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Investigation on the Engine Parameters of a DI Diesel Engine using Diesel and Canola Biodiesel-blended Fuel with 1-4 Dioxane Additive

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Abstract

The present work investigates the effect of 1-4 dioxane (10 ml) as additive to the diesel and blend of canola biodiesel (CABD20) on the performance of a diesel engine. The physiochemical properties of diesel, CABD20, diesel+1-4 dioxane and CABD20+1-4 dioxane fuels were measured and improved fuel properties were identified with the additive based fuels. From the experimental results, BTE was enhanced (by 1.9-2.2%) with additive based fuel over both the diesel and CABD20 fuels. The presence of HA, CO and smoke emissions were decreased in the exhaust emissions for CABD20 fuel with a marginal increment of NOx emissions. Furthermore, adding 1-4 dioxane to diesel and CABD20 fuel significantly reduced the exhaust emissions. From the observations, it is concluded that better engine performance can be obtained with the use of additives in the diesel and the blend of biodiesel.

Keywords: *Biodiesel Blends, Canola Biodiesel, Combustion, 1-4 dioxane, Engine Performance*

1.0 Introduction

A limited source of fossil fuel stocks and their continuous depletion affect the energy demand for various sectors of industries, transportation, and power generation. Additionally, using fossil fuels extensively produces hazardous pollutants which are the prime reasons behind global warming, deteriorated human health and disturbs the balanced environmental ecology[1]. Recently, different alternative fuels were investigated to minimize the consumption of fossil based fuels. Among such potential strategies, using biodiesel is a promising alternative to conventional fuels in which edible and non-edible oils, algae, fats from animal sources, etc. are blended into the fuel. Various sources for biodiesel production have been extensively explored and processes to produce biodiesel blends have been actively investigated to enhance the scope of using biodiesel to reduce the ill effects of fossil based fuels. Biodiesel can be directly used in the engines or can be blended with other fuels to use in diesel engines without making additional modifications to the existing engines which work on diesel[2].

In order to improve the properties of biodiesel, addition of selective fuel additives is the best technique instead of an engine modification. S. Vedharaj *et al.*[3] investigated the role of 1,4-Dioxane (0.5 and 1%) with an optimal blend

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B25 (25% kapok methyl ester and 75% diesel) to improve the performance of a diesel based engine. From the results, they reported 5.7% improvement in BTE for B25-10 ml than B25 at maximum load. In addition, 25.3%, 22.5%, 15.2% and 24.6% decrement in HC, CO, NO_x and smoke emission have been observed when B25-10 ml was used as the fuel. Similarly, V. Rajendran *et al.*[4] prepared the test fuel denoted as DWSD that contains 79.7% of diesel in addition to 10%, 10% and 0.2% water, 1,4-dioxane and surfactant as the additives and operated the diesel engine with different FITs. The results showed that brake thermal efficiency was increased for the blended fuel compared with the regular diesel fuel. Moreover, the emissions of CO, HC, BSEC were also observed as significantly decreased with the fuel blend. Samuel Panithasan *et al.*[5] studied the influence of 20% blended pine oil with diesel and 10 ml of 1-4, dioxane additive to run the diesel engine without and with (10%) EGR. They observed reduction of emissions significantly due to the addition of pine oil. With the 10ml of 1-4, dioxane, further reduction (32.61, 28.15 and 4.36% respectively) was noticed. It can be learnt that there are limited studies on the effect of oxygenated additives; especially on the 1-4 dioxane in the scientific literature. Therefore, in this study, 1-4 dioxane is used as additive in the diesel and canola biodiesel blend to analyze the engine performance and emission parameters of a diesel engine.

