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Performance Testing On an Agricultural Diesel Engine Using Waste Cooking Oil Biodiesel

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Abstract

This research work focused on the production of waste cooking oil biodiesel through mechanical stirring followed by the performance testing of WCO biodiesel blends on an agricultural diesel engine. Results show higher biodiesel yield is obtained using molar ratio 6:1 as compare to molar ratio 4.5. As per performance testing performed in this work it is evident that waste cooking oil biodiesel blends gives better thermal efficiency and have got safer impact on environment as compared to diesel fuel

1. Introduction

Talking about the Indian energy scenario presently India is fifth largest primary energy consumer and fourth largest crude oil and natural gas consumer in the world after United States, China and Russia and expected to be third largest energy consumer by 2030. Despite the recent global economic slump, India's economy is expected to continue to grow at 6 to 8 percent per year in the near term.This economic, infrastructural and socio-economic development will accelerate an increase in energy consumption and demand across all major sectors of the India. As India is not self sufficient in the petroleum and has to rely on imports for a considerable amount of its energy use, consequently increasing India's oil import expenditure to over $135 billion in Indian fiscal year 2011/12, up 22 percent over the previous year ((Source: Petroleum Planning and Analysis Cell, GOI).since India is the fourth largest global contributor to carbon emissions, the Indian government's new policy has targeted EURO-III and IV vehicle emission norms for vehicles, which in turn would require adoption of clean burning biofuels.

In this context biodiesel is potentially most promising replacement to petroleum-based fuels as it refers to clean burning fuel produced from domestic renewable sources. The main sources for biodiesel in India are edible and non-edible oils obtained from plant species such as soya bean oil, corn oil, peanut oil, olive oil, cotton seed oil, rape seed oil, linseed oil, sunflower, coconut oil, palm oil, jatropha seed oil etc. Edible vegetable oils such as canola, soybean, and corn have been used for biodiesel production and are proven diesel substitutes. [1, 2]

However, a major restriction in the commercialization of biodiesel production from edible vegetable oils is their high production cost which is due to the demand for human consumption. One alternative to reduce the cost of biodiesel fuel is to use less expensive feed stocks including waste cooking oils and vegetable oils that are non-edible or require low harvesting costs. Waste cooking oil (WCO), which is much less expensive than edible vegetable oil, could be a promising alternative to edible vegetable oil [3-4].

Biodiesel can be produced by various conventional methods with catalysts like alkali, acid, and lipase etc [5, 6].Transesterification is the most common method of conversion of vegetable oil and fats into biodiesel which leads separation of glycerine from fatty acids. Biodiesel thus produced by transesterification process has a high low viscosity and improved calorific value compared to those of raw vegetable oil.

Pal et al. (2010) [7] investigated the biodiesel conversion from thumba through hydrodynamic cavitation technique using base catalyst and methanol results showed that the rate of tranesterification

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reaction is much higher as compared to conventional method like mechanical stirring. This is attributed to the fact that mixing is much uniform and fast with this technique of cavitation.

Arslan (2011) [8] investigated the use of waste cooking oil (WCO) biodiesel as an alternative fuel in a 4-stroke turbo diesel engine with four cylinders, direct injection. A test was performed with diesel and three different blends of diesel/biodiesel (B25, B50 and B75) made from WCO. The test engine was run at eighteen different speeds with a full load, and the results were analyzed. The blend fuels produced slightly less smoke than the diesel fuel, which could be attributed to better combustion efficiency. The use of biodiesel resulted in lower emissions of total hydrocarbon and CO, and increased emissions of NOx.

Cho et al. (2008) [9] investigated the suitability of preheated waste cooking oil as fuel in diesel engines with minor modification in the engine. Since waste cooking oil is too viscous to be used in the engine directly so needs to be heated up before using it. In order to use unmodified oil one require minor modification in the existing diesel engine. The modification were very simple which requires an extra fuel tank and a system for heating and filtering the oil before it reaches the engine , which can be then used in a diesel engine without any modifications. The results showed increase in brake thermal efficiency for diesel upto 26% at 4800 W and for waste cooking oil the maximum efficiency obtained 25.3% at 3600 W of applied load. The particulate matter emission was found to be decreased with waste cooking oil, hence reduction in smoke. However, increase in NO_X emission than diesel because of presence of oxygen in waste cooking oil.

