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INFLUENCE OF DODECANOL ADDITION ON THE ENERGY VALUE OF DIESEL OIL MIXTURE WITH ETHANOL

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ВПЛИВ ДОБАВКИ ДОДЕКАНОЛУ НА ЕНЕРГЕТИЧНУ ЦІННІСТЬ СУМІШІ ДИЗЕЛЬНОГО ПАЛИВА З ЕТАНОЛОМ

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INTRODUCTION

The emission of carbon dioxide (CO_2), considered to be a greenhouse gas, and toxic compounds, including particulate solids and nitrogen oxides (NO_x), which are generated by compression ignition engines, is a serious problem related to the development of the automotive business. Therefore, there is a strive to lower the emission. One of the methods to achieve that is to apply alternative fuels, among which those of plant origin enjoy growing interest, and this includes ethyl alcohol. In compression ignition engines, ethanol is applied as a mixture with diesel oil in order to avoid costly changes in the structure of the engine, and possibly adjustment parameters are changed [1,7,9]. The mixture of ethanol with diesel oil (ON) may be affected by water content in fuel, as even a small quantity of water may result in delamination of the mixture. Such mixture has some limitations compared to conventional fuel, including lower viscosity and comparatively low stability.

One of the additions applied as stabilisers of ethanol mixture with diesel oil is dodecanol ($C_{12}H_{26}$). Dodecanol is produced by reduction of methyl esters [11]. At the temperature of 24°C it is a solid body insoluble in water, however, it is well miscible with the aforesaid fuels [2].

For such types of mixtures to be used in fuelling a compression ignition engine, it is necessary to determine their physical and chemical characteristics, as these affect the process of fuel spraying, the correct operation of a combustion engine, the operating parameters and the cleanliness of the exhaust gas emitted to the environment [8]. Replacement fuels have different physical and chemical properties compared to diesel oil, which contributes to a change in the fuel dose supplied by the injectors.

Biofuels usually reflect lower calorific value than diesel oil, so in order to ensure an equivalent fuel dose is injected in the combustion chamber, a proper adjustment of the injection time must be selected. For that purpose, it is necessary to determine the heat of combustion and the calorific value of such fuels.

Papers [5,6] discuss the influence of adding $C_{12}H_{26}$ on the Cold Filter Plugging Point (CFPP) and self-ignition properties of the mixture of diesel oil and dehydrated ethanol. From the research carried out it appears that dodecanol does not practically affect the aforesaid physical and chemical parameters of the tested fuels. The possibility of applying $C_{12}H_{26}$ as a stabiliser is also supported by its influence on the fuel calorific value, which is the subject matter of this article.

TEST BENCH AND METHODS

The heat of combustion test, based on which the calorific value of fuel has been determined, was carried out with isoperibolic method, using the IKA C5000 calorimeter (Fig. 1). The test was carried out in accordance with the PN-C-04062:2018-05 standard. The determination of the heat of combustion consists in continuous measurement of the temperature of water surrounding the calorimetric bomb filled with oxygen at the pressure of 30 bars. The result of the heat of combustion is the increment of water temperature between the beginning and end of the measurement.

The difference between the heat of combustion Q_s and the quantity of heat needed to vaporise water contained in the fuel and that originating from the combustion of hydrogen present in the fuel is the calorific value W_p. The calorific value was determined based on the following formula [10]:

$$W_P = Q_S - r \cdot m_W \quad (1)$$

where:

W_P – is the calorific value [kJ/kg],
Q_S – is the heat of combustion [kJ/kg],
m_W – is the total mass of water produced in the combustion of one unit of weight of fuel [kg of water/kg of fuel].

The determination of the heat of combustion was carried out for nine samples with various volume percentages of ethanol in the diesel oil. The samples were made with commercial diesel oil, which in accordance to the standard could contain up to 7% FAME and up to 200 mg/kg of water. The addition of dodecanol was fixed and equalled 2%.

The basic properties of dodecanol and ethanol are presented in Tables 1 and 2, and the identification of fuels for which the heat of combustion has been determined is presented in Table 3.

Figure 1 – IKA C5000 calorimeter used in measuring the heat of combustion

The calorific value of the tested mixtures was calculated based on formula 2:

$$W_{pp} = Q_S - 24.42 \cdot (8.94 \cdot H - W) \quad (2)$$

where:

W_{pp} – is the calorific value of the tested fuels [kJ/kg],
Q_S – is the heat of combustion [kJ/kg],
H – mass share of hydrogen in the tested fuels [%],
W – moisture content in the tested fuel [%].

