The effect of hard coal density on its flotation performance

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Vplyv hustoty čierneho uhlia na účinnosť jeho flotácie

Hard coal flotation depends on many factors, one of which is the density of the grains floated. The heavier the grain, the greater the gravitational force that counteracts the force of adhesion between the grain and an air bubble, and the lower the probability of forming the grain-air bubble aggregate. This paper presents the results of a study on the effect of grain density on hard coal flotation. To eliminate the effect of grain size, densimetric fractions of very similar grain sizes were floated. Significant differences in the floatability of grains of the same size but of different densities were found. The floatability of coal grains dramatically decreased with their density.

Key words: *coal, flotation, density, grain-size distribution, densimetric fraction, hexanol*

Introduction

Hard coal flotation depends on both the natural properties characterising coal slimes and variable flotation parameters, which can be modified to ensure an optimal performance. Natural properties of coal slimes include primarily the coalification degree affecting their surface properties, petrographic composition of the coal, and the nature of intergrowth with the gangue. These are objective factors, which depend on the origin of the coal and cannot be changed for a given coal. The variable factors in flotation are the concentration of solids in the pulp, the grain-size distribution, the type of chemicals used, their dose and the feed method, the pulp aeration degree and the air dispersion degree, and the type of flotation cell. (Jasienko et al., 1971; Sablik, 1980, 1998; Małysa, 1981, 2000). An accurate analysis of the influence of individual factors on the coal slime floatability is hindered by an interaction between the individual parameters (Sablik, 1998; Małysa, 1981; Małysa et al., 1982).

Flotation is statistical in nature. The probability for floating a grain is the product of the probability of a collision between a mineral grain and an air bubble ,Pc, the probability of adhesion ,Pa, and the probability of detachment ,(1-Pd), of the grain from the air bubble, which can be described by the equation:

$$P = Pc.Pa.(1 - Pd), \qquad (1)$$

The probability of a collision between an air bubble and a grain is defined by hydrodynamic conditions, which are affected by the grain and bubble sizes and the system's turbulence (Ray et al., 1973; Weber et al., 1983; Bustamante et al., 1983; Yoon et al., 1989; Yoon, 1991; Schimmoller et al., 1993; Małysa, 2000). The probability of adhesion depends mainly on surface forces occurring in the system and on the induction time. The probability of detachment of a grain from an air bubble depends, among other factors, on the grain specific weight (Laskowski, 1976; Bustamante et al., 1983).

This work studies the effect of the density of grains of similar size on the flotation performance of coking coal, with values of such parameters as the flotation pulp density, mixing time, flotation time, the type and quantity of the chemical used held constant.

Subject and methods

The study uses narrow densimetric fractions within narrow grain-size fractions obtained from the jig concentrate and the raw slime of the coking coal. All the material was crushed in a drum crusher to below 0,5 mm and then separated into narrow grain classes: 0,5-0,4; 0,4-0,315; 0,315-0,2; 0,2-0,1 and 0,1-0,04 mm after dry-screening to remove the fraction below 40 μm. The latter fraction was also wet-screened from individual fractions. Thus, the obtained classes were dried and separated into narrow densimetric fractions in heavy media of the following densities: 1,25, 1,3, 1,4, 1,6, 1,8, 2,0 Mg/m^3. Separation in the density range 1,25-1,6 Mg/m^3 was done in carbon tetrachloride diluted to a proper concentration in denatured ethanol. In the density range (1.6-2.0) [Mg/m^3] the separation was done in zinc chloride.

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The upper limit of the fraction +2,0 Mg/m^3 was checked in bromoform. All densimetric fractions were washed in warm water. Thus, separated narrow fractions were used as the feed in flotation. The ash content in the studied weight fractions within narrow coal grain fractions is shown in Tab. 1. and in Fig. 1.

Flotation experiments were performed in a 1 dm^3 laboratory cell. A sample of 50 g was soaked for 30 minutes in distilled water and then mixed for 5 minutes. In the experiment, n-hexanol was used as a collector and frother – its concentration in the cell was 1,5 .10^{-4} mol/dm^3.

Hexanol reduces the surface tension at the gas-solid interface and thus increases air dispersion in the flotation pulp, stabilizes air bubbles and counteracts their coalescence. Also, hexanol adsorbs on the coal surface, thus acting as a collector (Małysa, 1981; Małysa et al., 1982; Małysa et al., 1987).

