Experimental investigation of using kerosene-biodiesel blend as an alternative fuel in diesel engines

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Abstract. Researchers are seeking alternative ways to deal with conventional fuels depletion and global warming. Biodiesel appears as one of the most candidate alternatives in this regard. The present work deals with biodiesel produced by transesterification of sunflower oil. The produced biodiesel was further mixed with kerosene to obtain a blend between new and traditional fuels. The physicochemical properties of the bio-fuel blended with kerosene have been tested in the laboratory maintaining different ASTM standards. In this study, blends of biodiesel and kerosene were tested on TQ small engine test set (TD200). BK60 (biodiesel 60 vol. % and kerosene 40 vol. %), BK45 (biodiesel 45 vol. % and kerosene 55 vol. %), BK30 (biodiesel 30 vol. % and kerosene 70 vol. %) and BK15 (biodiesel 15 vol. % and kerosene 85 vol. %) were tested. Three mixing speeds were used in the tests, namely; 1000 rpm, 2000 rpm, and 3000 rpm at constant high load of 80%. The performance parameters studied included; brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC). Regarding the emissions, carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NOx) were also recorded. Results showed that the new blends produce higher BTE and lower BSFC than the conventional kerosene and biodiesel.

Keywords: Diesel Engine, Biodiesel, Sunflower Oil, Kerosene, Emissions.

1. INTRODUCTION

The preservation of environment is a concerning issue nowadays. Polluting products of the industries constitute a real threat especially if the same old fossil fuels are in use. Diesel engines are still abundant in heavy industries to produce electricity or direct high torques. However, the harmful emissions of diesel combustion limit the adoption of diesel engines in areas of high air pollution [1]. Biodiesel is a renewable alternative fuel that can be made from plant oils, such as; palm, jatropha, curcas, soybean, rapeseed and sun flower. Waste cooking oil can also serve in this regard. Biodiesel is a renewable liquid fuel that can be produced by transesterification process of oil and alcohol in the presence of a suitable catalyst [2]. Biodiesel can be used to replace petroleum diesel, with no need to modify the original diesel engine. It can also be blended with conventional diesel at different levels, producing a biodiesel blends. The two main advantages of these blends are the high energy yield and the drastically lower emission rates.
O. Can et al. [3] tested canola biodiesel blends in four proportions (5%, 10%, 15% and 20%) at four different loads (4.8, 3.6, 2.4 and 1.2 bar BMEP) in a single cylinder direct injection diesel engine. They concluded that there is an increase in NOx emissions at all loads in proportion to the blend ratio. HC and CO emissions were reduced with the increase in biodiesel concentration at all loads. Biodiesel has a higher viscosity than petroleum diesel, which leads to higher surface tension, larger droplet size, and poor atomization, while fuel is injected into the cylinder. High viscosity also resulted in lower injection velocity of the biodiesel [4]. This problem can be solved by blending biodiesel with kerosene, which has low viscosity, low density, and high volatility. Kerosene has an advantage of high miscibility and good stability at any mixing ratio [5].

H. Aydin et al. [6] tested three different fuel types: D100, B20, and BK20 in a single cylinder, 4-stroke, and direct injection compression engine. They concluded that the addition of kerosene increases engine power and decreases brake-specific fuel consumption. NOx was reduced by 6-10% in BK20, compared to B20. There are three different methods of adding water: spraying water into the intake manifold, which is known as manifold fumigation [7–9]; injecting water directly into the combustion cylinder [10, 11], and introducing water into the diesel emulsion fuel. The direct injection method reduces NOx at a higher rate than manifold fumigation because water droplets are closer to the flame during combustion, which enhances fuel penetration [12]. With the introduction of water into diesel fuel, a micro explosion occurs and, due to this phenomenon, the spray characteristics are enhanced, which in turn improves the pace of combustion and reduces emissions [13]. However, manifold fumigation and direct injection tend to increase NOx and HC emissions [14]. Of the three methods, the blending method proved to be more effective in reducing emission because it can reduce NOx and PM emissions simultaneously, and improve efficiency [15, 16].

The main goal of the present study is to reduce the operation cost of diesel engine by using an alternative fuel, namely biodiesel-kerosene blend. The kerosene price is low in hot and warm periods of year since no kerosene operated appliances are used. As a result, employing biodiesel-kerosene blend becomes feasible. The aim of the present work is to investigate the improvement in performance and emissions in diesel engines through the use of biodiesel-kerosene blends an alternative fuel.

2. PREPARATION OF FUEL SAMPLES

To carry out this experimental study, we used sunflower biodiesel produced through transesterification reaction of sunflower oil with methanol and NaOH as a catalyst in a reactor located at University of Technology (Iraq). After separating biodiesel from glycerin, it was washed and purified. Kerosene was obtained from Al-Dura oil refinery. Four volumetric values of blends were prepared by using high speed mixer to homogenize the blends of fuel samples. Table (1) shows the Characteristics of the investigated fuels.

| Properties                  | Test method | Diesel | Sunflower biodiesel | Kerosene | Bk40 | Bk55 | Bk70 | Bk85 |
|-----------------------------|-------------|--------|---------------------|----------|------|------|------|------|
| Approx. formula             | GC mass     | C16H34 | C19H36O2            | C11H21   | 1.38 | 3.40 | 2.87 | 2.41 |
| Kinematic viscosity @40°C (mm²/sec) | ASTM D445   | 2.8    | 4.92               | 1.38     | 3.40 | 2.87 | 2.41 | 1.86 |
| Density Kg/m³               | ASTM D1298  | 833    | 870                | 807      | 845  | 835  | 826  | 816  |
| Calorific value (MJ/Kg)     |             | 43.1   | 37                 | 43.15    | 39.46| 40.38| 41.30| 42.22|
| Flash point °C              | ASTM D93    | 67     | 176                | 45       | 125  | 105  | 81   | 63   |

