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PETROGRAPHIC CHARACTERISTICS OF HARD COALS OF DIFFERENT DEGREE OF CARBONIFICATION IN THE ASPECT OF USE THEM FOR COAL-WATER SLURRIES (CWSs) PRODUCTION

Summary. In the paper the characteristics of petrographic composition of coals of different degree of carbonification from three coal mines of Upper Silesia Coal Basin, was investigated. In the study coals ranks of 35.1 (sample A), 33 (sample B) and 31 (sample C), according to the Polish Standards were tested. The degree of carbonification was determined on the basis of vitrinite reflectance. Petrographic characteristics was done by investigation of macerals, microlithotypes, carbominerites and minerites distribution.

On the basis of combined petrographical analysis was stated, that in the tested samples of coals were recorded unimaceral, bimaceral and trimaceral microlithotypes. The tested coals considerably differ in the petrographic composition and it is connected with the coal rank.

CHARAKTERYSTYKA PETROGRAFICZNA WĘGLI KAMIENNYCH O RÓŻNYM STOPNIU UWĘGLENIA W ASPEKCIE ZASTOSOWANIA ICH DO WYTWARZANIA ZAWIESINOWYCH PALIW WĘGLOWO-WODNYCH

Streszczenie. W artykule przedstawiono charakterystykę składu petrograficznego węgli kamiennych o różnym stopniu uwęglenia. Do badań wybrano węgle z trzech kopalń Górnośląskiego Zagłębia Węglowego o różnych typach technologicznych, tj. węgiel typu 35.1 (próbka A), typu 33 (próbka B) oraz typu 31 (próbka C). Stopień uwęglenia badanych węgli określono na podstawie badań zdolności refleksyjnej witrynitu. Charakterystykę składu petrograficznego dokonano na podstawie analiz udziału poszczególnych grup macerałów oraz mikrolitotypów, karbominerytów i minerytów. Na podstawie petrograficznej analizy kombinowanej stwierdzono, że w próbkach badanych węgli występują unimaceralne, bimaceralne i trimaceralne mikrolitotypy. Badane węgla różnią się znacznie składem petrograficznym, co związane jest z typem węgla.

1. Introduction

Coal is an extremely complex heterogeneous material that is difficult to characterize. It is a chemically undefined organic sedimentary rock which has composition dependent on origin, degree of carbonification, place of coal basin and many others. Coal is composed of macerals, which each have a distinct set of physical and chemical properties that contol the behavior of coal. It seems, that petrographic composition is very important from the point of view of coal utilization.

One of ways of coal usage is preparing highly loaded coal-water slurries CWSs in order to use them as the substitute fuel oil or mazout with them. They must however be characterized by proper rheological and stability properties to guarantee possibility of pumping them for long distances and transportation in tankers. The high coal loading is essential too. The kind of coal used, particle size distribution as well as additives are also very important (Ślączka et al. 1996; Ślączka 2004). Coal rank is often regarded as the major factor governing the utilization characteristics of a given feedstock. The more precise researches on coal petrography may throw more light on CWSs behaviour (Crelling, J.C. et al. 1988; Arnold B.J., Aplan F.F., 1989).

The studies showed that inertinite group has more pore volume and specific surface area than vitrinite; vitrinite contains more alkyl side chains and the cationic group, while the inertinite group contains more aromatic group and oxygen-containing functional group; inertinite group has a lower isoelectric point than vitrinite (Kröger, C., 2009). The knowledge of the structure and properties of different coal macerals can thus predict the various properties of coal processing and utilization as well as the coal water slurry performance.

The main objectives of the present investigation are research on the maceral composition of three coals differ in degree of carbonification in the aspect of coal-water slurry performance.

This work was performed in order to check whether are any connections of coal petrography with stability and apperent viscosity of highly loaded CWSs which were investigated in the prior works (Ślączka A.,2004; Ślączka A. Wasilczyk A. 2011a, 2011b) and which may be used as Coal-Water Flurry Fuels. On the basis of the result obtained one can suppose that maceral composition of coal plays a significant role in CWSs behaviour.

