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APPLICATION OF THE NEWEST METHOD BASED ON INFRARED SPECTRA ANALYSIS AND MATHEMATICAL MODELS FOR ESTIMATING AN EFFECT OF BIOCOMPONENT SHARE IN A MIXTURE WITH DIESEL OIL ON CETANE NUMBER

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Summary. The paper presents results of tests obtained by application of new method based on an analysis of infrared spectra and mathematical models for determining the cetane number of fuels and biofuels. The research aimed at estimating the effect of biocomponent share in a mixture with diesel oil on the cetane number. The tests were conducted on two various commercial diesel oils and one RME biofuel. Values of cetane numbers ranged between 51.8 for basic diesel oil and 55.2 for type B40 biofuel, i.e. diesel oil with 40% supplement of RME. Growing share of biocomponents caused an increase in the fuel cetane number, while at 40% addition the CN increased maximally by 5.8%.

Key words: cetane number, biodiesel, biofuels, RME.

INTRODUCTION

The main parameters determining biofuel usefulness for diesel engine fueling comprise also cetane number. Cetane number is a measure of the ignition quality of diesel fuel. It affects the self-ignition and the course of combustion process.

The higher the cetane number the shorter ignition delay period, therefore smaller amount of fuel accumulates in the ignition chamber until ignition. This situation causes that combustion process goes on more mildly and there are smaller pressure increases in the combustion chamber in crank angle function. Therefore, the engine works more silently and its life lengthens due to lesser loads of piston-crank system. Higher cetane fuels cause better start up, particularly when the engine is cold. Increasing the cetane number also leads to lesser toxic exhaust emission of nitrogen oxides, not combusted hydrocarbons, carbon oxides and solid particles as well as lower smokiness of exhaust gases.

Among methods of increasing the cetane number is application of biocomponents. Irrespectively of the above-mentioned arguments, an act on biocomponents and liquid biofuels and other regulations, which have been in force since 2007 put an obligation to use biofuels and biocomponents for fuelling ZS engines.

Due to the fact that an increasing number of diesel oils with added biocomponents have appeared currently, the author determined to conduct investigations aimed at an assessment of biocomponent effect on the cetane number of fuels and biofuels.

In Poland the cetane number is determined on the basis of Polish standard PN-EN ISO 5156. CN is assessed on the basis of comparing ignition properties of the tested fuel with the analogous properties of standard fuel mixtures with known cetane numbers. The tests are conducted on a specially constructed one-cylinder test engine. Determining the cetane number is difficult, requires maintaining a number of test engine work parameters, all in all it is time consuming and relatively expensive. Therefore, new methods are sought which would make it possible to determine the cetane number in an alternative way but at simultaneously maintained repeatability and reliability of results. The new method of determining the cetane number was used to obtain the results presented in this paper. In his former investigations the author tested the correctness of the applied method by using it for pure diesel oils. It turned out that the obtained results concerning the cetane number were similar to the ones obtained on a test engine, according to PN-EN ISO 5156. Values of the cetane number ranged within the error limit of the above-mentioned engine method, which demonstrated that the applied method gives reliable and repeatable results.

AIM AND SCOPE OF RESEARCH

Fig. 1. Experimental stand with fuel and biofuel Irox Diesel analyzer

The research aimed at an estimation of the effect of biocomponent share in a mixture with diesel oil on the cetane number. The tests were conducted on two various commercial diesel oils and one RME biofuels. The diesel oils originated respectively from PKN ORLEN S.A. refinery and from LOTOS Group S.A. The biocomponents were RME rape esters manufactured in a GW-10 reactor constructed and owned by the Małopolskie Centre of Renewable Energy Sources ‘BioEnergia’. All the tests were conducted at the Laboratory of Technology and Assessment of Physicochemical Properties at the Faculty of Agricultural Engineering, University of Agriculture in Krakow.

In the transesterification process methyl alcohol was used and the catalyst was KOH Potassium hydroxide pure. Methanol to rapeseed oil molar ratio was 9:1.

The process was conducted in two stages. Transesterification process began in the temperature of 330K. In the following example the manner of conducting the transesterification process with the use of KOH as a catalyst was described.

