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ASSESSMENT OF PURPOSEFULLNESS OF THE PREMIUM TYPE DIESEL FUELS' USE IN REDUCING THE UNFAVOURABLE INFLUENCE ON THE ENVIRONMENT

Summary

As a result of the conducted tests on the gross calorific value and the volumes of ash for fuels of Standard and Premium type available at Polish fuel distributors it was found that the tested parameters in most cases showed no substantial differences. The tests conducted with the use of a calorimeter showed relationship between the gross calorific value and the volume of the deposit that remained for both the types of fuels (the higher results of the gross calorific value the lower volume of deposit remaining after burning).
***Key words**: diesel fuel, fuel type Standard, fuel type Premium, fuel consumption in agricultural vehicles*

OCENA CELOWOŚCI STOSOWANIA OLEJÓW NAPĘDOWYCH TYPU PREMIUM W ZMNIEJSZENIU NIEKORZYSTNEGO ODDZIAŁYWANIA NA ŚRODOWISKO

Streszczenie

W wyniku przeprowadzonych badań ciepła spalania oraz ilości popiołu dla paliw typu Standard oraz paliw typu Premium dostępnych u polskich dystrybutorów paliw stwierdzono, iż badane parametry nie wykazują w większości przypadków istotnych różnic. Badania prowadzone przy użyciu kalorymetru wykazały zależność pomiędzy ciepłem spalania, a ilością pozostałego osadu dla obu typu paliw (im wyższe wyniki ciepła spalania, tym mniejsza ilość osadu pozostałego po spaleniu).
***Słowa kluczowe**: olej napędowy, paliwo typu Standard, paliwo typu Premium, zużycie paliwa w pojazdach rolniczych*

1. Introduction

The agricultural machines and the vehicles used for transport in agriculture are driven with engines with self-ignition. Fuels that are used for these engines' feeding are one of the biggest sources of air pollution origination. Out of concern for the environment protection, there are being taken up activities aiming at reduction of harmful compounds' emission and reduction of the fuel's consumption by machines and vehicles. The use of fuels having parameters conductive to the reduction of the volume of the burnt fuel and as a consequence of reduced harmful impact on the environment is one of the suggested solutions. Smaller harmfulness for the environment resulting from the decrease of the sulphur content in fuel and as a result the decrease of the volume of sulphur oxides in exhaust gases which in contact with steam and water contribute to the environments' acidification, is the next prerequisite for the use of the fuels of Premium type. The assessment of the combustion residue of the diesel fuel of premium and Standard type has not been found in the available descriptions. Dissemination of charging in the engines has, apart from many positive effects (increase of effectiveness, increase of the unit power, increase of power and the turning moment), also contributed to adverse phenomena. Changes in the course of the combustion process resulted, as a consequence, instead of relatively easy separation of carbon black (carbon) as unburnt fuel residues, remaining of solid particles of complex composition hard to separate. The content of pollutants in fuel influences the increase of their volumes in exhaust gases. Crude oil is the natural energy raw material formed from extinct organisms during biochemical conversions [1]. The awareness of existence of crude oil has been functioning in the society for a long time, however it was Ignacy Łukasiewicz who in 1853 initiated its extraction and use [2]. In the first period of crude oil's processing it was done in boilers of periodical operation, later on there were gradually used boilers with continuous movement and continuous distillation and ratification.

Crude oil is an oily fluid of characteristic odour and the shade of amber black, of mass density 849,9 $kg\cdot m^{-3}$ and viscosity amounting to 0,7400 $mm^2\cdot s^{-1}$ in the temperature of 50°C. Hydrocarbons constitute a bigger part of chemical compounds contained in crude oil. A detailed composition of crude oil is presented in table 1.