2.0 Materials and Methods

The biodiesel used for testing in the present work was produced by using KOH catalyst and methanol through transesterification method. Initially, one liter of raw oil was taken and heated to 650°C for 45 min and next methanol was added with oil to methanol molar ratio of 1:6. Then the mixture was subjected to stirring (450 rpm for 60 min) with a magnetic stirrer. KOH (catalyst, 0.5w/w) was also added during the stirring process for 1h. The solution was transferred into a funnel and allowed for settling down for 12hr. Two different layers were found in the funnel. The top layer was the intended biodiesel and bottom layer was glycerin. Then it was washed with water to get rid of impurities. The canola biodiesel-diesel blend (CABD20) was obtained by the blending of 20% of

Table 1. Comparing the fuel properties used in the present work

Fuel properties	Diesel	CABD20	Diesel+1-4 DI	CABD20+1-4 DI
Density @15°C in kg/m^3	830	856	834	862
Kinematic Viscosity at 40°C in Cst	3.18	3.54	3.16	3.6
Flash point (°C)	54	76	52	74
Calorific value (MJ/kg)	42,850	38,980	42,610	38,910
Cetane Number	51.5	52	52.4	52.8

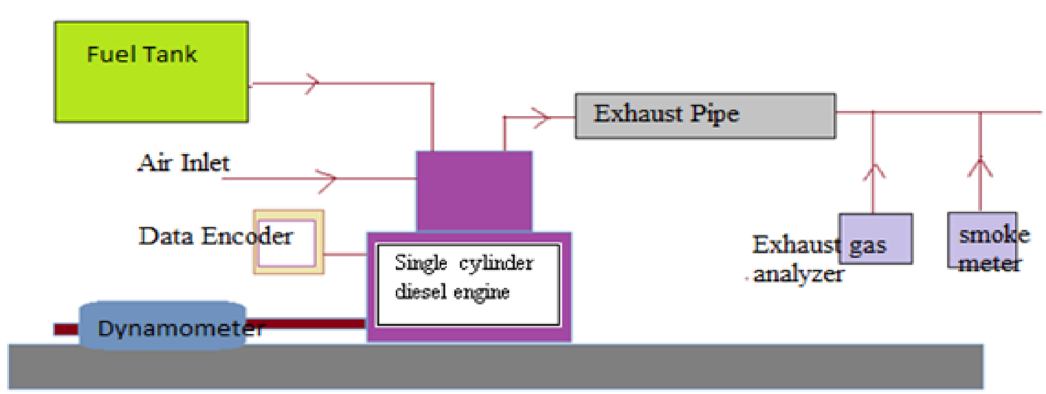

Figure 1. Schematic illustration of DI diesel engine.

biodiesel in diesel fuel by volumetric approach and then 10 ml of 1-4 dioxane was added into the CABD20 fuel sample. Magnetic stirrer was used in the blending process for proper mixing of biodiesel with diesel fuel and stirring time was maintained 60 min. The fuel properties of diesel, CABD20 fuels with and without additive was measured as per ASTM standards and the results are shown in Table 1. The FTIR analysis was carried out for canola biodiesel to categorize its functional groups in the range of 4000-400 cm^{-1}.

A single cylinder (Kirloskar make and TV1 model) 4 stroke DI diesel engine was used in the present experiments which was coupled with a dynamometer. The schematic diagram of the DI diesel engine is shown in Figure 1. For measuring fuel consumption, burette and stopwatch (to note down the time required for 100 cc of fuel) were arranged in the panel of the test rig. K-type thermocouples were used to measure the temperatures of exhaust gases, cooling water, oil and the readings were displayed in digital display unit. This setup also consists of emission gas analyzer, ECU, DAS, digital manometer, "Engine soft" software, crank angle encoder and piezosensors. The engine was operated first with diesel fuel, next with CABD20 fuel, finally with diesel and CABD20 fuel with 1-4 Dioxane fuel samples. The readings have been recorded after running the engine in a stabilized condition for at least 15min.

