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# A COMPARATIVE STUDY OF PERFORMANCE PARAMETERS OF SINGLE CYLINDER FOUR STROKE DIRECT INJECTION CI ENGINE OPERATING ON WASTE FRYING OIL METHYL EASTER AND WASTE FRYING OIL ETHYL EASTER

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## ABSTRACT

As the price of petroleum oil is increasing rapidly day by day. It is necessary to develop a substitute of petro-diesel fuel. An alternate fuel should be economically attractive in order to compete with currently used conventional diesel fuels. Biodiesel is a clean burning diesel alternative and has attractive many features including renewability, biodegradability, and non toxicity and comparable performance. The aim of the present study is to investigate the performance parameters of diesel engine operating on waste frying oil methyl ester (WFOME) and waste frying oil ethyl ester (WFOEE) when these are used as a fuel in diesel engine and then compared with the diesel fuel. It is investigated that the Brake Specific Energy Consumption (BSEC) of WFOME is increased by approximately 8% and Brake Thermal Efficiency (BTE) is decreased by around 7.6% at 50% load while the BSEC of WFOEE is increased by approximately 10.3% and BTE is decreased by around 9.3% than that of diesel fuel when the 100% (neat) WFOME & WFOEE are used in diesel engine. As the blends are increased for the same load, engine consumed the more fuel consumption as compared to diesel fuel. When the 100% WFOME & WFOEE are used in CI (Compression Ignition) engine, WFOME & WFOEE consumed higher fuel in comparison to conventional diesel. The result showed that the neat WFOME and WFOEE when used in diesel engine WFOEE consumed approximately 3% higher fuel in comparison to WFOME at 50% engine load.

In general, the physical and chemical properties and performance of ethyl esters are comparable to those of the methyl esters. Methyl and ethyl esters have almost the same heat content. The viscosity of ethyl esters is slightly higher while cloud and pour points are slightly lower than those of methyl esters. The engine tests demonstrated that methyl esters produced slightly higher brake thermal efficiency than ethyl esters. The ethyl ester consumed slightly less fuel as compared to methyl ester.

**Keywords:** Diesel (CI) engine, WFOME, WFOEE, Performance

## INTRODUCTION

From 1973 to 2004 the global primary energy consumption increased from 252 to 463 billion MJ [1]. In addition, high emissions of $CO_2$, $NO_x$, $SO_2$ and particulate matter (PM) are produced during fossil fuel use, generating environmental problems. These facts have converged in the search of renewable energies, such as biofuels. The lack of conventional fossil fuels, their increasing costs and rising emissions of combustion-generated pollutants will make bio-based fuels more attractive [2]. Due to the rise in price of petroleum products, especially after the petrol crisis in 1973 and then the Gulf War in 1991, geographically reduced availability of petroleum and more rigorous governmental regulations on exhaust emissions, many researchers have studied alternative fuels and alternative solution methods [3, 4].

Recently biodiesel has turned into more attractive because of its ecological benefits [5, 6]. Due to the depletion of petroleum reserves and increases in environmental concerns the importance of biodiesel increases gradually [7]. As a future prospective fuel, biodiesel has to compete economically with petroleum diesel fuels. India imports petroleum products at an annual cost of approximately $50 billion in foreign exchange. The use of 5% of biofuels in place of petroleum fuel enables India to save $2.5 billion per year in foreign exchange [8]. The use of raw vegetable oils in engines without any modification results in poor performance and leads to wear of engine components [9]. The value of higher viscosity causes poor fuel atomization during the injection process that increases the engine deposits and increases more energy consumption to pump the fuel which wears fuel pump elements and injectors [10]. The investigations showed that esters of vegetable oils provide better performance and reduced emissions than that of raw vegetable oils. Since the biodiesels are derived from plant oils, they produce negligible net greenhouse gas emissions [11]. Reuse of WCO minimizes the production cost of biodiesel significantly but also helps the government to disposing waste oils, maintaining treating oily waste water and public sewers. A lot of quantities of the WCO are generated in food processing industries, fast food shops and house cooking every day. Waste cooking oil was selected as a substitute because it is cheaper and also avoids the cost of waste product disposal and treatment [12].