Table 1. Composition of crude oil
Tab. 1. Skład ropy naftowej

Name	Volume in percentage [%]
Sulphur	0,0047
Nitrogen	0,0603
Oxygen	0,042
Saturated aliphatic hydrocarbons	2060
Oil hydrocarbons	2040
Aromatic hydrocarbons	10

Source: / Źródło: Ewa Śliwka, Technologia chemiczna – surowce i nośniki energii. Skład węglowodorowy ropy naftowej i gazu, Politechnika Wrocławska, Wrocław, 2010

In order to obtain products that can be applied in motorization industry, the techniques used at the time of crude oil's conversion have been divided into distillation and rectification [4]. Distillation of crude oil separates mixtures into individual fraction groups of boiling temperature from an appropriate range. Many chemical components occurring in crude oil have very similar boiling temperatures, that is why the next necessary method includes rectification that is separation of mixtures consisting of components of similar volatility. The diesel oil and petrol are the mixtures of hydrocarbons, however it is the mass density and boiling temperature that constitutes their crucial difference. Petrol has the mass density of 0,70 kg·dm^{-3} and the boiling temperature of 40-200°C, while the diesel oil has the mass density of 0,84 kg·dm^{-3} and the boiling temperature of 150-350°C. The diesel oil which is designed for compression-ignition engines should guarantee quick and full combustion and not to create any danger for correct functioning of the supply system (for ex. lubricating properties), allow for easy start-up of an engine irrespective of the ambient temperature, ensure protection of a motor and the combustion chamber's elements [5].

2. Purpose of the studies

The analysis of the gross calorific value and the mass of dust coming into being at the time of combustion of diesel oils having the basic parameters and diesel oils of premium type, originating from five different networks distributing diesel oil in Poland, as well as the assessment of the volume of ash remaining after fuel combustion, constitutes the purpose of the studies. The examined volumes of the fuel consumption and the gross calorific value, the value of the calorific value and the ash mass, have been accepted to be the factors influencing the environment.

3. Materials and methods

The standard diesel oils produced by oil corporations, have basic low-temperature properties or base improvers such as agents improving lubricating ability and cleaning detergents. Fuels type Premium are enriched with improvers, in case of the diesel oil the cetane number which has impact on fuel's tendency to self-ignition [6], is increased. Moreover, a depressant and WASA components are added to fuel, which results in lowering cloud point threshold and the cold filter's blockade, what protects the engine at the time of its start-up and operation in low temperatures. Most often, the content of sulphur is also reduced. Diesel oils are enriched with improvers in order to improve the fuel's quality. There may be distinguished the following additives: additives increasing the cetane number, antioxidant additives, cleaning additives, anticorrosive additives, metal deactivators, deicing additives, biocides, dispersion additives preventing deposition of deposits and deemulsifiers [7].

In the study there have been accepted for analysis fuels of Standard and Premium type purchased at five different networks of fuel stations. The standard diesel oils are the fuels of basic parameters meeting the criteria of the PN-EN 590+A1:2017-06 standard [8] and technical conditions developed by the producer's group. They ensure the highest properties necessary for correct engine's operation, however they do not increase its potential just like in case of the Premium fuels. The biggest oil corporations present on the market, offer fuels of Standard type, which have a lower cetane number than fuels of Premium type, however they meet the requirements necessary for the correct engine's operation and ensure low harmfulness for the natural environment.

In order to verify the differences between the fuels of Standard and Premium type resulting from the improvers applied in these fuels, there have been conducted preliminary tests of the diesel oil's consumption purchased at a given station, conducted for a given vehicle operating on a farm. That vehicle selected for the tests was a delivery truck driven with a Diesel engine with charging, of swept capacity 1461 cm^3 and power 65 kW (82 KM). Charged by turns with examined, that vehicle covered four times the same section (2 times to the target place and back) of the distance of 99 km (in total 396 km), in similar weather conditions and at the similar traffic. The tests were conducted on days with no precipitations, of the ambient temperature 15-25^{0}C, when the speed of the wind did not exceed 5 m·s^{-1} The vehicle was each time driven by the same person. Before starting the measurements, the fuel tank was filled (earlier emptied in at least 95%) up, in turn with individual fuels of Standard and Premium type. After each covering of the section, the fuel tank was filled up to get information on fuel consumption during the test. The values measured were compared with the readings of the vehicle's data computer and the consistency of the readings with measurements were established. The results were subject to the statistical analysis with the Tukey test (α=0,05) with the use of the FR-ANALWAR software on the basis of Excel.

