Optimization of Injection Pressure on Performance and Emission Characteristics of Diesel Engine Using Waste Cooking Oil

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Abstract. Biodiesel is one of the alternative fuels made from vegetable oil, environment friendly and can reduce the emission compared with diesel fuel. In this present work, an effort has been made to investigate the performance and emission characteristics of a single cylinder diesel engine fueled with blends of waste cooking oil (WCO). Experiments were conducted with different blends of waste cooking oil (25, 50, 75%) in diesel engine for various loads. Also, experiments were conducted by changing the injection pressure from 200 bar to 240 bar in the step of 20 bar. The results clearly show that lower brake thermal efficiency and higher brake specific fuel consumption were obtained with WCO by varying the injection pressure. Lower in CO and HC and higher in NOx emission were observed for WCO for different injection pressure. Lower smoke opacity was found by changing pressure. Taguchi method were used to find the optimum level of injection pressure, fuel fraction and blends of waste cooking oil.

Keywords: Waste Cooking oil; CI engine; Injection Pressure; Taguchi method.

1. Introduction

Due to massive growth in the automobile usage, the necessity for petroleum products has increased. This increasing demand has directed to the oil emergency. Because of this, need to find alternatives and, focus to swap the fuels for vehicles. Senthil Kumar et al. [1] experimenting the jatropha oil on engine, stated that the engine can work with small smoke releases and higher thermal efficiency, CO and hydro carbon emissions. Arunprasad et al. [2] experimented on CI engine using mixed biodiesel and concluded that the biodiesel can be used in the engine for better performance.

Wei et al. [3] experimented with WCO biofuel blends on a CI Engine and the reported HC, CO, NOx and smoke emission characteristics. From these experiments, a decrease was observed in xylene and toluene was decreased. Kumar et al. [4] experimented with Jatropha and Pongamia biodiesel in diesel engine and 20% blend gave a good performance and a smaller amount emission. Due to chemical structure, viscidness of WCO is larger than diesel by Karmakar et al. [5]. This is the reason that confines the practice of WCO in CI engines. Venkateswara Rao et al. [6] resolved that related to jatropha and neem, Pongamia gave an enhanced performance.

In an attempt on CI engine, the different fuels were mixed and tested in engine. For thevetia periviana ester, higher performance and lesser emissions were got compared to other blends. The brake thermal efficiency was observed to increase with the increase in load for all fuels owing to the reduction in heat loss and the rise in power established with the rise in load. The brake thermal efficiency of all blends nearly equal to diesel and the determined deviation at the maximum load was 9.39% for neem oil and only 2% for METPSO. This was researched by Balusamy et al. [7].
Bhupesh Sahu et al. [8] evaluated the diesel and jatropha fuelled diesel engine for finding the performance and emission values. From the research, decrease in BTE and rise in brake specific fuel consumption was achieved. While CO, HC, NOx and Smoke opacity reduced, and rise in CO$_2$ and NOx emission was detected. Araujo et al. [9] experimented with WCO biofuel nearly forty five percent production cost were saved. Abed et al. [10] experimented on a CI engine with Jatropha, palm, algae, and WCO and the emission releases were found and related with diesel. CO, hydro carbon, CO$_2$ and smoke were lesser for B10 and B20 blends compared to diesel. NOx emissions were higher than diesel fuel. Arunprasad et al. [11] studied the mixed fuel of different fuel like Thevetia peruviana, Jatropha, Pongamia, and neem oil by altering the injection pressure and timing. The injection pressure was varied with an increment of 10 bar and the injection timing was changed at an increment of 2° bTDC. The results were analyzed with diesel which displayed that the BTE increased by 2.4% and by 1.5% for IP and IT for the maximum load. Furthermore, bsfc showed a drop of 5.08% for the rise in IP and IT with loads. The reduction in hydro carbon, carbon monoxide, and smoke were 34.17%, 53.85%, and 29.7% and 29.17%, 53.85%, and 21.95%, at injection pressure of 230 bar and 27° before TDC injection timing respectively. Also, with the increase in injection pressure and injection timing an increase in NOx and CO$_2$ emissions at the higher load was detected. Arunprasad et al. [12] trialed with neem biodiesel blends and comparison with corresponding values of diesel were presented. The optimum value was determined using the Taguchi method. The result shows that the optimum parameters are for the blend B60, CR 18:1, and 6 Kg load.

2. Experimental Test Setup
A Kirloskar diesel engine of 3.5 kW power, running at 1500 rpm, was used in this investigation. This engine was used by Sivalakshmi et al. [13] The specification is specified in Table 1. Two fuel tanks consist of diesel and biodiesel were used. Consumption of fuel was measured by means of sensor. To measure the airflow rate, a differential pressure transducer was used. Engine torque was controlled by an eddy current dynamometer. The combustion pressure was measured by installing a PZ pressure transducer. To measure the emission parameters and smoke intensity, exhaust gas analyzer and smoke meter were used. Thermocouples (chromel alumel) were used to measure temperature of exhaust, inlet air. The properties of the fuel are shown in Table 2.

| Table 1 Engine Specifications |
|-------------------------------|
| **Company** | Kirloskar –TV1 |
| **Power, Speed** | 3.5 kW, 1500 rpm |
| **Engine Type** | Single cylinder, DI and 4 Stroke |
| **Cooling Method** | Water |
| **Type of ignition** | CI |
| **IVO** | 4.5° before TDC |
| **IVC** | 35.5° after BDC |
| **EVO** | 35.5° before BDC |
| **EVC** | 4.5° after TDC |
| **Fuel injection timing** | 23° bTDC |
| **Nozzle opening pressure** | 210 bar |
3. Experimental Procedure