Tab. 1. Ash contents in densimetric fractions of different grain classes of the coal studied.

Grain class [mm]	**Ash content** [%] **in different density classes** [Mg/m^3]						
	-1,25	1 ,25 – 1,3	1,3 – 1,4	1,4 – 1,6	1,6 – 1,8	1,8 – 2,0	+2,0
0,5-0,4	1,7	4,3	7,2	15,3	26,0	50,5	80,8
0,4-0,3	1,4	2,8	3,4	17,7	27,0	49,8	80,6
0,3-0,2	1,9	4,5	3,2	17,9	34,3	58,7	80,5
0,2-0,1	1,6	1,5	7,8	13,1	32,1	64,2	76,7
0,1-0,04	4,2	6,7	13,5	13,7	16,7	_	_

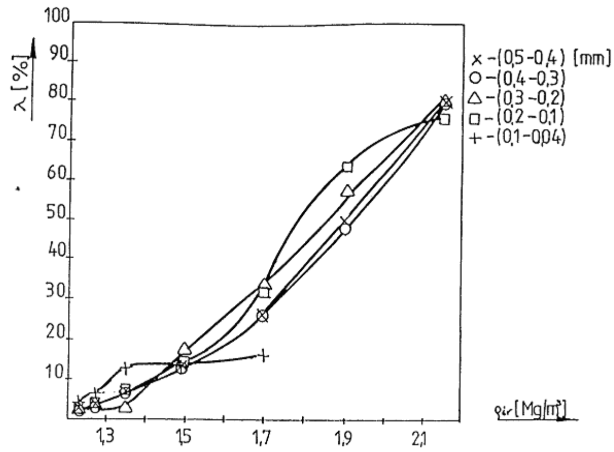

Fig. 1. Dependence of the ash contents on the grain size for different densimetric coal fractions.

The process was performed as the fractional flotation. After drying, the samples were weighted and analysed for the ash content. The results are shown in Fig. 2-7. They show the dependence of the concentrate yields (Σγ) and the ash content in the concentrates (υ) and tailings (β) on the flotation time (t).

Results and diskusion

The narrow densimetric fractions used in the flotation experiments differed in ash content. As Fig. 1 and Tab. 1 show, the ash content rises dramatically with the increase in the densimetric fraction density in all grain classes; for instance in the 0,4-0,3 mm grain class the ash content changes from 1,4 % for the –1,25 Mg/m^3 fraction to 80,6 % for the +2,0 Mg/m^3 fraction.

Fig. 2.-6. show the results of flotation kinetics for narrow densimetric fractions, for various grain classes. Concentrate yields increased with the flotation time for all densimetric fractions within the same grain-size class, but for coarser grains, above 0,3 mm, the density fractions in excess of 1,8 Mg/m float poorly. Concentrate yields reach the values of up to 20 % after two minutes (Figs 5, 6). This is because the greater density combined with the coarser grain size results in the greater gravitational force, which detaches the grain from the air bubble and consequently reduce the probability of the effective collision. Heavier fractions of finer grains, below 0.3 mm, float much better (Figs. 2-4).

The floatability of grains greater than 0.2 mm was observed to increase with decreasing the fraction density (Figs 4-6). The lower the grain density in a given grain-size class, the higher the probability of the effective collision with a bubble because the gravitational forces trying to detach the grain are lower. Such dependence was not observed for grains smaller than 0,1 mm, and for such grains the fractions with densities greater than 1,4 Mg/m^3 floated better than those with densities below 1,4 Mg/m^3. The 1,3-1,4 Mg/m^3 fraction floated the worst (Fig. 2).

The ash content in the concentrate (υ) and tailings (β) increased with the flotation time, as well as with the weight of flotation fractions (Figs. 2-6).