There have also been conducted the tests of the gross calorific value in laboratory conditions. The tests were conducted with the use of the calorimeter KL 12 Mn. The measurement of the gross calorific value was controlled by the computer and was conducted automatically. The gross calorific value generated at the time of complete using up of the unit of fuel's mass, is determined by condensation of water steam liberated at the time of using up and cooling down of the combustion products to the initial temperature of the combusted components decreased by the volume of heat released at synthesis and dissolution [10]. The calorific value of a tested substance is characterized by the gross calorific value decreased by the volume of heat necessary to evaporate water in the tested substance [11]. The calorimetric measurement has been conducted by complete combustion of the fuel's sample in the atmosphere of oxygen.

4. Results of the studies

The obtained results of the tests of fuel consumption in the field conditions are presented in the table 2.

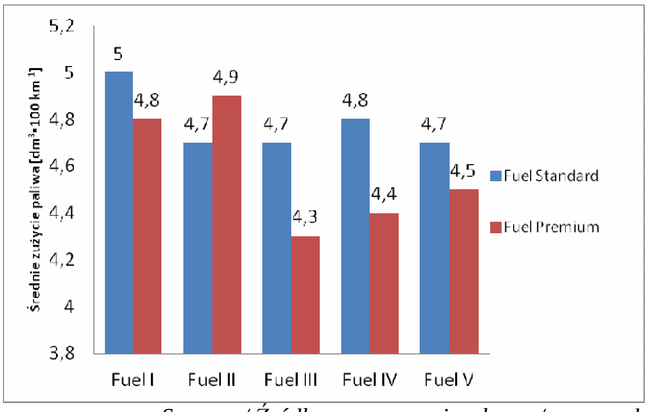
Table 2. Specification of the use of fuel type Standard and Premium in a vehicle for individual stations

Tab. 2. Zestawienie zużycia paliwa typu Standard oraz Premium w pojeździe dla poszczególnych stacji

Station	Average fuel consumption [L/100 km]	
	Fuel type Standard	Fuel type Premium
I	5,0^{a}	4,8^{ab}
II	4,7^{b}	4,9^{ab}
III	4,7^{b}	4,3^{c}
IV	4,8^{ab}	4,4^{c}
V	4,7^{b}	4,5^{c}

Source: / Źródło: opracowanie własne / own work

In case of two networks (I and II) occurrence of statistically essential differences in fuel consumption between the types Premium and Standard has not been established. In case of the network II there has been established even a slight increase in fuel consumption, however it was not statistically essential. In the remaining cases there was observed the drop in fuel consumption, amounting from 4,2% (for fuels sold in network V) to 8,5% for fuels in network III. The average fuel consumption [dm^{-3}·100 km^{-1}].



Source: / Źródło: opracowanie własne / own work

Fig. 1. Average use of fuel type Standard and Premium
Rys. 1. Średnie zużycie paliwa typu Standard oraz Premium

As a result of the conducted laboratory tests, the results of the following parameters have been obtained: gross calorific value and ash content after testing. Each substance was examined in four repetitions and the average results are presented in the table 3 and 4.

