Performance of Diesel Engines Burning Used Cooking Oil (UCO) Biodiesel

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Abstract-- Biodiesel has a vital role in recent years as an alternative fuel for diesel engines due to the depletion of petroleum resources in the near future. It is an environmentally friendly renewable resource of energy and can be produced from used cooking oil (UCO) by transesterification process. The properties of biodiesel have comparable performance and emission characteristics to diesel fuel. In this study, a comparative study had been done between blends of biodiesel derived from UCO and diesel fuels. Diesel- UCO biodiesel blends of 10 and 20\% was prepared. Experimental investigations were tested in a four stroke, single cylinder, diesel engine at a constant speed of 1500 rpm and variable loads. Diesel- biodiesel blends showed an increase in fuel consumption and specific fuel consumption in comparison with diesel fuel. Biodiesel blends showed a decrease in engine thermal efficiency about diesel fuel. At full load, CO\textsubscript{2} emissions for biodiesel blends achieved an increase about diesel fuel. There were reductions in HC and CO emission for biodiesel blends compared to diesel fuel. It is recommended to use used cooking oil biodiesel up to 20\% with diesel fuel without any engine modifications.

Index Term-- UCO, Biodiesel, Diesel Engine, Performance, Exhaust, Emissions.

I. INTRODUCTION

Biodiesel is considered as promising substituent to diesel fuel in internal combustion engines and produced from vegetable oils and animal fats. The utilization of used cooking oil (UCO) is a new trend in the production of biodiesel to save money and overcome some problems. Huge amounts of used cooking oil poured in the sewer system of countries and cause pollution of rivers and underground water. High viscosity of used cooking oil causes poorly atomization in the engine and hence insufficient worthy combustion. Performance of diesel engine is improved by reducing oil viscosity either by transesterification of oil with short chain alcohol or cracking in the presence of mineral catalyst. Diesel fuel was blended by waste cooking oil biodiesel with a ratio of 25\% on volume basis. Specific fuel consumption for blend B25 increased up to 5.69\% compared to diesel fuel. However, HC and CO emission reductions compared to diesel fuel were found to be around 16.24\% and 19.81\%, respectively. Transesterification method was used to reduce viscosity of waste cooking oil. Thermal efficiency for blend B25 were slightly lower than those of diesel fuel. CO and HC emissions reduced when the blend fuels of B25 in diesel engines. The reductions in these exhaust emissions for waste cooking oil biodiesel were 11.66\% and 23.12\%, respectively [1]. Waste cooking oil biodiesel fuel produced by transesterification of waste cooking oil had shown very promising chemical and physical properties compared with diesel fuel. Biodiesel of waste cooking oil B50 resulted in a considerable reduction in unburnt hydrocarbons associated with an increase in the CO\textsubscript{2} emissions. Results indicated an increase in specific fuel consumption with simultaneous reduction in the engine thermal efficiency compared to conventional diesel fuel due to the oxygen content and the lower calorific value of biodiesel compared to diesel fuel [2].

Waste cooking oil methyl ester and its blends with diesel fuel of 20\%, 40\%, 60\% and 80\% had been studied. Biodiesel blends gave a reduction of carbon monoxide, hydrocarbon and increase in nitrogen oxides emissions. Engine performance reduced with increase in biodiesel percentage in the blend. The exhaust gas temperature for the blends was higher compared to that of standard diesel fuel. Emission of oxides of nitrogen from the waste cooking oil blend B40 is higher than that of diesel fuel. CO emission of the blend B40 is closer to the standard diesel fuel. CO\textsubscript{2} emission is also lesser at the same conditions. The experimental result also proves that lower and medium percentages of waste cooking oil methyl ester can be substituted for diesel fuel [3]. Fuel consumption was higher for biodiesel blends because of biodiesel having a lower heating value compared to diesel fuel [4]. Experiments were conducted on direct injection diesel engine using diesel fuel, biodiesel and their blends to investigate the exhaust emissions of the engine under different engine loads at an engine speed of 1800 rpm. Blended fuels containing 19.6\%, 39.4\%, 59.4\% and 79.6\% by volume of biodiesel, corresponding to 2\%, 4\%, 6\% and 8\% by mass of oxygen in the blended fuel, were used. Biodiesel used in this study was converted from waste cooking oil. Specific fuel consumption and the thermal efficiency increase. HC and CO emissions
Waste cooking oil biodiesel blends of B5 and B10 were tested and compared to diesel fuel. Biodiesel blends of B5 and B10 resulted in slightly increment on specific fuel consumption up to 4% and reduction on thermal efficiency up to 2.8%. Biodiesel blends decreased hydrocarbon emissions for all engine loads. There were no significant changes on CO emissions at the low and medium engine loads, some reductions were observed at the full engine load. CO2 emissions were slightly increased for the all engine loads. HC emissions showed decreasing trend up to 5% for low and medium engine loads and up to 29% for the high engine load with the addition of the biodiesel fuel [6].

