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Research Article

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Determınıng the Effects of Canola Bıodıesel on Engıne Smoke Darkness

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Abstract This study aimed to determine the effects of diesel fuel and canola biodiesel on engine smoke darkness. For this purpose, the powers obtained by mixing %5 (B5), %10 (B10), %20 (B20), %50 (B50), %80 (B80) of canola biodiesel with diesel fuel (B0), canola biodiesel (B100) and diesel fuel had been used. These fuels were tested in direct injection, water–cooled diesel engine with four cylinders. Depending on the engine speed, exhaust emission values were measured for diesel fuel and B5, B10, B20, B50, B80, and B100 fuels. The tests conducted on the engine were carried out according to TSE 1231 standard. The change values of smoke darkness obtained in this study were significantly different according to the statistical analysis performed. According to the results from exhaust emission changes, the smoke opacity values of B100 have decreased compared to B0. B0 fuel yielded better results in terms of engine performance and smoke darkness.

Keywords Biodiesel, Engine, Smoke, Darkness, Opacity

1. Introduction

Today, the primary energy source of the motor vehicle industry is petroleum products. The fact that the world's oil reserves are concentrated in certain regions has caused oil crises from time to time due to political and economic reasons. Especially at the end of the oil crisis in the 1970s, petroleum products were withdrawn from the market and, in parallel, increased their prices. The negativities in oil resources indicate that alternative fuels will become widespread [1]. The rapid increase in the world's population, industrialization and the fact that environmental problems due to excessive use of fossil resources have become a global problem by moving away from regional and national dimensions over time has changed the perspective of governments on renewable energy sources. In particular, renewable energy sources, a significant opportunity for countries dependent on foreign energy, are an essential driving factor in developing countries, together with the cost advantages. There are positive developments in alternative energy sources worldwide and in our country In this context, the importance of alternative energy sources is increasing. In developed countries, using modern technologies and efficient bioenergy conversions using economically competitive biofuels with fossil fuels tends to increase. After the 2000s, biodiesel production accelerated worldwide and in our country. Use of biodiesel; It gains importance in terms of being economical, being a cleaner fuel in terms of environmental pollution, and making a versatile contribution to the country's economy by being obtained from its resources instead of foreign dependency. Biodiesel is a necessary fuel that accepts its raw material widely from agricultural products, can be produced from all kinds of waste oil, and whose supply can be easily adjusted and stored compared to other alternative energy sources. The fact that biodiesel production is less costly and easier to produce compared to other alternative energy sources, such as wind and solar energy, contributes to the widespread use of its production. However, biodiesel production allows especially agriculture, industry, and environmental sectors to work together and provides additional employment and income opportunities to these sectors, causing the rapid development of biodiesel technology. As a result of the increase in biodiesel production, the amount of crude oil processed and imported crude oil in our country is decreasing. In this study, biodiesel (B100), 5% (B5), 10% (B10), 20% (B20), 50% (B50), 80% (B80) diesel-biodiesel mixture obtained from canola oil using the trans esterification method and B0 (diesel) fuel is used.

Biofuels derived from bio-resources (biomasses) can be an ideal option to replace fossil fuels because biofuels have the cheap cost of materials to make them; they are renewable, and they are suitable for the environment given their net zero CO2 emission [2,3,4,5]. Various fuels can be produced from plant biomass and fatty acids such as ethanol, methanol, butanol, and biodiesel [6,7,4,5]. Compared to conventional fossil fuels, biofuels have several advantages; the source of biofuel is renewable [2,8,9,4,5], the combustion of biofuels produce less toxic compound [8,9], and biofuels can reduce net carbon emissions up to a shallow level [2,8,10,4,5].

It is aimed to determine the effects of the obtained fuels on engine performance, exhaust emission, and torque increase. In the tests, engine characteristics were determined by using biodiesel and biodiesel-diesel fuel mixtures in different ratios. Power, torque, torque increase, fuel consumption, and exhaust emission parameters were examined, and evaluations were made on creating an alternative to diesel (B0) fuel.

2. Materials and method

The experiment was conducted in the laboratory of the Automotive Technology Program of Çorlu Vocational School University of Tekirdağ Namik Kemal.

2.1. Biodiesel production

Canola biodiesel was produced using the alkali-catalyzed transesterification process with methanol and potassium hydroxide. The alcohol reacted with the triglycerides to form a mono-alkyl ester, biodiesel, and glycerol. Biodiesel produced with canola oil in the Energy and Agriculture Laboratory of the Karadeniz Institute of Agricultural Research and commercially sold diesel (B0) were used. The results of the analyses on the B100 fuel produced at Black Sea Agricultural Research Institute Research and kinematic viscosity, flash point, and pour point values of the biodiesel – diesel mixtures were determined via analyses run at the Fuel Analysis Laboratory of TUBITAK Marmara Research Center, Energy Institute. Some properties of the fuels determined after measurements are provided in Table 1. Physical and chemical property information of the B0 fuel was taken from TUPRAS Turkish Petroleum Refineries Company.

