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Influence of Biodiesel Inlet Temperature on the Performance of a Small DI Diesel Engine

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Abstract: Because of the expanding interest to the depletion of petroleum fuel assets and ecological issues, biodiesel turned out to be increasingly alluring in the last decades. Biodiesel is an alternative fuel comparable to ordinary or petrodiesel. Biodiesel can be created from vegetable oil, creature oil/fats, fat and used cooking oil. Biodiesel has numerous naturally useful properties. The most advantage of biodiesel is that it can be depicted as 'low carbon emission fuel'. Beside that biodiesel encompasses a higher flash point than petrodiesel and so is more secure within the occasion of a crash. In this paper, an experimental study has been conducted on a small DI diesel to compare between the performance of the engine performance using petrodiesel and biodiesel fuels. An AC electric generator is used as an engine load. The effect of engine load and fuel inlet temperature on the brake thermal efficiency as well as brake specific fuel consumption on the brake thermal efficiency as well as brake specific consumption are experimentally investigated. The results indicate that no obvious changes in brake thermal efficiency of both biodiesel and petrodiesel fuels at low engine load while, the brake thermal efficiency of biodiesel is slightly higher than petrodiesel at high engine load. However, the higher the engine load, the higher the brake thermal efficiency and the lower brake specific consumption. This effect was slightly evident in petrodiesel than biodiesel. The increase in the inlet fuel temperature leads to reduction in fuel viscosity especially in biodiesel fuel. As a result of an increase in the biodiesel temperature from 25°C to 70°C, the kinematic viscosity decreases by about 0.57%. Also, there is a reduction in the petrodiesel kinematic viscosity with the increase in temperature. As the fuel temperature increases from 25°C to 70°C, the petrodiesel kinematic viscosity decreases by about 54%. And as a result, there is an improvement in brake thermal efficiency especially with the biodiesel fuel.

Keywords: Biodiesel, Inlet Diesel Temperature, Engine Performance, Diesel Emissions, Fuel Viscosity

1. Introduction

Fuels are one of the most important commodities because they can be burned to produce significant amounts of different forms of energy such as mechanical, electrical and heat. Many aspects of daily life depend on fuel, especially the transport of goods and people. Certainly, energy comes mainly from fossil fuels such as petroleum oil, natural gas and coal. Global energy requirements are fulfilled mainly from the fossil fuels. A large part of the present-day industries uses diesel engines for the production process. However, in the transport sector, most ships, buses, trucks and some passenger cars run with the petrodiesel. This situation leads to a strong dependence of everyday life upon the fossil fuels. Nonetheless, the increasing demand of the growing population may not be covered merely by the domestic crude oil production [1]. Therefore, the access to the alternative energy resources is one of the superior problems confronting humanity. In other words, there is a dire need to find a sustainable and renewable alternate to the fossil fuels [2] and [23].

Fossil fuel resources will be depleted in over 60-70 years. Furthermore, the engine exhaust emissions, especially the hydrocarbons and carbon monoxide, produced by burning of the fossil fuels contribute to the air pollution and the global warming [3]. Likewise, the insufficient quantities of petroleum oil for a steady increase in the population and the changing price is a matter of great concern for the mankind. On the other hand, the renewable energy is a promising alternate because it is clean and environmentally safe [4], [19] and [22].

Since the petrodiesel and the petrol fuels comprise of mixtures of several unique chemicals of differing hydrocarbon chains, a large number of these are risky and poisonous. They have a tremendous impact on the environment safety that the world has suffered from at least last hundred years. Carbon monoxide (created when ignition leads to incomplete combustion or deficient burning), nitrogen oxides (delivered when burning occurs at high temperatures), and particulates that are for the most part delivered amid burning are other particular emanations of concern. It is, therefore, the right time to think intensely about the alternative fuel. There are a few optional wellsprings of fuel like vegetable oils, biogas, biomass, essential alcohols which are all renewable in nature. Among these fuels, vegetable oils seem to have a remarkable significance as they are generally accessible, biodegradable, non-poisonous and environment benevolent. The alternative fuel that meets these requirements for diesel engines is biodiesel [5].

