The Performance and Emissions Characteristics of a Diesel Engine Fueled with Biodiesel and Diesel Fuel

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Abstract— This paper presents the performance and emission characteristics of a diesel engine fueled with biodiesel and diesel fuel. The tests were performed in a four stroke, single cylinder, naturally aspirated, air-cooled and direct injection diesel engine at the different engine speed under full-load conditions. The results obtained with biodiesel were compared with the diesel fuel as reference fuel. The engine torque and power obtained in biodiesel were less, and the specific fuel consumption was found to be higher, which could be attributed to lower calorific value of biodiesel. CO emissions for biodiesel were lower than that of diesel fuel. However, it was observed that NO_x emissions for biodiesel were higher than that of diesel fuel.

Index Terms— Canola oil ethyl ester, Biodiesel, Diesel engine performance, Exhaust emissions.

I. Introduction

Biodiesel is an alternative diesel fuel which can be obtained from the transesterification of vegetable oils or animal fats and methy or ethyl alcohols in the presence of an catalyst (alkali or acidic). An important property of biodiesel is its oxygen content of about 10%, which is usually not contained in diesel fuel. Biodiesel fuels have been recently stood out due to some important advantages such as requiring little or no modification for use in diesel engines. Moreover, they are non-toxic, have higher biodegradability and contain almost no sulphur [1]. Although biodiesel can be used in modern unmodified compression–ignition (diesel) engines in neat form, it is more commonly encountered as a blend component in petrodiesel, such as B20 (20% biodiesel by volume in petrodiesel [2]. The molecular structure of biodiesel is similar to diesel fuel, and it contains additional oxygen, which is useful to reduce unburned HC, CO, and smoke opacity in the exhaust. However, a diesel engine fueled with biodiesel or its blend generally releases higher NO_x emission than that of petroleum-based diesel fuel [3]. Common vegetable oils for biodiesel production are sunflower, cottonseed, rapeseed, palm oil and soybean etc. Soybean oil is of primary interest as biodiesel source in the United States, while many European countries are concerned with rapeseed oil, and countries with tropical climate prefer to utilize coconut oil or palm oil [4]. Furthermore, other sources of biodiesel such as animal fats and used or waste cooking oils was also studied by researchs [5,6]. Many study have carried out to eveluate the performance and emission characteristics of diesel engines fueled with biodiesel and its blends with diesel fuel. For instances, Yamık and İçingür [7] examined the performance and emission characteristics of both the sunflower oil methyl and ethyl esters. It was concluded in their studies that performance of ethyl and methyl ester of sunflower oil were close to petoluem diesel fuel. Çelikten and Arslan [8] made a study to evaluate the use of biodiesels from canola and soybean oil in a diesel engine. Their study showed that the smoke density was significantly reduced and NO_x emissions was increased with the use of biodiesels compared to diesel fuel. Rakopoulos et al. [9] conducted a study to evaluate the use of sunflower and cottonseed oil methyl esters of Greek origin as supplements in the diesel fuel at blend ratios of 10/90 and 20/80, in a six-cylinder, four stroke, turbocharged and direct injection (DI) diesel engine. They reported that the engine performance with the blends of sunflower or cottonseed oil methyl ester was similar to that of the neat diesel fuel. Öztürk and Bilen [10] reported on canola oil methyl ester and its blends with diesel fuel as a fuel in a direct injected diesel engine and they concluded that the NO_x emissions was slightly increased and smoke opacity was reduced. Sugözü et al. [11] tested to sunflower methyl ester and sunflower methyl ester-diesel fuel blend in a diesel motor which has single cylinder, air cooled, an pre-combustion chamber at different engine speeds. It was reported in their study that the use of biodiesel and its blend results in engine torque and power decreased, but specific fuel consumption increased. They also reported that a decrease with biodiesel and its blend was observed for CO emissions, while NO_x emissions were increased.

In this study, the performance and emission characteristics of a diesel engine fueled with biodiesel and diesel fuel were experimentally investigated.

II. EXPERIMENTAL MATERIAL AND PROCEDURE

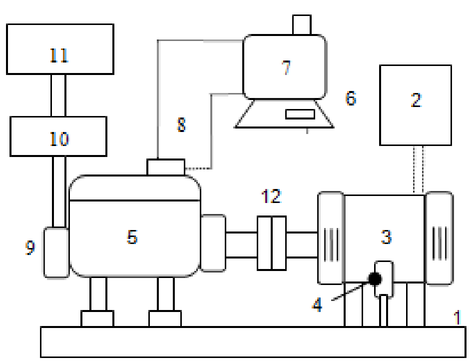
This study aimed to test the performance and emissions of diesel engine using biodiesel and diesel fuel. Table 1 shows the some fuel properties of canola oil ethyl ester and diesel fuel. The engine tests were performed on Lombardini 6 LD 400 single cylinder, four-stroke, air-cooled and a direct injection diesel engine. The basic specifications of the engine are given in Table 2. Tests were held on a laboratory test bed which consisted of a diesel engine, an electrical dynamometer and an exhaust emissions analyzer. The speed and load was recorded from digital indicator of the test ring. Engine torque and power were calculated from these values. Fuel consumption was determined by weighing fuel used for a period of time on an electronic sensitive scale with using a chronometer. Figure 1 shows the experimental setup.

