

Analysis of technical parameters of black coals used in low-power boilers

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The article presents the results of technical analysis of black coals available in retail sales in Poland. A comprehensive list of fuel technical parameters and analysis of the possibilities of their use in low-power boilers was supported by the experience of the authors of the study. A thorough analysis of technical parameters of fuels concerned basic thermodynamic parameters of fuels responsible for the quality of thermal processes occurring in boilers. The collected data is presented in a uniform description of the current state of the sold fuels. In the last point, the researchers were looking at the technical aspects of the fuels offered in relation to the existing emission standard for low-power boilers.

Keywords: black coal, low-power boilers, technical analysis

Admission

Individual heating in Poland has undergone major quality changes over recent years. Resulting from the introduced changes in the energy efficiency of low-power boilers. In recent years, the current emission requirements have been significantly changed. In publications [2, 4, 11,], the authors present current emission requirements for low-power boilers. In publications [7, 13], the authors presented numerical methods allowing to limit the emission of harmful substances from the heating devices. In publications [3, 12], the authors showed direct methods that affect the improvement of harmful substances emissions from low-power boilers.

Recently, boilers with automatic fuel delivery have become popular in Poland. These boilers are characterized by maintenance free maintenance and high thermal and emission parameters. These constructions additionally require special fuel adapted for burning in burners used in these boilers. The basic burners used in solid fuel boilers are retort and suction burners. The possibility of carrying out the combustion process in these constructions requires an appropriate type of fuel. A suitable fuel for automatic boilers is stone coal with granulation of grains from 5 - 25 mm. The leading leaders are boilers with a screw feeder equipped with a retort burner. Most boiler manufacturers already have such boilers in their offer.

From October 1, 2017, low temperature boilers for solid fuel that can be produced are boilers that meet the fifth class conditions in accordance with the PN-EN 303-5:2012 standard. This fact results from the implementation of the Regulation of the Minister of Development and Finance regulating the requirements for boilers. However, the standards introduced did not cover fuels used in boilers.

Therefore, the market offers many types of coals, differing in the parameters of the heat of combustion, humidity or grain size. The research and literature studies [8, 9] show that not only boiler designs are responsible for the emission parameters, but the quality of the fuel burned. The information on the offered carbons, undertaken in the research, can be used by researchers of heating boilers in their matching selection to the required emission parameters.

1.Characteristics of tested coal fuels

The most commonly used coal fuel for boilers with an automatic fuel feeding system is small grain coal. In Poland, it is often called fine grained coal. This is due to the erroneous assignment of this assortment of fuel to the group of ecological fuels.

The majority of black coal offered for sale in Poland comes from domestic mines. Coal fuels from other parts of the world have also become popular recently. You can read [1, 5, 6, 10] on processing and coal technologies in other countries. The variety of fuels offered causes that customers have a big problem with choosing the right fuel for them. In addition, the variety in terms of technical parameters of offered fuels causes that many users are guided only by the price criterion as the best. One of the key aspects of the correct operation of low-power boilers is the appropriate selection of fuel for them.

The use of the right fuel allows to achieve the best thermal parameters while maintaining low parameters of harmful substances emission. An example of the appearance of coal fuel of the fine grained coal type is presented in Figure 1.



Fig. 1. Example of fine grained black coal

Among users increasing popularity of this type of fuel. Packaged in bags, delivered on a pallet, it offers great convenience during transport and storage at the distributors as well as at the individual recipient. Coal in the bag does not require the organization of fuel storage sites, it can be freely placed anywhere in the boiler room. An additional advantage of fuels in bags is easy to use when pouring into the boiler's container. It is easy to use it and at the same time maintain order in the boiler room. Hence the growing popularity of automatic boilers for solid fuel and the use of bagged fuel type fine grained coal.

Recently, the emergence of this fuel in DIY stores has become popular. The location of stores in large cities and the stability of fuel supplies to them gives easy availability of fuel and great convenience in the use of such boilers. This convenience is also due to the fact that we don't need to create additional space in the boiler room for storage, each time we can buy fuel only in the amount of the necessary heat demand in a given period.

In many cases, customers have a good choice between manufacturers and the parameters of the offered fuel. Buying coal based

only on the price criterion, regardless of the fuel calorific value, is the right choice only from the point of view of a one off financial expense. Choosing coal without prior analysis of the local market may turn out to be wrong. It results from the fact that there are various technical parameters of fuel within even one delivery. This fact results directly from the diversity of coal seams in the exploited deposit and from the often unfair practices of mixing different coals by distributors within one delivery. In the further stage of coal use, users can conclude that its heating value is relatively low and the amount of fuel we need to burn to obtain the appropriate temperature of heated rooms is higher than that resulting from the initial cost calculation. Often it turns out that in the operation of a low-power boiler, the user tests several types of fuel before finding the right fuel for him. It is connected with incurring costs for the wrong fuel, loss of the user's time and even damage to the boiler. Hence, the low price does not mean that the purchase was good.

