# Behavior of Macerals in the Process of Hard Coal Flotation

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## Abstract

*Due to the inherent hydrophobic nature of coal, flotation is very effective in upgrading coal fines of particle size below 0.5 mm. To verify the applicability of flotation on black coal slurry samples from the Upper Silesian Basin, black coal slurries from four mines were selected, namely CSM Mine and CSA Mine in the Czech Republic, and Jankowice Mine and Kleofas Mine in Poland. The article further aims to describe the transfer of different coal macerals into the flotation concentrates and the flotation tailings. For this purpose, Flotalex and Montanol flotation collectors were used. These collectors are generally applied in coal preparation plants both in the Czech Republic and Poland. The flotation and petrological results imply that the floatability of the given coal slurry samples is approximately equal when applying Flotalex or Montanol. It is apparent from the petrological analysis results that 82.3% (applying Flotalex) and 88.8% (applying Montanol) of vitrinite maceral group pass into the flotation concentrate in three minutes.*

*Keywords: vitrinite, maceral analyses, flotation, bituminous coal*

**Introduction**

Flotation, as an effective method for fine coal concentration [1], has also been used to separate organic macerals. Honaker et al. [2] and Shu et al. [3] have used flotation to separate vitrinite, and inertinite in their studies, and Jorjani et al. [4] researched into the association between particle size and flotation separation effect.

Coal macerals have various surface properties, on which the principle of flotation is based on. As the coal microlithotypes vary due to their degree of hydrophobicity, their flotation kinetics is also different. This is demonstrated by the mutual ratio of the amounts of floated coal types into the relevant frothy product. Predominantly, vitrite is the first to transfer into the frothy product. Clarain and the coal matt components float later as they are characteristic for longer flotation times. [5] [6]

A characteristic petrographic feature of coal slurries is a high content of vitrinite group macerals with dominant vitrinite and telinite. The macerals from the inertinite and liptinite groups are dominated by detrital macerals. [7], [8], [9]

**Materials and Methods**

The flotation tests were carried using black-coal slurries of coal fines, particle size below 0.5 mm, from the following localities: CSM Mine (Czech Republic), CSA Mine (Czech Republic), Jankowice Mine (Poland) and Kleofas Mine (Poland). The flotation tests were undertaken in the laboratories of the Institute of Environmental Engineering, Faculty of Mining and Geology, VSB-Technical University of Ostrava. The condensation of the pulp was $150 g.l^{-1}$ and the collector dosage (Flotalex, Montanol) was $500 g.t^{-1}$.

Fractional froth flotation was used to draw the flotation concentrate samples after 1, 2, 3, and 5 minutes. Later on, the flotation concentrate and flotation tailings were filtered in a press filter and dried in a drying room at the temperature of 105°C.

The coal polished sections were prepared according to CSN ISO 7404-2 Standard. The macerals were analysed on grain polished sections according to CSN ISO 7404 – 3 Standard. All the coal-petrological analyses were executed on an NU 2 microscope of C. Zeiss Jena company in oil immersion, under the following conditions: $n_D = 1.515$, $\lambda = 546$ nm and temperature of 20°C. A planimetric analysis was carried out for each sample. The contents of inorganic foreign matter, pyrite, carbonates, clay minerals and other constituents were determined.

**Results and discussion**

Macerals are classified into 3 groups: vitrinite, liptinite and inertinite, either because of a similar origin, or because of differences in preservation. The vitrinite group comprises the most abundant macerals

Tab. 1. Distribution of vitrinite in flotation time (%)

Tab. 1. Rozkład witrynitu w czasie flotacji (%)

| Flotalex | Jankowice | ČSM | ČSA | Kleofas |
|---|---|---|---|---|
| 1st min | 35 | 26 | 34.1 | 28.5 |
| 2nd min | 35 | 26 | 31.6 | 25.4 |
| 3rd min | 21 | 29 | 18.2 | 28.7 |
| 5th min | 7 | 16 | 8.8 | 0 |
| after 5 min | 2 | 3 | 7.3 | 17.4 |

Tab. 2. Distribution of vitrinite in flotation time (%)

Tab. 2. Rozkład witrynitu w czasie flotacji (%)

| Montanol | Jankowice | ČSM | ČSA | Kleofas |
|---|---|---|---|---|
| 1st min | 40 | 33.1 | 34.7 | 29.5 |
| 2nd min | 29 | 28 | 32 | 29.8 |
| 3rd min | 24 | 20.4 | 23.2 | 31.7 |
| 5th min | 5 | 16 | 8 | 6.7 |
| after 5 min | 2 | 2.5 | 2.1 | 2.3 |

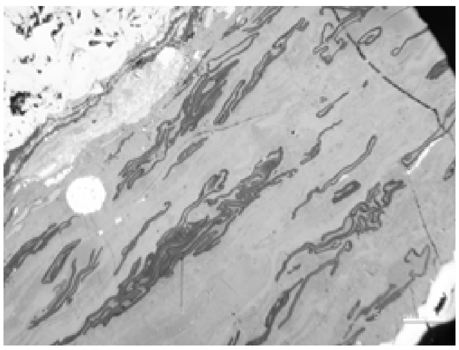

Fig. 1. Cutinite clarain

Rys. 1. Klaryn w kutynicie

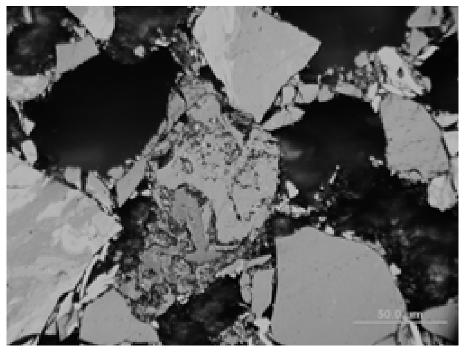

Fig. 2. The mineralization of a colinite grain

Rys. 2. Mineralizacja ziarna kolinitu

in coal. These macerals are derived from the woody tissue and bark of trees. [10]

Table 1 implies that, on average, 82.3% of the vitrinite maceral group float in three minutes using Flotalex. Applying the collector Montanol, 88.8% of the vitrinite maceral group float in three minutes.