2. Materials and methods

For the study three coals origin of Upper Silesia Basin, Poland of a different rank according to the Polish Standard were chosen. The proximate and petrographical analysis of the coal samples is given in Table 1.

Petrographic characteristics of the chosen coals comprise of coal carbonification and its petrographic composition. The coal carbonification and macerals composition were determined on the basis of reflection index of vitrinite, as well as distribution of macerals, micrilitothypes, carbominerites and minerites.

Determination of vitrinite reflectance and petrographic composition of coals were performed with the Zeiss microscope Axioscope at the wave length of 546 nm. The immersion liquid has refractive index equal to 1.5176.

Petrographic composition was determined in accordance with the manner recommended by International Committee for Coal and Organic Petrology (ICCP). The analysis was based on morphologic characteristic, colour and fluorescence. Microscopic tests were performed using polished section samples.

3. Results and discussion

As one can see from the Table 1, the tested coals differ significantly in degree of carbonification as well as in petrographic composition.

The vitrinite reflectances of these coals are in the range of 0.62% to 1.14%; The reflerograms obtained are unimodal. The mean reflectance value is highest for the sample A (R_r = 1.14%) and the lowest for sample C (R_r = 0.62%).

From the Table 1 it is visible, that the amount of vitrinite group (Vt^{mmf}) is the highest in all the tested samples and varies between 62 - 72 vol %. The highest values were observed in the samples A and C.

The amount of liptynite group (L^{mmf}) in the samples A and B is low (4 and 7 vol. % respectively). For the sample C it is visibly higher (11 vol.%).

The analysis revealed 17 to 31 vol. % of inertynite group (I^{mmf}). The highest its amount is in the sample B (31 vol. %) and the lowest in the sample C (17 vol. %).

Table 1

Proximate and petrographical analysis of investigated coals

Coal	Ash [%]	Sulphur [%]	Higher calorific value [MJ/kg]	Volatile matter [%]	R_r	Vt^{mmf}	L^{mmf}	I^{mmf}	Rank	
					%	% vol.			Polish Standard	ECC Geneva
A	4.7	0.4	34.2	23.8	1.14	71	4	25	35.1	11 0 2 1 8 24 04 04 36
B	3.4	0.4	33.1	30.1	0,.2	62	7	31	33	09 0 3 2 6 30 03 04 35
C	6.9	0.6	27.8	32.3	0.62	72	11	17	31.2	06 0 1 3 0 38 07 06 33

R_r – vitrinite reflectance, Vt^{mmf} – vitrynite, L^{mmf} – liptynite, I^{mmf} – inertynite
mineral matter free

It was also stated that, among the macerals of inertynite group semifusynite and inertodetrinite are the dominant components. (7-16 vol. % and 7-11 vol. % respectinely). Micrinite and macrinite were also recorded but in low amounts (les then 2 vol. %). In this group analysis also revealed traces of fusinite, funginite and secretinite.

Besides the determination of the total amount of macerals of inertinite group in accordance with rules given in literature (Gabzdyl at. all 1991, 1992, Varma 1996a, Varma 1996b, Wasilczyk 2004) the total amounts of macerals regarded as typical inert, namely inertoditrinite, fuzinite, macrinite, funginite and secretinite (Id+F+Ma+Fg+Sk) as well as amount of macerals having the partial coking properties namely semifusinite and micrinite (Sf+Mi) were determined (fig. 1).