Table 1: Analysis Values of the B0, B5, B10, B20, B50, B80 and B100 fuel

Fuel	B0	B5	B10	B20	B50	B80	B100
Density (g/cm^3, 15 °C)	0.83	0.84	0.84	0.84	0.86	0.86	0.88
Kinematic viscosity (mm2/s, 40°C)	2.0-4.5	2.83	2.91	3.12	3.88	4.69	4.90
Flash point (°C)	>55	61.50	64.00	67.00	77.50	90.50	150.00
Pour point (°C)	-35-15	-24.00	-23.00	-21.00	-18.00	-9.00	-19.00
Net combustion heat (MJ/kg)	-	45.92	45.51	44.78	42.88	40.97	40.00

2.2. Engine

A four-cylinder and four-stroke engine was used in the experiments. Diesel engine is water cooled and general properties of the engine are provided in Table 2.

Table 2: Technical properties of the engine used in the experiment.

Type	Direct injection diesel
Number of cylinders	4
Cooled systems	Water cooled
Diameter x stroke	104×115 mm
Volume (cm^3)	3908
Engine power (HP)	90
Engine revolution at maximum power	3500 rpm
Engine revolution at maximum torque	1700 rpm
Fuel pump	Rotary type, automatic advance
Air filter	Oil bath, pre-cleaner

2.3. Smoke Thickness Meter of Exhaust Gases

Smoke darkness (K factor); It is the percentage that the particles in the exhaust gas reduce the luminous intensity of the light passing through the gas (light flux per illuminated unit surface). For fully transparent gas, the smoke density is 0%. For gas that absorbs light completely, that is, it is impermeable; the smoke density is 100% [11]. According to the TS 11365 standard [12], the K factor is the light absorption coefficient, and it is a coefficient related to the reduction of the luminous intensity of the light passing through the gas (luminous flux for the illuminated unit surface) of the non-transparent particles in the exhaust gas [13]. Mod 2100 brand device was used to measure the smoke density of the exhaust gases. The measurement components, measuring ranges, and sensitivities of the Mod 2100 emission device are given in Table 3.

Table 3: Technical specifications of the device used in exhaust smoke density measurement

Measurement	**Measuring rates**	**Measurement accuracy**
Opacity (degree of haze)	%0 – 100	0.10%
K (Number of blackouts)	0 – 9.99	0.01 m^{-1}
Rated output (rpm)	0 - 9990	10

2.4. Setting up the experimental setup and performing the tests

The fuel tank of the four-cylinder diesel engine was canceled, and an external tank was prepared. A line is drawn from the external tank to the diesel (B0) fuel supply pump. A line from the supply pump goes to the fuel metering device. The diesel (B0) fuel passing through the measuring device was transferred to the injection pump with the help of a line. Another line taken from the return in the fuel system is given to the fuel meter again. The measured fuel information was collected in the electronic power measurement unit, and the collected data were transferred to the computer from there (Figure 1).

The motor connected to the shaft input of the dynamometer was operated at maximum speed. Power, torque and fuel consumption values can be recorded at different speeds by loading the engine via the manual control unit. Before starting the experiment for each fuel mixture, the effect of the other fuel type was eliminated by running it with the fuel to be tested for 5 minutes.