Biodiesel, as an alternative fuel, is portrayed as unsaturated fat methyl or ethyl esters from the vegetable oils or creatures. It is renewable, biodegradable and oxygenated. Albeit numerous explorers brought up that it may decrease gas emanations, advance economical rustic advancement, and enhance pay circulation, there still exist some reservations for utilizing it [2] and [6]

The main problem for using biodiesel is the absence of reliable information about the impact of biodiesel on diesel engines. For instance, the decrease of brake force for biodiesel, and in addition the expansion of fuel utilization, is not as much as expected. The early research conclusions have been kept in numerous individuals' psyche, that is, it is more inclined to oxidation for biodiesel which may bring about insoluble gums and residue that can plug fuel channel and, in this way, it will influence motor strength [7] and [20].

Mamat et al [8] have carried out an experimental study aimed to investigate the effect of boost temperature of the intake air on the engine performances and emissions. There results indicated that the higher the inlet temperature the lower the in-cylinder trap mass and hence the reduction of the heat oxygen capacity of the charged compressed air. Moreover, the brake specific fuel consumption increases at low load but slightly decreases by increasing the charge air temperature especially at part loads. Using the ultra-low sulfur diesel leads to a slight increase in the exhaust gas emissions, whereas there are no noticeable effects on the exhaust gas emissions by using the rapeseed methyl ester. Besides, the carbon monoxide emission is reduced by increasing the charge air temperature [9], [21] and [10].

In the last few years, reducing emissions from diesel engines was the main concern of the researchers and engines manufacturers. Many investigators concluded that emissions of biodiesel fuel are lower than those of diesel fuel. For example, Kumar et al, [11] mentioned in their experimental study that the biodiesel emissions are lower than the emissions of petrodiesel fuels. However, many investigations found that the hydrocarbons and carbon monoxide emissions are lower with the petrodiesel fuel. But, the nitrogen oxides (NO) emissions are higher with the biodiesel than with the petrodiesel fuels [12]. On the other hand, a considerable reduction in NO and the soot emissions could be achieved by using the biodiesel in comparison with the petroleum diesel [13] and [14].

This paper introduces a set of experiments conducted on a small direct diesel engine to investigate the engine performance parameters with the petrodiesel and biodiesel at different conditions. Variations in the engine load and the fuel inlet temperature are the main parameters that are taken into account to compare the mechanical thermal efficiency as well as the brake specific fuel consumption with the petrodiesel and biodiesel fuels.

2. Experimental Setup

To measure the fuel flowrate, the fuel system is modified such that a heat exchanger is installed covering the fuel tank. To control the diesel inlet temperature of the petrodiesel and biodiesel, a heat exchanger is designed and constructed. The heat exchanger has two inlets; one inlet is for the cold water and the other inlet for the hot water beside one drain. A thermocouple is installed inside the fuel tank to measure the inlet fuel temperature. A digital flowmeter is inserted in series. Heat exchanger is installed directly upon the fuel tank. The heat exchanger is meant to control the diesel temperature within the desired value. The thermally-controlled fuel is delivered to the fuel pump and hence to the engine. The fuel flowrate is measured using a digital flowmeter.

Figure 1 and Figure 2 show the construction of the test rig and its equipment's. To calculate the brake thermal efficiency η, two thermal load resistors each with 1.5 kW load are used for engine loading. A wattmeter is used to measure the output electrical power P. The brake thermal efficiency can be expressed as:

$$\eta_b = \frac{P_b}{\dot{m}_f \; Q_{c.v.}}$$

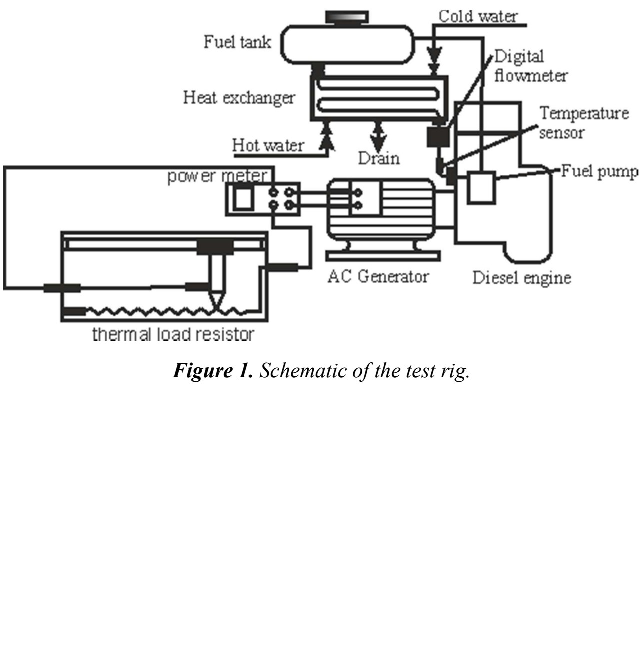

Figure 1. *Schematic of the test rig.*

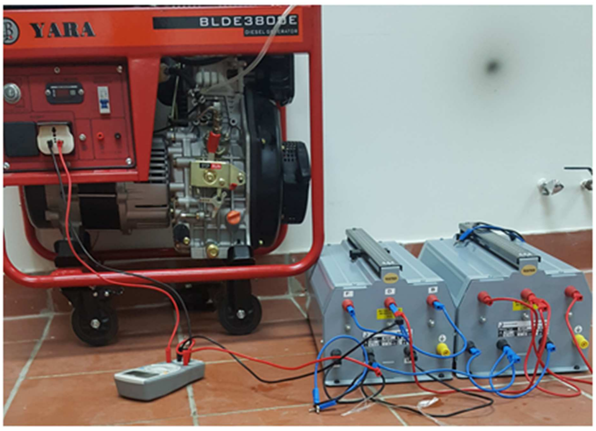

Figure 2. *Photo of the test rig.*

Table 1 shows the engine specifications used in this study.

Table 1. *Engine specifications.*

Maximum power (kW)	**3.1 at 1800 rpm**
Bore (mm)	55
Stroke (mm)	70
Compression ratio	16.5
Type of cooling	Air cooling
Direct injection	DI

3. Biodiesel Production

Biodiesel is made through a transesterification reaction. Transesterification is the chemical process through which one ester. is changed into another. When the original ester is reacted with an alcohol, the process is called alcoholysis. Biodiesel Laboratory makes biodiesel using vegetable oil (an ester compound) and methanol (an alcohol) as the reagents. A potassium hydroxide (KOH) as a catalyst. Figure 3 illustrates the based equation reaction of biodiesel [15].

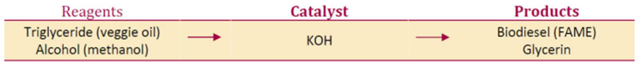

Figure 3. *Biodiesel production reaction.*

So, 1 liter of waste oil is heated to 155°C. Then, it is left to cool until the degree of 75°C. 7.2 g of potassium hydroxide is dissolved in 200 ml of methanol and added to the waste oil. Then, stirring the solution for about an hour and then it is thermally isolated for about 24 hours. Then washing it with warm water several times to separate the biodiesel. And then it is heated up to 70°C to make the dissolved water to be evaporated.

4. Results and Discussions

The brake thermal efficiencies of the petroleum diesel and the biodiesel at different engine loads are shown in Figure 4. From this Figure, it can be seen that the higher the engine load, the higher the brake thermal efficiency for petroleum diesel and biodiesel. The brake thermal efficiency of the petroleum diesel was higher than the biodiesel; whereas at low engine loads there is no noticeable differences between the two cases. However, with the increase of engine load, the brake thermal efficiency of petroleum diesel was evidently higher than that of biodiesel.

