FUEL PROPERTIES OF DIESEL BLENDED WITH ALTERNATIVE FUELS

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ABSTRACT
Nowadays, many researches are focused on alternative fuels in internal combustion engines because fossil-based fuels have many negation not only environmental aspects but also economical aspects. Especially, Diesel engines need alternative fuels because of their widespread use and harmful emissions mainly Nitrogen Oxides and Particulate Matter. Alcohols and biodiesel are the main alternative fuels to diesel fuel. They can be used in diesel engines as additive without any modification of engine. In this study, the effect of blending alcohols (ethanol, methanol, 2-propanol, 2-butanol) and biodiesel with diesel fuel on the diesel fuel properties was investigated experimentally. The alcohols were blended as 15% and biodiesel as 20%, 40% and 60% with diesel fuel. The results showed that the use of alcohols with diesel fuel as alternative fuels leads to a decrease in density, viscosity, calorific value, flash point and cetane number values. On the other hand, biodiesel led to an increase in density, viscosity and flash point values, and a decrease in Calorific value and Cetane Number.

Keywords: *Diesel, Alternative Fuels, Alcohols, Biodiesel, Fuel Specifications*

1. INTRODUCTION

Nowadays, most of the energy needs are met by fossil fuels. In the transport sector, particularly diesel and gasoline vehicles, fossil fuels are commonly used energy sources (Barreto, 2018). However, instability in the prices of these fuels, increases in energy consumptions, environmental factors and the limited availability of these resources have led to the search for alternative energy sources (Ugurlu and Oztuna, 2015). Biodiesel and alcohols, which are biomass energy sources, are among the alternative energy sources for diesel fuel (Erdiwansyah *et al.*, 2019).

Biodiesel is the name given to esters formed by the reaction of oils in the presence of any alcohol and catalyst. Many types of edible or non-edible oil can be used in biodiesel production. Soybean, canola, sunflower are the most common vegetable oils used in biodiesel production (Hosseinzadeh-Bandbafha *et al.*, 2018). Apart from these vegetable oils, animal fats and waste oils is widely used in the production of biodiesel. In particular, the use of waste oils results in significant reductions in biodiesel production costs (Hajjari *et al.*, 2017). Many scientific studies on the production of biodiesel and the use of biodiesel in compression ignition (CI) engines are being carried out by researchers (Abed *et al.*, 2019; Goga *et al.*, 2019; Asokan *et al.*, 2019; Manigandan *et al.*, 2019). In these studies, It seemed that the biodiesel has a positive effect for diesel engines. Compared to diesel fuel, oxygen content in its structure, high flash point, improvement effect of engine emission characteristics and production with domestic resources are generated the main advantages of biodiesel (Singh *et al.*, 2019).

Alcohols are the most common sources of energy used as alternative fuels in diesel engines after biodiesel (Yusri et al., 2017). Alcohols obtained from vegetable wastes and renewable biological sources can be used as alternative fuels in CI engines by blending with diesel fuel in certain ratios. Thanks to the oxygen content, it improves the combustion efficiency and creates a catalyst effect on the engine characteristics (Tutak et al., 2015). Compared to biodiesel, alcohols have lower density and viscosity values, which make it advantageous to use alcohols with biodiesel (Emiroğlu and Şen, 2018).

The properties of fuels provide preliminary information on fuel efficiency and quality. Considering the various standards developed on fuel properties, it is possible to make comments on the similarity of alternative fuel types to diesel fuel and their usability in diesel engines. In this study, the effect of blending biodiesel and 4 different alcohol types with diesel fuel on the diesel fuel properties was investigated experimentally. After the alternative fuels were blended with diesel fuel in certain ratios, the basic fuel properties as density, viscosity, calorific value, flash point and Cetane number of each mixture were determined. The obtained values were compared with the fuel standard values.

2. MATERIAL AND METHODS

This section clearly describes the process of preparing fuels and determining the properties of fuels.

2.1. Preparation of Fuels

The biodiesel used in the study was obtained from a commercial company. Ethanol, Methanol, 2-Butanol and 2-Propanol were got commercially from Merck.