Patil et al. (2012) [10] studied the biodiesel production from high fatty acid waste cooking oil using sulphuric acid (Two-step) and microwave-assisted transesterification (One-step) was carried out. A two-step transesterification process was used to produce alkyl esters from high free fatty acid waste cooking oil and microwave-assisted catalytic transesterification using BaO and KOH was evaluated for biodiesel production from waste cooking oil. It was estimated that the microwave-heating method consumes less than 10% of the energy to achieve the same yield from the conventional heating method.

Singh et al. (2010) [11] studied hybrid fuels consisting of coconut oil, aqueous ethanol and a surfactant. The engine performance and exhaust emission were investigated and compared with diesel. The experimental results show that the efficiency of the hybrid fuels is comparable with to that of diesel and exhaust emission was lower than those for diesel, except carbon monoxide emissions, which increased. As the percentage of ethanol in the hybrid fuels increases, the CO emission level decreases due to higher air –fuel ratio of the fuel. NO emission Values were 459,454,442 ppm for 87CCO 10E 3B, 70CCO 17E 13B, 54CCO 23E 23B respectively, compared to 852 ppm for diesel at 86% load. Hence it is concluded that these hybrid fuels can be used as an alternatives fuel in diesel engines without any modifications. Their completely renewable nature ensures that they are environment friendly with regard to their emission characteristic.

2. Reagents and Materials Used For Experiment

Waste Cooking oil used in the present study for biodiesel production was received from a five star hotel named Hotel Paris Hilton, Delhi. Waste cooking oil (WCO) in Delhi and commercially available diesel oil was purchased from the nearby Indian Oil Corporation petrol pump in Rohini, Delhi. Anhydrous methanol (99.8% min.) and Potassium hydroxide (85% min.) was purchased from local chemical store.

3. Biodiesel Production Technology

3.1 Mechanical stirring

In this method, mixing of WCO and methanol is done in a tank equipped with mechanical stirrer as shown in figure 1. An electric motor is used to rotate the shaft around which blades are provided to stir the mixture of immiscible liquids (oil and alcohol are not miscible with each other), as shaft starts rotating a turbulence is created which disrupt the phase boundary between two immiscible liquid and thus resulted in proper mixing. Temperature is measured with the help of a thermometer and kept in the range of the 60-65 °C.

3.2 Experimental results

As shown in figures 2 and 3, biodiesel yield increases as reaction time increases and eventually it becomes constant after 75 min of reaction time. The yield is more for molar ratio 6:1 and 1 % catalyst as compared to molar ratio 4.5:1 and 0.75% catalyst.