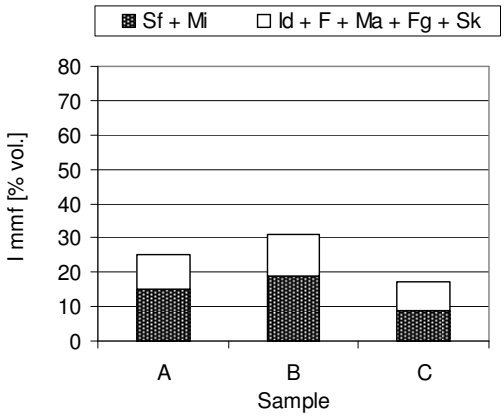

Fig. 1. Composition of inertinite group divided into total amount of semifusinite and mikrynite (Sf+Mi) and total amount of inertodetrinite, fusinite, macrinite, funginite and secretinite (Id+F+Ma+Fg+Sk)

Rys. 1. Zawartość grupy inertynitu z podziałem na łączny udział semifuzynitu i mikrynitu (Sf+Mi) oraz łączny udział inertodetrynitu, fuzynitu, mikrynitu, funginitu i sekretynitu (Id+F+Ma+Fg+Sk)

It was revealed that amount of typical inert macerals is lower then these of partial inert and they are in the range of 8-12 vol. % and 9-18 vol. % respectively (fig. 1).

In the Table 2 are gathered the content of microlithopypes, carbominerites and minerites in the tested samples.

Table 2

Distribution of microlithotypes, carbominerites and minerites in the tested coals

Coal	Rank	Uninaceral			Bimaceral			Trimaceral	Carbominerite and minerite
		Vitrite	Liptite	Inertite	Clarite	Durite	Vitrinertite	Trimacerite	
		% vol.							
A	35.1	22	0	3	2	5	37	29	2
B	33	11	<1	6	5	2	28	43	5
C	31	29	0	2	13	1	14	32	9

On the basis of combined petrographical analysis was stated, that in the tested samples of coals were recorded unimaceral, bimaceral and trimaceral microlithotypes.

Among unimaceral microlithotypes dominates vitrite. Its content varies from 11 to 29 vol. %. The highest its amount is in the sample C and the lowest in the sample B. The traces amount of liptite was found only in the sample B. Recorded also inertite in amounts of 2-6 vol. % (table 2).

Among bimaceral microlithotypes depend on its maceral composition one can observe clatrite, durite and vitrinertite. Their amonts can be seen in the Table 2.

In the Figure 2 are presented compositions of microlitothypes found in tested coals.

Content of clarite varies between 2 and 13 vol. % and in the sample C is the highest (13 vol. %). In the remaining samples its content does not exceeded 5 vol. % (table 2). Composition of clarite comprise mainly of vitrinite. In the samples A and B vitrinite content exceeds 80 vol. %, whereas in the sample C its content is equal to 68 vol. % (fig. 2 A).

Content of durite in the tested samples varies between 1 and 5 vol. % (table 2) and its main component is inertenite (above 90 vol. % fig.2 B).

In all the samples vitrinertite is a dominant component. Its content varies between 14-37 vol. % and in the sample A is the highest (37 vol. %). In the all tested coals vitrinertite comprise mainly with vitrinite (above 60 vol. %, fig. 2 C).

In the tested samples were also recorded trimacerites composed of vitrinite, liptinite and inertinite. Their content varied in the range between 29 and 43 vol. % (table 2). Depend on the content of individual components in trimacerite one can observed duroclarite (dominates vitrinite), clarodurite (dominates inertinite) and vitrinertoliptite (dominates liptinite) (fig. 2 D).