Table 1 Fuel properties of biodiesel and diesel fuel.

PROPERTIES	DIESEL	COEE
Density (kg/m^3) (at 15 °C)	837	870
Viscosity (mm^2/s) (at 40 °C)	3.9	5.2
Calorific value (kJ/kg)	43300	39600

Table 2 Technical details of the test engine

TYPE	6 LD 400 LOMBARDINI
Operating principle	Four stroke, direct injection
Numbers of cylinder	1
Volume	395 cm^3
Compression ratio	18:1
Standard injection pressure	200 bar



1. Test Bed 2. Speed/load control 3. Dynamometer 4. Load cell
5. Engine 6. Electronic sensitive scale 7. Fuel tank 8. Fuel pump
9. Exhaust manifold 10. Smoke measure 11. Exhaust gases analyzer
12. Shaft

Figure 1. Schematic diagram of the experimental set-up.

III. THE RESULTS AND DISCUSSIONS

The engine performance and emissions with the biodiesel and petroleum based diesel fuel was evaluated in terms of engine torque and power, specific fuel consumption, NO_x and carbonmonoxide (CO) emissions at different engine speed and full-load conditions. The variations in engine torque, power and specific fuel consumption with the biodiesel and diesel fuel are presented in Fig. 2, 3 and 4, respectively. The engine torque and power were found to increase with the increasing engine speed for both fuels. Maximum engine torque and power were obtained at 2400 and 2800 rpm, respectively, by the biodiesel and diesel fuel, as shown in Fig. 2 and 3. The average engine torque and power for biodiesel were lower than that of diesel fuel by about 8% and 7%. Since the calorific value of biodiesel was lower than that of the diesel fuel, there were reductions in the engine torque and power. It was concluded in a study that engine power of biodiesel decreased due to lower heating value than those of diesel fuel [12]. The specific fuel consumption was found to decrease with increase in engine speed for both fuels, as seen in Fig. 4. The mean specific fuel consumption for biodiesel was higher than that of diesel fuel by about 17%. The specific fuel consumption when using a biodiesel fuel is expected to increase. The loss of calorific value of biodiesel must be compensated with higher fuel consumption [13]. As a result, it can be said that when a diesel engine is fuelled with biodiesel from different sources, it provides, in generally, reduction in the engine torque and power and increase in the specific fuel consumption which is to be a combined effect of lower calorific value and higher density.

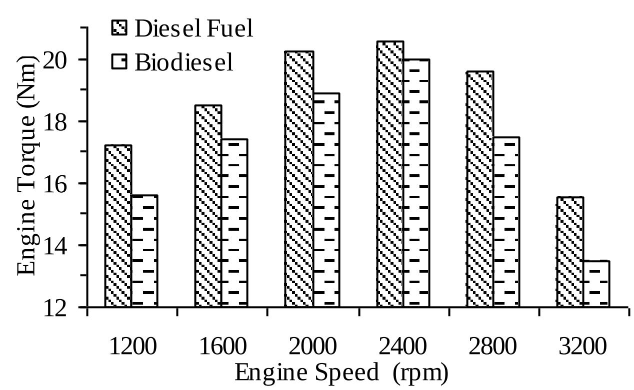


Figure 2. Engine torque versus engine speed for the diesel fuel and Biodiesel.

The variation of NO_x emissions with engine speed for fuels are presented in Fig. 5. As seen in Fig.5, the NO_x emissions for test fuels were increased with the increase in engine speed and then it was decreased. Biodiesel produced higher NO_x emissions than diesel fuel for all engine speeds, except at 2800 rpm where diesel fuel gave the highest. The average NO_x emissions of all engine speeds for biodiesel was calculated to be around 6% higher than that of diesel fuel. As it is known, biodiesel fuels have oxygen content and thus, this leads to a better combustion. Özsezen et al. [3] reported that the oxygen content of biodiesel is an important factor in the high NO_x formation levels, because oxygen content of biodiesel provides high local peak temperatures and a corresponding excess of air. The study of Labeckas and Slavinskas showed that maximum NO_x emissions increase with increased mass percent of oxygen in the biofuel and increased engine speeds [14;15]. Therefore, the higher NO_x emissions can be attributed to the more complete combustion of the biodiesel with presence of more oxygen in the combustion chamber.