3.0 Results and Discussions

The FTIR spectrum of canola biodiesel is shown in Figure 2. The peak observed at 3007.14cm^{-1} denotes the O-H stretching. The peaks in the ranges from 2850-2950 cm^{-1} indicates the C–H stretch of asymmetric alkanes. The

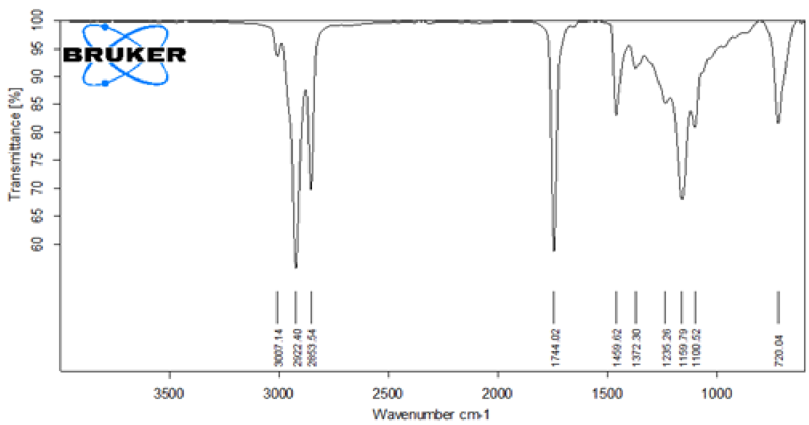

Figure 2. FTIR spectrum of canola biodiesel.

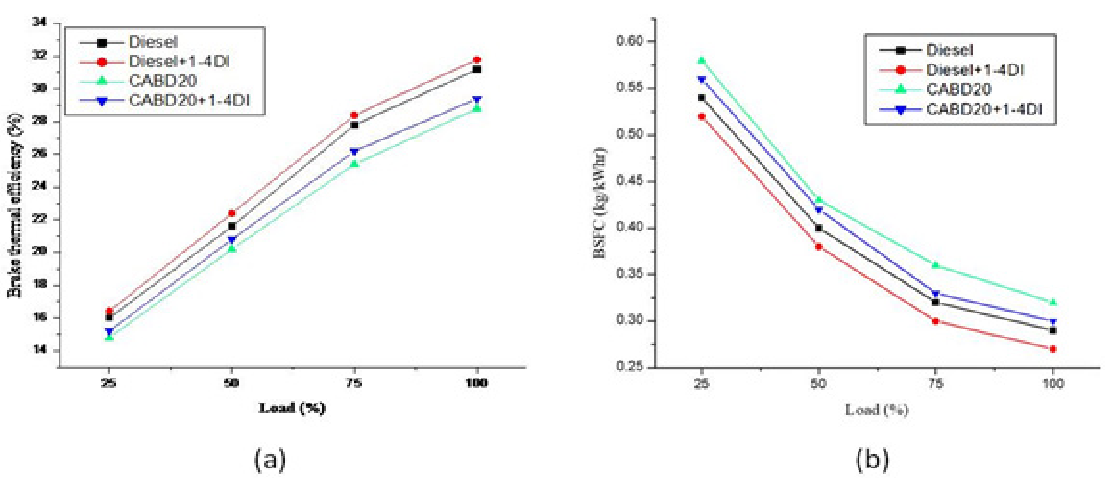

Figure 3. **(a)** Variation of BTE with load of tested fuels, and **(b)** variation of BSFC with load of tested fuels.

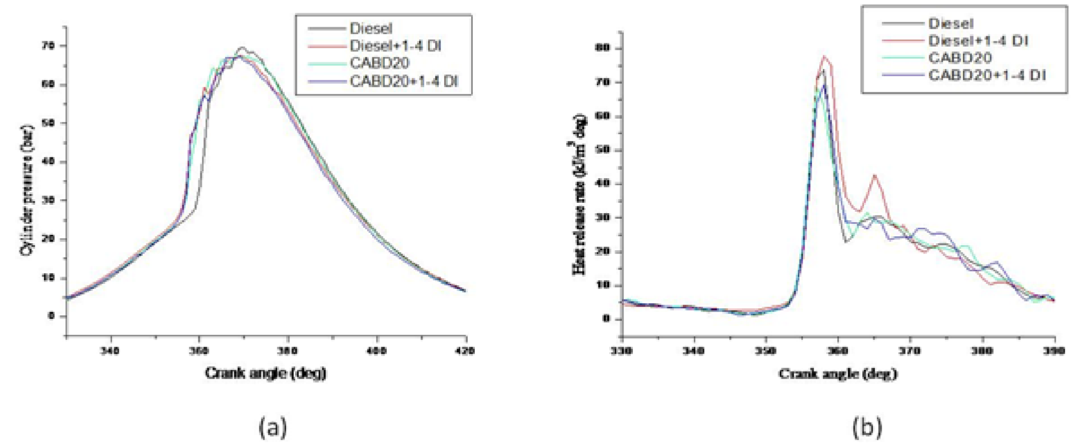

Figure 4. **(a)** Values of cylinder pressure with respect to crank angle and **(b)** values of HRR with respect to crank angle.

