SUITABILITY OF BIOETHANOL AND METHANOL BLENDS AS FUEL FOR INTERNAL COMBUSTION ENGINES

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Abstract
This paper presents the results of a study on the suitability of ethyl and methyl alcohol mixtures with varying percentages for use in spark-ignition combustion engines. The volumetric mass, heat of combustion, sediment amount, and compositional homogeneity of ethyl and methyl alcohol mixtures were examined. It was found that the highest volumetric mass values in the tested fuels were found for 30% ethanol and 70% methanol. Fuel containing ethanol alone had the highest heat of combustion, with increasing methanol content resulting in a decrease. The amount of sediment remaining after combustion of the alcohol mixtures was lowest for the fuel containing 30% ethanol and 70% methanol. Based on spectrographic studies, it was determined that no chemical reactions occur in the alcohol-methanol mixtures and the fuel has the character of a mixture.

Key words: *Biofuels, ethanol, methanol, combustion engines,*

INTRODUCTION

Both regulatory requirements and growing environmental awareness are driving broader interest in renewable fuels. Fossil fuels, besides the prospect of depletion, also pose economic and political dependence. Biofuels, widely known for years, are gaining increasing popularity, not only among scientists but also in the economy. The widespread use of biofuel additives in both diesel and gasoline confirms the determination of many countries to increase the share of renewable fuels in their overall consumption.
The most commonly used biofuels include bioesters added to diesel fuel, as well as ethyl and methyl alcohols used as gasoline additives. Bioethanol is also used as a diesel fuel additive, but to a lesser extent due to its high heat of vaporization and low cetane number *(Balata, et al. 2008)* Both alcohols are also used as standalone fuels. The possibility of using a blend of these alcohols as fuel for spark-ignition engines is an important prospect for increasing the use of biofuels. In the search for fuels with a lower environmental impact, gaseous fuels are used, both of fossil origin and those produced from renewable raw materials or even waste (engines powered by biogas generated from sewage or municipal waste).
Bioethanol can also be produced from agricultural, municipal, and wood waste *(Saravana,et al. 2012).* Combustion of gaseous fuels primarily reduces the emission of particulate pollutants, but the exhaust gases produced during combustion also have a chemical composition that is less harmful to the environment. For safety reasons, alcohols used as fuels are often colored or supplemented with additives with intense odor and flavor *(Fanick, et al. 1984).* Alcohols used as fuels are also supplemented with additives that reduce corrosion and improve lubricity (*Estefan, et al. 1990).* In addition, they increase the thermal efficiency of the engine (Bilgin, *et al.* 2008)
The variety of fuels used to power internal combustion engines and their selected properties are presented in Tables 1 and 2.
Currently constructed engines are most often adapted to run on fuels containing very high shares of biofuels, and are even equipped with systems adapting the engine settings (mainly the fuel supply sys-

tem) to the specific requirements of alcohols (lower air demand during combustion, higher octane number allowing for changes in the ignition timing settings, higher heat of vaporization favoring the use of alcohols in engines with direct fuel injection).

Tab. 1 Selected properties of some fuels for internal combustion engines

Fuell	Methan	LNG	CNG	LPG	ON	gasoline
Calorific value [MJ/kg]	49.80	49,30	48,80	46.05	42.80	43,00
Research octane number	130	110	110	115	-	98
Motor octane number	100	105	105	110	-	88
Cetane number	-	-	-	-	43	-
Heat of vaporization [kJ/kg]	510	510	510	426	250	230- 255

Based on the information contained in Table 1, the calorific value of gasoline is similar to that of diesel fuel and lower than that of gaseous fuels. The calorific values of methyl alcohol and bioethanol presented in Table 2 are significantly lower than the corresponding values for gaseous fuels and gasoline, however, the higher octane number and a different combustion process allow for achieving satisfactory results in practice during the operation of an engine fueled with alcohols (*Anderson*, *et al. 2010).*

Tab. 2 Selected properties of bioethanol and methanol

Fuel	Metanol	Bioetanol
Research octane number	107	108
Motor octane number	92	91
Calorific value [MJ/kg]	19,90	26.8
Heat of vaporization [kJ/kg]	1100	910