The mass share of hydrogen in diesel oil was calculated based on the following formula [10]:

$$H_{ON} = 0.001195 \cdot Q_S - 41.4 \quad (3)$$

where:

H_{ON} – mass share of hydrogen [%],
Q_S – is the heat of combustion [kJ/kg].

Table 1 – Basic dodecanol characteristics [4]

Parameter	Value	Unit
Density at 16°C	0.9	g/cm^3
Solubility in water at 25°C	0.037	g/l
Autoignition point	275	°C
Flash-point at 101.3 kPa pressure	134.8	°C
Melting/solidification point at 101.3 kPa pressure	24	°C

Table 2 – Basic characteristics of ethyl alcohol [3]

Parameter	Value	Unit
Alcohol content at 20°C	99.9	%
Density	0.7897	g/cm^3
Esters content	<0,2	mg/100 cm^3
Methanol content	<0,6	mg/100 cm^3
Water content	<=0,1	%(m/m)
Auto-ignition point	425	°C

Fuels used in the tests were stored in closed containers (Fig. 2 and 3) with regard to the water-absorption capacity of ethanol, and at the temperature of 15±2°C. In these conditions, the mixture with 15% ethanol got delaminated, while the other mixtures with 5% and 10% of ethanol were homogeneous and clear. The samples containing 2% (v/v) of dodecanol, with the same percentages of ethanol (5%, 10% and 15%, respectively), have not delaminated.

The addition of ethanol in the quantity of 20% or more requires higher concentration of dodecanol in order to keep the mixture stable, particularly at lower temperatures [5].

Table 3 - Fuels used to determine the heat of combustion

Fuel identification	Percentage v/v		
	Diesel oil	Ethanol	Dodecanol
ON 100	100	0	0
ET 100	0	100	0
D 100	0	0	100
ON+ET 5	95	5	0
ON+ET10	90	10	0
ON+ET15	85	15	0
ON+ET5+D	93	5	2
ON+ET10+D	88	10	2
ON+ET15+D	83	15	2

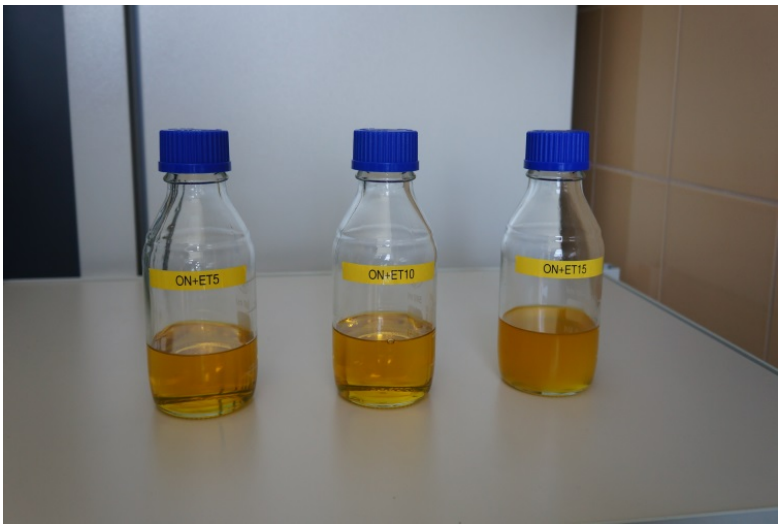

Figure 2 - Mixture of diesel oil with 5%, 10% and 15% of ethanol by volume

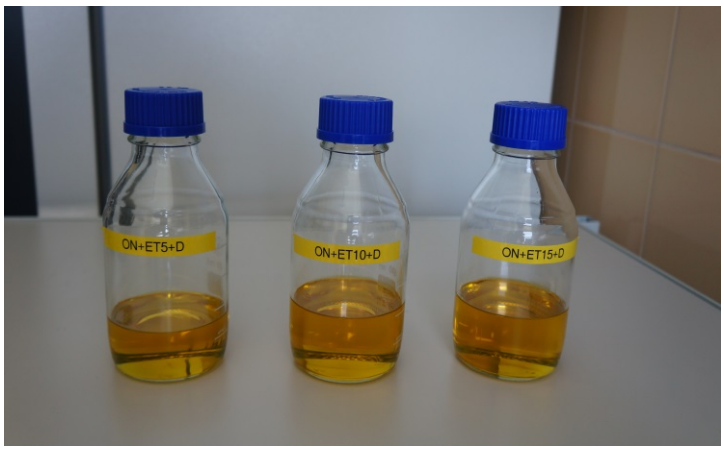

Figure 3 – Mixture of diesel oil with 5%, 10% and 15% of ethanol by volume and 2% dodecanol addition

