Petrographic analysis of hard coal in grain class <1mm

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Abstract. There are presented results of petrographic analysis of the finest class of hard coal (<1mm). Examined Medium-Rank coals – orthobituminous C – came from four seams of western part of Upper Silesian Coal Basin. The coal samples have been obtained from froth flotation in processing plant. Microscopic analysis comprised defining of vitrinite reflectance and determining of percentage of maceral groups and group of microlithotypes. Petrographic characteristic of examined coals enable to count them to high-vitrinite coals with vitrinite content V=22-88%vol., low liptinite content L=2-3%vol. and medium inertinite content I=3-11%vol. (where the most often semifuusinite and inertodetrinite occurred). The highest content of mineral matter (72%vol.), carbominerites and rock have been stated obviously in tailings. Concerning grain size (<1 mm) detailed determining of the art of mineral matter using microscope in transferring light was impossible – there were distinguished only quartz and feldspars. There was mostly approved occurring of isolated macerals. Too fine granulation (<1mm) did not allow to conduct combine analysis, because grain size classified counting mainly as mentioned ‘isolated’ macerals or ‘on the border of the grain’. The amount of sections of the net did not allow to distinguish microlithotypes, among which there was only possibility to observe vitrite as ‘observed’ microlithotype.

1. Introduction

Coal in grain class <1mm is one of the most numerous grain classes occurring in the coal mines. This class, named very often dust, originating due to the mining works, transport of hard coal and in processing, occurs both underground (in workings), as on the surface (e. g. in processing plants) of the coal mine [1, 2].

Concerning specific character, it is a raw material difficult for management and causing lots of problems for the mines [3]. In the last time in the connection with intensive re-structuring of hard coal mining branch, appeared new conceptions of ecologic management of the finest grain class of these rocks, e.g. different projects connected with production of briquettes. Production of these fuels requires just in the beginning and even before planning stage detailed recognition of the raw material quality, which would be used as a fuel.

Investigations of coal quality comprise very wide spectrum of analysis, depending mostly on its rank (generally power coal/coking coal) and concerning usually technical, chemical and elementary analysis, the analysis of coking parameters and they end usually in more or less advanced analysis of petrographic composition [4].

If in the case of all from the beginning mentioned types of laboratory tests the subject dust class is required (because it diminishes the stage of preparing samples for lab tests allowing often to omit process
of crushing of coal to the grain size <1mm), so in the petrographic composition analysis it makes a big
difficulty, because mentioned microscopic tests are based on samples in the form of briquettes, consisted
of grains with size of 1mm. Smaller grain sizes did not fulfil recommended standards and influence
the representativeness and reliability of obtained results. These results thus are required by potential
producers of fuels, who often do not realise that there are special requirements.

The content of the paper and presented results have purpose to bring forward the problem signed
already earlier, basing on the results of conducted research [5-8].

2. Method

2.1. Localization and geological characteristics of study area

Study area is localized in the western part of the Upper Silesian Coal Basin (USCB) on the border of
tectonics zone and faults tectonics zone, on Western side of Main saddle of USCB: (figure 1).

![Figure 1. Localization of study area on the background of USCB tectonics sketch, after [9]
1 – Přibor trough, 2 – Stařice trough, 3 – Svinov trough, 4 – Paskov saddle, 5 – Michalkowice
saddle, 6 – Orlova fold, 7 – Sośnica-Knurow fold, 8 – Concordia trough, 9 – Ruda syncline, 10
– Malinowice trough, 11 – Sarnów saddle, 12 – Grodków saddle, 13 – Maczki dome fold, 14
– Długoszyn-Wilkoszyn syncline, 15 – Ciężkowice-Trzebinia saddle, 16 – Siersza trough, 17
– Miękinia antycline, 18 – Nowa Wieś Szlachecka trough (only the structures marked by numbers
have been explained).]

In geological composition take part layers of Quaternary, Miocene, Triassic and Upper
Carboniferous: (figure 2 and figure 3). Upper Carboniferous strata comprise three lithostratigraphic
series: Mudstone Series (Orzesze and Załęże Beds – Bashkirian), Upper Silesian Sandstone Series (Ruda
and Zabrze Beds – Bashkirian) and Paralic Series (Poruba, Jaklovec, Hrusov and Petrkovice Beds – Serpukhovian).