Transesterification process was used to remove the triglycerides and fatty acids for reducing the viscosity of waste cooking oil for using the engines without any modification. Tests were conducted at a constant speed with different load conditions with diesel and neat WCO. Parameters like injector opening pressure were varied in case of waste cooking biodiesel to study their influence on performance, combustion and emission. Injection pressure was varied (200, 220 and 240 bar) by adjusting the screw of injector.

| Table 2 Properties of fuel |
|---------------------------|
| Property                  | Diesel | WCO Vegetable oil | WCO Biodiesel | ASTM code |
| Calorific value, kJ/kg    | 43200  | 39900            | 38700         | D4809     |
| Specific gravity          | 0.823  | 0.882            | 0.830         | D445      |
| Kinematic viscosity       | 2.5    | 36               | 4.12          | D2217     |
| (at 40°C) cSt             |        |                  |               |           |
| Cetane number             | 50     | 47               | 51            | D4737     |
| Flash point, °C           | 56     | 138              | 85            | D92       |
| Fire point, °C            | 64     | 150              | 92            | D92       |
| Cloud point, °C           | -8     | 8                | 10            | D97       |
| Pour point, °C            | -20    | 6                | 8             | D97       |
| Ash content, %            | 0.001  | 0.003            | 0.003         | D976      |

4. Results and Discussion

4.1 Performance Characteristics

Figure 1 shows the graph between BTE with load for various blends of waste cooking oil. The BTE was found to increase with all loads and blends of biodiesel. The same result was achieved by Nurun Nabi [14]. From the graph, it can be found that for P220F25, the BTE is maximum and is minimum for P240F75. The Taguchi method is used here to find the optimum value. Minitab 16 was used to find the results. From the analysis, R2 and R2(adj) values are above 95%. Hence, 200 injection pressure, 25% fuel fraction and 80% load give the optimum value of BTE.
Figure 1. (a) BTE Vs Brake Power (b) SN ratio

Figure 2 shows the graph between bsfc and load for various blends. The BSFC is found to decrease with an increase in load, for all blends. P220F25 gives lower BSFC than other blends at the higher load. This was achieved because of higher viscosity. From the Taguchi analysis, R2 and R2(adj) values are above 95%. Hence, 200 injection pressure, 75% fuel fraction and 20% load give the optimum value of BSFC.

Figure 2. (a) BSFC Vs Brake Power (b) SN ratio
4.2 Emission Characteristics

For various blends, the variation of CO emissions with blends is shown in Figure 3. From the figure, the CO emissions are found to decrease with the rise in load. The increase in CO emission is accounted for by incomplete combustion. P220F25 gives lower CO emissions for 80% load when compared to other pressure, load and fuel fraction. Taguchi method was used by using various data and from the analysis, more than 95% is achieved for R2 and R2(adj) values. 240 bar injection pressure, 75% fuel fraction and 20% load give the optimum value of CO.

Figure 3. (a) CO Vs Brake Power (b) SN ratio

Figure 4 shows the graph between HC emissions with load. HC emission decrease with load. The same result was obtained for Zafer Utlu et al. [15] For different blends of waste cooking oil, HC emission decreases with the increase in load. P200F25 at 80% load has given lower HC emission when compared to other combinations of waste cooking oil. Taguchi method was used by using various data and from the analysis, more than 95% is achieved for R2 and R2(adj) values. 240 bar injection pressure, 75% fuel fraction and 20% load give the optimum value of HC.
Figure 4. (a) HC Vs Brake Power (b) SN ratio

Figure 5 shows the graph between NOx emission with brake power for various blends of WCO. The NOx emission is higher for all blends of WCO than biodiesel. NOx emission is minimum for P200F25 and maximum for P240F75 for all loads. From Taguchi analysis, P240, fuel fraction 75% and 20% load were given better results as the R2 and R2(adj) value is more than 95% achieved.
Figure 5. (a) NOx Vs Brake Power (b) SN ratio

Figure 6 shows the graph between smoke emissions with load. Compared to diesel, all blends of WCO have lower smoke emission. At all load, P240F25 gives lesser smoke when compared to other combinations. This is due to oxygen present in the WCO. This is also reported by Dhinesh Balasubramanian et al. [16]. Taguchi method was used by using various data and from the analysis, more than 95% is achieved for R2 and R2(adj) values. 200 injection pressure, 75% fuel fraction and 20% load give the optimum value of smoke emissions.
5. Conclusions

Tests were conducted with various blends of WCO in diesel engine for 20, 40 and 80 % load and varying the injection pressure and taguchi method was used to find the optimum result as follows

- The BTE was maximum for P220F25 and minimum for P240F75. From taguchi method, 200 injection pressure, 25% fuel fraction and 80% load give the optimum value of BTE.
- At the higher load, P220F25 gives lower BSFC and the other blends are in the higher side.200 injection pressure, 75% fuel fraction and 20% load give the optimum value of BSFC.
- P220F25 gives lower CO emissions for 80% load when compared to other pressure, load and fuel fraction.240 injection pressure, 75% fuel fraction and 20% load gives the optimum value of CO.
- P200F25 at 80% load has given lower HC emission when compared to other combinations of waste cooking oil. 240 injection pressure, 75% fuel fraction and 20% load give the optimum value of HC. P200F25 gives lower NOx and maximum for P240F75 for all loads
- At all load, the smoke emission was lower for P240F25. 200 bar injection pressure, 75% fuel fraction and 20% load give the optimum value of smoke emissions.

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