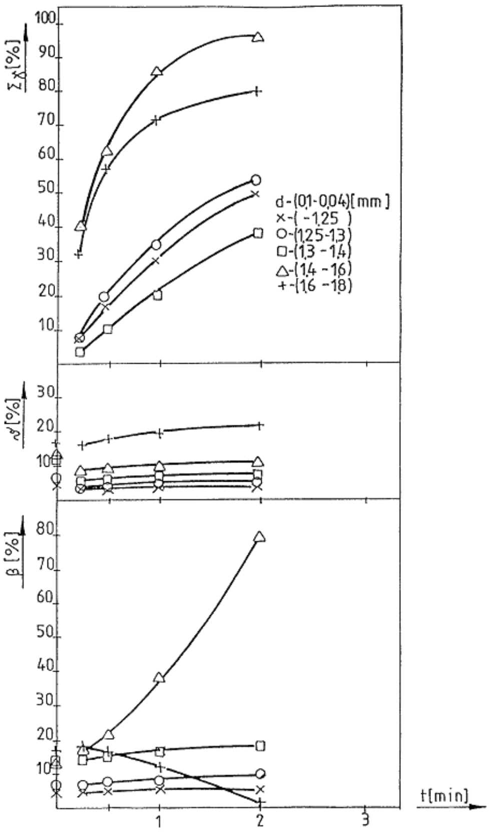

Fig. 2. Flotation results of densimetric fractions of the coal grain size 0,1-0,04 mm as a function of the flotation time

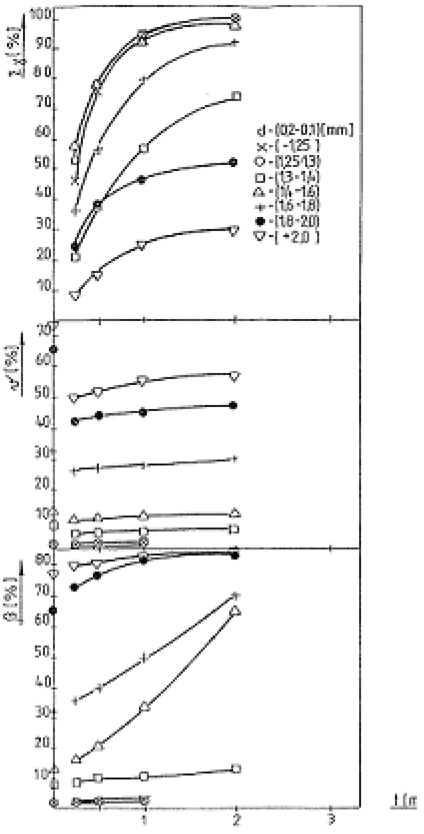

Fig. 3. Flotation results of densimetric fractions of the coal grain size 0,2-0,1 mm as a function of the flotation time.

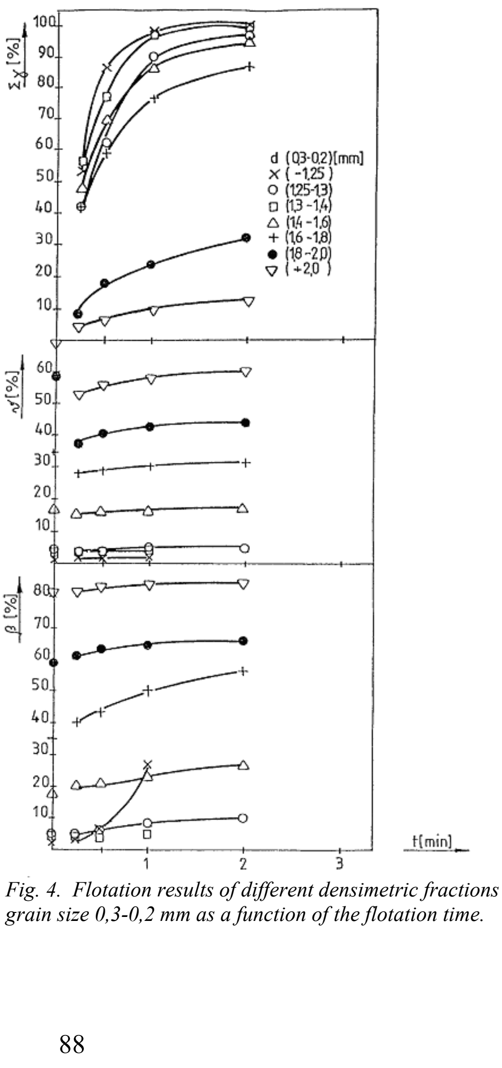

Fig. 4. Flotation results of different densimetric fractions of coal grain size 0,3-0,2 mm as a function of the flotation time.