With increase percentage of waste cooking oil biodiesel in diesel-biodiesel blends, higher exhaust gas temperature of waste cooking oil biodiesel which increased with percentage increase of waste cooking oil biodiesel in the blend. CO and HC emissions were found to significantly decrease with biodiesel and its blends due to a more complete combustion caused by higher oxygen content. An increase in specific consumption had been found when using biodiesel blends compared to diesel fuel due to the lower heating value of biodiesel and its blends. There was a decrease in thermal efficiency with increase in percentage of biodiesel in biodiesel blends [7, 8, 9, 10].

This work is aimed to the reutilization of used cooking oil (UCO) in the production of biodiesel. Fuel properties were compared to diesel fuel. Performance and exhaust emissions of a diesel engine were tested using two blends of diesel-biodiesel (B10 and B20).

II. USED COOKING OIL BIODIESEL PRODUCTION

Used cooking oil has sufficient potential to run diesel engines. It is available in the local market at cheaper rate. Huge quantities of used cooking oil can be collected from restaurants and food item industry. UCO was obtained from Tagadod Company. Viscosity of used cooking oil is about ten times, greater and its density is about 10% higher than that of diesel fuel. Biodiesel is derived from vegetable oils or animal fats which are basically long chain triglyceride esters with free fatty acids. The long chain triglyceride ester is converted into mono ester by the process called transesterification, it reduces viscosity of waste cooking oil and converting it to biodiesel. In this process, the vegetable oils were reacted with methanol or ethanol in the presence of acid or base catalyst producing fatty acids methyl or ethyl ester. In this study, used cooking oil was transesterified using 1% sodium hydroxide and 20% methanol at the temperature range of 65-69°C. The reaction time was two hours and conversion efficiency was 92.5%. Transesterification process was shown in Fig.1. Properties of used cooking oil biodiesel such as density, viscosity, heating value and flash point were measured in Egyptian Research Petroleum Institute, Cairo, Egypt and were indicated in Table 1 [10, 11, 12].

![Fig. 1. Transesterification Process](image)

<table>
<thead>
<tr>
<th>Properties</th>
<th>Diesel</th>
<th>B20</th>
<th>B100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (kg/m³)</td>
<td>830</td>
<td>841</td>
<td>885</td>
</tr>
<tr>
<td>Kinematic Viscosity (mm²/sec) at 40°C</td>
<td>3.05</td>
<td>4.9</td>
<td>12.5</td>
</tr>
<tr>
<td>Flash Point°C</td>
<td>65</td>
<td>74</td>
<td>179</td>
</tr>
<tr>
<td>Heating Value (MJ/kg)</td>
<td>42</td>
<td>41.25</td>
<td>38.6</td>
</tr>
</tbody>
</table>
III. EXPERIMENTAL SET UP

The present study was carried out to investigate the performance and emission characteristics of biodiesel derived from waste cooking oil blends with diesel fuel in diesel engine and compared to diesel fuel. The test engine is a Kirloskar make, single cylinder, four stroke, water cooled, direct injection, AV1 model diesel engine. Its specifications are given in Table 2. The engine was connected to an eddy current dynamometer to measure the power output and speed. The engine was equipped to measure fuel consumption, engine speed and exhaust gas temperature. The engine receives air through an air box fitted with an orifice for measuring the air consumption. A pressure differential meter is used to measure the difference in pressure between the two sides of the orifice. Fuel consumption rate was determined using a glass burette and stop watch. The engine speed was measured using a digital tachometer. MRU DELTA 1600-V exhaust gas analyzer was used for measuring the exhaust gas emission concentrations of CO, HC and CO₂. A data acquisition card (National Instrument 6210) was used to acquire data to be fed to personal computer. The schematic diagram of experimental set up and test rig is shown in Fig.2. The engine was warmed up before taking all readings. When the engine reached its stable condition, the experiments were started and measurements recorded. The engine was then operated with blends of diesel and waste cooking oil biodiesel (B10 and B20). For every operating condition, the engine speed was checked and maintained constant at rated speed of 1500 rpm. The performance parameters and exhaust gas emissions concentrations investigated were fuel consumption, specific fuel consumption, thermal efficiency, carbon dioxide (CO₂), carbon monoxide (CO and unburned hydrocarbons (HC).
IV. RESULTS AND DISCUSSION

A. Fuel Consumption

The variation of fuel consumption with brake power is shown in Fig.3. It is observed that as the load increased, fuel consumption increased for all fuel blends. This variation increased from lower loads to higher loads due to the increase in injected fuel with the increase in output power. As percentage of biodiesel increases, the fuel consumption tends to increase because of lower heating value of biodiesel. At full load, the maximum increase in fuel consumption for blends B10 and B20 in comparison with diesel fuel was about 1.4 and 2.6 %, respectively.