TEST RESULTS AND ANALYSIS

The content of hydrogen in fuel affects the heat of combustion and decides, among other things, about the self-ignition characteristics of fuel. Table 4 presents the values of the percentage share of hydrogen in the samples of fuels for which the analysis has been made. The largest mass percentage of hydrogen applies to the mixture with dodecanol.

Table 4 - Mass share of hydrogen in the tested fuels

Fuel identification	Mass share of hydrogen H [%]
ON 100	13.14
ET 100	13
D 100	14.43
ON+ET5	13.3
ON+ET10	13.13
ON+ET15	13.12
ON+ET5+D	13.16
ON+ET10+D	13.15
ON+ET15+D	13.14

The chart (Fig. 4) presents the results of the heat of combustion determination for the tested mixtures. The ON100 fuel reflects the highest value of the heat of combustion equal to 45.65 MJ/kg, whereas the lowest value of 42.87 MJ/kg applied to the ON+ET15+D fuel.

Figure 5 presents the results of the calculated calorific value for all of the tested mixtures. The highest calorific value of 42.78 MJ/kg is reflected by the commercial diesel oil.Along with the growth of the concentration of ethanol and after adding 2% of dodecanol, the calorific values decrease. For the mixture of ON+ET15+D, the calorific value equalled 40 MJ/kg and was the lowest compared to the other fuels.

