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Relationship between random reflectance of ulminite B/collotelinite and technological parameters of Polish low-rank coal

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HIGHLIGHTS

- Correlation between Rr and GCV and Rr and C^{daf} is very high.
- It is possible to determine Rr of ulminite B from M_t^{af}, GCV^{maf}, and C^{daf}.
- The suborder of Polish lignite can be determined with use of Rr.
- The boundary between lignite C and lignite B should be set at Rr equal to 0.35%.

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ABSTRACT

The main objective of the study is to determine the correlation between random reflectance of ulminite B/collotelinite and chemical and technological parameters in Polish low-rank coals. The study includes results from 284 samples of humic low-rank coal from Polish deposits tested by the author and supplemented with data from the literature. Research on the properties of different types of coal include: technical analysis, physico-chemical and petrographic analysis. Among the studied deposits, the average random reflectance (Rr) is 0.28, with a standard deviation of 0.06 and the coefficient of variation at 20%. Gross calorific value in the tested coal varies from 7.25 MJ/kg to 26.30 MJ/kg, with average value of 12.46 MJ/kg. Average total moisture in Polish low-rank coal deposits is 47.8% and ranges from 15% up to 60%. Carbon content in the tested coal recalculated to dry ash-free basis varies from 56.4% to 79.0% while on average it is 68.1%. Basic parameters of Polish low-rank coal are characterized by low variability, while gross calorific value and carbon content are of very low variability. The highest variability is observed in case of ash content and sulphur content. The correlation between random reflectance, gross calorific value and carbon content is very high. There is high correlation between moisture, net calorific value and random reflectance. The analysis shows that it is possible to calculate random reflectance of ulminite B/collotelinite from gross calorific value, carbon content and total moisture with a correlation coefficient equal to 0.97. By analyzing the correlation between the measures of the degree of coalification and using multiple regression, it has been found that the suborder of Polish lignite can be determined with use of the random reflectance of ulminite B/collotelinite. Based on the results of multiple regression, it is proposed that the boundary between low-rank C (soft brown coal) and low-rank B (dull brown coal) for Polish low-rank coal should be set at a random reflectance of ulminite B equal to 0.35%.

1. Introduction

Random reflectance of huminite or vitrinite is one of the parameters used to determine the degree of coalification. Coalification is the alteration of vegetation to peat and then to lignite, subbituminous coal, bituminous coal and anthracite [1]. The degree of coalification determines the rank of coal. To understand the rank of coal, physical and chemical parameters were given [1–5] (Table 1). Increasing coalification is accompanied by decreasing moisture and hydrogen content, while carbon content and calorific value are increasing. The change in vitrinite reflectance – along with the increase of coalification – is linked to the increase in aromatization [1,3,6]. Currently, there is no single classification parameter for low-rank coal and in order to assess the degree of coalification, the following parameters are being used: huminite/vitrinite random reflectance, bed moisture and the gross calorific value calculated on a moist, ash-free basis.

According to Standard ISO 11760/2005 [7], the boundary between low- and medium-rank coal is set at vitrinite reflectance equal to 0.50%. The low-rank category is divided into three subcategories: low-rank C (lignite C, soft brown coal), low-rank B (lignite B, dull brown coal) and low-rank A (Sub-bituminous coal). The

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Table 1
Classification of low-rank coal on the basis of different rank parameters [1–5].

References	Parameter	Peat	Lignite		Subbituminous Coal	Bituminous Coal
			ortho	meta		
Diessel [3]	Random Reflectance [%]	0.2			0.4	0.6
Teichmüller [4]	Random Reflectance [%]	0.26			0.38	0.49
Diessel [3]	Carbon [dry. ash free; %]	60			71	80
Stach et al. [1]	Carbon [dry. ash free; %]	60			71	77
Stach et al. [1]	Calorific Value [moist. ash free; MJ/kg]			16.7	23	28.3
Alpern et al. [5]	Calorific Value [moist - holding capacity. ash free; MJ/kg]			18	21	24
Diessel [3]	Gross Specific Energy [MJ/kg]	14.7			23	33.5
Alpern et al. [5]	Calorific Value [dry. ash free; MJ/kg]			28	30	31
Taylor et al. [2]	In situ Moisture [%]	75			30	5
Stach et al. [1]	Bed Moisture [%]	75		35	25	8-10
Alpern et al. [5]	Bed Moisture [ash free; %]			50	35	22

boundary between the low-rank coal A and B is determined by 0.40% random reflectance measured on ulminite B. Bed moisture of lignite (determined on ash-free basis) at 35% divides low-rank C and B. In addition, this parameter sets a lower limit of low-rank C with a value of 75%.

