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CHANGES IN THE PETROGRAPHIC COMPOSITION OF COAL DURING COAL PROCESSING

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(2 figures and 1 table)

ABSTRACT. The changes in petrographic composition and in some technological properties of coal have been investigated in the deposit, as well as during the exploitation and preparation process of coal, i.e. from seam to "saleable coal". The changes have been presented as an example of two seams in which coal shows similar reflectance (0.91-0.93%), but which differ in petrographic composition and technological parameters. It has been ascertained that the petrographic composition of coal during technological processing undergoes changes, which are dependent on the processing method. The changes of petrographic composition are accompanied by changes of the technological parameters of coal. These lie mainly in significant increase, in the final product, of the content of the vitrinite macerals group. Amongst microlithotypes an important increase in vitrite contents is observed; it is greater the smaller the final product fraction is. The content of clarite, as well as vitrinertite and trimacerite increases slightly, which in the case of the last two materials is particularly true for bigger fractions. The content of carbominerite and rock material significantly decreases independent of fraction size.

Keywords: Upper Silesian Coal Basin, quality parameters, production cycle, preparation process.

1. Introduction

The knowledge of the full characteristics of coal quality, especially of its petrographic composition, both in the deposit and in the exploitation and the preparation processes of coal, substantially influences the possibility of obtaining "saleable coal" of desired and constant quality parameters. The problem, as it appears according to the literature data, has not been recognised enough and has usually been investigated with reference to the seam/deposit itself (Gabzdyl & Probierz, 1996). Occasionally, however, the total production cycle of coal is subjected to the investigation of petrographic composition (Mastalerz & Padgett, 1999).
The fulfilment of environmental requirements imposed upon mineral fuels resulted in the situation where steps had to be undertaken in the Polish coal mining industry with the aim of carrying out extensive research on the quality of coal, especially on its petrographic composition.

The initiated research aimed to investigate the changes of petrographic composition of coal and the selected technological (ash content, volatile matter content, calorific value and sulphur content) and optical (reflectance) parameters, from the mineral in the deposit, through particular phases of processing, through to the end product ("saleable coal") assigned for the customer.

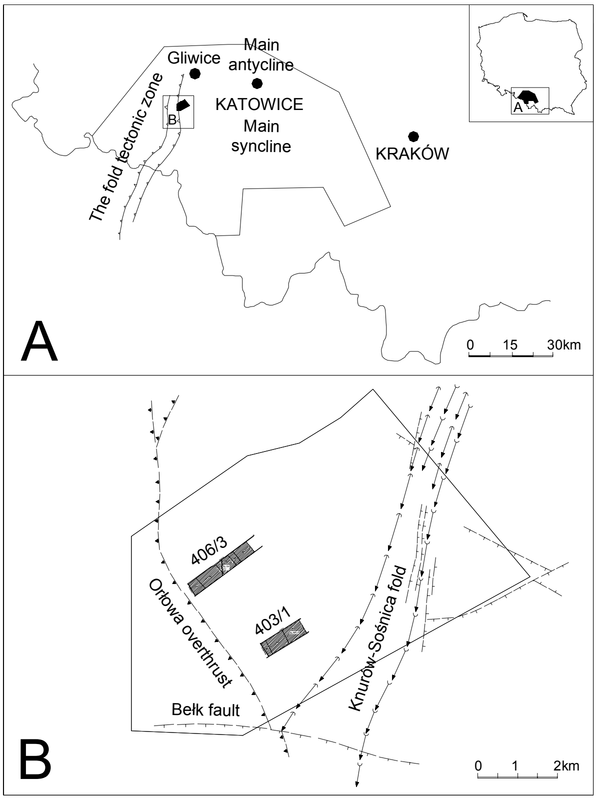

Figure 1. Location of the investigation area within the Upper Silesian Coal Basin.