In the coal slurry sample from the locality Jankowice, 81% of the vitrinite maceral group floated into the concentrate during the first three minutes using Flotalex. Using Montanol, an even higher percentage of vitrinite group floated in three minutes, namely 93%. The maceral group of vitrinite was predominantly represented by colinite and a rather abundant telinite. The occurrence of colinite is accompanied by the occurrence of pyrite, which formed the matrix of clarain, often of a cutinite character (Fig. 1).

In the coal slurry sample from ČSM Mine using Flotalex or Montanol, 81% or 81.5% (respectively) of the vitrinite group floated into the flotation concentrate in three minutes. The maceral group of vitrinite was mainly represented by large whole colinite grains. Telinite was rare. Clay mineralisation often occurred in colinite (Fig. 2). There were several grains of semifusinite on the transition between vitrinite and fusinite. Fragments of vitrinertite were also observed.

Applying the Flotalex collector in the coal slurry sample from ČSA Mine, we identified 83.9% of the vitrinite maceral group floating into the flotation concentrate. Using Montanol, as much as 89.9% of vitrinite maceral group floated in three minutes. In the sample, the maceral group of vitrinite is predominantly represented by colinite appearing as large grains. The grains were often damaged and with cracks – see Fig. 3. Telinite was less frequent and fragments of vitrinertite were observed. Frequent clay mineralisation occurred in colinite.

In the sample from Kleofas Mine, 82.6% of the vitirinite group floated in three minutes using Flotalex and using Montanol, 91% of vitrinite floated in three minutes. The vitrinite maceral group was mainly represented by colinite and telinite was also frequent (Fig. 4). Colinite formed the matrix of clarain, which was often cutinite-like. Vitrodetrinite fragments were also frequent.

Fig. 3. Micro-crack in a vitrinite grain

Rys. 3. Mikropęknięcia ziarna witrynitu

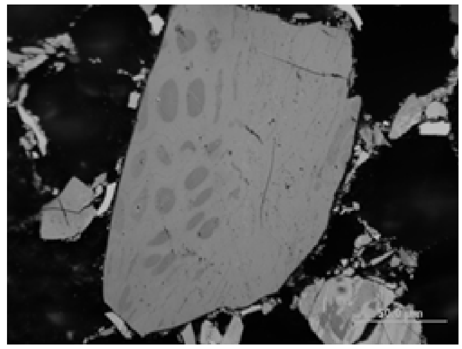

Fig. 4. Telinite grain

Rys. 4. Ziarno telinitu

**Conclusion**

Froth flotation is an effective method for fine-coal separation. As it is grounded in the differences between the surface hydrophobicity of mineral and organic matter, the research observed the transition of the vitrinite maceral group into the flotation concentrate in the course of froth flotation testing four different samples of black coal slurries from coal preparation plants in the Czech Republic and Poland. For the flotation tests and for the purposes of comparison, two collectors were used, namely Flotalex and Montanol. The flotation experiments imply that the collecting and selection effects of both collectors are almost identical in the used samples.

It is clear from the petrological analyses that using Flotalex, 82.3% of vitrinite maceral group floats in three minutes. A characteristic petrographic feature of the coal slurries is a high content of vitrinite maceral group. The prevailing macerals in the vitrinite group are vitrinite and telinite. Furthermore, detrital macerals prevail among the macerals from the inertinite and liptinite groups.

Applying two different collectors (Montanol and Flotalex), it is clear from the microscopic analyses that the black coal slurries from the four mines are highly floatable and flotation time may thus be shortened to under 3 minutes. This may bring time and cost savings for the industry.

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*Zachowanie macerałów w procesie flotacji węgla kamiennego*


*Ze względu na naturalną hydrofobowowość węgla, flotacja jest bardzo skuteczną metodą wzbogacania mułu węglowego o wielkości ziaren poniżej 0,5 mm. W celu weryfikacji możliwości zastosowania flotacji przeprowadzono badania flotacji węgla przeprowadzono na czterech próbkach węgla kamiennego pochodzących z kopalń CSM i CSA w Czechach oraz kopalń Jankowice i zamkniętej kopalni Kleofas w Polsce. Celem artykułu jest także opis zachowania się macerałów węglowych w procesie flotacji: przechodzenie do koncentratów i odpadów flotacyjnych. Wykorzystano kolektory flotacyjne Flotalex i Montanol. Kolektory te są standardowo stosowane w procesie flotacji węgla zarówno w Czechach , jak iw Polsce. Wyniki flotacji i analizy petrograficznbe sugerują, że badane węgle flotują zarówno przy stosowaniu Flotalexu lub Montanolu. Analizy wykazały że uzysk witrynitu w koncentracie wyniósł 82,3% (stosując Flotalex) i 88,8% (stosując Montanol) trzy minuty.*



*Słowa kluczowe: witynit, analiza macerałów, flotacja, węgiel kamienny*