In this study, 7 different fuel mixtures were prepared by blending biodiesel and alcohols with diesel fuel in different ratios. Biodiesel was blended as 20%, 40% and 60% and 4 different types of alcohol (ethanol, methanol, 2-propanol, 2-butanol) as 15% with diesel fuel. High rates of blending of alcohols with diesel fuel have a negative effect on diesel fuel properties and combustion efficiency. Therefore, the ratio of alcohols in diesel was determined as 15%. Mixture fuels are named as indicated in the table below, taking into account the fuel content in them (Table 1).

Table 1. The blends

Fuel Code	Fuel rates
D	%100 Diesel
BI20	%20 Biodiesel + %80 Diesel
BI40	%40 Biodiesel + %60 Diesel
BI60	%60 Biodiesel + %40 Diesel
ET15	%15 Ethanol + %85 Diesel
ME15	%15 Methanol + %85 Diesel
PR15	%15 2-Propanol + %85 Diesel
BU15	%15 2-Butanol + %85 Diesel

2.1. Determination of Fuel Properties

In determining the properties of fuels, 5 different property values (density, viscosity, calorific value, Cetane number and Flash Point) were measured.

In the measurement of density, Kyoto Electronic DA-130 Density Meter was used. The measuring range is 0-2 g/cm^3 and 0-40 ^{o}C. The device is measured according to TS 6311 and ASTM D 4052-96 standards.

In determining viscosity values, Saybolt Universal Viscometer was used. It consist mainly a heater, fuel cup and fuel spill part. In the measurements carried out at 40 ^{o}C, the flow times of the samples were determined and these values were used in the conversion table and the viscosity values of each mixture were determined. Measurements were made in accordance with TS EN 14214 standard.

IKA-Werke C2000 calorimeter was used for the measurement of calorific values of fuels. Measurements can be made in TS1740, ASTM 240D, ISO1928, DIN51900, BSI standards.

TANAKA Flash Point Detection Device was used to determine the flash point of fuels, while ZX-440 Analyzer was used to determine Cetane numbers.

3. RESULT AND DISCUSSION

In this section, the comparison of the density, viscosity, calorific value, flash point and cetane number values of the mixtures and diesel with each other and also with the EN 590 and EN 14214 standards are discussed in detail.

EN 590 and EN 14214 are the standards published by the European Committee for Standardization that describes the physical properties of diesel fuel and biodiesel respectively (Table 2).

Table 2. EN 590 (Diesel) and EN 14214 (Biodiesel) Standards

	EN 590	**EN14214**
Density at 15 ºC (kg/m³)	820-845	860-900
Viscosity kinematic at 40ºC (mm²/s)	2.0-4.5	3,5-5
Calorific value (MJ/kg)	-	-
Flash Point (ºC)	Min 55	Min 101
Cetane number	Min 51	Min 51

3.1. Density

Density is defined as the weight of the unit volume. Fig. 1 shows the density values for the mixtures. Density values increased with the use of biodiesel and decreased with alcohol use. The lowest density value was obtained with PR15 fuel using 15% propanol with 832.84 kg/m³. The highest density value was obtained with BI60 fuel. Considering the EN 590 standard, it was found that all alcohol mixtures were in compliance with the standard. Due to the high-density values of biodiesel, density values of biodiesel mixtures were obtained higher than EN590 standard.

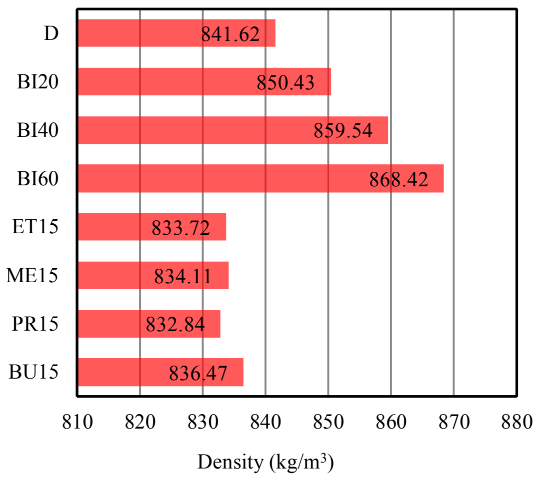

Fig. 1. Density value of blends

3.2. Viscosity

Viscosity is the strength of fluids to flow and is an important factor for diesel engines, especially fuel supply and injection systems. Temperature and pressure significantly affect viscosity. The viscosity of diesel fuel directly affects the injector spray characteristics and consequently the combustion in the cylinder.