Biodiesel showed higher BSEC as compared to that of diesel for all loads. At 100% load condition, BSEC of 15.5 MJ/kWh was observed with biodiesel, which was 3.1 MJ/kWh higher than that of diesel. This is mainly because of the lower calorific value of biodiesel. The brake thermal efficiency of biodiesel was slightly lower than that of traditional diesel fuel at 100% load condition. With the use of biodiesel the NO and smoke emission decreased as compared to diesel. Biodiesel showed a lower heat release rate, a minute ignition delay and slightly higher combustion duration compared to diesel. [13].

The thermal efficiency of CI engine depends on the compression ratio and the fuel–air ratio. With a fixed compression ratio, the thermal efficiency mainly depends only on the fuel–air ratio [14]. Maximum brake thermal efficiency of 23.1% was observed with biodiesel (WCO-ME), which is 6% lower than that of diesel at 100% load condition. The Brake thermal efficiency of diesel engine is lower due to the lower calorific value and higher viscosity of biodiesel [13]. Higher viscosity of biodiesel fuel results poor fuel atomization during the spray process which increasing the engine deposits and also requires more energy to pump the fuel which wears fuel pump elements and injectors [10]. Biodiesel has a relatively high flash point (150$^o$C), which makes it less volatile and safer to transport or handle than petroleum diesel [15]. It provides lubricating properties that can reduce engine wear and extend engine life [16].

**Experimental Setup and Methodology:**

Experimental setup is shown in Figure 1.

**Figure 1: Experimental set up of test Engine**

The detail of technical specification of test (diesel) engine is given in table 1.

**Table 1: Technical Specification of test engine**

| Engine Parameters | Details |
|---|---|
| Make | Kirloskar Oil Engine, Pune |
| Model | SV1 |
| Type | Vertical, Totally Enclosed, CI, Four Stroke Engine, Water Cooled |
| No. Of Cylinder: | ONE |
| Bore Size | 87.5 mm |
| Stroke Length | 110 mm |
| Cubic Capacity | 662 CC |
| Compression Ratio | 16.5:1 |
| Engine RPM | 1500 |
| Rate of Output | 5.88kW / 8 HP |

## RESULT AND DISCUSSION

### Properties of Fuels

The properties of WFO**,** WFOME, WFOEE and Diesel are carried out by the help of IOCL, Bhopal, and Department of Chemistry in Sri Institute of Science and Engineering College Bhopal. The results of various fuel properties are mentioned in table 2.

**Table 2: Comparison of the Physical properties of WFO, WFOME, WFOEE, and Diesel fuel**

| Property | WFO | WFO ME | WFO EE | Diesel |
|---|---|---|---|---|
| Density at 50 $^oC$ (kg/m$^3$) | 909 | 882.5 | 896 | 836 |
| Specific Gravity | 0.909 | 0.8825 | 0.896 | 0.836 |
| Kinematic Viscosity at 40$^o$C (cst) | 42.8 | 4.833 | 4.87 | 2.649 |
| Cloud Point ($^o$C) | -3.9 | 2 | 1 | 6.5 |
| Pour Point ($^o$C) | -12.2 | -1 | -4 | 3.1 |
| Flash Point ($^o$C) at 40$^o$C | 254 | 171 | 174 | 51 |
| Lower CV (kJ/kg) | 37400 | 38400 | 38000 | 42850 |

### Performance of Diesel Engine

All the experiments are performed at a constant speed of 1500 rpm by varying the brake load and the data obtained from the experiments are used to evaluate the performance of the diesel engine. The performance parameters studied are fuel consumption (FC), Brake specific fuel consumption (BSFC), Brake specific energy consumption (BSEC), and Brake thermal efficiency (BTE).

The performance test of diesel engine shows the BSEC of WFOME & WFOEE is increased and brake thermal efficiency of WFOME & WFOEE is decreased as compared to diesel fuel when the blends are used 50% and more. As the blends are increased the fuel consumptions of diesel engine slightly increased with load in comparison to diesel fuel for the same load. When the neat WFOME is used in a CI engine then the engine consumed approximately 20% more fuel in comparison to diesel, and when the WFOEE is used in CI engine the fuel consumption is around 24 % more than that of conventional diesel. For the same brake power the brake specific fuel consumption of the diesel engine is slightly increased than that of diesel. When the neat WFOME and WFOEE are used in diesel engine WFOEE consumed slightly more fuel in comparison to WFOME. WFOME & WFOEE showed higher Brake Specific Energy Consumption as compared to diesel for all loads.