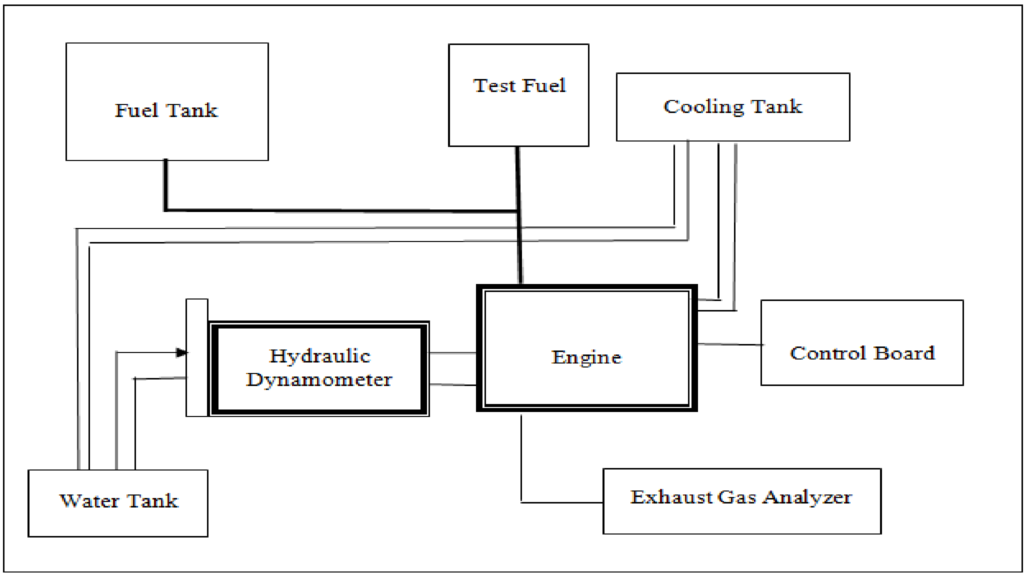

Figure 1: View of the Experimental Setup

For the tests using biodiesel blends, the engine was run with diesel until a steady operating condition was achieved. The fuel was then changed to a biodiesel blend. After running the engine for five minutes, data acquisition commenced ensuring the removal of residual diesel in the fuel line. After each test, the engine was again run with diesel to drain all of the remaining blends in the fuel line [14].

3. Results and Discussion

In the engine test trials, the results of the multiple analysis comparison (Duncan) test of the change in smoke density of B0 fuel, B100 fuel and biodiesel fuels mixed with B0 fuel at different rates depending on different engine speeds are given in Table-4.

Table 4: Smoke darkness values of diesel (B0) fuel and biodiesel - diesel mixture fuels depending on engine speed.

Engine Rotation (rpm)		N	1100	1400	1700	2000	2300	2600	2900	3200	3500	3800
Mean + sh		21	2.21**	2.07**	1.98**	1.74**	1.39**	1.06**	0.85**	0.58**	0.40**	0.35**
Smoke darkness (1/m)	**B0**	2.47a	2.32a	2.30a	2.10a	1.78a	1.34a	1.08a	0.80a	0.58a	0.48a	0,48a
	B5	2.42b	2.23b	2.23b	2.06b	1.66b	1.29b	1.01b	0.73b	0.55b	0.45b	0,45b
	B10	2.33c	2.18c	2.10c	1.86c	1.43c	1.16c	0.90c	0.64c	0.43c	0.40c	0,40c
	B20	2.29d	2.16d	1.98d	1.71d	1.38d	1.06d	0.85d	0.56d	0.39d	0.38d	0,38d
	B50	2.14e	2.08e	1.84e	1.59e	1.28e	0.95e	0.78e	0.50e	0.32e	0.32e	0,32e
	B80	1.95f	1.81f	1.73f	1.46f	1.12f	0.84f	0.70f	0.43f	0.28f	0.24f	0,24f
	B100	1.90g	1.76g	1.68g	1.42g	1.08g	0.80g	0.62g	0.40g	0.25g	0.22g	0,22g

**P<0.01

It was observed that the smoke density values obtained with the use of B0 fuel were higher than the smoke density values obtained with all other biodiesel mixtures in the experiments conducted at all engine speeds. In the analysis of variance, it was observed that the smoke density variation among the fuels was statistically different in terms of all rates ($p<0.01$). According to the Duncan multiple comparison tests performed to determine the statistical difference between the groups, it was observed that all groups were statistically different ($p<0.01$). In the trials, the minimum smoke density was obtained when the engine speed reached 3800 rpm, and the maximum value was obtained when the engine speed was 1100 rpm. The use of biodiesel at different rates in the diesel engine showed a decrease in smoke density compared to B0 fuel. When the engine speeds of the smoke density of B0 fuel are 1100, 1400, 1700, 2100, 2400, 2700, 3000, 3500, and 3800 rpm, respectively, according to B100 fuel; increased 23%, 24%, 27%, 32%, 39%, 40%, 43%, 50%, 57%, 54%. Compared to B0 fuel, in the B5 fuel test, when the engine speed was 1700 rpm, there was a decrease of 1.90% in the smoke density change. In the experiments, the smoke intensity decreases as the speed of the engine increases. The main reason for this situation is that the oxygen content of biodiesel increases the amount of oxidation in the cylinder by providing the necessary oxygen in the combustion zones. In addition, the fact that biodiesel contains almost no aromatic compounds significantly reduces particulate and soot emissions. In the engine tests, the change in smoke density of B0 fuel and biodiesel fuels mixed in different proportions, depending on engine speeds, is seen in Figure 2.