The viscosity values of the mixtures are shown in Fig. 2. Similar to density values, viscosity values decreased with the use of alcohols and increased with the use of biodiesel. The lowest viscosity value was obtained with ME15 fuel as 2,348 mm²/s, while the highest viscosity value was measured as 3,732 mm²/s with BI60 fuel. All the viscosity values of the mixtures comply with EN590 standard.

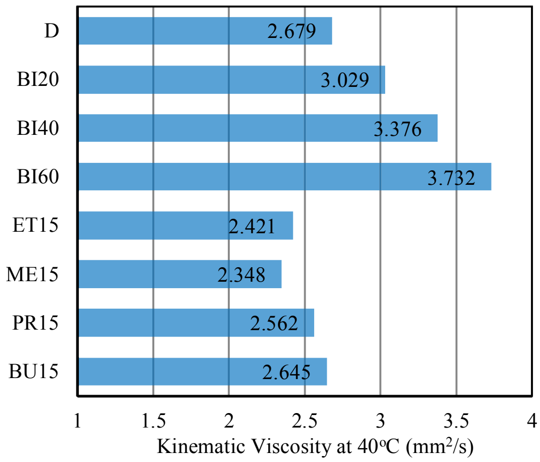

Fig. 2. Viscosity value of blends

3.3. Calorific Value

The calorific value is equal to the thermal energy given to the environment when the fuel is fully burned in a continuous flow open system and the end-products are converted into combustion products. In other words, the calorific value of a fuel is equal to the absolute value of the combustion enthalpy of the fuel. The calorific values of fuels are usually given by the energy of the unit mass (kj/kg or kcal/kg).

The calorific value depends on the phase of H_2O in the end-products. Thus, it is called as the higher calorific value (HHV) in the liquid phase of the H_2O at the end-combustion products and the lower calorific value (LHV) in the vapor phase of the H_2O at the end-combustion products.

The calorific value or combustion enthalpy of a fuel can be calculated from the enthalpy of formation of compounds involved in the combustion process. The higher calorific value of a fuel is equal to the lower calorific value and the latent heat of evaporation of the water vapor in the post-combustion products. Since the water is always present as steam at the end of combustion temperatures in the engines, the calorific value should be given as the lower calorific value. The calorific value is desired to be large because it indicates the amount of fuel energy.

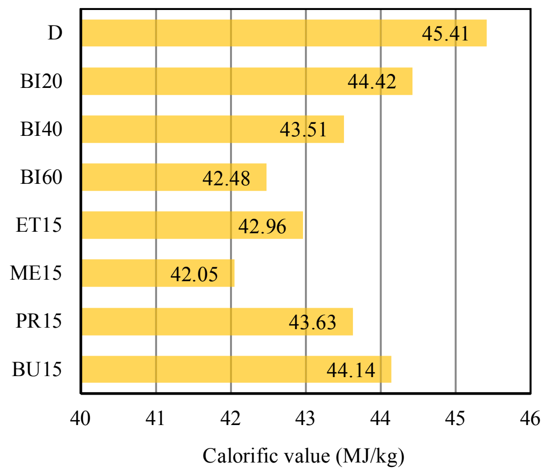

Fig. 3. Calorific value of blends

The calorific value of each mixture is shown in Fig.3. The calorific values of all of the mixtures were measured at a lower value than that of fossil based diesel fuel produced from crude oil. Calorific value is the most important indicator of fuel performance. However, although the use of biodiesel and alcohol causes a decrease in calorific value, it improves combustion performance. The main reason for this is that biodiesel and alcohols contain oxygen in the content and this has a catalytic effect on combustion.