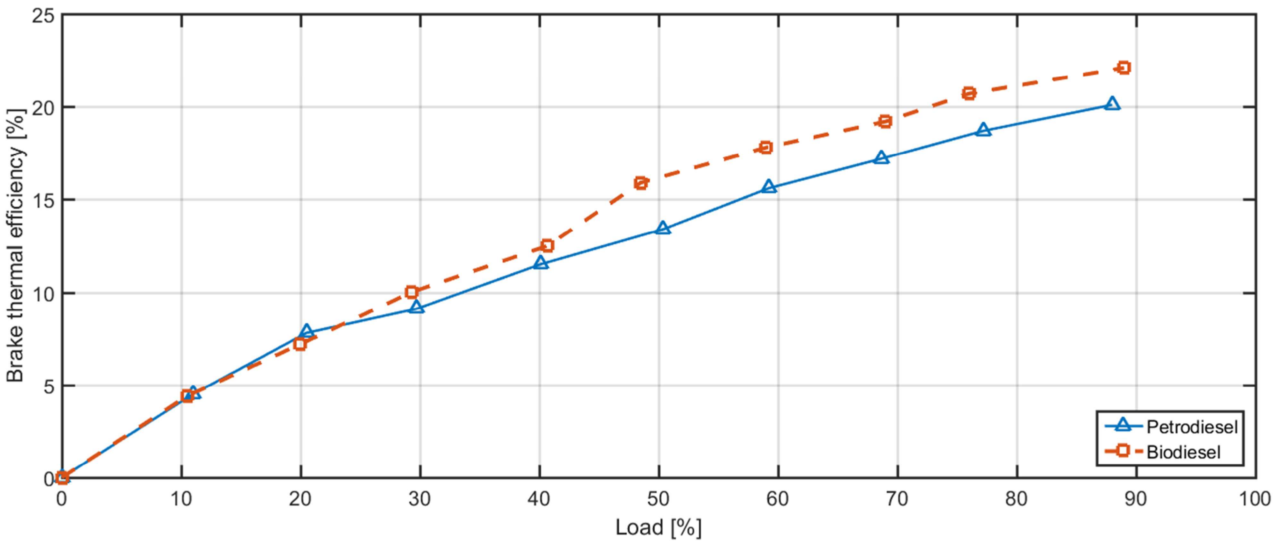

Figure 4. *Brake thermal efficiency vs load for petrodiesel and biodiesel.*

Figure 5 illustrates the brake specific fuel consumption (BSFC) of petroleum diesel and biodiesel as a function of engine load. With the increase of engine load, there is a decrease in BSFC with petrodiesel and biodiesel fuels. The BSFC is higher in the case of biodiesel at all engine loads. This could be attributed to the lower calorific value of the biodiesel fuel, which is 9% less than that of the petrodiesel. These results are in agreement with [3].