**Figure 2.** Localization of study area on the background of USCB geology structure sketch, after [9].

**Figure 3.** Stratigraphic division of Upper Carboniferous in USCB.
The coals from study area belong generally to Medium-Rank coals – orthobituminous C.

2.2. Characteristic of analyzed hard coals

The tests concerned hard coals coming from four coal seams: 401, 403 and 405 from Załęże Beds and 415 from Ruda Beds, which mean values of quality parameters are showed below: (table 1).

| Coal seam | R (%) | V (%vol.) | L (%vol.) | I (%vol.) | MM (%vol.) |
|-----------|-------|-----------|-----------|-----------|------------|
| 401       | 0.88  | 62        | 9         | 29        | 1          |
| 403       | 0.81  | 61        | 10        | 29        | 3          |
| 405       | 0.94  | 62        | 6         | 32        | 3          |
| 415       | 0.90  | 78        | 3         | 19        | 13         |

R – vitrinite reflectance, V – vitrinite content, L – liptinite content, I – inertinite content, MM – mineral matter content

2.3. Sampling and samples

Samples of coal of class <1mm have been collected in processing plant, where is applied froth flotation to the enrichment of the finest part of minerals. This is the most suitable place for collecting of representative samples to subject studies and its choice is connected with market conditions, where mentioned fuels are the most often produced from flotation concentrate or they contain this concentrate in different or even large amount.

There were taken 12 samples of coal blend comprising output from examined seams in ratio: 24% seam 401, 40% seam 403, 15% seam 405 and 21% seam 415. Moment of sampling was precisely defined for the time when the mine exploited chosen seams with the same productivity and output. Process of sampling lasted four weeks. The samples were taken during first shift in the middle of the week (Wednesday), when mining and preparation processes are the most stable i.e. the output in time is constant. In each week there were taken three samples including: feed directed to flotation (N7, N13, N20, N27) and two output products in the form of flotation concentrate (F7, F13, F20, F27) and flotation tailings (O7, O13, O20, O27): (figure 4). Each taken sample is a collective of single samples taken every half an hour during the whole shift.

![Figure 4. Scheme of samples collection from froth flotation cells.](image-url)
2.4. **Laboratory (microscopic) analysis**

Microscopic analysis covered determining of random reflectance of vitrinite and defining of percentage of maceral groups and percentage of microlithotypes groups. Maceral analysis had in view defining of percentage of macerals in examined sample of coal. The differences in optical features of macerals, observed under the microscope, prove the differences in chemical composition and differentiation of their technological properties. On the other hand the aim of microlithotype analysis was fixing of percentage of microlithotypes, carbominerites and rock in collected samples [10, 11, 12].

These tests have been done on briquettes, which have been made from coal coming both from the feed directed to froth flotation cells, and output products, meaning flotation concentrate and flotation tailings.

Measurements of vitrinite reflectance $R$ were done using microscope Axioskop of company Zeiss in polarized reflected light applying immerge liquid with coefficient of light reflection $n_0=1.5180$. Microscope have been equipped in double ocular with magnification $10\times$ and immerge lens with magnification $50\times$. The measurements were done using software „Photan” of company Zeiss, which enabled making of reflectograms.

Analysis of petrographic composition comprised quantity analysis of particular maceral and microlithotype groups, i.e. participation of particular macerals, microlithotypes and mineral matter content. In this purpose there was applied so called combined analysis, which rule is based on using 20 point net for signing microlithotypes, where one and the same point signs in the point maceral. It gives then a measurement of maceral in given microlithotype. This analysis was conducted using microscope of company Leitz in polarized reflected light applying immerge liquid with coefficient of light reflection $n_0=1.5180$. The tests were done using machine counting particular maceral groups of company Leitz.

3. **Results and discussion**

3.1. **Reflectance**

Coals making examined coal blend, both in seams, and after flotation showed similar values of parameters.

Vitrinite reflectance, in the seams creating coal mixture, contained in the limits 0.81-0.94 %: (table 1). In examined samples mean reflectance oscillated between $R=0.88-0.90\%$ (in feed 0.90%, in concentrate 0.88% and in tailings 0.89%) by the standard deviation $s=0.07\%$: (table 2).