In the case of a decision to buy coal for retort boilers, this investment should be considered not in the meaning of the amount of fuel purchased in kilograms but the amount of heat that we are able to buy for the same amount. That is why it is worth completing the market analysis and calculation of offers before the purchase, which will result in calculating the price to calorific value ratio. The calculated index in the form of the price to calorific ratio shows the price of 1 GJ of heat contained in the fuel. The formula used for calculations is presented in equation No. 1.

$$\frac{\text{price} \left[\frac{\$}{\text{kg}} \right]}{\text{heating value} \left[\frac{\text{Gj}}{\text{kg}} \right]} = \text{price to calorific} \left[\frac{\$}{\text{Gj}} \right] \quad (1)$$

In the case of this criterion, it is best to choose a product whose index will be the lowest, then the net cost of heating on the side of the purchased fuel is the lowest.

Users of low-power boilers can use multiple indicators to choose the right fuel to their boilers. The choice of features that can be guided in the selection of fuel are many. Such indicators also include: availability of fuel, humidity, incineration, chemical composition, share of sulfur in the fuel, source of origin, etc. The criteria the user will be guided by when choosing fuel depends on his own approach or suggestions from the manufacturer of the used boiler regarding parameters and quality fuels used in them. The variety of technical features of the coal fuels sold causes that the topic of selecting fuels in local heating is becoming a popular issue. In addition, the growing environmental awareness of societies causes the search for ecological fuels and their combustion techniques to reduce environmental pollution. What causes withdrawal of various fuels from sale that do not meet the latest criteria and parametric standards. Currently, brown coal has been withdrawn from the retail sale of coal fuels. It was withdrawn due to low emission and thermal parameters. Instead, it was replaced with high calorific black coal, whose minimum calorific value is 24 MJ/kg. These criteria have been in force since mid 2018 in the Greater Poland Province and the city of Poznan. These activities are aimed at preventing high emissions of harmful substances from individual heating and to prevent the formation of smog in the heating season.

In order to approximate the issues related to the selection of the most favorable fuel, the one that gives us the most heat, an attempt was made to combine and estimate the amount of heat generated from the offered bagged carbons. In addition, the analysis was expanded to include technical parameters such as humidity and ash residue. The list gave synthetic characteristics of given fuels in terms of economy, heat and emissions. Fuels are summarized in

the table using generalized names such as fuel 1, fuel 2, etc. Four construction stores with branches in each provincial city in Poland were selected for the analysis. Only small coal in the form of black coal were used for the comparison. As a place for fuel purchases, construction stores have been chosen as they offer the largest selection among packaged fuels and are the most popular place to buy fuel bagged in large cities. The obtained analysis and comparison of results are presented in the table No. 1.

Tab. 1. Selected parameters of tested coal fuels

	calorific value [MJ/kg]	humidity [%]	ash content [%]	price [PLN/ton]	heat price [PLN/GJ]
Fuel 1	25	13%	10%	700	30.43
Fuel 2	26	10%	7%	850	35.42
Fuel 3	26	9%	6%	800	33.33
Fuel 4	28	9%	6%	840	32.31
Fuel 5	30	6%	4%	920	32.86
Fuel 6	23	15%	10%	550	28.95
Fuel 7	25	10%	7%	700	30.43
Fuel 8	23	12%	7%	750	35.71
Fuel 9	28	8%	5%	840	32.31
Fuel 10	26	10%	7%	840	35.00
Fuel 11	24	15%	8%	650	29.55
Fuel 12	26	11%	8%	975	40.63
Fuel 13	29	6%	5%	1040	38.52
Fuel 14	28	7%	4%	879	33.81
Fuel 15	24	14%	9%	785	35.68

2. Parametric analysis of the conducted tests of black coals

From the conducted research, a lot of data was obtained, which is summarized in the summary table number 1. From the received data, the basic parameters of parameters divided into given fuel features were made.

The first obtained distribution from the conducted research is Figure 2 presenting the distribution of calorific value for each examined fuel. The arithmetic mean of the heating value of the coals sold is: 26.07 MJ/kg. The minimum calorific value is: 23 MJ/kg, and the maximum is 30 MJ/kg, the median is 26 MJ/kg.