The investigations were carried out on the coal from the "Szczygłowice" coal mine which is situated in the north-west part of the Upper Silesian Coal Basin (Fig. 1). It is characterised by large resources of coal of which long-term exploitation is expected. It will enable long-term petrologic and coal quality monitoring and it will help to explain the differentiation of ash and sulphur shown in the deposit (Probierz & Marcisz, 2001, 2002). The analysis involved coal from two seams, subjected to simultaneous and combined processing and cleaning. The seams selected for the investigation are characterised by a medium thickness of 2.3 m in the case of the 403/1 seam (min. 2.1, max. 2.7 m) and of 1.7 m in the case of the 406/3 seam (min. 1.5, max. 1.7 m).

2. Method

In the technological process of production covering the exploitation and processing of coal, there are three independent production lines, which supply "saleable coal" (Fig. 2). These production lines, which have both common and separate elements, were sampled. The seams 403/1 (samples No. 31, 32) and 406/3 (samples No. 61, 62) were sampled with channel samples located in longwalls. In addition, coal blend obtained in the preparation plant was sampled as a collective sample (S1). Coal blend is made of coal from seams 403/1 and 406/3 in a ratio of 3:2. Common elements of the technological process of each of the three production lines therefore include exploitation, blend creation and a vibrating screen CDR (Fig. 2). Then, the coal is exposed to a separate cleaning process resulting in the acquisition of "saleable coal" (samples P3, P4 and NP4). Sample P3 represents a large fraction of the coal (coal concentrate), with grain size ∅ 20-200 mm, obtained through a cleaning process in heavy liquid (magnetite suspension). Sample P4, so-called "dressed small coal (washed small coal)", with grain size ∅ 2-20 mm, is obtained through cleaning in small coal jigs. Sample NP4 is a collective concentrate obtained through several kinds of processing, depending on grain size. The large fraction of grain size ∅ 2-20 mm is cleaned in a small coal jig. The small fraction of grain size ∅ 0-2 mm is cleaned in cyclones. From the small fraction, a fraction of grain size ca. ∅ 0-1 mm is additionally freed and subjected to cleaning in a flotation process. The end product (collective concentrate) is a collective blend of all those fractions of the final grain size ∅ 0-20 mm. The collected samples were subjected to laboratory investigations, and petrographic composition was determined (macerals groups and microlithotypes), using a so-called combined analysis, according to ICCP directives. The values of the technological parameters were determined according to Polish Standards.

3. Results

The results of the investigation on petrographic composition, reflectance and technological properties, including both pillar samples and processed samples are compared in table 1.

Coal of the 403/1 seam are characterised by the following percentages of macerals groups: vitrinite (51-53%), inertinite (11-15%), liptinite (2-5%) and mineral matter (29-34%). Amongst the mineral matter clay minerals, carbonates and predominant sulphides (pyrite) were found. The dominant microlithotypes are: vitrite (28-29%) and trimacerite (11-14%). Macerals of lesser amounts are: vitrinertite (5-8%), inertite (5-7%) and clarite (6-7%). Durite is present as 1-3%. However, the presence of liptite was not observed. A high percentage of carbominerite and rock (33-34%) is also present. The reflectance ranging 0.92 of 0.93% (±0.05%) classifies this coal as Medium-Rank coal - orthobituminous C. Coal in the seam 403/1 have a high ash content of 18.04-29.53% and a total sulphur content of 0.82-0.88%. Volatile matter undergoes changes within the range 33.18-34.34%, while the calorific value is within the range 31.10-31.69 MJ/kg.

Coal from the seam 406/3 is characterised by a percentage of vitrinite macerals group (73-74%), inertinite (14-20%) and liptinite (2-5%). Mineral matter makes up only 2-10%. In this seam, as in the seam 403/1, the dominant microlithypes are: vitrite (39-44%) and trimacerite (18-24%). A relatively high proportion of vitrinertite (11-14%) and clarite (10-15%) can be observed. A lower percentage of inertite (3-7%) is present while durite is only (0-1%). The proportion of carbominerite and rock is small and ranges between 3% and 11%. Coal from the 406/3 seam has a low ash content of 6.43-9.47%, and a total sulphur content ranging from 1.04% to 1.57%. Volatile matter content ranges from 30.27% to 33.47%, whereas calorific value ranges from 29.64 to 32.79 MJ/kg. The reflectance values of 0.91-0.93% (±0.05%) also classify the coal from the 406/3 seam as Medium-Rank coals – orthobituminous C.