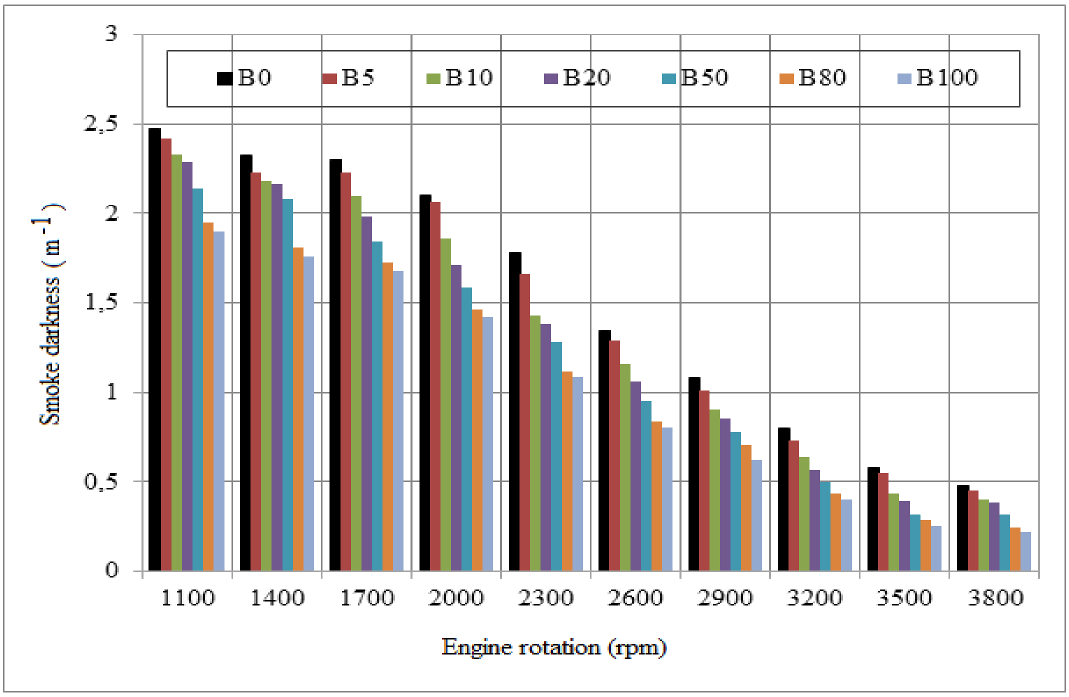

Figure 2: Smoke density variation of diesel (B0) fuel and biodiesel-diesel blend fuels depending on engine speed

The fuel's oxygen content must increase the oxidation amount in the cylinder by providing the necessary oxygen in the combustion zones. In addition, the fact that biodiesel contains almost no aromatic compounds offers significant reductions in particulate and soot emissions. It was determined that the smoke density decreased as the ratio of biodiesel fuel mixed with B0 fuel increased. As the engine speed increases, the smoke density decreases. The main reason for this situation is that biodiesel's oxygen content increases the oxidation amount in the cylinder by providing the necessary oxygen in the combustion zones. In addition, the fact that biodiesel contains almost no aromatic compounds significantly reduces particulate and soot emissions. Aromatic compounds in the fuel can be shown as the main reason for the high smoke density in using B0 fuel as a fuel. The fact that biodiesel fuel contains almost no aromatic compounds and sulfur significantly reduces soot emissions. Similar to these results, it is stated in their study that the main reason for the high smoke density in the use of B0 fuel as a fuel is the aromatic compounds in the fuel [15]. They also stated that the fact that biodiesel contains almost no aromatic compounds and sulfur provides significant reductions in soot emissions. Therefore, oxygenated fuels reduce soot and particulate emissions. It is observed that there was a slight decrease in smoke density with the increase of oil ratio, especially for blended fuels, in the trials depending on the engine speed of B0 fuel, cottonseed oil methyl ester, and cottonseed oil ethyl ester fuels [16]. İt is stated in their study that there were significant decreases in the smoke density change of canola oil methyl ester blended fuels at all engine speeds compared to the use of B0 fuel [17]. They said that as the engine speed increases, the combustion quality increases and the smoke density decreases, and the reduction in dark smoke emission of canola biodiesel and blended fuels could be explained by the fact that the fuel burns more efficiently in the rich mixture region due to the oxygen contained in canola biodiesel.

4. Conclusion

Smoke darkness of B0 fuel when engine speeds are 1100, 1400, 1700, 2100, 2400, 2700, 3000, 3500, and 3800 rpm, respectively, according to B100 fuel; increased 23%, 24%, 27%, 32%, 39%, 40%, 43%, 50%, 57%, 54%. Compared to B0 fuel, in the B5 fuel test, the smoke density decreased by 1.90% when the engine speed was 1700 rpm. The smoke density decreased as the ratio of canola biodiesel fuel mixed with B0 fuel increased. The decrease in smoke density due to biodiesel fuel is that biodiesel contains almost no aromatic compounds. This also leads to significant reductions in particulate and soot emissions.

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