The International Classification of Coal in Seam [8] uses gross calorific value calculated on ash-free basis with maximum moisture holding capacity (GCV^{maf}) as classification parameters. The low-rank in this classification marks the coal with a total moisture – determined according to Standard ISO 1015 [9] – of below 75%, which gross calorific value – recalculated to mineral matter-free basis and at maximum moisture holding capacity – is higher than 8.3 MJ/kg and lower than 24 MJ/kg. This parameter also determines the division of low-rank coal into the three classes, namely:

- low-rank C (ortho-lignite) defines coal, which gross calorific value – at maximum moisture holding capacity and calculated on ash-free basis – is 15 MJ/kg, while the boundary between coal and peat (not distinguished by the classification) is set at 75% of moisture,
- low-rank B (meta-lignite) denotes coal with gross calorific value – at maximum moisture holding capacity and calculated on ash-free basis (maf) – in the range between 15 and 20 MJ/kg,
- low-rank A (subbituminous coal) is the coal characterized by gross calorific value – at maximum moisture holding capacity and calculated on ash-free basis – between 20 and 24 MJ/kg and random vitrinite reflectance below 0.5%.

As shown in many studies, gross calorific value on moist ash-free basis (GCV^{maf}) [6,10,11], largely depends on the petrographic composition and total moisture of coal, which is the result of the inhomogenity of coal. Additionally, due to the specificity of the determination of total moisture – although the analysis is performed correctly – the obtained results tend to differ in the same order of samples [12,13]. Therefore, this value significantly affects the classification parameter (GCV^{maf}) and consequently, it is not useful to make universal comparisons between seams from different areas. In Poland, gross calorific value recalculated to moist, ash-free basis is not used, while the analysis employs gross calorific value recalculated to dry, ash-free basis and net calorific value. Meanwhile, the measurement of the reflectance of huminite in lignite is affected by errors due to the low variability of this parameter in low-rank coal [1,2,4,10] while huminite reflectance is dependent of the organic and inorganic composition of the original peat deposit and its depositional environment [2]. Therefore, the possibility of introducing an alternative parameter designating the degree of coalification of Polish low-rank coal – random reflectance of ulminite B/collotelinite, which is independent of petrographic composition and moisture of coal – has been examined. It appears to be useful, because random reflectance is the parameter classifying medium-and high-rank coal. An attempt to replace the gross calorific value with random reflectance as the parameter designating the degree of coalification of coal has been made by – inter alia – Wagner and Kwiecińska [14], Kwiecińska and Wagner [10,11], Wagner [15], Ercegovac et al. [16], Bielowicz [17,18].

The main objective of the study is to determine the correlations between random reflectance of ulminite B/collotelinite and other important parameters of lignite applied in the classification of Polish low-rank coal. Examination of these relationships would allow to – already at the stage of determining the degree of coalification – pre-set some of the technological and chemical properties relevant to the processes of gasification and combustion.

2. Research methodology

The study includes results from 284 samples of humic low-rank coal from Polish deposits tested by the author and supplemented with data from the literature [10,11,19]. Despite the large number of samples, a uniform distribution of results could not be obtained (247 samples of ortho-lignite and meta-lignite and 37 samples of subbituminous coal). This is the result of various coal-bearing formations of Polish low-rank coal. Deposits of low-rank coal are mainly represented by lignite occurring in the Polish Lowland (lignite formations of Paleogene and Neogene age). Therefore, lignite accounts for the majority of samples analyzed in this study. Subbituminous coal occurs locally in the Cretaceous Jurassic formations in the Carpathian Foredeep, the Carpathian Mountains and the Kraków–Częstochowa Upland. The map (Fig. 1) shows the location of the major deposits with an indication of the ones currently exploited.

Research on the properties and usability evaluation of the different types of coal include: technical analysis, physico-chemical and petrographic analysis.

Petrographic examination was performed under white reflected light and blue light excitation using an Axioplan Zeiss Opton coal-petrography microscope.