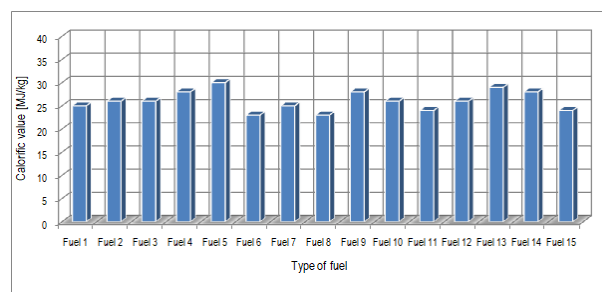


Fig. 2. Distribution of calorific value for a given fuels

The next received distribution is figure 3, which presents the heat price distribution for a given fuel. The arithmetic mean of the heat price depending on the given fuel is: 33.66 PLN/GJ. The minimum value is: 28.95 PLN/GJ, and the maximum is: 40.63 PLN/GJ, the median is: 33.33 PLN/GJ.

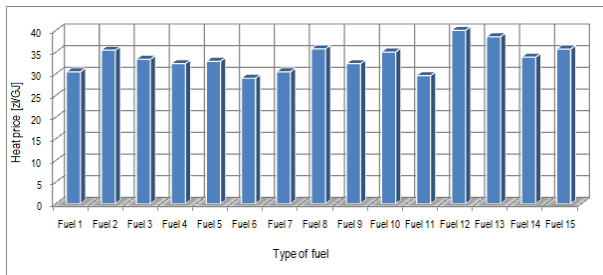


Fig. 3. Distribution of heat price for a given fuels

The next distribution is the distribution of fuel humidity. During the tests, 10 different humidity of the fuel were distinguished. The course of the distribution is presented in Figure 4. The average moisture content of the tested fuels is: 10%. The minimum value is: 6% and the maximum is: 15%. The median humidity is: 10% of the total moisture in the forest.

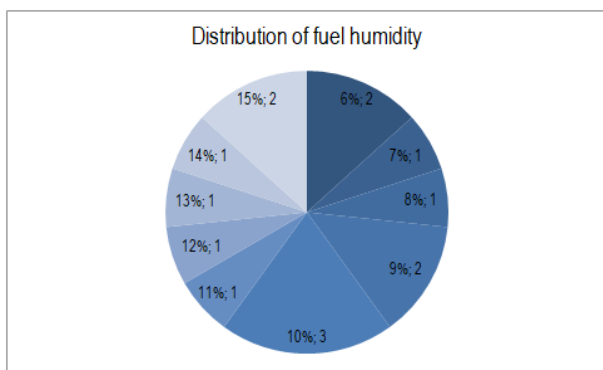


Fig. 4. Distribution of fuel humidity for a given fuels

The next distribution prepared by the authors is the distribution of ash content in the fuel. There are 7 different ash content in fuels. The course of the distribution is presented in Figure 5. The average ash content of fuels is 7%. The minimum value is: 4%, and the maximum value is 10%, the median is: 7%.

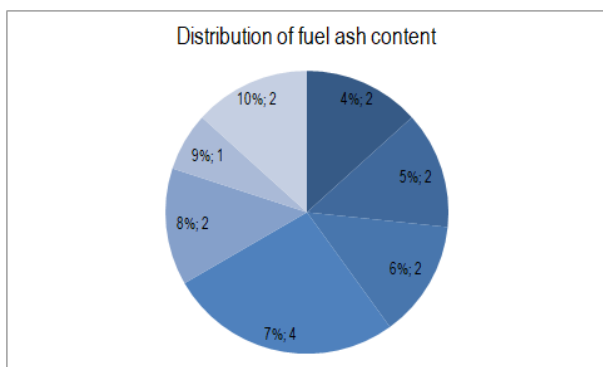


Fig. 5. Distribution of ash content for a given fuels

The last prepared mileage is a joint comparison of the calorific value with the price of fuel for the heat price that users buy by selecting the given fuel.