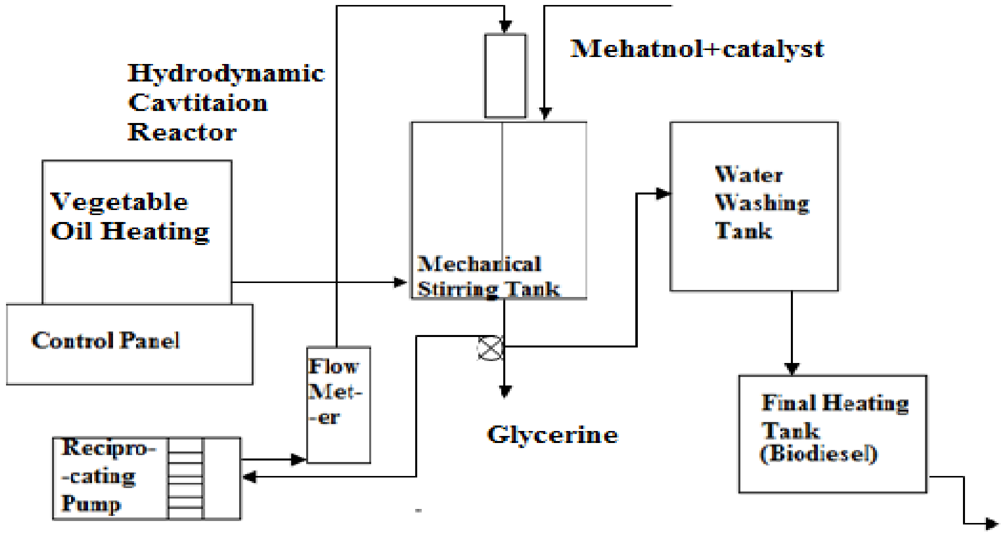

Fig: 1. Schematic representation of biodiesel reactor

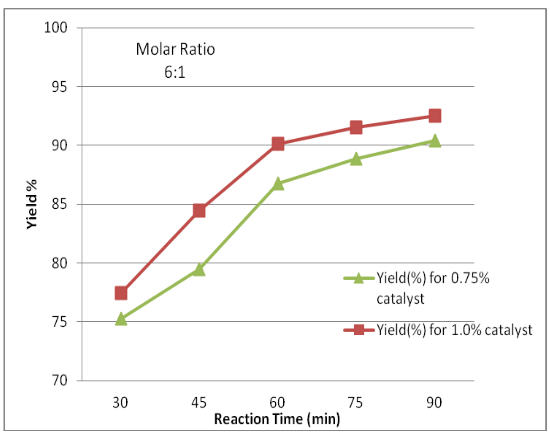

Fig: 2. Time v/s Yield (%) for molar ratio 6:1 and different catalyst percentage

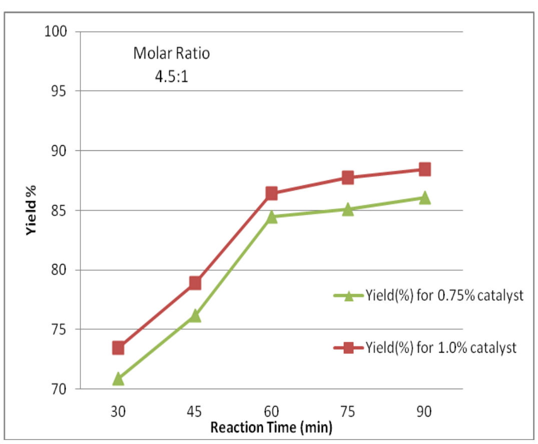

Fig: 3. Time v/s Yield (%) for molar ratio 4.5:1 and different catalyst percentage

4. Experimental Performance on A CI Engine

The biodiesel from WCO is tested on a single cylinder, four strokes, diesel engine which is equipped with eddy current type dynamometer for loading. Engine performance characteristics were analyzed using computer software package "Engine soft". AVL 437C smoke meter is used for the smoke opacity measurement. Experiment has been performed by taking WCO biodiesel blends with diesel in proportion of volume 20%, 40%, 60%, 80% and 100% respectively. The engine performance parameters and their variation are discussed below:

4.1 Brake thermal efficiency v/s brake power

Figure 4 shows comparison of Brake thermal efficiency v/s brake power for different blends in comparison to diesel. For WCO-B20 AND WCO-B40 blend brake thermal efficiency values are higher as compared to diesel at higher load. This is due to better combustion efficiency of blends caused by presence of extra amount of oxygen. The maximum thermal efficiency achieved by WCO-B40 is around 40.33 % at 4.0 kW.

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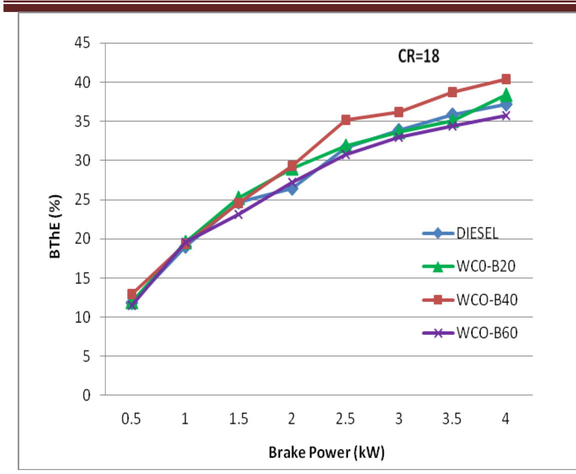

Fig: 4. Comparison of brake thermal efficiency v/s brake power

4.2 Brake specific fuel consumption v/s brake power

The variation of specific fuel consumption vs. brake power is shown in figure 5 for blends and diesel. For all cases the sfc initially decreases sharply with increase in brake power and afterward remains stable. In case of blends sfc values are higher at the beginning because of higher viscosity. Once the required temperature is attained inside the engine cylinder the values are comparable with diesel but little bit higher specifically for WCO-B20 and WCO-B40 as compared to diesel.