The experiments were conducted using fuel Irox Diesel analyzer made by Grabner Instruments – see Fig. 1

METHODS

Menstruation in fuel analyzer Irox Diesel is based on methodology of menstruation of infrared absorption in infrared scope from 2,7 to 15,4μ, in a Fourier spectrometer (based on Fourier transform analysis). The obtained spectrogram of this characteristic – dactyloscopic area is correlated with spectrum table for different concentration of analyzed substances.

Menstruation chamber possessing small width in direction of transmission (for Irox Diesel is 0,1 mm), is situated in front of infrared rays beam. Intensity of rays is measured after they pass the chamber with the tested sample inside it and without the sample. Measured absorption for the given wave length tells about the concentration of a tested component. Compounds that raise the cetane number possess two distinctive absorbent maxima 1275cm^{-1} and 1635cm^{-1} (accordingly 7,8μ i 6,11μ). It is impossible to exactly determine cetane number, cetane index or distillatory characteristics exactly out of spectrum. However, with the use of complicated mathematical models (differently from what it was in the case of a menstruation) we can anticipate those values. The method to determine those parameters is based on estimation on the basis of spectrum and on calculation of mathematical models. Usually, the method of coefficients analysis or multilinker regression is applied to correlate the obtained spectrum or absorption straight with cetane number, cetane index and distillatory characteristics. It is difficult to introduce additional volumes into the coefficients analysis method and the correlation of components and concentrations is not completely clear. Irox Diesel is using cluster analysis together with the method of multilinker regression. Into such a model other volumes can be easily introduced, in order to determine better dissolved compounds – saturates.

Irox Diesel analyzer may determine physicochemical properties of biofuels to the 40% content (v/v) of the biocomponent, therefore mixtures of diesel oil with type B0 to B40 RME were prepared for the tests determining the effect of biocomponent on the cetane number. For instance, B5 biofuel is a fuel with 5% content (v/v) RME in the mixture with diesel oil. Mixtures for two oils with RME were prepared, which gave altogether sixteen kinds of samples.

RESULTS AND DISCUSSION

First, the basic diesel oil samples were tested to check whether the fuel parameters were in accordance with the ones declared in quality certificates. The results of tests on diesel oil from PKN ORLEN S.A. were given in Table 1, whereas results for the diesel oil from LOTOS S.A. Group in Table 2.

Table 1. Physicochemical properties of basic diesel oil from LOTOS S.A Group

Paramerers	Value	Individual
Total aromatics	26,3	%
Total polyaromatics	1,3	%
Cetane number	51,8	-
Cetane index	51,3	-
T 90	333,3	°C
T 95	353,6	°C
Ethylesther	0	%
Methylesther	0,1	%
Biodiesel	0,1	%
Density	843	g/dm^3
Temperature	21,2	şC

Table 2. Physicochemical properties of basic diesel oil from PKN ORLEN S.A.

Paramerers	Value	Individual
Total aromatics	28,6	%
Total polyaromatics	1,7	%
Cetane number	52,1	-
Cetane index	50,7	-
T 90	331,6	°C
T 95	351,3	°C
Ethylesther	0	%
Methylesther	0,1	%
Biodiesel	0,1	%
Density	828	g/dm^3
Temperature	25,6	şC

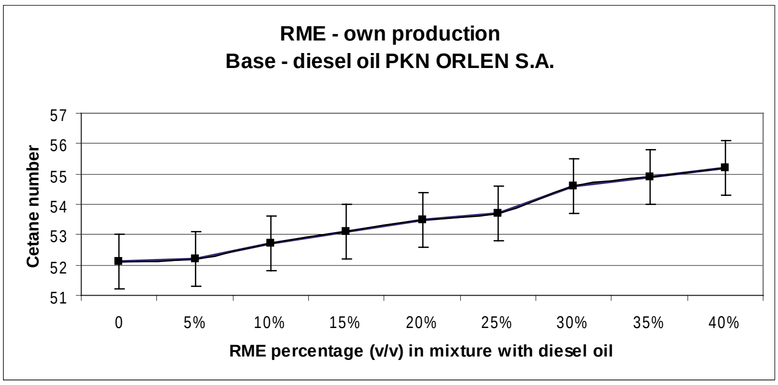

Fig. 1. Estimating an effect of biocomponent share in mixture with diesel oil on the cetane number of prepared fuels

Tyhe test results presented in Tables 1 and 2 show that both fuels meet the quality standard for diesel oil PN-EN 590:2006. Additionally, the obtained values of the cetane number were in accordance with the values declared in diesel oil quality certificates [PN-EN 590:2006]. The research revealed that neither of the fuels contained biocomponent additions.