All, drawn for 12 samples, reflectograms (histograms of reflectance) have one-mode character showing different coefficients of asymmetric though: four samples show distinct negative asymmetry (F7, F13, O13 and O27), three samples show positive asymmetry (N13, F20 i F27) and five samples show zero asymmetry (N7, N20, N27, O7 and O20). Reflectograms do not include gaps, and their distribution is close to Gaussian distribution: (figure 5).

| Product             | $R$ (%) | $s$ (%) |
|---------------------|---------|---------|
| Feed N              | 0.90    | 0.07    |
| Flotation concentrate F | 0.88    | 0.07    |
| Flotation tailings O | 0.89    | 0.07    |

$s$ – standard deviation
As a result of conducted microscopic analysis of petrographic composition it may be noticed that values of particular parameters are changing in the way showed in the tables below: (table 3 and table 4).

### Table 3. List of percentage of maceral and microlithotypes groups.

| Product      | V (%) (vol.) | L (%) (vol.) | LM (%) (vol.) | Vl (%) (vol.) | Ll (%) (vol.) | It (%) (vol.) | Ct (%) (vol.) | Dt (%) (vol.) | Vt (%) (vol.) | Lt (%) (vol.) | It (%) (vol.) | Ct (%) (vol.) | Dt (%) (vol.) | Vtt (%) (vol.) | Tmt (%) (vol.) | Cmt (%) (vol.) |
|--------------|--------------|--------------|---------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|---------------|
| Feed N       | 88           | 2            | 6             | 4            | 85           | 0            | 0            | 0            | 0            | 0            | 5            | 0            | 0            | 4             | 6             |
| Concentrate F| 85           | 2            | 11            | 2            | 87           | 0            | 0            | 0            | 5            | 0            | 0            | 5            | 0            | 3             | 5             |
| Tailings O   | 22           | 3            | 3             | 72           | 1            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0             | 99            |

V – vitrinite content, L – liptinite content, I – inertinite content, MM – mineral matter content, Vt – vitrite content, Ll – liptite content, It – inertite content, Ct – clarite content, Dt – durite content, Vtt – vitrinertite content, Tmt – trimacerite content, Cmt – carbominerite and rock.

### Table 4. List of percentage of inertinite maceral group.

| Product      | Mi (%) (vol.) | Ma (%) (vol.) | Sf (%) (vol.) | F (%) (vol.) | Fg (%) (vol.) | Sc (%) (vol.) | Id (%) (vol.) |
|--------------|---------------|---------------|---------------|-------------|--------------|--------------|--------------|
| Feed N       | 0             | 0             | 1             | 0           | 0            | 0            | 5            |
| Concentrate F| 0             | 0             | 1             | 0           | 0            | 0            | 10           |
| Tailings O   | 0             | 0             | 0             | 0           | 0            | 0            | 3            |

Mi – micrinite content, Ma – macrinite content, Sf – semifusinite content, F – fusinite content, Fg – funginite content, Sc – secretinite content, Id – inertodetrinite content.

Vitrinite content, in the coals from seams creating coal blend: (table 1), were stated in the limits V=61-78%vol. Qualitative analysis of maceral groups in all collected samples showed large share of this.
group, which counts $V=22-88\%$ vol. of petrographic composition: (table 3, figure 6 and figure 7). The highest vitrinite content was observed in feed $V=88\%$ vol., in concentrate it counts $V=85\%$ vol., and in tailings there is minimum $V=22\%$ vol.

Figure 6. Cutinite in colotelinite (sample N7).

Figure 7. Semifusinite with colotelinite (sample N13).

Liptinite content in the coals of examined seams counts $L=3-10\%$ vol.: (table 1). Conducted tests showed low content of this group counting $L=2-3\%$ vol.: (table 3, figure 8 and figure 9). The lowest liptinite content was determined in feed $L=2\%$ vol. and concentrate $L=2\%$ vol. The highest liptinite content $L=3\%$ vol. was determined in tailings.

Figure 8. Grain of porinite (sample F20).

Figure 9. Fluorizing grain of sporinite (sample F20).

Inertinite content in the coals of analyzed seams varies between $I=19-32\%$ vol.: (table 1). Analysis of percentage of this group in petrographic composition showed content of inertinite $I=3-11\%$ vol.: (table 3, figure 10 and figure 11). In the feed this content results $I=6\%$ vol., concentrate contains the largest amount $I=11\%$ vol. and in tailings this content is the lowest $I=3\%$ vol. Between macerals of this group the most often occurred inertodetrinite and semifusinite. There were seen traces of macrinite, micrinite and fusinite: (table 4).
Figure 10. Inertodetrinite (sample F7).

Figure 11. Semifusinite (sample O20).

Figure 12. Framboidal pyrite (sample F7).