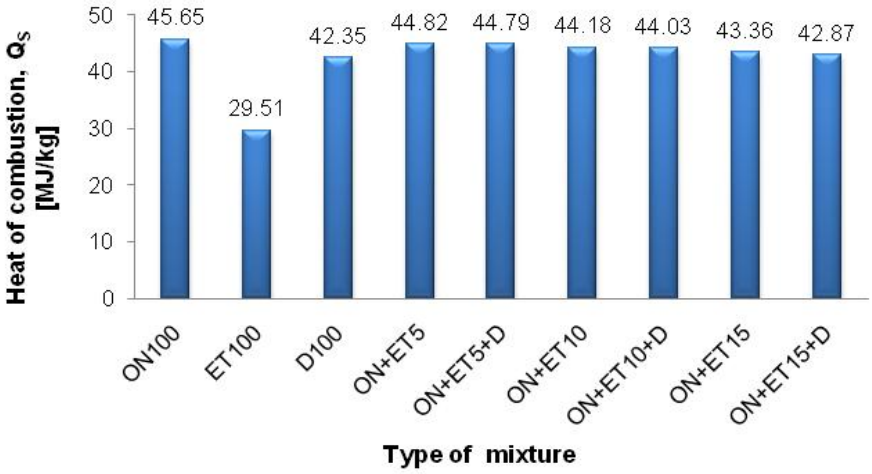

Figure 4 – Heat of combustion values for the tested mixtures

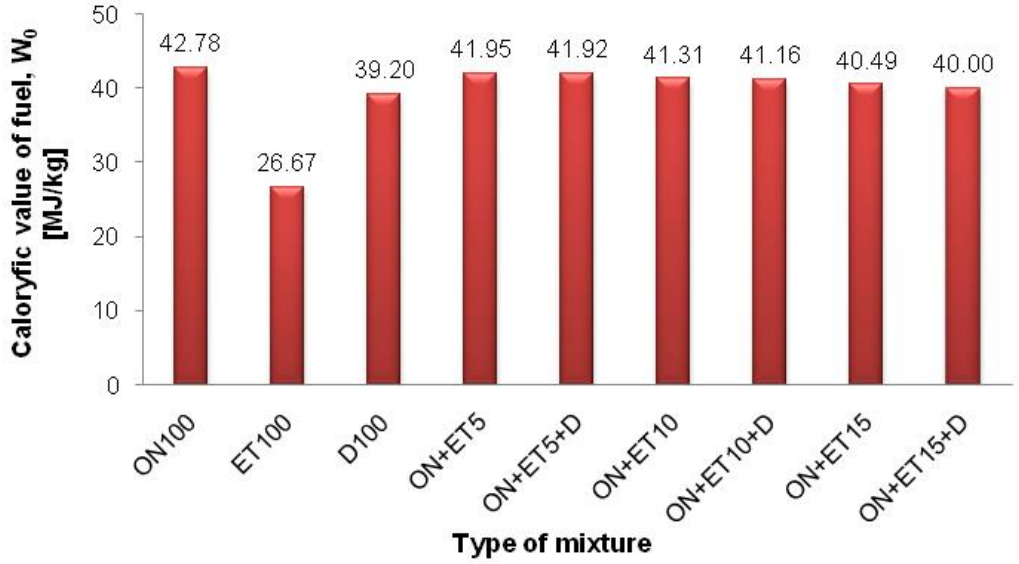

Figure 5 – Calculated calorific value for the tested mixtures

Table 5 – Comparison of the calculated and measured calorific values for tested fuels

[redacted]

Table 5 presents a comparison of calorific values obtained experimentally and calculated as the function of the percentage of components in the mixture. It shows that the relative errors between both calorific values does not exceed 1%.

CONCLUSIONS

The highest value of the calorific valueequal to 42.78 MJ/kg was obtained for ON100. Increase of the share of ethanol in the tested fuels results in a decrease of the heat of combustion and calorific value. Addition of 2% (v/v) dodecanol slightly decreases the heat of combustion even more, owing to the fact that the value of this parameter for dodecanol is 92.7% of the heat of combustion of diesel oil. Introduction of dodecanol addition to the mixtures of diesel oil and ethanol resulted in increasing the mass share of hydrogen compared to that in the commercial diesel oil or diesel oil mixtures with ethanol, resulting in dodecanol calorific value of only 91.6% of the calorific value of diesel oil.

The lowest heat of combustion compared to other fuels was determined for the ON+ET5+D, ON+ET10+D, ON+ET15+D mixtures. The same mixtures with $C_{12}H_{26}$ addition have a lower percentage of diesel oil to the benefit of dodecanol. Both ethyl alcohol and dodecanol reflect lower energy value compared to diesel oil. Therefore, it resulted in decreasing the value of the heat of combustion.

A decrease in calorific value in reference to diesel oil, as a result of adding small percentages of ethanol, equals approximately 2% for the ON+ET5 and ON+ET5+D fuels. The largest difference of the energy parameter applies to the higher concentrations of ethanol in the tested fuels and equals nearly 5.5%, while after adding dodecanol, the difference increased to 6.5%.

The differences in calorific value between the mixtures of diesel oil and ethanol and the same samples with stabiliser in the form of dodecanol are small and reach the maximum value of 1.2%.

The deterioration of energy parameters results mainly from the addition of ethanol, as it reflects the lowest value of the heat of combustion, namely 29.51 MJ/kg and the lowest calorific value equal 26.87 MJ/kg.

Dodecanol may be added as a stabiliser as it has an insignificant impact on the calorific characteristics of fuel.As a result of the carried out tests it may be stated that the use of diesel oil mixtures with ethanol and dodecanol may result in lowering the operating parameters of an engine, therefore, maintaining the parameters at the level applicable to diesel oil only requires an adequate adjustment of the time of injection.

The calorific values of tested fuel mixtures calculated on the basis of percentage composition do not differ by more than 1% from the experimental values. However, due to the variances of the calorific value of various types of diesel oils, this parameter should be each time determined for the specified fuel used at preparing the mixtures with ethanol.

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ABSTRACT

KRZEMIŃSKI Artur, LEJDA Kazimierz, USTRZYCKI Adam. Influence of dodecanol addition on the energy value of diesel oil mixture with ethanol. Visnyk of National Transport University. Series «Technical sciences». Scientific and Technical Collection. Kyiv. National Transport University. 2019. Vol. 3 (45).

