*3.1.2 Effect of IT on the HC and CO*

The injection timing effect on HC and CO emissions for diesel and ACOME is shown in figure 3 and 4. The emission of hydrocarbons is due to improper combustion in diesel engines. The HC and CO emissions was more at all injection timings for ACOME by comparing with diesel for all tested IT. This could be due to poor combustion characteristics of ACOME. The emission values of HC are 80 ppm, 78 ppm, 74 ppm and 84 ppm for $19^0$, $23^0$,$27^0$ and $31^0$ BTDC IT at 80 % load respectively. The HC levels were decreased at the injection timing of $27^0$ BTDC.

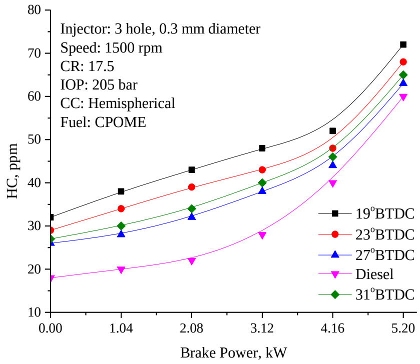


**Fig. 3.2** Injection timing effect on Unburned Hydrocarbon Emissions

**Carbon Monoxide Emissions**

Generally, for any CI engines, CO emission should be low because it indicates the incomplete combustion inside the engine cylinder. The percentage of CO is 0.28%, 0.19% and 0.29% for $19^0$ $23^0$, $27^0$ and $31^0$ BTDC injection timings at full load respectively. At the injection timing of $27^0$ BTDC, the emission of CO was found less.

By comparing the HC and CO emissions from all the four injection timings with ACOME as fuel, injection timing of $27^0$ BTDC was found to be less.

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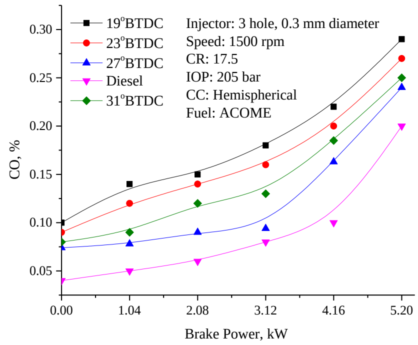


**Fig. 3.3** Injection timing effect on Carbon Monoxide Emissions

*3.1.3 Effect of IT on NOx Emissions*

The injection timing effect on emissions of nitrogen oxides with brake power for diesel, ACOME is shown in Fig.4. 1 With ACOME, NOx emissions were lower in comparison with diesel fuel at all the injection timings. The reason for increased $NO_X$ emission using diesel is due to improper Air- fuel ratio. Due to lower peak temperature, the concentration of nitrogen oxides is less using ACOME. From these results it was observed that the injection timing of $27^0$ BTDC is the optimum for ACOME as the BTE increased while smoke, CO and HC emissions were lesser at this injection timing.

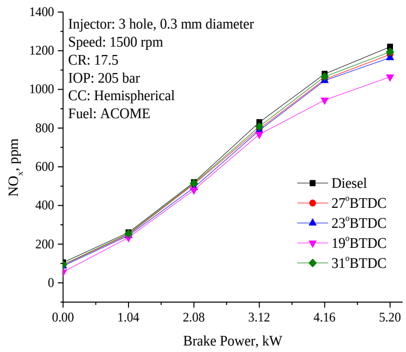


**Fig. 3.4** Injection timing effect on $NO_x$ Emissions

*3.1.4 Effect of IT on Combustion parameters*

**Peak Pressure**

Figure 3.5 shows injection timing effect for diesel and ACOME operation on peak pressure with brake power respectively. As the injection timing advances, peak pressure is increased which further increases the delay period for ACOME. Again by delaying the injection timing, delay period is reduced and smooth and less noise operation was achieved. Hence for smooth operation, retard the injection timing so that the peak pressure is lowered.

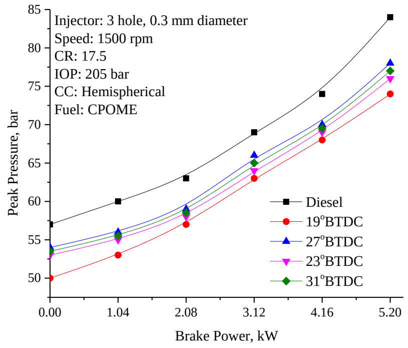


**Fig. 3.5** Injection timing effect on Peak Pressure

**Ignition Delay**

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The injection timing effect on ignition delay with brake power is shown in Fig.5.38.Static injection timing is essential to calculate the ignition delay. As the load is increased, ignition delay is increased however, by advancing the injection timing, ignition delay decreased as the increased brake thermal efficiency provides improved combustion for ACOME operation.

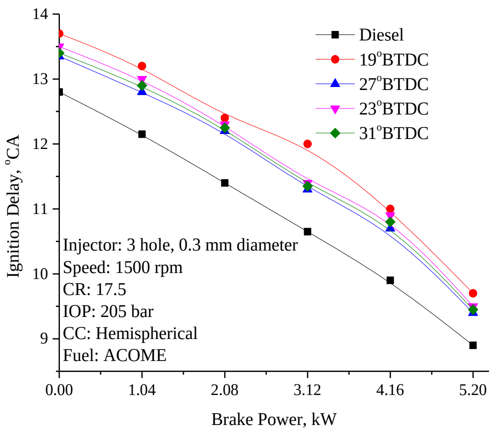


**Fig. 3.6** Injection timing effect on Ignition Delay Period

**Combustion Duration**

The combustion duration for diesel and ACOME is shown in fig. 3.7 which can be concluded that combustion duration is more for ACOME due to prolonged combustion which could be more in biodiesels due to high viscosity which leads to improper mixing of air and fuel. The combustion duration is reduced by advancing the injection timing.

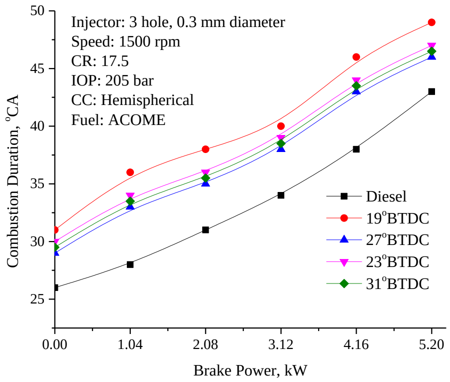


**Fig. 3.7** Injection timing effect on Combustion Duration

## 4. Conclusions

From the experimental tests conducted on ACOME powered diesel engine running with 17.5 compression ratio and 1500 rpm the following conclusions were drawn:

At IOP of 240 bar, IT of 27 $^0$BTDC, CR of 17.5, 3-hole injector and engine speed of 1500 rpm following are concluded,
At IOP of 205 bar, CR of 17.5, engine speed of 1500 rpm and load of 80% following were reported,

- ACOME can be used as substitute fuel for Compression Ignition engine with a small compromise in BTE.
- Fuel Injection Timing of 23 $^0$BTDC yielded good performance in terms of high BTE and less emissions.
- HC emissions of 80, 78, 74 and 84 ppm were revealed with Injection Timing of 19$^o$, 23$^o$,27$^o$ and 31$^o$BTDC respectively.
- For ACOME, the combustion duration is reduced by advancing the injection timing.
- By advancing the injection timing, ignition delay decreased as the increased brake thermal efficiency provides improved combustion for ACOME operation.

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