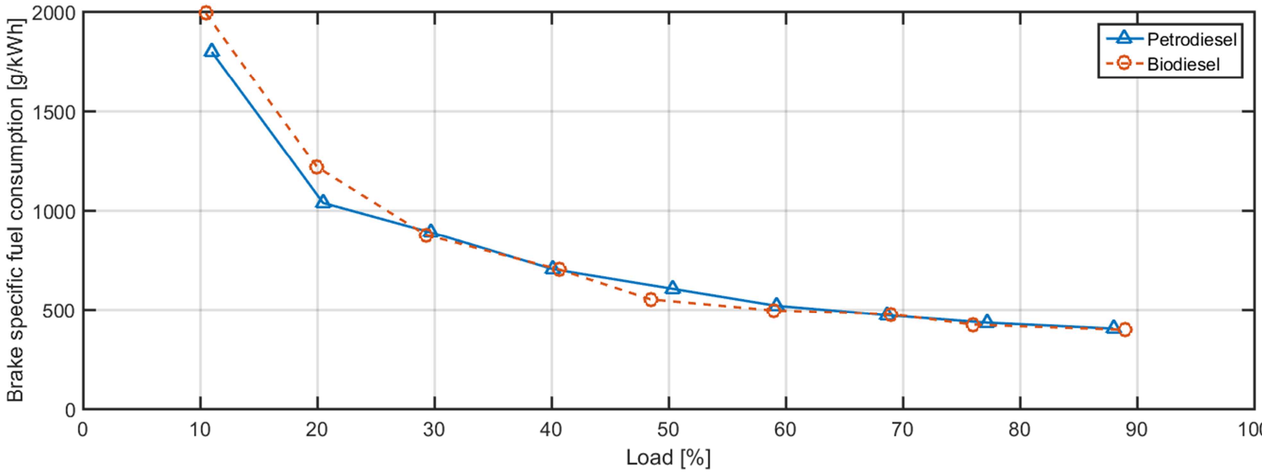

Figure 5. *Brake specific fuel consumption for petrodiesel and biodiesel.*

The effect of inlet petrodiesel on the brake thermal efficiency is shown in Figure 6. The petrodiesel inlet temperature is increased gradually from ambient (about 25°C) to 50 and 70°C. With the increase of petrodiesel inlet temperature from ambient temperature to 70°C, there is a slight improvement in the brake thermal efficiency especially at high engine load. This improvement is a result of increase in the fuel temperature which, in turn, leads to the weakening of fuel chain and hence a better combustion of the diesel is achieved. This improved combustion eventually yields an increased brake thermal efficiency. These results are in agreement with [3], [7] and [16]. They concluded that the brake thermal efficiency increases with an increase in the fuel inlet temperature.

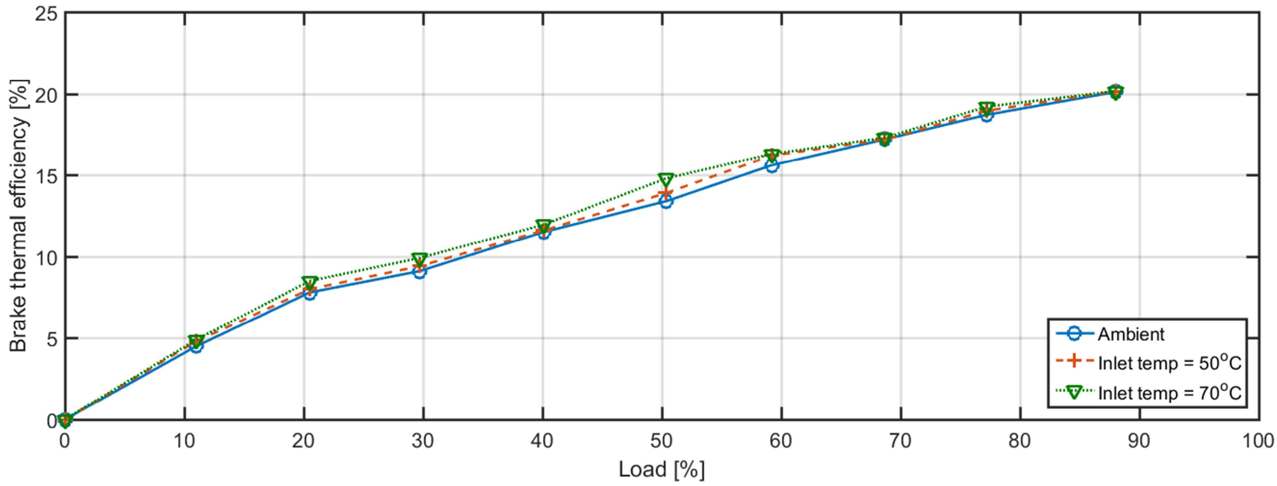

Figure 6. *Effect of inlet petrodiesel inlet temperature on the brake thermal efficiency.*

Figure 7 illustrates the effect of biodiesel temperature on the brake thermal efficiency. The testing conditions were identical to that of the petrodiesel case i.e. ambient temperature, 50°C and 70°C. From this Figure, it can be seen that there is a significant increase in the brake thermal efficiency with the increase of biodiesel inlet temperature. The brake thermal efficiency increases at high engine load. The brake thermal efficiency improvement with the increase of biodiesel inlet temperature can be interpreted as a result of breaking and weakening of the fuel chains, so that leading to the improved combustion.