3. EXPERIMENTAL SETUP AND PROCEDURE

In this study a single cylinder, air-cooled, 4 stroke, and direct injection diesel engine mounted on a test bed, has been used(Fig. 1). The engine was coupled to a hydraulic variable fill dynamometer. TEXA
wireless data acquisition exhaust gas analyzer was used for engine emission analysis of NOx, HC and CO. The engine was first run fuelled with diesel to define the baseline parameters as well as for the warm up purpose. Engine performance parameters that were measured are; brake power, brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE). The fuels were tested at three speeds: 1000, 2000, and 3000 rpm at constant high load (80%) for each speed. For data logging, Versatile Data Acquisition (VDAS-F) data control system was used. Emission analysis was also conducted at all speeds at constant load. Specifications of the engine are given in Table (2).

![Image](image_url)

Fig. 1: Image of the experimental setup (left) and schematic view of the experimental setup (right).

| Manufacture       | TecQuipment Ltd. UK |
|-------------------|---------------------|
| Model             | TD212               |
| Type              | Direct injection, 4 stroke |
| No. of cylinders  | 1                   |
| Max. power        | 3500 W              |
| Bore              | 69 mm               |
| Stroke            | 62 mm               |
| Method of cooling | Air cooled          |
| Max. speed        | 3600 rpm            |

4. RESULTS AND DISCUSSION

4.1 Engine Performance

4.1.1 Brake Thermal Efficiency (BTE)

Figure (2) shows the brake thermal efficiency of the engine for different blends. It can be seen that Biodiesel-kerosene blends show higher BTE than diesel fuel due to the oxygen content (about 10%) in
biodiesel fuel, which enhances the combustion. The BTE of kerosene was higher which means that
kerosene is suitable for use in diesel engines, due to the higher heating value, and the low viscosity of
kerosene enhances the atomization of fuel. The BTE is increased with the increase of kerosene percentage
in the blends. On average, the BTE of Bk15 increased about 2% compared to BK45.

4.1.2 Brake-Specific fuel Consumption (BSEC)

Figure (3) shows the BSFC of different blends at three different speeds and constant load (80%).
BSFC is defined as the fuel consumption rate to produce unit brake power. BSFC is directly proportional
to the fuel mass flow rate. BSFC decreases with the addition of kerosene due to the high heating value of
kerosene and its better thermal efficiency as compared to D100 and B100. The decrease in BSFC is in the
range of 2.5-3.5% for BK15 compared to D100 at different speeds and constant load. It is also clear that
BSFC follows the same trend for all fuels; it decreases with engine speed increase until 2000rpm and then
increases with engine speed increase.

![Fig. 2: Brake thermal Efficiency vs speed](image1)

![Fig. 3: Brake specific fuel consumption vs speed](image2)
4.2 Emissions

4.2.1 CO Emissions

Figure (4) shows CO emission of the blends, at constant engine load and various speeds. CO and HC are products of incomplete combustion. Biodiesel has more oxygen content (about 10%) than petroleum diesel (D100); hence, more complete combustion takes place and therefore less CO and un-burnt hydrocarbon (HC) are expected. Kerosene has a slightly lower CO than D100, and with the addition of kerosene in biodiesel; a noticeable increase in CO is observed. The extra oxygen content in fuel blends ensures the oxidation of CO, even on locally fuel-rich zones which helps to reduce CO emission [17,18]. Therefore the CO emissions for kerosene-biodiesel blends are about 40% lower than that of diesel.

4.2.2 HC Emissions

Figure (5) illustrates HC emissions at constant load and different engine speeds. It is clear that HC emissions decrease with the increase in engine speed. This decrease in HC emission is attributed to the increase in combustion temperature and complete fuel combustion. HC trend is quite similar to that of CO, there is about 45-55% of HC reduction for biodiesel-kerosene blends than that of D100. Adding kerosene in blends significantly increases HC emissions. It can also be observed that oxygenated compounds available in the biodiesel made the HC emissions lower in the case of biodiesel-kerosene blends. However, BK60 always produces lower HC than other blends and D100.

4.2.3 NOx Emissions

Figure (6) shows a comparison of NOx emissions of the diesel and the blends of biodiesel-kerosene at different engine speeds and constant load. The reasons behind the high NOx emission are high combustion temperature and oxygen content in fuels. Due to 10% oxygen content in biodiesel, Biodiesel-kerosene blends produced about 10-28% more NOx than D100 at different engine operation conditions. Kerosene NOx emissions are similar to that of diesel. Adding kerosene in biodiesel helps in reducing NOx emissions.

Fig. 4: CO emission vs Brake power
5. CONCLUSIONS

Experiments and analysis of engine performance and emissions were conducted on various biodiesel-kerosene blends. It is concluded that brake thermal efficiency (BTE) increases with the increase in kerosene concentration with BK15 having the maximum BTE. The increase in kerosene concentration increases the calorific value, which tends to increase its BTE. For all engine speeds at constant load, BTE increases with engine speed. Brake-specific fuel consumption (BSFC) was initially high, for blends of high biodiesel concentration, because of their low heat content, but subsequently decreased with the kerosene concentration. Carbon monoxide (CO) and hydrocarbons (HC) emissions showed similar trends, as both are products of incomplete combustion. Both CO and HC decrease with biodiesel concentration, and increase with engine speed. NOx is considered to be the major challenge in using biodiesel as an alternative fuel. NOx decreased with the kerosene concentration. In this experimental study, we achieved NOx reduction by 10-18% in a blend that contains 15% biodiesel as compared to a blend with 60% biodiesel.

Fig. 5: HC emission vs speed

Fig. 6: NOx emission vs speed
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