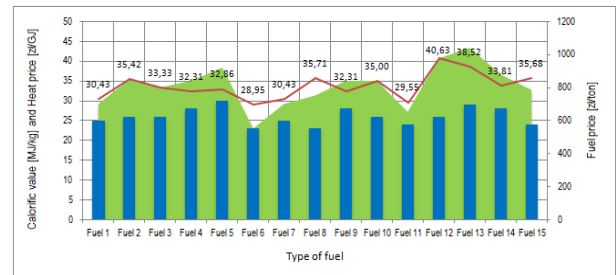


Fig. 6. Distribution of calorific value and heat price to fuel price

The analysis shows that it is best to buy fuel 6, the heat price for this fuel is 28.95 PLN/GJ. However, this fuel is characterized by a low calorific value of only 23 MJ/kg, which is why this fuel is worth using in the period of medium or low heat demand. In the transitional period, most of the thermal energy is lost to maintain the combustion process and the efficiency of this process is low, during this period worse fuel will not increase its consumption and may contribute to savings. The lowest profitability was the purchase of fuel 12, because the heat price was here 40.63 PLN/GJ with an average calorific value of 26 MJ/kg. The most favorable price of heat is offered by fuels at the lowest price per ton, but their calorific value is at the lower level, which in the period of increased heat demand can cause more fuel and thus more frequent fuel purchases and smoking. A good fuel proposition for the entire heating period is fuel 9. The fuel has an average calorific value of 28 MJ/kg and the price per ton is 840 PLN. This fuel can be a good proposition for people who value the price/quality ratio because this fuel has only 8% humidity and 5% ash in it. These parameters can translate into a correct and ecological combustion process while maintaining a balanced fuel consumption resulting from its calorific value. In addition, the low moisture content in the fuel will guarantee lower heat losses resulting from the evaporation of moisture from the fuel during combustion, which will ultimately translate into improved thermal and emission efficiency of the boiler. It is also a good proposition as a basic fuel in the period of increased heat demand.

One of the important criteria for the selection of fuel is its humidity. Most of the coals offered do not have reliable information regarding this parameter. In addition, a considerable difficulty associated with the use of packed fuel is to maintain excessive moisture in the fuel. Frequent practice among fuel distributors is its deliberate wetting. An additional portion of water in the bag increases its weight at the expense of coal being poured. In total, it gives you the sale of less fuel at the price specified for the coal itself and not for the wet coal. This practice further aggravates the quality of the fuel sold and the need to dry it after purchase. Too high humidity of the fuel causes a number of complications in the combustion process. The moisture content in the fuel is important in the case of the combustion process, because the higher its content, the combustion process deteriorates, mainly in terms of the heat output in the convection parts of the boiler. The water contained in the fuel evaporates absorbs part of the heat which is released into the heating surfaces in dry fuel combustion conditions. The high moisture content in the fuel affects the deterioration of the efficiency of the combustion process and this is associated with a higher cost of heating.

Large selection of fuels available for sale and their availability causes that customers are able to choose the energy carrier with selected parameters and the price they are interested in. An important aspect when buying coal is the conversion of the amount of heat we buy by selecting the product. Buying fuel with the best ratio of heat to price, we guarantee a low heat consumption and its lower consumption for our heating needs. This is directly related to the

lower emission of harmful substances and the protection of the local environment.

Summary

The purpose of the undertaken research was to determine the technical parameters of hard coals available in retail sales. The topic addressed answers the basic question of what parameters to follow when buying fuel for low-power boilers. This problem is important because in recent years in Poland there is a significant deterioration of air quality during the heating season. This is due to the often occurring in this period of smog taking directly from individual heating based on the combustion of solid fuels including hard coal. During the work, a dozen or so coals were available for sale. For this purpose, the most popular source of this fuel was selected in large cities, such as building shops. The result of the conducted research is the fact of parametric diversity of offered fuels. During the research, authors managed to rank the fuels in terms of their technical values such as: calorific value, wetness or ash residue. In addition, the authors used a parameter of the price of heat purchased for a given fuel. This ratio may be the basic criterion for the selection of fuel for low-power boilers operating in individual heating. This is due to the small scale of this type of heating, which is directly related to the validity of the price criterion as the basic indicator in the selection of fuel. The final stage of the tests carried out are the conclusions regarding the directions of optimal selection and emission of fuel, subject to the validity of technical parameters such as: calorific value per kilogram of fuel, moisture content in the fuel, quantity of ash and sulfur content. The resulting specification and presented approach to the development of technical parameters of coal in relation to individual heating gives a synthetic statement of the basic steps to be made before choosing the right fuel for the heating process or research.

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Analiza parametrów technicznych węgla kamiennych stosowanych w kotłach małej mocy

W artykule przedstawiono wyniki analizy technicznej węgla kamiennych dostępnych w sprzedaży detalicznej w Polsce. Obszerna lista parametrów technicznych paliw i analiza możliwości ich zastosowania w kotłach o małej mocy została poparta doświadczeniem autorów badań. Dogłębna analiza parametrów technicznych paliw dotyczyła podstawowych parametrów termodynamicznych paliw odpowiedzialnych za jakość procesów cieplnych zachodzących w kotłach. Zebrane dane prezentowane są w jednolitym opisie aktualnego stanu sprzedawanych paliw. W ostatnim punkcie badacze przyglądali się technicznemu aspektowi oferowanych paliw w stosunku do istniejącego standardu emisji dla kotłów o małej mocy.

Słowa kluczowe: węgiel kamienny, kotły małej mocy, analiza techniczna

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