Coal blend (sample S1), obtained by blending the coal of both seams in a ratio of 3:2, is characterised by the following petrographic composition: vitrinite macerals group 59%, inertinite 15% and liptinite 6%. The proportion of mineral matter is 20%. Microlithotype composition does not diverge from that observed in the pillar samples of the 403/1 and 406/3 seams. Dominant microlithotypes are vitrite (29%) and trimacerite (20%). Also present are: clarite (9%), vitrinertite (8%) and inertite (6%). The percentage of durite is 2% while the presence of liptite has not been observed. The blend shows a high ash content of 30.32%. The share of total sulphur is 0.93%. Comparing to pillar samples, a higher volatile matter content (34.49%) and calorific value (34.49 MJ/kg) is observed. The average reflectance of the blend is 0.92% (±0,05%).

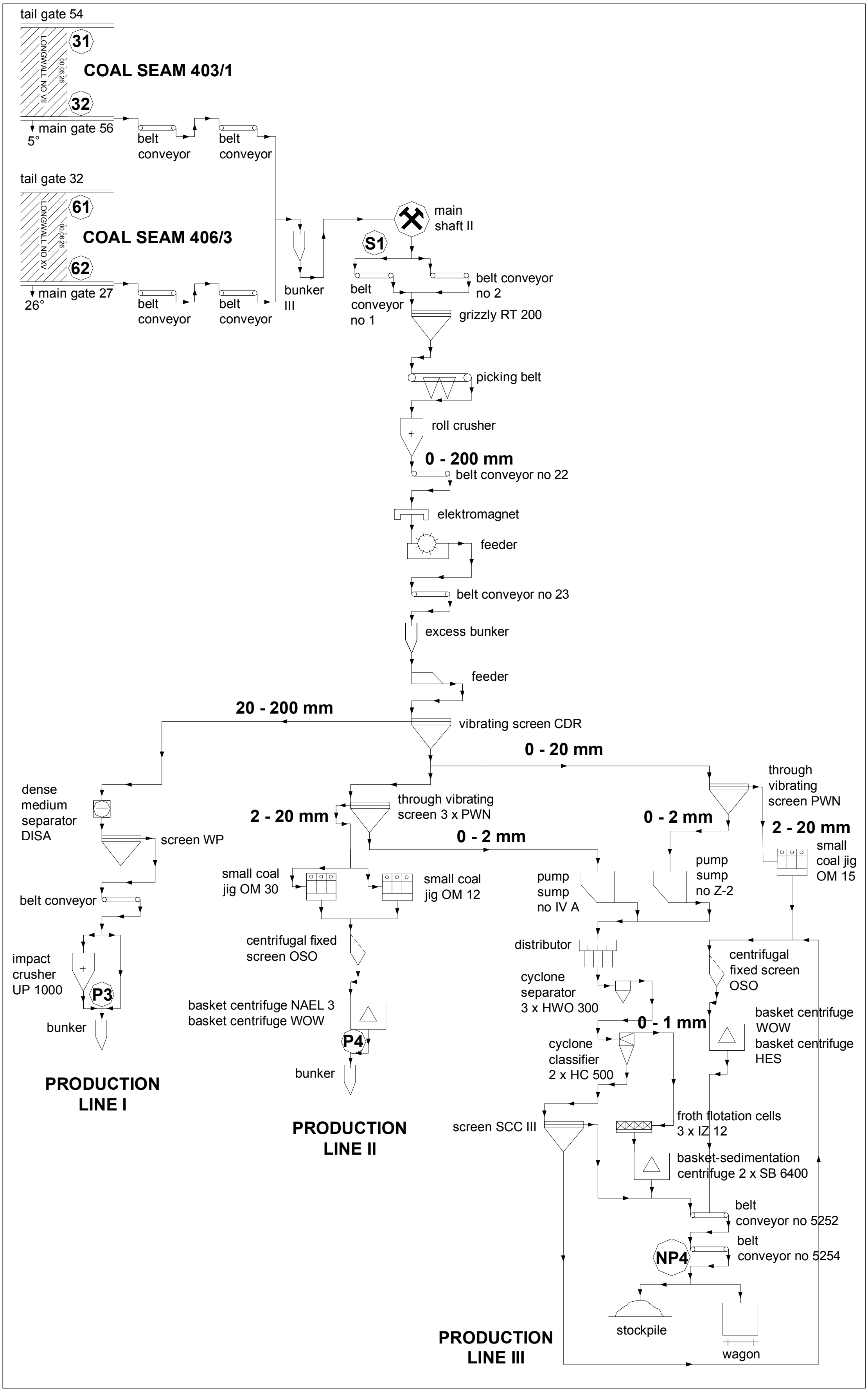

Figure 2. Scheme of exploitation and coal processing in the analysed mine.

Production line		Common elements of production process					I	II	III
Sample number		31	32	61	62	S1	P3	P4	NP4
Localization		Coal seam 403/1		Coal seam 406/3		Coal sizing plant	Coal washing 20-200 mm	Coal washing 2-20 mm	Water--slurry circuit 0-20 mm
Macerals Groups, % vol.	V	51	53	73	74	59	70	76	76
	L	5	2	5	2	6	6	5	4
	I	15	11	20	14	15	21	18	17
	MM	29	34	2	10	20	3	1	3
Microlithotypes, % vol.	Vitrite	28	29	39	44	29	35	43	47
	Liptite	0	0	0	0	0	0	0	0
	Inertite	7	6	7	3	6	6	7	6
	Clarite	7	5	15	10	9	10	11	12
	Durite	3	1	1	0	2	3	1	1
	Vitrinertite	8	5	11	14	8	13	13	8
	Trimacerite	14	11	24	18	20	28	22	20
	Carbominerite & rock	33	43	3	11	26	5	3	6