Fig. 1 presents results of the test determining an effect of biocomponent share in the mixture with diesel oil from PKN ORLEN S.A. refinery on the cetane umber of the prepared fuels.

As may be seen in Fig. 1, the cetane number ranged from CN = 52.1 and CN = 55.2. As might have been supposed the lowest CN was obtained for pure diesel oil. The difference between the highest and the lowest CN was CN = 3.1, i.e. about 5.7%.

Fig. 2 shows results of tests determining the effect of biocomponent addition in the mixture with diesel oil from LOTOS group S.A. refinery on the cetane number of the prepared fuels.

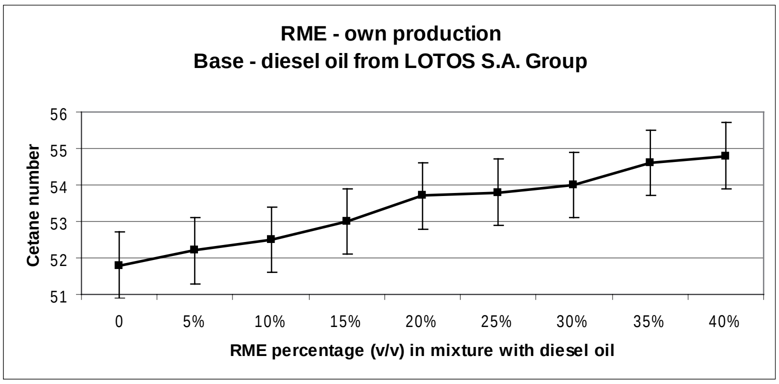

Fig. 2. Estimating the effect of biocomponent share in mixture with diesel oil on the cetane number of prepared fuels

As may be seen from Table 2, increasing share of RME in the mixture with diesel oil is accompanied by growing value of the cetane number. The lowest CN was obtained for B0, i.e. basic diesel oil – CN was 51.8, whereas the highest CN = 54.8 was registered for B40 biofuels. The above data demonstrates that CN for B40 type fuel is by about 5.85 higher than for pure diesel oil.

It is worth noticing that increasing the share of biocomponent gradually by 5% practically leads to linear increase in CN. It demonstrates that the applied method correctly estimates CN of the tested fuels.

The conducted tests allow to draw a practical conclusion that the new analytical method (using Irox Diesel analyzer) may be used for CN determination in checking tests or in case when fast measurements are required. Such analyzer may undoubtedly constitute a part of equipment of mobile laboratories which verify the quality of biofuels manufactured in small biofuels plants in fuel stores or on fuel stations. The applied method has not been admitted by the standard, therefore in order to make the approved methodology, it is necessary to conduct comparative laboratory tests in which all the certified laboratories would participate.

Nomenclature

CN – Cetane number

RME – Rapeseed Methyl Esters

ZS – Diesel engine

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ZASTOSOWANIE NAJNOWSZEJ METODY OPARTEJ NA ANALIZIE WIDM W PODCZERWIENI ORAZ MODELACH MATEMATYCZNYCH DO SZACOWANIA WPŁYWU UDZIAŁU BIOKOMPONENTU W MIESZANINIE Z OLEJEM NAPĘDOWYM NA LICZBĘ CETANOWĄ

Streszczenie. W referacie zaprezentowano wyniki badań z zastosowania nowatorskiej metody opartej na analizie widm w podczerwieni oraz przy użyciu modeli matematycznych do określenia liczby cetanowej paliw i biopaliw. Celem badań było oszacowanie wpływu udziału biokomponentu w mieszaninie z olejem napędowym na liczbę cetanową. Badania przeprowadzono z udziałem dwóch różnych handlowych olejów napędowych oraz jednego biopaliwa typu RME. Wartości liczb cetanowych zawierały się w przedziale 51,8 dla bazowego oleju napędowego do 55,2 dla biopaliwa typu B40, czyli oleju napędowego z 40% dodatkiem RME. Zwiększanie udziału biokomponentu powodowało wzrost liczby cetanowej paliwa, a przy 40% dodatku LC wzrosła maksymalnie o 5,8%.

Słowa kluczowe: liczba cetanowa, biodiesel, biopaliwa, RME.