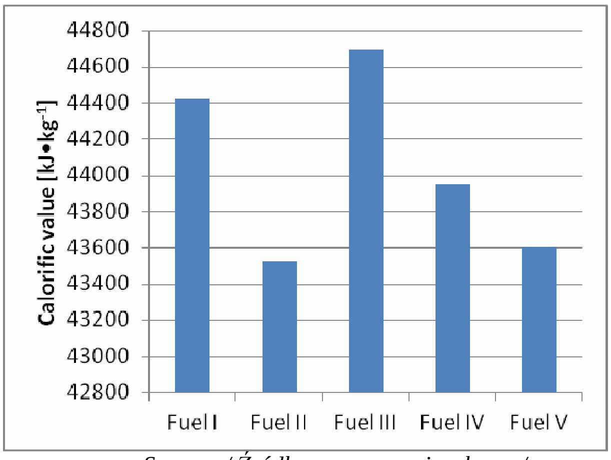


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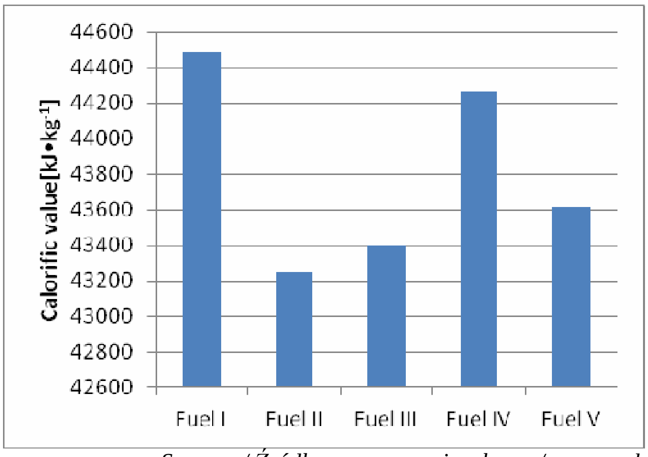
Fig. 2. The average result of gross calorific value of fuel type Standard [kJ•kg^{-1}]
Rys. 2. Średnia wartość ciepła spalania dla paliw Standard [kJ•kg^{-1}]

The results obtained for two samples have been compared and presented in a graphic manner in the below graphs.



Source: / Źródło: opracowanie własne / own work

Fig. 3. The average result of gross calorific value of fuel type Premium [kJ·kg^{-1}]
Rys. 3. Średnia wartość ciepła spalania dla paliw typu Premium [kJ·kg^{-1}]

In spite of the fact, that as a result of measurements of the gross calorific value the fuels type Premium have a higher gross calorific value, these differences were statistically unessential (p=5%).

Having conducted the test on the gross calorific value, the deposit that remained following combustion was weighted. The weight of the deposits was differentiated and was within the range from 0,00330 g for fuel Standard from the network I to 0,0095 g for the fuel Premium from the network II. For all the types of the networks, it was found that their fuels type Premium leave a bigger mass of ash following combustion. A different situation was observed for fuels from the network III but this difference was not statistically essential. A statistical increase was measured for the fuels from the stations of networks II, IV and V. These dependencies are presented in the table 5.

It's worth emphasizing, that the ash mass constitutes in the tested fuels from 0,3-0,9% of the combusted fuel's mass. In publications there have not been found any similar analyses, and the materials of the companies producing and selling fuels are the only publications, which most often mention that the drop in fuel consumption amounts from 2-5% and they declare reduction of the solid particles' mass. Hard to combust additives improving the fuel's properties could have an impact on the increase of the ash mass.

Table 3. Results of examination of the mass of ash and gross calorific value for fuels type Standard
Tab. 3. Wyniki badania masy popiołu i ciepła spalania dla paliw typu Standard

Examined parameter	Station I	Station II	Station III	Station IV	Station V
Ash mass [g]	0,0033	0,0052	0,0043	0,0036	0,0048
Gross calorific value [kJ•kg^{-1}]	44426,5	43526	44694,5	43957	43605
Content of ash [%]	0,3335	0,5185	0,454	0,36	0,479

Source: / Źródło: opracowanie własne / own work

Table 4. Results of examination of the mass of ash and gross calorific value for fuels type Premium
Tab. 4. Wyniki badania masy popiołu i ciepła spalania dla paliw typu Premium