	R_r, %	0.93	0.92	0.91	0.93	0.92	0.92	0.90	0.89
Technical Properties	A, %	29.53	18.04	6.43	9.47	30.32	6.48	6.82	9.65
	VM, %	34.34	33.18	30.27	33.47	34.49	31.84	34.12	33.43
	GCV, MJ/kg	31.69	31.10	29.64	32.79	34.47	35.47	36.18	36.34
	S, %	0.88	0.82	1.04	1.57	0.93	1.00	0.76	0.92

Table 1. Characteristics of changes of petrographic composition and quality parameters of coal in the mine's production cycle. [V-vitrinite, L-liptinite, I-inertinite, MM-mineral matter, R_r-random reflectance of vitrinite in oil immersion, A-ash (dry), VM-volatile matter (dry, ash-free), GCV-gross calorific value (dry, ash-free), S-sulphur total (dry), I-dense-media separation, II-small coal jigs, III-small coal jigs+cyclones+froth cell flotation]

The end product of the first production line (sample P3) is characterised by a high percentage of vitrinite macerals group (70%) and inertinite (21%) and a low content of liptinite (6%). The content of mineral matter is 3%. Dominant microlithotypes are, as in the seams, vitrite (35%) and trimacerite (28%). There are lower proportions of vitrinertite (13%), clarite (10%) and inertite (6%). Liptite has not been observed while the proportion of durite is 3%. The proportion of carbominerite and rock (5%) is clearly decreased, especially when compared to the 403/1 seam and blend sample. The "saleable coal" from the discussed production line has a low ash content of 6.48% and an increased sulphur content of ca. 1%. It shows low volatile matter content (31.84%) and high calorific value (35.47 MJ/kg). Reflectance value does not diverge from the values ascertained previously and is 0.92% (±0,05%).