### Performance of Diesel Engine For 50% WFOME & WFOEE Blends

### Fuel Consumption

Figure 2 shows the variation in fuel consumption for diesel, WFOME & WFOEE when 50% blends are used in diesel engine. As the loads are increased the diesel engine connsumed more fuel as compared to diesel engine. The fuel consumption (FC) of WFOME and WFOEE is increased by approximately 9.7% and 11.45% than that of diesel fuel when the load on the engine is 50% and run at constant speed of 1500 rpm. It is observed that at same load conditions the diesel engine consume more fuel (WFOME & WFOEE) in comparison to conventional diesel. During testing of diesel engine WFOEE consume 1.64% more than that of the WFOME.

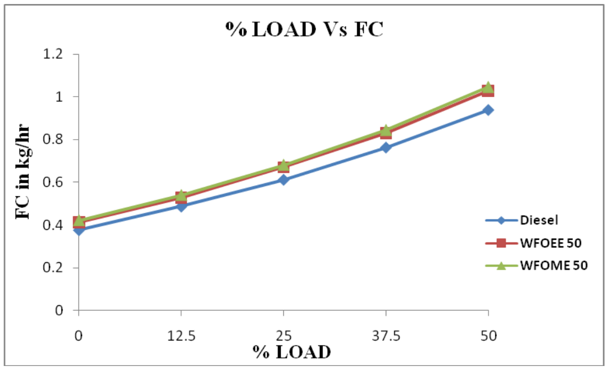


**Figure 2: Variation of FC with Load for Diesel, and 50% WFOME & WFOEE Blends**

## Brake Specific Fuel Consumption

Figure 3 shows the variation in Brake Specific Fuel Consumption (BSFC) for diesel, WFOME & WFOEE when the 50% blends are used in diesel engine. The BSFC is an essential parameter to compare engines and determine the fuel efficiency of an engine. The BSFC of diesel engine decreases as the loads are increased. The brake specific fuel consumption of WFOME & WFOEE are increased by 9.6% and 11.45% correspondingly than that of diesel fuel when the 50 % load on the engine and run at constant speed . It is investigated that the BSFC of WFOEE is approximately 1.7% less as compared to WFOME. It is also investigated that the BSFC of WFOME & WFOEE is higher than that of diesel fuel when the 50% blends are used in diesel engine.

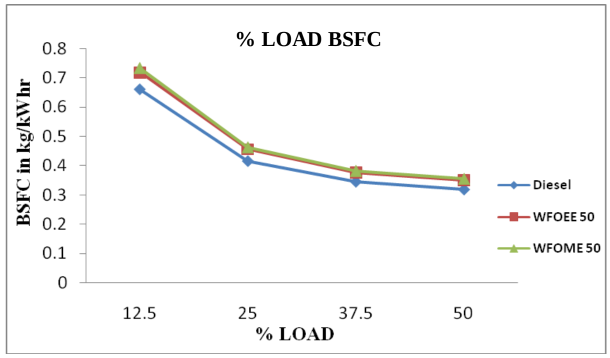


**Figure 3: Variation of BSFC with Load for Diesel and 50% WFOME & WFOEE Blends**

## Brake Specific Energy Consumption

Figure 4 shows the variation in BSEC for Diesel, WFOME & WFOEE when 50% blends are used in diesel engine. The lower calorific value and higher viscosity of WFOME & WFOEE fuels resulted higher BSEC in a diesel engine in comparison to diesel. WFOME & WFOEE are resulted higher Brake Specific Energy Consumption (BSEC) than that of diesel fuel for all loads. As the loads are increased the engine consumed more energy for all fuel. The engine showed BSEC of WFOME & WFOEE has increased by approximately 3.96% and 5.2% respectively higher than that of diesel for 50% engine load. It is observed that the BSEC of WFOME is less around 1.2% as compared to WFOEE.