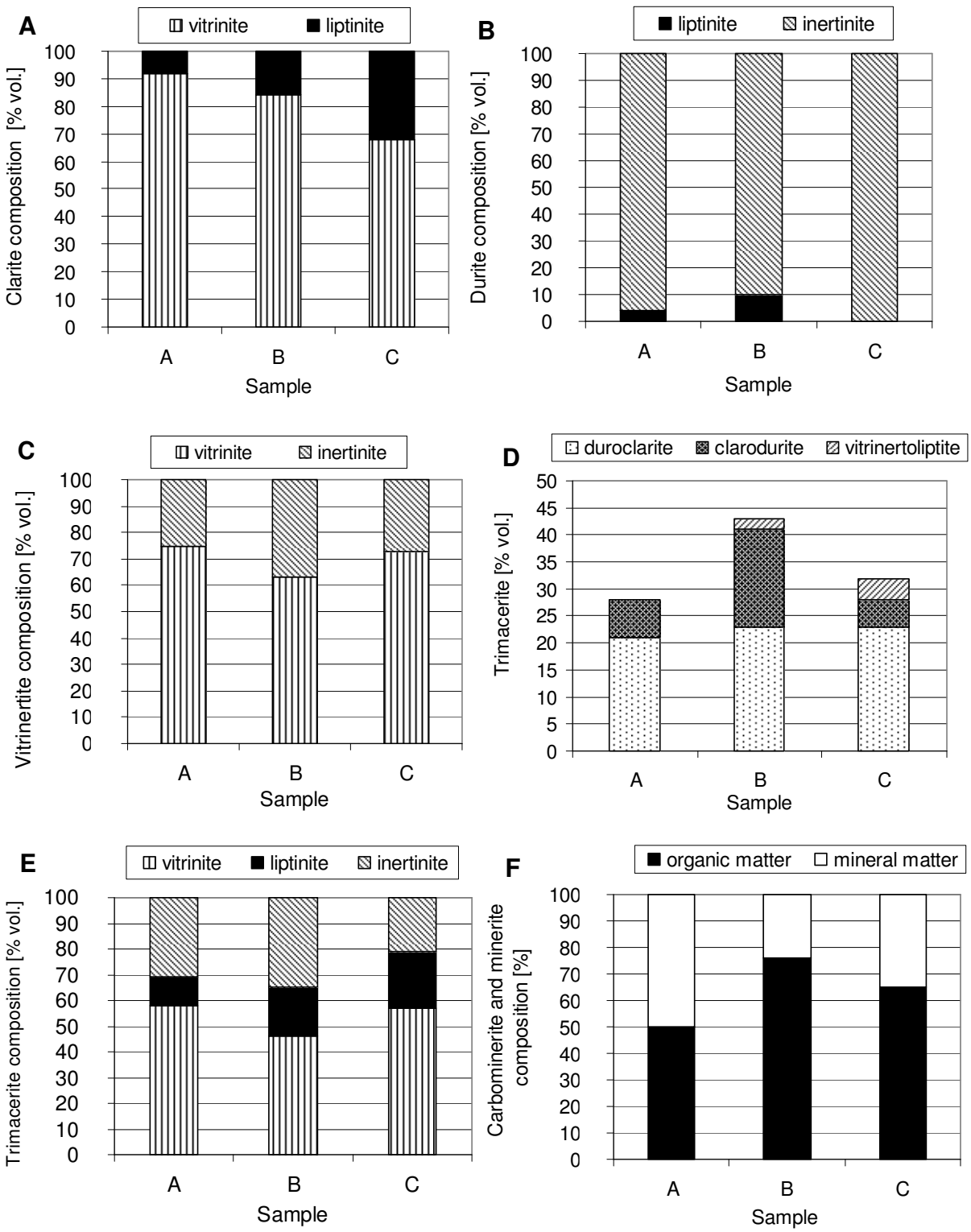

Fig. 2. Composition of bi and tri maceral microlithotypes as well as carbominerite and minerite in the samples of coals tested A – compostion of clarite, B – composition of durite, C – composition of vitrinertite, D – amount of trimacerite divided into duroclarite, clarodurite and vitrinertoliptite, E – composition of trimacerite, F – composition of carbominerite and minerite

Rys. 2. Skład mikrolitotypów bimaceralnych i trimaceralnych oraz karbominerytu i minerytu w badanych próbkach węgla: A – skład klarytu, B – skład durytu, C – skład witrynertytu, D – zawartość trimacerytu z podziałem na duroklaryt, klaroduryt i witrynertoliptyt, E – skład trimacerytu, F – skład karbominerytu i minerytu

Carbominerite and minerite contents (table 2) because of their low amounts were joined together. Their total amount varies in the range of 2 to 9 vol. %. The highest amoint carbominerite and minerite was found in the sample C. In the samples A and B their content does not exceed 5 vol. %. Composition of carbominerite and minerite comprises mainly with organic matter (50-76 vol.% fig. 2F). In carbominerite most often is present corbopoliminerite, rarer carbankerite and carbargilite and occasionally carbopirite.