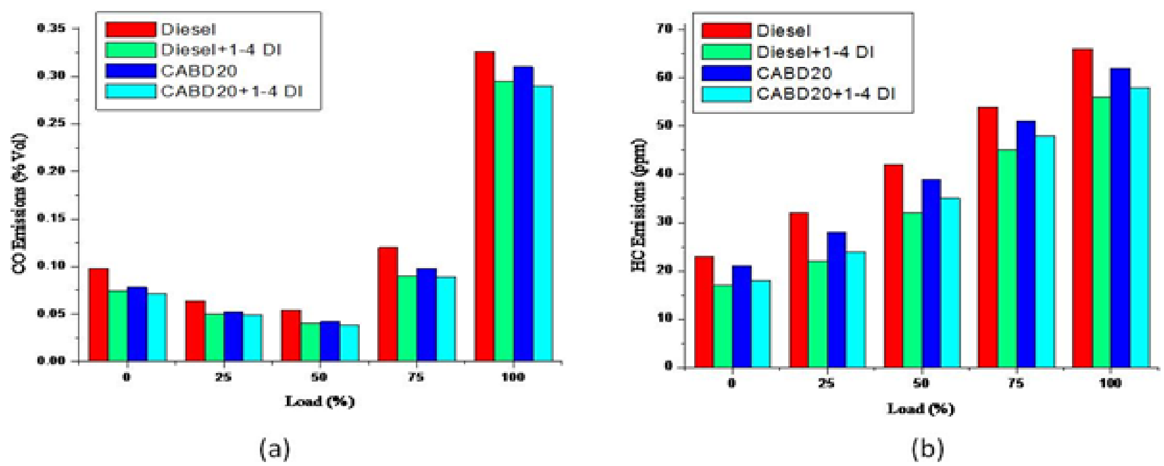

Figure 5. **(a)** Variation of CO with load and **(b)** variation of HC with load.

alkenyl group presence can be identified from the peak at 1744.02cm^{-1}. The number of peaks observed between 1500-1000 cm^{-1} indicates the presence of ketone, esters, aldehydes and carboxylic acids. Because of the alcohol, peaks were observed at 720.04cm^{-1}. Figure 3 (a) and (b) shows the values of BTE and BSFC with respect to load for tested fuels. Diesel fuel exhibits the higher BTE values (by 2.4-7.6%) compared to biodiesel due to higher viscosity and lower heating value. Further, the addition of 10 ml of 1-4 dioxane to the diesel and biodiesel enhanced the BTE of both the fuels by 1.9 and 2.2% than the diesel and CABD20 fuel because of an improved combustion process of enhanced fuel properties[6]. The BSFC was slightly increased by 9.6% for CABD20 fuel than diesel fuel because of the lower calorific value. It is noted that the addition of 1-4 dioxane to the diesel and CABD20 fuels lowered the fuel consumption due to increased combustion efficiency.

Figure 4 (a) and (b) presents the pressure variations in the cylinder and HRR with crank angle obtained in the present work. From the plots; it is clear that the cylinder pressure pattern for all tested fuels is almost similar. However, the process of combustion was observed as started earlier for the CABD20 fuel due to its rich oxygen content[7]. It is also observed that the peak CP was slightly reduced with the added additives for both diesel and CABD20 fuel. This can be understood by considering the higher value of the latent heat of vaporization. The higher