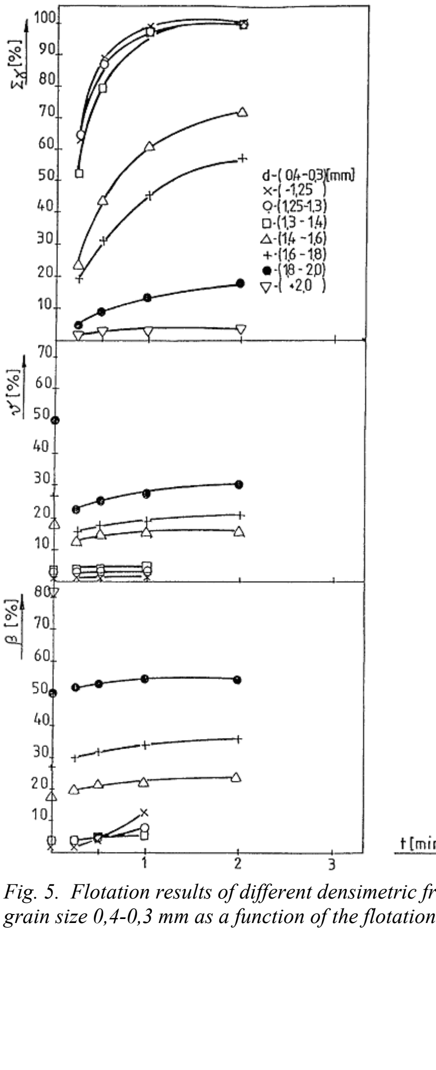

Fig. 5. Flotation results of different densimetric fractions of coal grain size 0,4-0,3 mm as a function of the flotation time

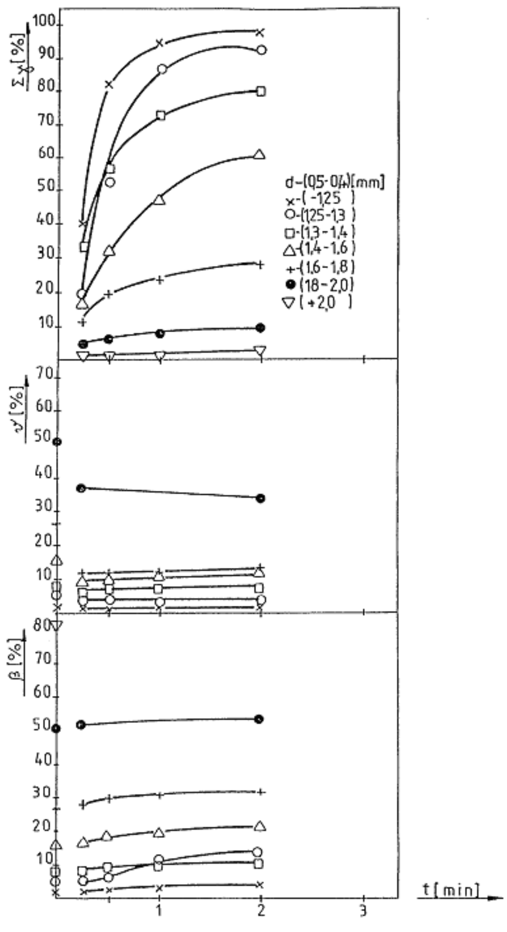

Fig. 6. Flotation results of different densimetric fractions of coal grain size 0,5-0,4 mm as a function of the flotation time.