On the other hand, a significant decrease in the viscosity and an insignificant change in the density is shown in Figure 8. From Figure, it can be noticed that increasing biodiesel temperature causes a considerable decrease in kinematic viscosity. As a result of an increase in the biodiesel temperature from 25°C to 70°C, the kinematic viscosity decreases by about 0.57%. Also, there is a reduction in the petrodiesel kinematic viscosity with the increase in temperature. As the fuel temperature increases from 25°C to 70°C, the petrodiesel kinematic viscosity decreases by about 54%. These results are in agreement with [17], [18] and [22]. Their experimental results indicated that at 120°C fuel temperature, the viscosity of all vegetable oils is below 6 mm^2s^{-1}.

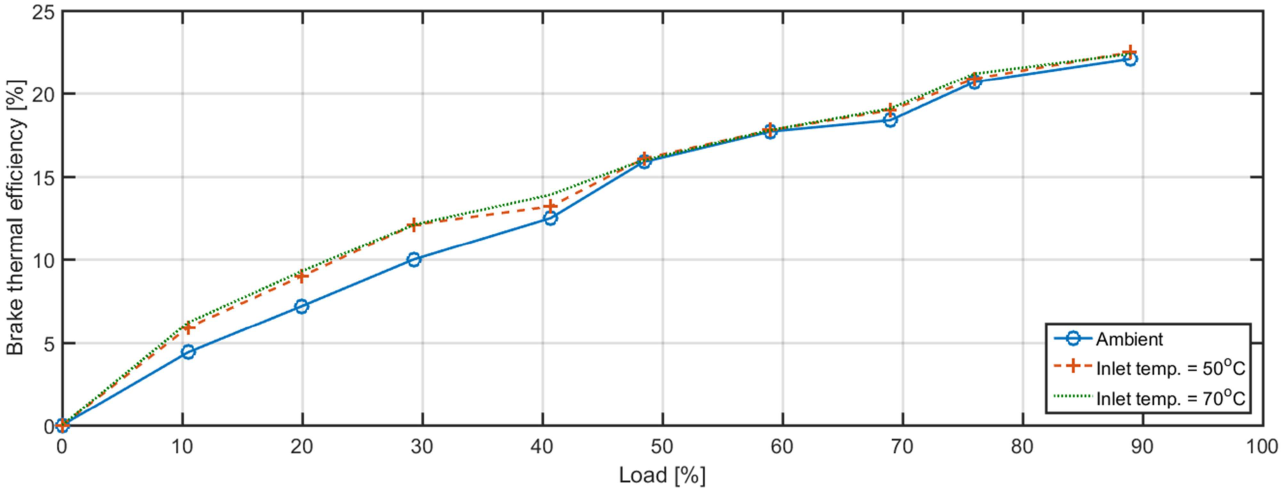

Figure 7. *Effect of inlet biodiesel temperature on the brake thermal efficiency.*