In minerite most often was found polimineral matter, rarer carbonates, clays minerals and pirite.

In the figures 3 - 12 are given chosen photomicrographs of macerals, microlithotypes and mineral matter in the magnification of 500x.

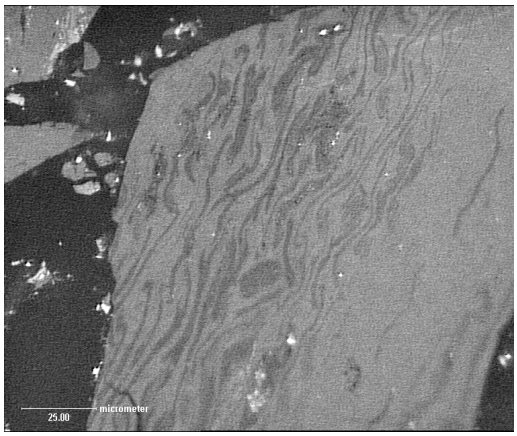

Fig. 3. Telinite – sample C
Rys. 3. Telinit – próbka C

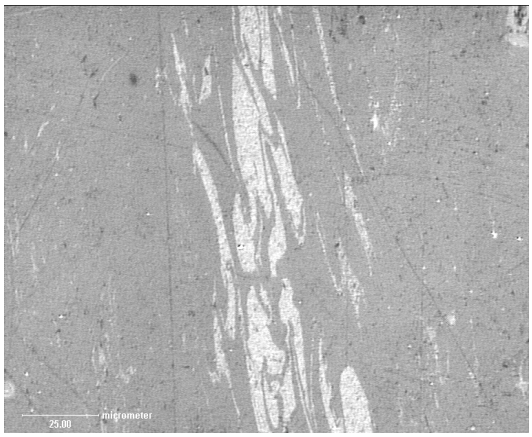

Fig. 4. Micrinite in vitrinertite – sample A
Rys. 4. Mikrynit w witrynertycie – próbka A

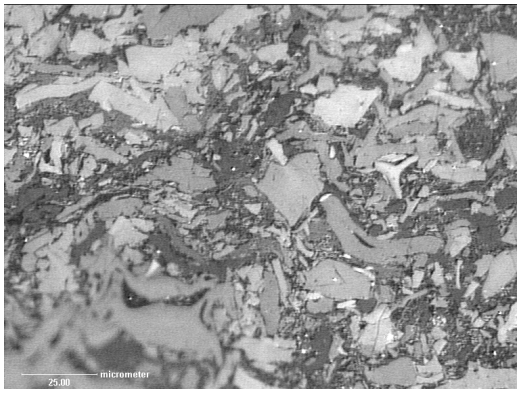

Fig. 5. Inertodetrynite win vitrinertite – sample A
Rys. 5. Inertodetrynit w witrynertycie – próbka A

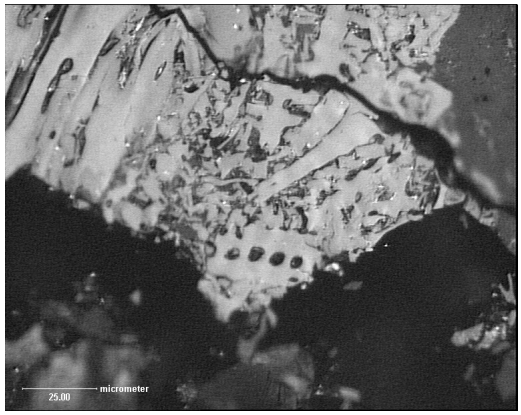

Fig. 6. Inertodetrinite and semifusinite in vitrinertite – sample C
Rys. 6. Inertodetrynit i semifuzynit w witrynertycie – próbka C