3.4. Flash Point

In order for a liquid fuel to burn, the vapor of fuel must be mixed with the air in certain proportions. The easier a fuel can become vapor, the easier it is to form a flammable mixture with air. This easily combustible property of the fuel is determined by the flash point. The flash point of a flammable object is the lowest temperature at which it emits a vapor, which forms a flammable mixture with air. The flash point is not a fuel feature directly related to engine performance. Rather, it is measured to determine the safe handling and storage of fuels.

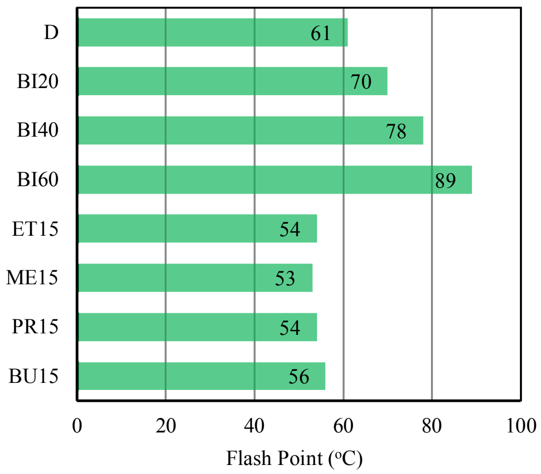

Fig. 4. Flash Point value of blends

Fig. 4 shows flash point values for mixtures and diesel. Significant increases in flash point values have been achieved with the use of biodiesel fuel. This is very useful for safer storage and transfer of diesel fuel. The flash point values of alcohol-containing mixtures were lower than those of diesel. The lowest flash point value was measured with a methanol-containing fuel mixture. Compared to EN 590 standard, ME15 has a flash point of 2 °C, ET15 and PR15 of a flash point of 1 °C lower. This has a limiting effect on the further use of alcohol-containing fuels by 15%.

3.5. Cetane Number

In diesel engines, the measure showing the fuel's self-ignition capability is called the Cetane number. It is one of the most important features of diesel fuel. The increase in the number of Cetane reduces the ignition delay time, which forms the most important part of the combustion process in the diesel engine, and therefore reduces the amount of fuel accumulated in the combustion chamber before sudden combustion. This leads to a decrease in the pressure increase rate during the sudden combustion phase.

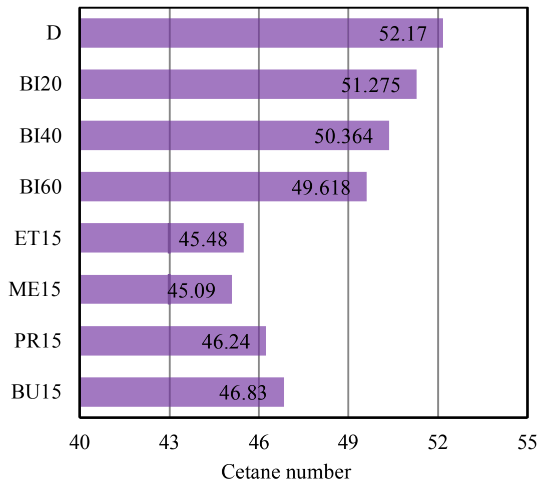

Fig. 5. Cetane Number of blends

Fig. 5 shows the values of the Cetane number of fuels. The use of biodiesel and alcohols with diesel fuel caused a decrease in the Cetane number values. The lowest Cetane number was measured as 45.09 with ME15 fuel.

4. CONCLUSION

As a result of the diesel blending of biodiesel and alcohol fuels which are alternative to diesel fuel, significant changes have been made on the fuel properties. Density and viscosity values increased with the use of biodiesel fuel compared with diesel fuel, but decreased with the use of alcohol fuels. The use of biodiesel and alcohols has led to some reductions in calorific value. However, oxygen content of biodiesel and alcohols completely prevents the decrease in combustion performance due to the decrease in calorific value. The flash point values of biodiesel-containing mixtures are higher than those of diesel fuels. This situation makes biodiesel storage and transfer processes safer. Some decrease in Cetane numbers was observed with the use of biodiesel and alcohols.

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