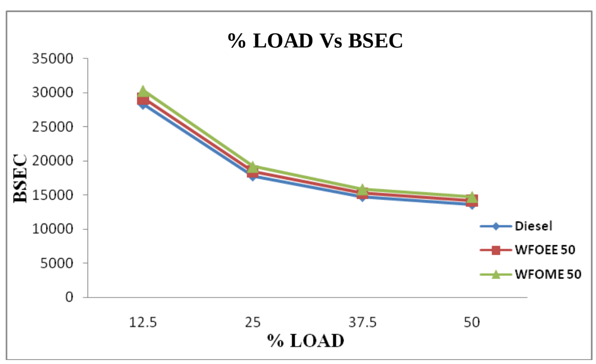


**Figure 4: Variation of BSEC with Load for Diesel and 50% WFOME & WFOEE Blends**

## Brake Thermal Efficiency

Figure 5 shows the variation of brake thermal efficiency of WFOME & WFOEE with diesel at various loads when the blends are 50%. The brake thermal efficiency (BTE) of WFOME & WFOEE is decreased with increase in load for all the fuels. The brake thermal efficiency of WFOME & WFOEE blends with diesel decreased with an increase in amount of WFOME & WFOEE in the blends. The BTE of WFOME & WFOEE is higher than that of diesel by approximately 3.8% and 4.89% respectively. It has been observed that the BTE of WFOEE is about 1.2% less as compared to WFOME for all loads.

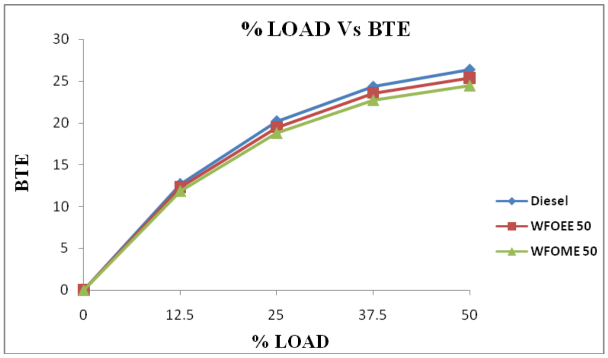


**Figure 5: Variation of BTE with Load for Diesel and 50% WFOME & WFOEE Blends**

## Performance of Diesel (Test) Engine For 100% (neat) WFOME & WFOEE

### Fuel Consumption (FC)

Figure 6 shows the variation of fuel consumption for neat Diesel, WFOME & WFOEE are used in diesel engine. It is investigated that the fuel consumption of diesel engine increased by approximately 20.8% and 24.4% higher than that of diesel when the neat WFOME and WFOEE are used at 50% load and engine speed of 1500 rpm. During testing of diesel engine WFOEE consume approximately 3% more fuel than that of WFOME. It is resulted that the fuel consumption of WFOEE is more than the conventional diesel fuel & WFOME.

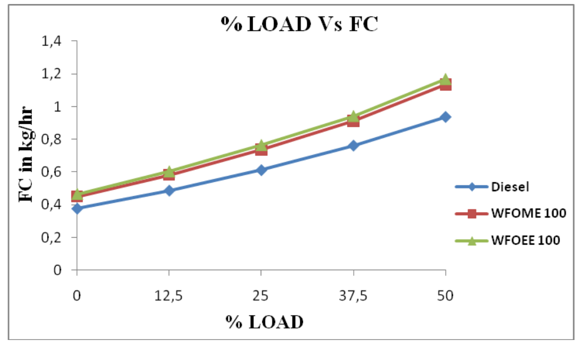


**Figure 6: Variation of FC with Load for Diesel and 100% WFOME & WFOEE**

### Brake Specific Fuel Consumption (BSFC)

Figure 7 shows the variation of brake specific fuel consumption for neat Diesel, neat WFOME & WFOEE are used in a diesel engine. It is observed that the BSFC of WFOME & WFOEE is increased by approximately 21% and 24% higher than that of diesel fuel at 50% load. The brake specific fuel consumption is decreased as the engine loads are increased. It is resulted that the brake specific fuel consumption of WFOME & WFOEE are higher in comparison to petro-diesel fuel. The BSFC of WFOEE is less around 3 % in comparison to WFOME.