![Graph showing fuel consumption vs brake power for different blends](image)

**Fig. 3.** Variation of Fuel Consumption with Brake Power for biodiesel blends.

B. Specific Fuel Consumption

Variation of specific fuel consumption with brake power for diesel and diesel- biodiesel blends was shown in Fig.4. Specific fuel consumption decreased with the increase from lower loads to higher loads for all fuels due to increase of fuel consumption with load. Specific fuel consumption for biodiesel blends was higher than diesel fuel. This may be due to higher fuel density, higher viscosity and lower heating value of biodiesel compared to diesel fuel and this leads to lower heat content. At full load, the highest value of specific fuel consumption for blend B10 and B20 in comparison with diesel fuel was about 1.3 and 2.2 %, respectively.

![Graph showing specific fuel consumption vs brake power for different blends](image)

**Fig. 4.** Variation of Specific Fuel Consumption with Brake Power for biodiesel blends.

C. Thermal Efficiency

The variation of thermal efficiency with brake power for diesel and diesel- biodiesel blends was shown in Fig.5. Thermal efficiency has the tendency to increase with increase in engine load. This was due to the reduction in heat loss and increase in power developed with increase in engine load. Thermal efficiency for biodiesel blends was lower than diesel fuel. This may be due to poor atomization, higher viscosity and reduction in heat loss of biodiesel blends compared to diesel fuel. Decrease of thermal efficiencies of biodiesel blends compared to diesel fuel in all loads was due to higher fuel consumption and lower heating value of biodiesel. At full
load, the maximum decrease in thermal efficiency for B10 and B20 about diesel fuel was 2.5 and 3.5%, respectively.

V. ENGINE EXHAUST EMISSIONS

A. Carbon Dioxide Emission

It can be observed from Fig. 6 that the amount of CO₂ emission increased with the increase of engine load due to higher fuel consumption at higher loads. Lower percentages of CO₂ emissions were produced when diesel engine fueled with biodiesel blends compared to diesel fuel. This was due to the lower carbon to hydrogen ratio in biodiesel blends compared to diesel fuel. Diesel fuel has 85% carbon content while biodiesel has about 76%. Biodiesel had oxygen content which improved combustion. B20 and B10 produced very low levels of CO₂ emissions. Using higher concentrations of biodiesel, CO₂ emission levels were lower than that of diesel fuel. At full load, the values of CO₂ emissions for diesel, B10 and B20 fuels were 6.5, 6.3 and 6.2%, respectively.

B. Carbon Monoxide Emission

Carbon monoxide emissions of diesel and waste cooking oil biodiesel blends are shown in Fig. 7. CO emissions increased with load increasing from lower to higher loads due to decrease of air-fuel ratio at higher loads. The higher combustion temperature at lower engine loads contributed to the general decreasing trend of CO emission. The decrease in carbon monoxide emission for biodiesel blends was due to more oxygen molecule present in the fuel, improved atomization and better vaporization of biodiesel resulting in complete combustion as compared to diesel fuel. The higher amount of oxygen in biodiesel will promote further oxidation of CO emission. At full load, CO emission for B10 and B20 blends were about 6 and 18% lower than that of diesel fuel.
Variations of HC emissions for diesel and biodiesel blends are shown in Fig. 8. HC emissions increased as the engine load increased due to the increase of fuel consumption at higher loads. Higher cetane number of waste cooking oil biodiesel resulted in a decrease in HC emissions due to shorter ignition delay. Lower HC emissions of biodiesel blends were due to the presence of fuel bound oxygen and warmed up conditions. The maximum concentrations of HC are 32 ppm, 27 ppm and 23 ppm for diesel, B10 and B20 fuels at full load, respectively.

**VI. CONCLUSIONS**

Used cooking oil biodiesel can be used as alternative fuel for diesel engines. Used cooking oil biodiesel blends of 10 and 20% were tested in a four stroke, single cylinder, diesel engine at a constant speed of 1500 rpm and variable loads. Experimental results of biodiesel blends compared with diesel fuel showed that:

- Diesel- biodiesel blends showed increase in fuel consumption due to the lower heating value of the biodiesel. B20 and B10 showed an increase of 2.6 and 1.4 %, respectively in fuel consumption compared to diesel fuel. Biodiesel blends B20 and B10 showed increase in specific fuel consumption about 2.2 and 1.3%, respectively in comparison with diesel fuel.

- Biodiesel blends B20 and B10 showed decrease in engine thermal efficiency about 3.5 and 2.5%, respectively in comparison with diesel fuel.

- At full load, the values of CO\textsubscript{2} emissions for diesel, B10 and B20 fuels were 6.5, 6.3 and 6.2, respectively.

- At full load, the maximum values of HC emission for diesel, B10 and B20 fuels were about 32, 27 and 23 ppm, respectively. At full load, The decrease of CO emissions for B20 and B10 in comparison with diesel fuel was about 6 and 18%, respectively.

Using neat used cooking oil biodiesel in conventional diesel engine is not recommended. Used cooking oil biodiesel blends can be used up to 20% with diesel fuel without any engine modifications. Performance and emissions of a diesel engine...
using biodiesel blends up to 20% with diesel fuel were closer to diesel fuel.

- Used cooking oils are very suitable as low cost feed stocks for biodiesel production. The environment will be cleaned by collecting and recycling these waste oils, human health will be protected and reducing the dependency on fossil fuel resources.

REFERENCES