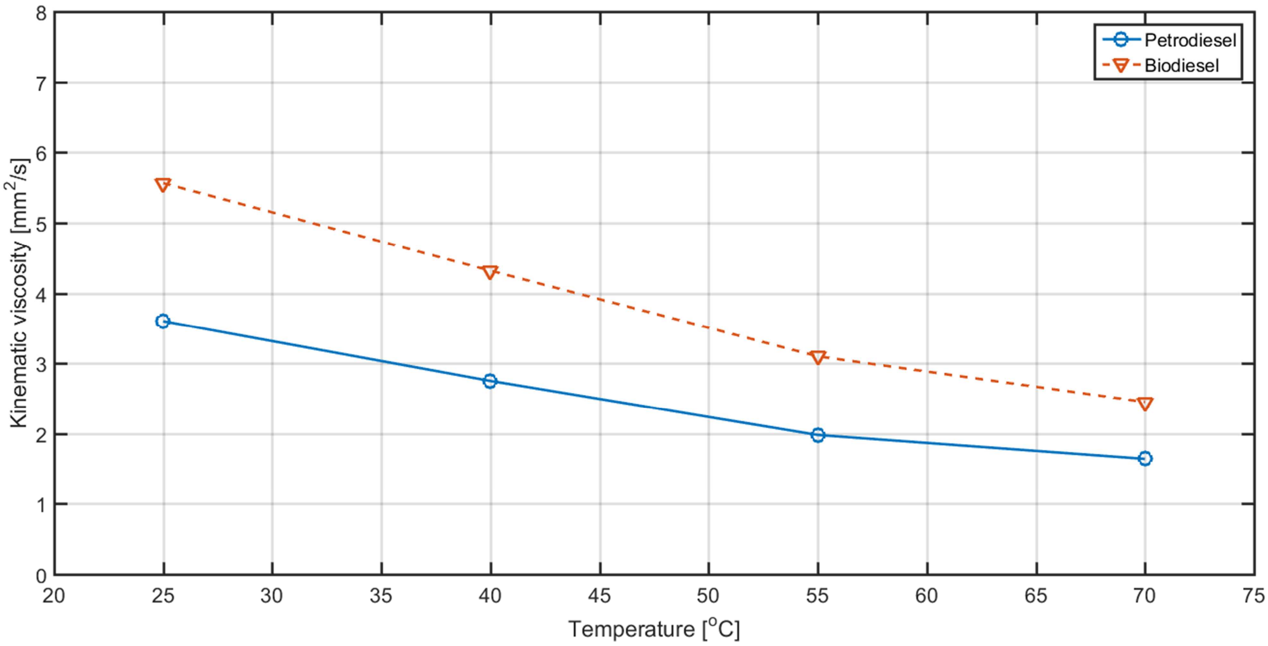

Figure 8. *Effect of temperature on fuel viscosity with petrodiesel and biodiesel.*

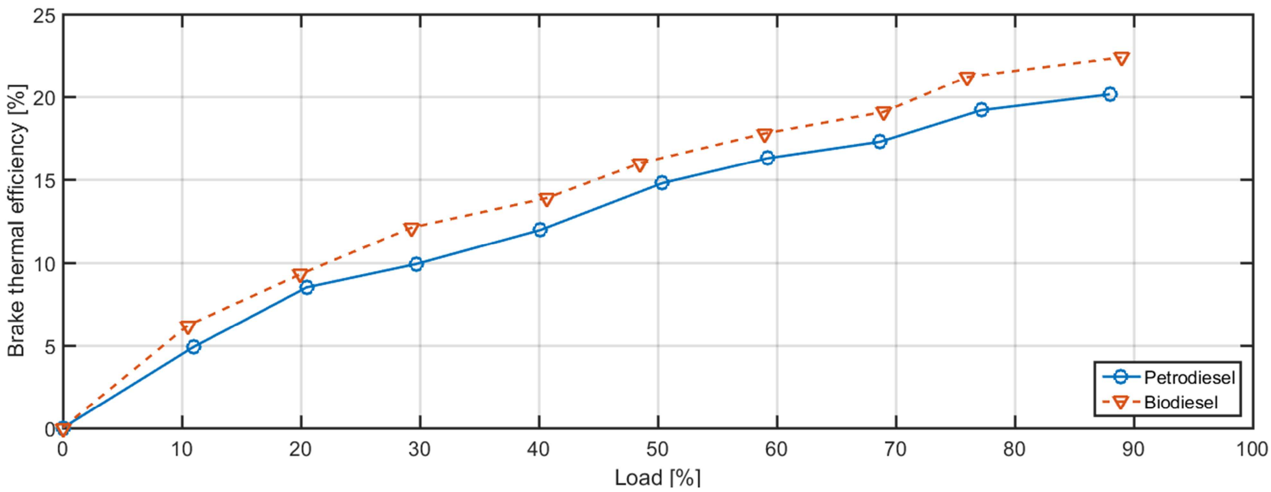

Figure 9. *Brake thermal efficiency of petrodiesel and biodiesel at 70°C fuel inlet temperature.*

The effect of fuel inlet temperature on brake thermal efficiency and BSFC at 70°C with the petrodiesel and the biodiesel is plotted in Figure 9 and Figure 10 respectively. It can be seen that as the petrodiesel inlet temperature increases from ambient to 70°C, there is a slight reduction in the BSFC. While for a similar rise in temperature, the biodiesel causes more pronounced reduction in the BSFC. It can also be noticed that the difference between the BSFC of petrodiesel and the biodiesel becomes trivial at 70°C fuel inlet temperature. In other words, the effect of increasing fuel inlet temperature on the BSFC led to a significant improvement in biodiesel case than in the petrodiesel case. The effect of increase the fuel temperature causes a considerable reduction in biodiesel kinematic viscosity that making improvement the biodiesel combustion.