Figure 13. Framboidal pyrite in mineral matter (sample O7).

Mineral matter content, in the coals from seams creating coal blend: (table 1), have been determined in the borders 1-13%vol. Conducted examinations of petrographic composition showed share of MM in the limits 2-72%vol.: (table 3, figure 12 and figure 13). Share of MM in feed counts 4%vol. and in the concentrate its content is the lowest: 2%vol. For tailings it is on the high level and counts 72%vol. Precise determining of the art of MM was not possible because of too small grains (<1 mm). In its composition there could be distinguished pyrite, quartz and feldspars. Pyrite occurred in the form of concretions (in framboid form) making larger grains, and in the form of single, small grains and spatters occurring within the limits of macerals and between MM. Pyrite made also accretions with macerals, and filled the fissures of cracks.

4. Summary and conclusions

Conducted petrographic characteristic of examined coals allow to count them to the high-vitrinite coals with vitrinite content $V=22-88$%vol., low liptinite content $L=2-3$%vol. and medium inertinite content $I=3-11$%vol. Dominant macerals group is vitrinite. Macerals of liptinite group constitute the lowest share. Amongst macerals of inertinite group occurred the most often semifusinite and inertodetrinite. Usually during microscopic examinations there was determined occurring of isolated macerals.

The analysis of petrographic and microlithotype composition allowed to define the highest amount of mineral matter, carboineerites and rock in tailings, what obviously prove the role of preparation process.

Precise determination of the art of mineral matter under microscope in transmitted light was impossible because of grain size (<1 mm). There were distinguished only quartz and feldspars.
Too fine granulation (<1mm) did not allow to conduct combine analysis according to standards of the International Committee for Coal and Organic Petrology (ICCP). It was possible only to do the maceral groups analysis. Grain size classified main countings as ‘isolated’ macerals or ‘on the grain border’. The amount of sections of the net did not allowed to distinguish microlithotypes. Amongst all microlithotypes it was possible to observe only vitrite as ‘observed’ microlithotype.

On the basis of the obtained results, it can be concluded that petrographic methods are not fully suitable for testing the smallest carbon grades, with a grain size <1 mm.

5. References

[1] Blaschke W 1985 Gospodarka Surowcami Mineralnymi – Mineral Resources Management 1 161
[2] Hanak B 1983 Prace Geologiczne 127 1
[3] Gabzdyl W and Probierz K 1996 Proceedings Conference on Problems of geology in ecology and underground mining vol 13 (Katowice: Central Mining Institute Press) p. 33
[4] Mastalerz M and Padgett P L 1999 International Journal of Coal Geology 41 107
[5] Probierz K, Gabzdyl W, Komorek J, Lewandowska M, Marcisz M and Wasilczyk A 2003 Monitoring of coal quality from deposit through mining and processing to commercial coal (Gliwice: Silesian University of Technology Press) p 487
[6] Probierz K, Błaszczyński S, Gabzdyl W, Komorek J, Lewandowska M, Marcisz M, Szpyrka J and Wasilczyk A 2006 Petrological monitoring of the bituminous coal quality (coal seams – processing – final product) (Gliwice: Silesian University of Technology Press) p 187
[7] Probierz K and Marcisz M 2002 Proceedings 5th European Coal Conference (Mons–Frameries: Belgium) p 118
[8] Probierz K and Marcisz M 2004 Geologica Belgica 7 351
[9] Probierz K, Marcisz M and Sobolewski A 2012 From peat to coking coals of Zofiówka Monocline in Jastrzębie area (South-West part of Upper-Silesian Coal Basin) (Zabrze: Institute for Chemical Processing of Coal Press) p 286
[10] Pusz S, Borrego A G, Alvarez D, Camean I, du Cann V, Duber S, Kalkreuth W, Komorek J, Kus J, Kwiecińska B K, Libera M, Marques M, Misz-Kennan M, Morga R, Rodrigues S, Smędowski Ł, Suarez-Ruiz I and Strzezik J 2014 International Journal of Coal Geology 131 147
[11] Gabzdyl W, Hanak B and Probierz K 1991 Proceedings International Conference on Structure and Properties of Coals (Wrocław: Wrocław University of Science and Technology Press) p 23
[12] Olszewska K, Magnes C, Ziółkowski J and Kuhl J 1965 Petrographic atlas of Upper-Silesian humic bituminous coals (Katowice: Śląsk) p 92