Examined parameter	Station I	Station II	Station III	Station IV	Station V
Ash mass [g]	0,0038	0,0095	0,00375	0,0048	0,00835
Gross calorific value [kJ•kg^{-1}]	44485	43249	43403	44269	43611,5
Content of ash [%]	0,38	0,95	0,3745	0,478	0,8345

Source: / Źródło: opracowanie własne / own work

Table 5. Statistical differences in the ash mass for the fuels Standard and Premium
Tab. 5. Statystyczne różnice w masie popiołu dla paliw Standard i Premium

	Station I	Station II	Station III	Station IV	Station V
Standard fuel	0,0033[d]	0,0052[b]	0,0043[bc]	0,0036[d]	0,0048[b]
Premium fuel	0,0038[cd]	0,0095[a]	0,0037[c]	0,0048[b]	0,00835[a]

Source: / Źródło: opracowanie własne / own work

For the purposes of full assessment of the ash mass remaining after fuel's combustion, the mass of ash has to be related to the volume of the consumed fuel. In case of fuel from the network II and V, the volume of the formed ash should be decreased respectively by 8 and 4,3% (what results from the reduced fuel consumption).

5. Conclusions

In the conducted studies it has been found, that not in all the cases the use of fuels of Premium type contributed to reduction in fuel consumption. For fuels from networks III, IV and V, the drop in consumption was statistically essential and amounted from 4,2% for the network V to 8,5% for the fuels sold in the network III. No differences in the value of the gross calorific value for individual types of fuels were found. There was found a statistically essential increase of the mass of ash for fuels from the network II, IV and V, what may reflect badly on the impact on the environment, but it requires additional studies concerning the composition of exhaust gases which at present are conducted by the team. For the fuel from the network III there was observed the drop in the mass of ash at combusting fuels of Premium type, but it is not statistically essential. In the analyses there have not been taken into consideration price relations between individual fuels.

On the basis of the conducted tests it may found, that application of the fuels of premium type in most of the cases, contributes to the decrease of unfavourable impact on the environment as a result of smaller fuel's consumption. In special cases, the drop for more than 8% of fuel consumption is a clear limitation of the mass of combustion gases, and consequently, pollution of environment (most of all of air). The obtained results of the tests are the basis for further research studies consisting in particular on examination of the exhaust gases both in terms of the chemical composition as well as the solid particles' content.

6. References

[1] Ney R.: Zasoby ropy naftowej. Polityka Energetyczna, 2006, 9 spec., 467-486.
[2] Brzozowski Stanisław, Ignacy Łukasiewicz. Warszawa: Wydawnictwo Interpress, 1974.
[3] Śliwka E.: Technologia chemiczna – surowce i nośniki energii. Skład węglowodorowy ropy naftowej i gazu, Politechnika Wrocławska, Wrocław, 2010.
[4] Woschni G.: A Universally Applicable Equation for the Instantaneous Heat Transfer Coefficient in the Internal Combustion Engine, SAE Technical, 1967.
[5] Zając P.: Silniki pojazdów samochodowych. Tom 1. Podstawy budowy oraz główne zespoły i układy mechaniczne. Warszawa: WKŁ, 2009.
[6] www.lotos.pl/dla_biznesu/paliwa_i_dodatki/oleje_napedowe.
[7] Canakci M.: Combustion characteristics of a turbocharged DI compression ignition engine fueled with petroleum diesel fuels and biodiesel, Bioresource Technology, 2007, Vol. 98, 6: 1167–1175.
[8] PN-EN 590+A1 2017-06 Paliwa do pojazdów samochodowych - Oleje napędowe - Wymagania i metody badań.
[9] www.orlen.pl/PL/DlaBiznesu/Paliwa/OlejeNapedowe.
[10] Budzianowski M.: Thermal integration of combustion-based energy generators by heat recircula. University of Technology, Wrocław, 2010.
[11] Ahn J., Ronney P.D., Shao Z., Haile S.M.: A thermally self-sustaining miniature solid oxide fuel cell. Journal of Fuel Cell Science and Technology, 2009, 6, 4.