The end product of the second production line (sample P4) is characterised by a high percentage of vitrinite (76%). The content of inertinite is 18%, liptinite 6%, while the content of mineral matter is very low (1%). The dominant microlithotypes are: vitrite (43%) and trimacerite (22%), and then: vitrinertite (13%) and clarite (11%). The content of inertite is 5%, durite 1%, while liptite has not been found. This production line is characterised, it seems, by a very low content of carbominerite and rock

(3%). The coal has a low ash content (6.82% of ash) and a low sulphur content (0,76%). It is characterised by both high volatile matter content (34.12%) and high calorific value (36.18 MJ/kg). The average reflectance value is 0.90% (±0.05%).

The end product of the third production line (sample NP4) shows a high proportion of the vitrinite macerals group (76%). The share of inertinite is 17% while the content of liptinite (4%) and mineral matter (3%) is very low. Vitrite (47%) and trimacerite (20%) are the dominant microlithotypes. These are followed by clarite (12%), vitrinertite (8%) and inertite (6%). The content of durite is 1% and that of microlithotypes and rock is 6%. The "saleable coal" of this line has an ash content of 9.65% and sulphur content of 0.96%. The content of volatile matter was 33.43% and calorific value 36.34 MJ/kg. The value of average reflectance is 0.89% (±0.05%) and is slightly lower than in the commercial products of line I and II.

4. Discussion and conclusion

The petrographic composition of coal during the technological process changes, as can be observed from longwalls in the seams, through blending in the processing plant as a result of the simultaneous exploitation of different seams, through to the "saleable coal" being the effect of using various processing methods. The changes of petrographic composition are accompanied by changes in the technological parameters of the coal, especially the decrease in ash content and the increase in calorific value, which is the desired aim of the processing. Some changes in the volatile matter content of coal have been displayed, probably related to its petrographic composition.

4.1. Effect of petrographic composition and technological properties of coal on properties of the coal blend

In the analysed technological-production process of coal from the "Szczygłowice" coal mine, exploitation and processing are applied to coal from two seams of similar rank but different petrographic composition and technological properties. The coal of the 403/1 seam is characterised by a lower proportion of vitrinite macerals group and higher proportion of inertinite and mineral matter than the coal from the 406/3 seam. At the same time, their microlithotype composition is characterised by a lower proportion of vitrite, clarite, vitrinertite and trimacerite and a clearly higher proportion of carbominerite and rock, compared to the coal from the 406/3 seam. The presented macerals and microlithotype composition of coal from both seams seem to explain the different technological properties of coals from the seams 403/1 and 406/3. A high content of mineral matter, confirmed by a high proportion of carbominerite and rock, explains the indicated ash content and low calorific value of coal from seam 403/1. Similarly, a low mineral matter content and a low proportion of carbominerites explains the lower ash content in coal from seam 406/3.

It would also appear that the lower volatile matter content of coal from seam 406/3 should be related to a higher proportion of the inertinite macerals group occuring far more often than in seam 403/1 in trimacerites and vitrinertites.

The petrographic and microlithotype composition of coal blend shows values approximating the average of pillar samples from both seams. The values do not diverge much from both the arithmetic average and the weighted average (where the weight is the percentage proportion of coal from a given seam in a by-shaft bunker). The same is observed in the case of sulphur content, while the values higher than those ascertained in the seam have the following: ash, volatile matter and calorific value. A high ash content (30.32%) in coal blend can be related to the extraction process. The coal seam is not constant lengthways but variations in thickness are observed. In the case of a continuous miner cutting a coal seam, it is difficult for the cutting height assigned for a given wall height to match the changes of seam thickness. This can result in a continuous miner cutting both the coal seam and roof and/or floor rocks. These rocks go with the coal to the bunker, which increases the percentage of ash in the coal blend. This additional share of rocks or dilution would, of course, not be discernible in pillar samples of the coal seam. The slightly increased volatile matter content and calorific value of the blend might be related to the low proportion of inertinite macerals group. It should be kept in mind that the procedure of fixing volatile matter content requires coal cleaning to less than 10% of ash content. Therefore, the results obtained might sometimes not be comparable.