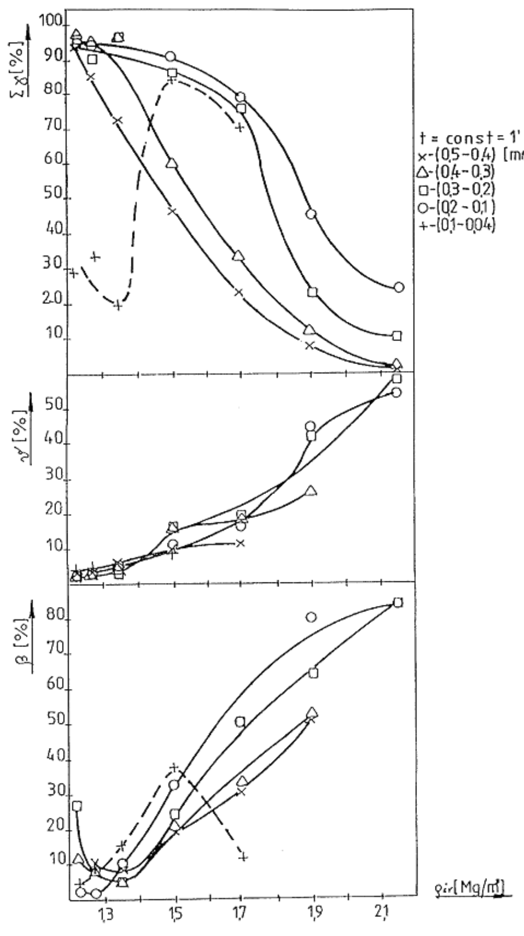

Fig. 7. Effect of the grain density on the flotation results of different size fractions, for the flotation time t=1 min.

Fig. 7 shows the dependence of flotation results on the grain density after 1 min. of the flotation process for various grain-size classes. For all grain classes in excess of 0,1 mm the concentrate yields decrease with the increase in the weight of the fraction, whereas the ash content in the concentrate and tailings increases. The values of υ and β are the lowest for fractions below 1,25 $Mg.m^{-3}$ and the highest for the heaviest fraction +2,0 $Mg.m^{-3}$. The finest grain class 0,1-0,04 mm behaved differently. As the fraction density rose to the value of 1,4 $Mg.m^{-3}$, the floatability decreased. Then, a sharp increase in the floatability of the 1,4-1,6 $Mg.m^{-3}$ fraction and again a decrease for the 1,6-1,8 $Mg.m^{-3}$ fraction was observed. In this class, the ash content in the concentrate increased and the ash content in the tailings followed the pattern of the concentrate yield. The floatability decreased with the increase in grain density. The lightest grains floated the best. This should be attributed to the fact that the gravitational force trying to detach the grain from the bubble increases with the grain density. Consequently, the higher the grain density, the lower the probability for an effective collision between the grain and the air bubble. Moreover, with the increasing density, the grains surface properties are changing. The carbon contents are diminishing while the contents of mineral parts are increasing and consequently the lowering of floatability is observed.

Summary

The understanding of the many factors affecting coal flotationis still not complete in spite of the fact that, in principle, coal is beneficiated easily.

The objective of this work was to study the effect of the coal grain density on the flotation performance. To eliminate the effect of grain size on the flotation process, narrow grain-size classes were prepared and floatability of densimetric fractions within individual classes was studied. The studied densimetric classes within individual grain-size classes differed in the ash content. The ash content rose dramatically with an increase in the densimetric fraction density in all grain classes studied (Tab. 1, Fig. 1).

In the flotation studies, n-hexanol was used, which acts as both the collector and the frother. Good flotation results were obtained in the 1,5 $.10^{-4}$ mol/dm^3 solution. For coarser grain classes, in excess

of 0,1 mm, and densities below the 1,25 $Mg.m^{-3}$, the concentrate yields were of about 95 %. This is because of coking coal, which has good flotation properties. Flotation times were short - of about 2 minutes.

Analysis of the flotation process' dynamics showed that the yields of concentrates from narrow densimetric fractions increases with the duration of the process. Flotation of narrow densimetric fractions significantly depends on their density. With an increasing grain density, the concentrate yield decreased dramatically and the ash content in the concentrate and tailings rose (Figs. 2-7). The higher the weight, the higher the ash density in a fraction, that is, the higher the content of mineral matter and consequently the more hydrophilic the coal which means a poorer flotation. In addition, the force "gluing" the mineral grain to the bubble is counteracted by the gravitational force trying to detach the grain from the air bubble. Hence, the higher the grain density, the lower the probability of an effective collision between the grain and a bubble. The smallest grains (below 0,1 mm) behave differently. With an increase in the fraction density up to 1,4 $Mg.m^{-3}$ the floatability decreases, than rises dramatically to fall again for fractions with densities in excess of 1,6 $Mg.m^{-3}$. One should suppose that when grains have a low kinetic energy (small grains with low density) they will be carried by the currents flowing around the air bubbles and the grains will not stick to air bubbles. With an increase in the density of fine grains, the floatability increases dramatically due to the grain's higher kinetic energy and the higher probability of attachment.

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