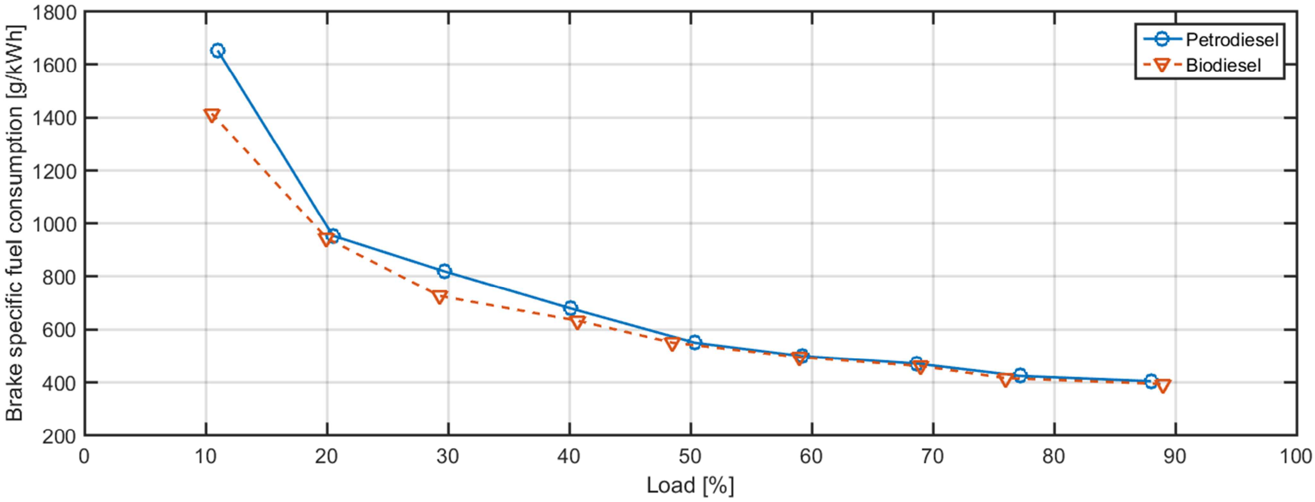

Figure 10. *Brake specific fuel consumption of petrodiesel and biodiesel at 70°C fuel inlet temperature.*

5. Conclusions

A biodiesel fuel is produced and successfully tested as an alternative fuel for diesel engine with reasonable efficiency in comparison with petrodiesel engine. a set of experiments conducted on a small direct diesel engine to investigate the engine performance parameters with the petrodiesel and biodiesel at different conditions. Variations in the engine load and the fuel inlet temperature are the main parameters that are taken into account to compare the mechanical thermal efficiency as well as the brake specific fuel consumption with the petrodiesel and biodiesel fuels. However, the brake thermal efficiency of biodiesel is up to 24%No changes in brake thermal efficiency of both biodiesel and petrodiesel fuels at low engine load while, the brake thermal efficiency of biodiesel is slightly higher than petrodiesel at high engine load.

With the increase of fuel temperature up to 70°C, there is no remarkable effect on brake thermal efficiency as well as bra ke specific fuel consumption. with the increase of petrodiesel fuel inlet temperature up to 70°C. The increase in the biodiesel fuel temperature up to 70°C leads to a slight increase in the brake thermal efficiency and a reduction in the brake specific fuel consumption. Increasing the fuel temperature leads to a considerable reduction in the kinematic viscosity of biodiesel and petrodiesel, whereas the reduction with biodiesel was more pronounced.

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