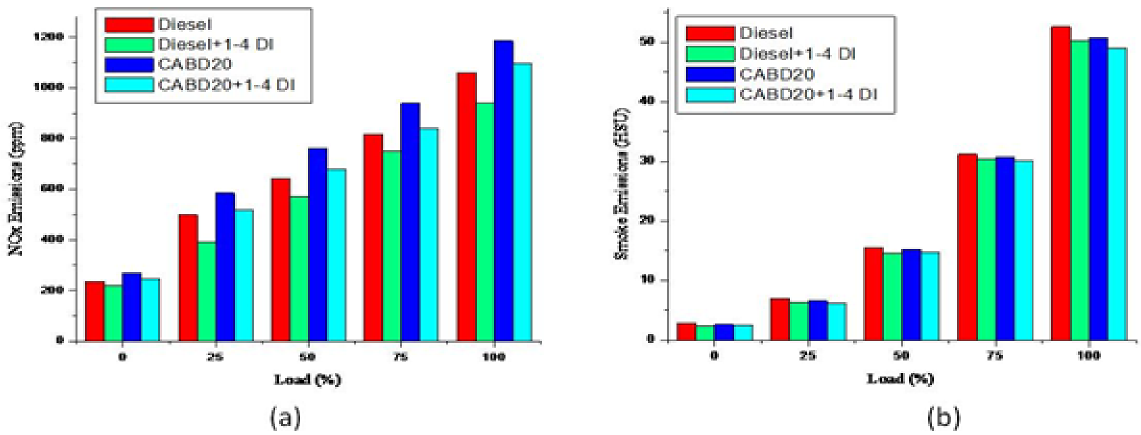

Figure 6. **(a)** Emission of NOx with respect to load **(b)** smoke emissions with respect to load.

heating value of diesel caused higher HRR than CABD20 fuel. From the results, it is also observed that the peak HRR for 1-4 dioxane additive fuel samples than diesel and CABD20 fuel samples at full load condition.

Figure 5 (a) and (b) presents the values of CO and HC at different loads for the fuels. From the data, the emission of CO was lower for CABD20 fuel compared with diesel because of the presence of oxygen and chemical behavior of biodiesel in which most of the CO will be converted to CO_2 emissions[8]. A significant reduction of CO emissions was noted with the combination of diesel, biodiesel blends and 1-4 dioxane at all loads due to better oxidation of CO emissions. The HC emissions for diesel were higher due to lower oxygen content than CABD20 fuel[9]. Due to the improved ignition properties of additives, HC emission was lowered for CABD20+1-4 DI and diesel+1-4 DI fuel samples than the other fuels.

Figure 6(a) shows the emission of NO_x with respect to load. The CABD20 fuel will release more quantity of NO_x emissions compared with diesel because of presence of oxygen and high flame temperatures[10]. A significant decrement of NO_x emissions was also observed with the addition of 1-4 dioxane to the fuels. Figure 6(b) shows the smoke emissions with respect to loads for the fuels. The chemical molecular structure of biodiesel helps to reduce the smoke emissions of CABD20 fuel compared with the diesel. The smoke emissions are further reduced with 1-4 dioxane additives to the diesel and CABD20 fuel due to the improved combustion rate. From the results, it can be summarized that the added 1-4 dioxane player important role on enhancing the performance of the engine. Decreased fuel consumption and improved efficiency of combustion were recorded for 1-4 dioxane added fuel. Further, increased combustion rate decreased the undesired emissions for the fuels containing 1-4 dioxane additives.

4.0 Conclusions

The role of 1-4 dioxane additives to blend of canola biodiesel (CABD20) and diesel on the performance of engine was investigated for a DI diesel engine. It has been observed that the presence of 1-4 dioxane in the diesel and CABD20 fuels decreased the consumption of the fuel and increased the brake thermal efficiency. Higher HRR was noticed for 1-4 dioxane additive fuels compared with the diesel and CABD20 fuel samples at maximum load. The improved ignition properties of additives helped to reduce the smoke emissions and further reduced with 1-4 dioxane additives for the diesel and CABD20 fuel. From the results, it can be concluded that the diesel and biodiesel fuels with 1-4 dioxane additives can enhance the engine performance and lowered amounts of polluting emissions which is a promising observation in this research.

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