4.2. Changes in petrographic composition and technological properties of the coal blend depending on coal processing method

Interesting results are obtained through comparing the petrographic composition and technological properties of the final effects of the cleaning process, namely "saleable coal" obtained through three different cleaning processes, to properties of coal obtained through the blending process.

The coal of the production "thread" I, having the thickest coal fraction (Ø 20-200 mm) after the cleaning process in heavy liquid, shows a higher content of vitrinite and inertinite, a similar content of liptinite and a very low mineral matter content.

This is also indicated in the change of microlithotypes shares. An increase in the proportion of vitrite, trimacerite and vitrinertite has been observed. Similar values are observed in the case of inertite and clarite while a distinct decrease in carbominerites and rock proportion is observed. The decrease of the proportion of mineral matter and of carbominerites and rock, confirmed by the decrease of ash content, attests to the efficiency of the cleaning process. It must nevertheless be indicated that the ash content obtained through this process is similar to its content in the coal of the 406/3 seam, which is "naturally clean" coal. A slightly increased sulphur content compared to the blend and to the less sulphated seam 403/1 can be explained by the grain size of the product. This grain size (Ø 20-200 mm) did not allow fine-grained pyrite (the basic form of sulphur occurring in the investigated coal) to be separated from the coal. Of course the increase in calorific value should be related to the decrease of ash content while the decrease in volatile matter content should be attributed to the increase of inertinite, trimacerite and vitrinertite share.

The production line II represents a smaller fraction, grain size Ø 2-20 mm, which is cleaned in small coal jigs. A different cleaning method and smaller grains of coal influence the character of the end product. In the end product, high vitrinite proportion and slightly decreased inertinite proportion can be observed. The liptinite proportion is similar. This method of cleaning resulted in the lowest (only 1%) proportion of mineral matter in the "saleable coal". With respect to microlithotypes, the largest increments compared to the blend are exhibited by vitrite and vitrinerite. Trimacerite and clarite show smaller increments. The most significant decrease is noticed in the case of carbominerites and rock, just as in the case of line I. As to technological parameters, an important decrease in ash and sulphur content and increase in calorific value is observed. The lowest sulphur content observed in this product, lower than in the end product of line II and in seam samples 403/1 and 406/3 may be related to smaller grain size, which allowed coal to be freed from the sulphur more easily than for the fraction Ø 20-200 mm.

On production line III, we deal with the smallest coal fractions. The cleaning method is also totally different, compared to both the first line and to the second one. The initial product of grain size Ø 0-20 mm is divided into a large fraction Ø 2-20 mm and a small one Ø 0-2 mm. The large fraction is cleaned separately in a dust jigger. The small fraction is initially cleaned in hydrocyclones, and then the smaller fraction Ø 0-1 mm is separated out and is assigned to cleaning through flotation. Such substrates, cleaned during separate processes, are blended again yielding the end product. Breaking the coal into particular fractions results in better cleaning. In this way each fraction is cleaned through the most effective method. The end product (collective concentrate) shows the desired values of quality parameters. In spite of this complicated method, the petrographic composition shows a similar character of changes as in the case of the second line. Compared to the blend, we observe an increase in vitrinite and inertinite proportion, similar liptinite content and a clear decrease in mineral matter content. With respect to microlithotypes, an increase, compared to the blend, was noticed only in the case of vitrite and clarite. Similar values are also showed by trimacerite, vitrinertite and inertite while the durite proportion was slightly decreased. As to technological parameters, there was a decrease in ash content and a slight increase in sulphur content compared to the blend. These ash and sulphur contents, the highest as compared to the other commercial products, probably result from difficulties related to the cleaning and desulphurisation of the smallest coal fractions. Additional relevant information might be delivered through more accurate investigation of mineral matter, especially of the forms in which it appears and of the grain size. It is also conceivable that the obtained technological parameters of production line III might depend on the producer's economic calculation results.

Finally, it should be emphasised that the results obtained indicate the usefulness of the research. They will help explain problems not solved so far, related to the exploitation processes and coal processing technology and at the same time make them economically feasible.

5. References

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