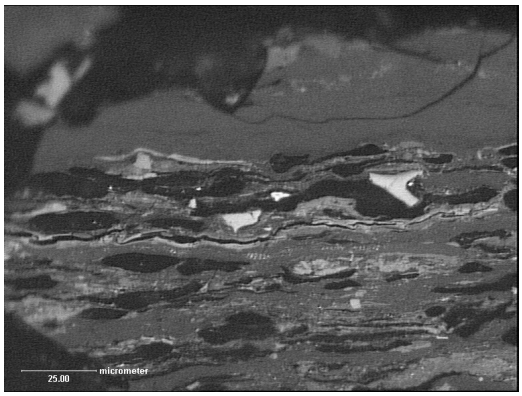

Fig. 7. Sporinite, inertodetrinite in trimacerite – sample C
Rys. 7. Sporynit, inertodetrynit w trimacerycie – próbka C

Fig. 8. Megasporinite in trimacerite – sample B
Rys. 8. Megaspora w trimacerycie – próbka B

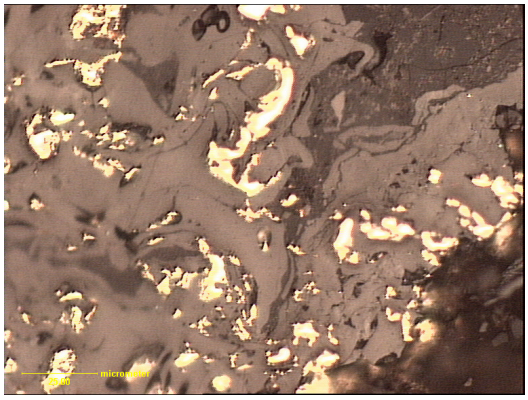

Fig. 9. Pyrite in empty cavern in semifuzinite – sample B
Rys. 9. Piryt wypełniający puste komórki semifuzynitu – próbka B

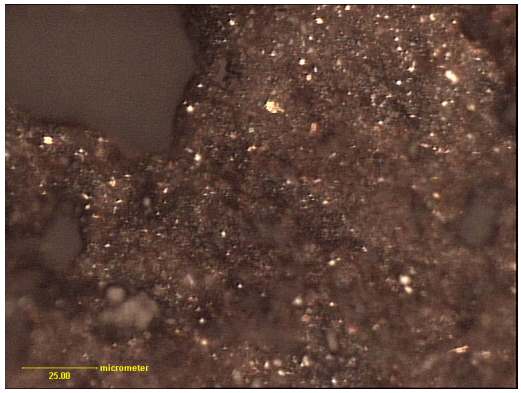

Fig. 10. Polymineral matter – sample C
Rys. 10. Substancja polimineralna – próbka C

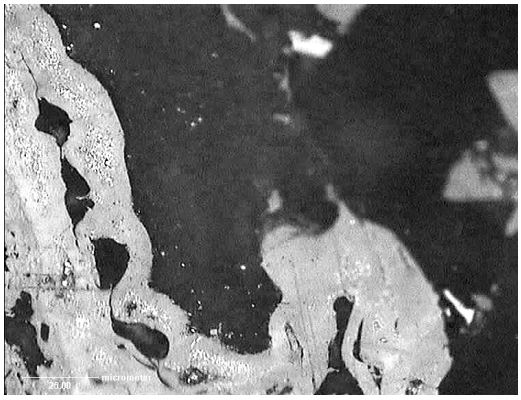

Fig. 11. Semifuzinite – cellural cavern filled with fluorescent bituminous matter – sample A
Rys. 11. Semifuzynit – przestrzenie komórkowe wypełnione fluoryzującą substancją bitumiczną – próbka A

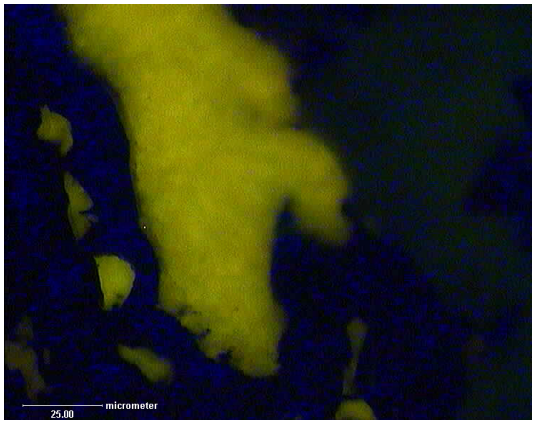

Fig. 12. The same as Fig.11 but in UV light. Visible phenomenon of fluorescence – sample A
Rys. 12. To samo co na rys 11 lecz w świetle UV. Widoczne zjawisko fluorescencji – próbka A