Currently, there is a strive to lower the emission of carbon dioxide, considered to be a greenhouse gas, and toxic compounds, including particulate solids and nitrogen oxides, which are generated by compression ignition engines. One of the methods to achieve the objective is to apply alternative fuels, among which those of plant origin enjoy growing interest. As a bio-component for fuelling compression ignition engines ethyl alcohol may be applied, which is mixed with diesel oil in order to avoid costly structural changes of engines. However, ethanol is hardly miscible with diesel oil, particularly at low temperatures, which calls for the application of additions improving that characteristic. Additions may, yet, affect other parameters of such fuel.

As a result of the tests carried out, the highest calorific value was obtained for diesel oil; it equals to 42.78 MJ/kg. Increase of the share of ethanol in the tested fuels results in a decrease of the heat of combustion and calorific value. Addition of 2% (v/v) dodecanol slightly decreases the heat of combustion even more, owing to the fact that the value of this parameter for dodecanol is 92.7% of the heat of combustion of diesel oil. Introduction of dodecanol addition to the mixtures of diesel oil and ethanol resulted in increasing the mass share of hydrogen compared to that in the commercial diesel oil or diesel oil mixtures with ethanol, resulting in dodecanol calorific value of only 91.6% of the calorific value of diesel oil. The results of the research indicate that the influence of dodecanol addition to diesel oil mixed with ethanol is small as regards calorific values. Dodecanol may be added as a stabiliser as it has an insignificant impact on the calorific characteristics of fuel. As a result of the carried out tests it may be stated that the use of diesel oil mixtures with ethanol and dodecanol may result in lowering the operating parameters of an engine, therefore, maintaining the parameters at the level applicable to diesel oil only requires an adequate adjustment of the time of injection.

KEY WORDS: DODECANOL, ETHANOL, BLEND, DIESEL FUEL, DIESEL, CALORIFIC VALUE, ADDITIVES.

РЕФЕРАТ

КШЕМІНЬСКІ Артур. Вплив добавки додеканолу на енергетичну цінність суміші дизельного палива з етанолом / А. КШЕМІНЬСКІ, К. ЛЕЙДА, А. УСТШИЦКІ // Вісник Національного транспортного університету. Серія «Технічні науки». Науково-технічний збірник – К.: НТУ, 2019. – Вип. 3 (45).

В даний час існує прагнення до зниження викидів двоокису вуглецю, що вважається парниковим газом і токсичних сполук, включаючи тверді частинки і оксиди азоту, які генеруються двигунами із запалюванням від стиснення. Одним із методів досягнення мети є застосування альтернативних видів палива, серед яких зростає інтерес для палив рослинного походження. Як біокомпонент для заправки двигунів із запалюванням від стиснення може застосовуватися етиловий спирт, який змішується з дизельним паливом, щоб уникнути дорогих структурних змін двигунів. Однак, етанол погано змішується з дизельним паливом, особливо при низьких температурах, що вимагає застосування добавок, що покращують цю характеристику. Добавки можуть, однак, впливати на інші параметри такого палива.

В результаті проведених випробувань найвище значення теплотворної здатності, що дорівнює 42,78 МДж / кг, було отримано для дизельного палива. Збільшення частки етанолу в досліджуваних паливах призводить до зменшення теплоти згоряння і теплотворної здатності. Додавання 2% (v / v) додеканолу дещо знижує теплоту згоряння ще більше, внаслідок того, що значення цього параметра для додеканолу становить 92,7% теплоти згоряння дизельного палива. Введення додеканолу до сумішей дизельного палива і етанолу призвело до збільшення масової частки водню порівняно з такою в комерційних дизельних нафтових або дизельних сумішах з етанолом, в результаті чого додеканольна теплотворна здатність лише 91,6% теплотворної здатності дизельного палива отриманого з нафти. Додеканол може бути доданий як стабілізатор, оскільки він має незначний вплив на теплотворну здатність палива. В результаті проведених випробувань можна стверджувати, що використання сумішей дизельного палива з етанолом і додеканолом може призвести до зниження робочих параметрів двигуна, тому підтримка параметрів на рівні, що застосовується до дизельного палива, вимагає лише відповідних регулювань часу впорскування.

КЛЮЧОВІ СЛОВА: ДОДЕКАНОЛ, ЕТАНОЛ, СУМІШ, ДИЗЕЛЬНЕ ПАЛИВО, ДИЗЕЛЬ, ТЕПЛОТВОРНА ЗДАТНІСТЬ, ДОБАВКИ.

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