It's worth mentioning that in the 1980s, most European car manufacturers (Volkswagen, Renault, etc.) produced cars for Brazil with engines adapted to run on ethanol alone. These engines, in addition to changes in the fuel system, featured an increased compression ratio, even higher than that of gasolines with an octane rating above 95, which were difficult to obtain at the time. Given that the octane rating of gasolines at that time was increased by adding tetraethyl lead, such fuel was significantly safer for the environment than conventional fuels. For years, research has been conducted on the suitability of alcohols as fuel for modern spark-ignition engines. The current bioethanol additive used in most EU countries is 5-10%. It does not significantly affect exhaust gas composition *(Johansson, 2016)* but it allows for a reduction in fossil fuel consumption. Methanol was also used as fuel in large fleets in the 1980s and 1990s, and interest in it as a fuel is currently growing again (*Sarkar, et al. 2012)*. Legal aspects within the European Union also favor research and practical use of renewable fuels, as well as fuels with low environmental impact during combustion *(Balata, et al. 2008, Directive (EU) 2018/2001)*. Using alcohols as fuel, both in their pure form and as additives, also reduces engine noise. This is due to both the reduced air requirement for fuel combustion (lower noise levels in the air intake system) and the resulting noise level associated with fuel combustion *(Iliev, 2015)*. Attempts are being made to simulate the effects of using methanol and bioethanol blends as fuel. While these do not capture all the effects, they can significantly shorten research cycles by suggesting more beneficial solutions *(Fanick, et al. 1984)*.
This paper presents the process and results of testing selected functional characteristics of methyl alcohol and bioethanol mixtures, in particular the calorific value and residue mass after combustion of mix-

tures of the above-mentioned alcohols in various proportions. The research was conducted in the laboratory of the Department of Mechatronics and Construction Machinery at the Bydgoszcz University of Technology and in the Department of Power Engineering and Means of Transport at the University of Life Sciences in Lublin.

MATERIALS AND METHOD

The tests were performed on mixtures of bioethanol and methanol with a purity of 99.9% pure component. To determine the suitability of various bioethanol and methyl alcohol mixtures for fueling spark-ignition engines, heat of combustion tests were conducted for mixtures with varying alcohol content. Furthermore, the mass of the residue formed after combustion of fuel samples was weighed to determine the ash content. The alcohol content in the mixture was determined by weight. The volumetric mass was also measured for each prepared fuel. The volumetric mass measurement results are presented in Table 3. The use of methanol and ethanol additives increases the thermal efficiency of the engine. *(Wang, et al. 2019).*

Tab. 3 List of fuels used in the research and their volumetric weight

Fuel	Volumetric weight [kg / m^{-3}]
Bioethanol 100%	782.0
Bioehtanol / methanol 70 / 30%	784.9
Bioethanol / methanol 50 / 50%	787.39
Bioethanol / methanol 30 / 70%	787.96
Methanol 100%	781.32

A nonlinear pattern of changes in the volumetric mass values can be observed, with the highest values measured for fuel containing 30% bioethanol and 70% methanol. The KL12Mn calorimeter shown in Figure 7 was used to measure the heat of combustion of liquid or solid substances in an oxygen atmosphere in a 350 ml bomb calorimeter immersed in a 4.4 l calorimeter vessel filled with water. The device automatically calculates the heat of combustion based on the recorded temperatures during complete combustion of the material at a pressure of 20 MPa. In the first stage, the temperature stabilizes, then the sample is ignited and the temperature is measured until the maximum temperature is reached. Each combustion step involves a fuel sample placed in a glass crucible. The sample mass was approximately 0.001 kg and was measured on an analytical balance with a measurement accuracy of 1 • 10-7 kg. A new crucible was used for each measurement, the mass of which was weighed before being filled with the fuel sample. Filling was performed immediately before being placed in the calorimetric bomb to prevent fuel evaporation. The fuel samples were combusted in oxygen at a pressure of approximately 500 hPa. Each measurement of the calorific value was repeated five times.

After fuel combustion was complete, the mass of the sediment was weighed for each fuel type. A view of the quartz glass crucible with sediment is shown in Figure 2.

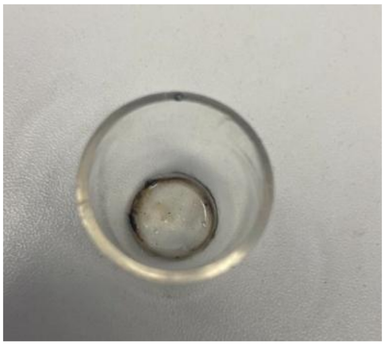

Fig. 2 View of an example crucible with sediment after combustion of a fuel sample [own photo]

To confirm the purity of the tested fuels, they were subjected to compositional homogeneity tests prior to their calorific value measurements. The tests were conducted using a Thermo Scientific Nicolet iS50 FT-IR spectrometer.

RESULTS AND DISCUSSION

The results obtained from the measurements were statistically analyzed using Statistica software. The average values of the combustion heat and sludge mass for each fuel are presented in Table 4.