The petrographic analysis according to (Gabzdyl W., Probierz K. 1987, Wasilczyk A. 2004) also revealed presence of fluorescent bitumic matter mainly in the sample A and B in durite as a filling cellural cavern in semifusinite (fig. 11 and 12).

4. Conclusions

The tested coals considerably differ in the petrographic composition and it is connected with the coal rank, the type of deposit and the place in the coal basin. The main differences are in the amount of vitrite, vitrinertite and trimacerite as well as in the distribution of microlithotypes, carbominerites and minerites.

Taking into account the prior works (Ślączka A. 2004, Ślączka A. Wasilczyk A. 2010, 2011a, 2011b) one can state that both the petrographic composition and the type of additives change the CWSs viscosity and sedimentation stability as well. For example sedimentation stability increases gradually with increasing in coal carbonification when Rokanol ŁO18 ($RO\,(CH_2\ CH_2\ O)_n\ H$, where R – alkyl radical consisting of 16 to 18 carbon atoms in the carbon chain and "n" is around 18), is used as the additive. In the case of coal B (rank of 33) and sodium lignosulphonate (LSP) one can observe significant increasing in the slurry stability and decreasing in its apparent viscosity. It also was stated that surface energy of coal grains in the CWSs depends not only on the additive used but also on the type of coal (Ślączka A. et al. 2005; Ślączka A., Wasilczyk A. 2010).

The petrographic composition of coal may effect the hydrophobicity of coal grains surface, and influence the coal grains interaction in the slurry. Moreover, different macerals may variously interact with additives used as the slurry stabilizers and fluidizers which leads to improvement or to become worse coal-water slurry properties.

Among other parameters, the petrographic composition of coal, seems to be very important for producing CWSs used as coal-water slurry fuels (CWSF).

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Streszczenie

W artykule przedstawiono charakterystykę składu petrograficznego węgli kamiennych o różnym stopniu uwęglenia, wytypowanych na zawiesinowe paliwa węglowo-wodne. Do badań wybrano węgle z trzech kopalń Górnośląskiego Zagłębia Węglowego (GZW), o różnych typach technologicznych, tj. węgiel typu 35.1 (próbka A), typu 33 (próbka B) oraz typu 31 (próbka C). Stopień uwęglenia badanych węgli określono na podstawie badań

zdolności refleksyjnej witrynit (R_r). Charakterystykę składu petrograficznego dokonano na podstawie analiz udziału poszczególnych grup macerałów oraz mikrolitotypów, karbominerytów i minerytów. Stwierdzono, że badane węgle wyraźnie różnią się między sobą zarówno w stopniu uwęglenia, udziale grup macerałów, jak i mikrolitotypów. Wykazano, oprócz istotnych różnic ilościowych udziału poszczególnych grup macerałów oraz mikrolitotypów, także obecność fluoryzującej substancji bitumicznej (FBS). W poszczególnych próbkach obserwuje się wzrastający stopień uwęglenia. Począwszy od próbki C, charakteryzującej się najniższym uwęgleniem, poprzez próbkę B, aż do najwyżej uwęglonej próbki A. W składzie grup maceralnych dominuje grupa witrynitu. Wśród mikrolitotypów stwierdzono głównie trimaceryt, witrynertyt i witryt. W próbkach zaobserwowano niewielki udział karbominerytu i minerytu (<10% vol.). Wykazane różnice w składzie petrograficznym analizowanych węgli mogą mieć znaczący wpływ na możliwość uzyskania zawiesinowych paliw węglowo-wodnych o wymaganych parametrach jakościowych.