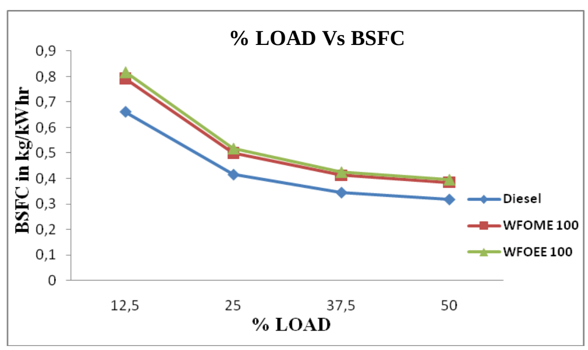


**Figure 7: Variation of BSFC with Load for Diesel and 100% WFOME & WFOEE**

### Brake Specific Energy Consumption (BSEC)

Figure 8 shows the variation of brake specific energy consumption for neat Diesel, neat WFOME & WFOEE are used in a diesel engine. The BSEC of WFOME is increased by approximately 8.2% and WFOEE is increased by 10.3% more than that of diesel. The BSEC of WFOME & WFOEE is less in comparison to diesel fuel due to lower calorific value and higher viscosity of fuel. It is investigated that the BSEC of neat WFOEE is approximately 1.88% higher than that of neat WFOME.

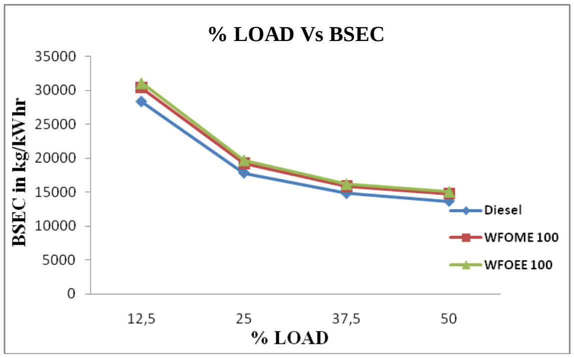


**Figure 8: Variation of BSEC with Load for Diesel and 100% WFOME & WFOEE**

### Brake Thermal Efficiency (BTE)

Figure 9 shows the variation in Brake Thermal Efficiency (BTE) of Diesel, neat WFOME & WFOEE fuel. The Brake thermal efficiency of four stroke single cylinder diesel engine running on neat WFOME & WFOEE is resulted lower brake thermal efficiency as compared to conventional diesel fuel. The BTE of WFOME is decreased by approximately 7.6% and BTE of WFOEE is decreased by approximately 9.3% than that of diesel. It is resulted that the BTE of WFOME is around 1.8% less in comparison to WFOEE.

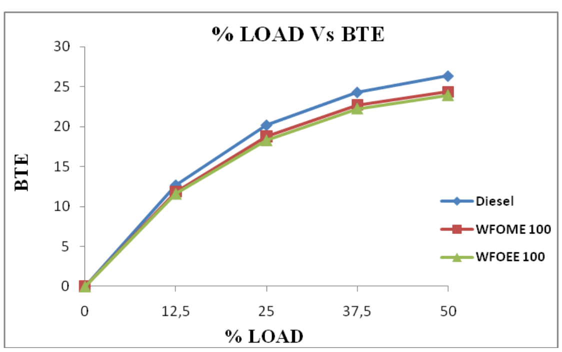


**Figure 9: Variation of BTE with Load for Diesel and 100% WFOME & WFOEE**

## CONCLUSION

In this study, the performance of single cylinder direct Injection diesel engine fuelled with WFOME & WFOEE and that's blends are investigated. The key results are summarized below:

1) The fuel properties of WFOME & WFOEE has a comparatively higher flash point (171-174$^{o}$C) which makes it less volatile and safer to transport than conventional diesel.
2) The viscosity of ethyl esters is slightly higher while the cloud and pour points are slightly lower than that of methyl esters of the WFO.
3) The Brake Specific Energy Consumption (BSFC) of WFOME & WFOEE and its blends are higher as compared to conventional diesel fuel due to its lower calorific value and higher viscosity.
4) The brake thermal efficiency of WFOME & WFOEE and its blends are lower than that of diesel for all loads.
5) It is investigated that the WFOME & WFOEE running normally during testing of diesel engine. From the above analysis it can be concluded that the WFOEE resulted poor performance in comparison to WFOME. Biodiesel obtained from waste frying oil can be used as a substitute fuel for conventional diesel fuel in future.

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