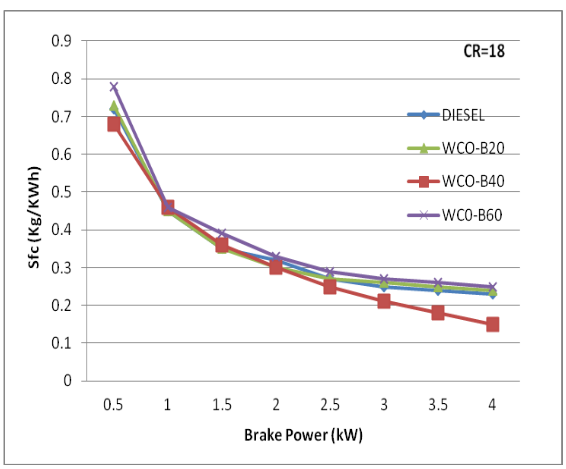

Fig: 5. Comparison of specific fuel consumption v/s brake power

4.3 Exhaust gas temperature v/s brake power

Exhaust Temperature of the blends such as WCO-B20, WCO-B40 and WCO-B60 at various brake powers compared to diesel are shown in the Figure 6. The Ex. Temperature values are higher for blends because of better combustion efficiency. This high temperature is also indication of more NOx emission in case of blends.

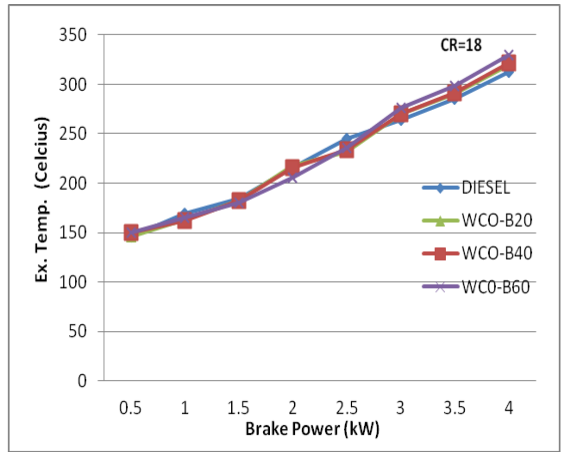

Fig: 6. Comparison of exhaust gas temperature v/s brake power

4.4 Smoke opacity v/s brake power

To understand the pollution aspect of WCO and diesel blends the variation of opacity v/s brake power are shown in Figure 7 for blends in comparison to pure diesel. The opacity value for pure diesel is higher as compared to all type of blends for wide range of Brake power. At all brake power condition the opacity of all blends has less value than diesel oil. Maximum value of opacity has obtained at 59.21 at 4.0 kW brake power for pure diesel and for blends 45.7 at 4.0 kW for B-20.

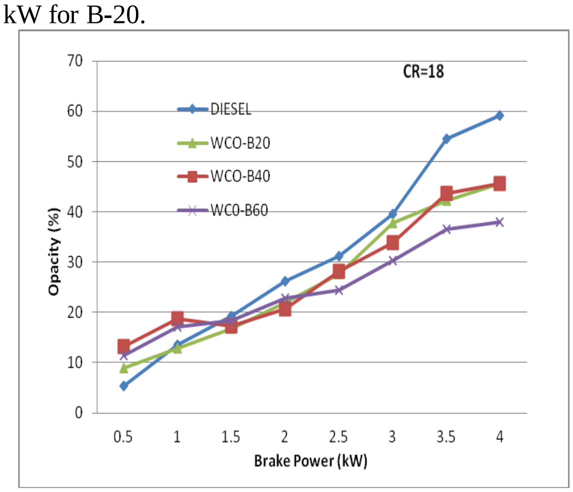

Fig: 7. Comparison of smoke opacity v/s brake power

5. Conclusions

The production and performance testing have demonstrated that waste cooking oil can be a good source of biodiesel production especially in Indian condition where large amount of waste oil is produced and then dumped either into land or river causing environmental pollution. As per performance testing performed in this work it can be seen that waste cooking oil biodiesel blends give better thermal efficiency and have got safer impact on environment as compared to diesel fuel.

Following conclusions have been made:

1. Higher biodiesel yield is obtained using molar ratio 6:1 as compare to molar ratio 4.5
2. The sfc is slightly higher (average percentage variation is in the range of 4 to 8% higher) than that of diesel for WCO-B20, WCO-B40 and WCO-B60 blends. As compared to WCO-B20 the sfc values are higher for WCO-B40 and WCO-B60
3. At all brake power conditions the opacity of all blends has less value (percentage variation is in the range of 10 to 25% lower) than diesel except lower bp values (0.5kW and 1kW). Maximum value of opacity has obtained at 59.21 at 4.0 kW Brake power for diesel and for blends 45.7 at 4.0 kW for B-20.

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