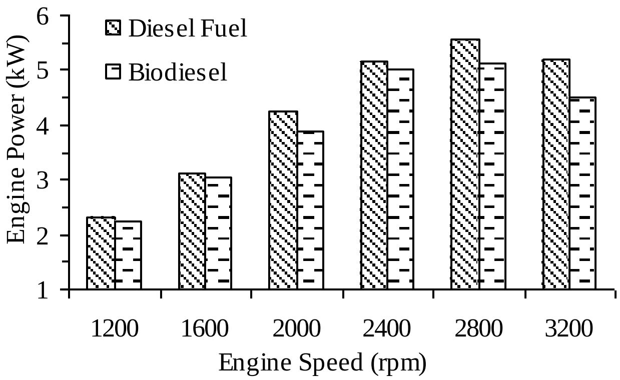


Figure 3. Engine power versus engine speed for the diesel fuel and Biodiesel.

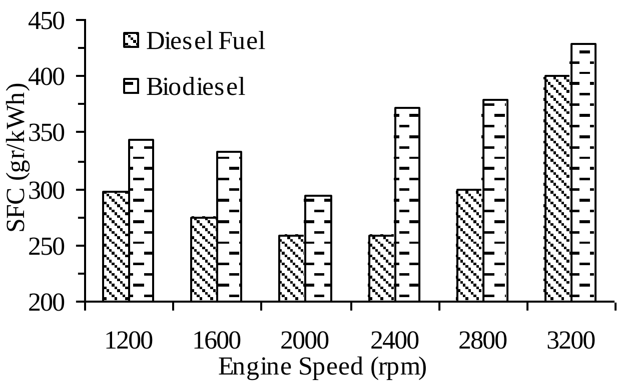


Figure 4. Specific fuel consumption versus engine speed for the diesel fuel and Biodiesel.

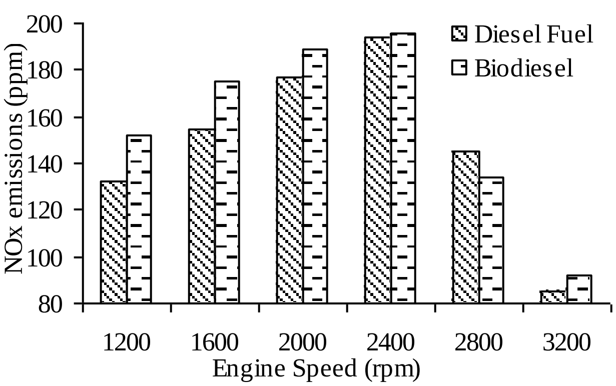


Figure 5. NO_x emissions versus engine speed for the diesel fuel and Biodiesel.

The variation of CO emissions with engine speed for fuels are presented in Fig.6. It was found that the CO was decreased with the increase in engine speed and the use of biodiesel. The average CO with biodiesel was decreased by about 12%. This may be due to the more complete combustion of biodiesel with presence of more oxygen in the combustion chamber. It was reported by Coronado et al. [16] that due to the oxygenated nature of biodiesel, where more oxygen is available for burning, this fuel produces decreased rates of unburned hydrocarbon and CO emissions in the exhaust.

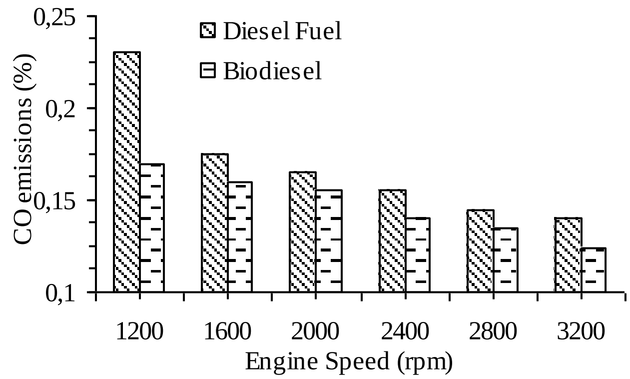


Figure 6. CO emissions versus engine speed for the diesel fuel and Biodiesel.

IV. CONCLUSIONS

In this experimental study, the effect of canola oil ethyl ester and diesel fuel on engine performance and exhaust emissions were investigated. Results showed that the engine torque and power were reduced due to lower calorific value of canola oil ethyl ester. As well, due to this reason, the specific fuel consumption for biodiesel had been obtained higher than that of diesel fuel. Carbonmoxide emissions was decreased with the use of biodiesel. The NO_x emissions of biodiesel were higher obtained with respect to diesel fuel. These can be attributed to the more complete combustion of the biodiesel with presence of more oxygen in the combustion chamber.

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