Tab. 4 Average values of combustion heat and sludge mass obtained for the tested fuels

Fuel	Heat of combustion [kJ/kg]	Sediment mass [%fuel mass]
Bioethanol 100%	27249	0.09
Bioehtanol / methanol 70 / 30%	25825	0.19
Bioethanol / methanol 50 / 50%	24649	0.17
Bioethanol / methanol 30 / 70%	23124	0.15
Methanol 100%	20806	0.43

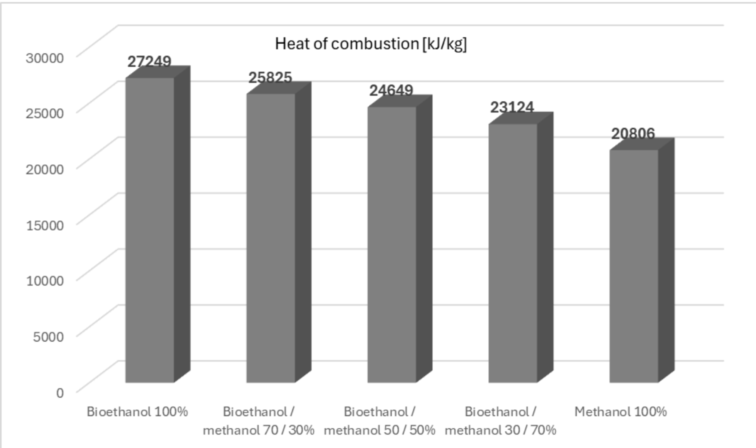

Fig. 3 Change in the heat of combustion value depending on the fuel composition

The heat of combustion decreases proportionally to the increase in methanol content in the fuel.

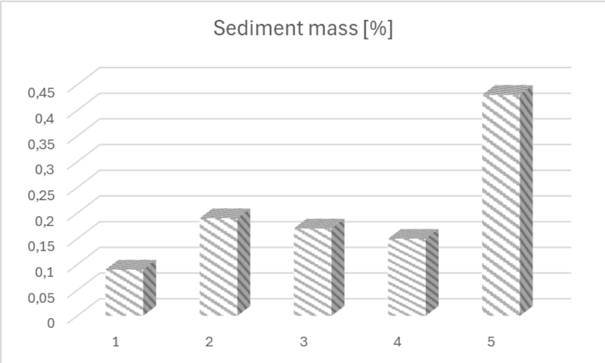

Fig. 4 Change in the sediment mass value depending on the fuel composition

The sediment mass changes in a nonlinear manner. The highest sediment amount was observed for the fuel containing 100% methanol.
Composition analysis conducted using a Thermo Scientific Nicolet iS50 FT-IR spectrometer confirmed that no compounds other than the alcohols were detected in both the tested fuels and their mixtures. A sample graph from the spectrographic analysis is shown in Figure 5.

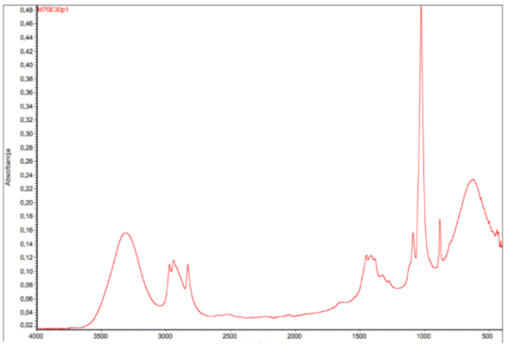

Fig. 5.Example spectrographic spectrum (mixture of 30% ethanol and 70% methanol)

CONCLUSIONS

Based on the conducted tests, the following can be concluded:

1. The change in volumetric mass for the tested blends is nonlinear, reaching the highest value for the blend containing 30% ethanol and 70% methanol, which was 787.9 kg/m-3. This nonlinear change in volumetric mass is characteristic of alcohol blending. Tests conducted using a spectrometer confirm that no new chemical compounds were formed in the tested alcohol blends, and the fuel remained solely a mixture of the tested alcohols.
2. The highest heat of combustion was found for fuel containing pure ethyl alcohol, at 27,249 kJ/kg. The heat of combustion decreases approximately linearly with increasing methanol content, reaching the lowest value for methanol alone, at 20,806 kJ/kg. The decrease in the heat of combustion is not a clear indicator of a decrease in the suitability of the alcohol mixture for engine fueling, as it does not account for combustion efficiency, which in the case of higher-octane fuels may result in an increase in the combustion process efficiency.
3. The amount of residue after combustion of fuel mixtures was highly uneven and lacked a uniform pattern. The highest average deposit amount was found for fuel containing only methyl alcohol – 0.43%. Lower deposit amounts were found for fuels containing alcohol mixtures. For fuel containing 30% ethanol and 70% methanol, the deposit content was 0.15%. Therefore, to achieve a lower deposit amount, it is advisable to use alcohol mixtures.

4. Based on spectrographic studies, it was found that no chemical reactions occur in alcohol mixtures and the fuel has the character of a mixture.
5. Based on the conducted research, the use of alcohol mixtures as fuel for internal combustion engines should be considered possible and advisable.
6. The research work should be supplemented with engine tests to determine the efficiency of the combustion process and the composition of exhaust gases generated during the operation of engines powered by such fuels.

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