THE USE OF PHYSICAL METHODS IN TREATING RAW MATERIALS OF THE BANSKÁ ŠTIAVNICA REGION

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Abstract

Laboratory experiments on beneficiation of feldspar using physical methods are described. The results of the tests in which table, magnetic and electrical separations were used show that it is not possible to reduce the concentration of iron in the final product below 1%. It is thus clear that physico-chemical techniques must be applied.

INTRODUCTION

Problems of treating raw materials for the ceramics manufacture in Slovakia are considerable which is understandable taking into account the existing material basis. This fact, together with the present economic situation in the Banská Štiavnica region initiated activities associated with utilisation of *granodiorite* as a source of feldspar for the ceramics manufacture in this locality. That is why the task of verifying the amenability of *granodiorite* was initiated.

The Banská Štiavnica region has been noted for very extensive mining and mineral processing activities during the centuries. In various historical periods the region occupied an important position among the mining centres of the former Austria–Hungary. Various complex ores (Ag, Au, Pb, Zn, Cu) were treated in

those days. At the present time, the mining activity has been interrupted since verified reserves of Pb–Zn ore do not allow effective utilisation. The objective of evaluation the amenability of *granodiorite* was to revive the above mentioned mining activity in the region.

Term *granodiorite* denotes igneous rocks being penetrated with mining works in an extensive underground. Neither the localisation not mineralogical composition of the supplied sample was known to the investigators. Chemical analysis of the sample was as follows: SiO₂ 61.45%, K₂O 4.80%, Na₂O 1.69%, CaO 1.42%, MgO 2.23%, Fe₂O₃ 4.29%, Al₂O₃ 12.69%, loss on ignition 3.05%. The analysis, together with visual examination indicates that *granodiorite* has a distinguishable impregnation of pyrite with crystals loosely placed in it.

In order to verify the amenability of the sample, physical separation methods were chosen, such as gravity (shaking table), magnetic and electrostatic separation and their combination. The flotation separation methods were investigated by another research group. This paper will summarise the results obtained using the physical separation techniques as applied to the above specified raw material.

THE AMENABILITY TESTS

From the averaged sample of the raw material supplied by the mining company Hell Corp., samples were collected for the physical and flotation research. The sample for the physical methods was crushed down by a conical crusher and the crushing roller mill and screened into grain sizes in accordance with the conditions of the experiment.

As optimisation parameters were chosen technological data: weight yield (wy) and Fe–content (weight %). In this case iron represents the waste – undesirable component. The concentrate can be considered as acceptable when the content of Fe is less than 0.8%.

To evaluate washability of the raw material, classical methods of planning experiments (Gauss method of gradual optimisation) were chosen. Only the results providing the best parameters will be presented in the paper.

From the results of the measurements errors of particular technological analysis methods were determined so that the results presented in the paper should be interpreted in the statistical sense using the confidence interval $x \pm \Delta x$ where Δx is the value calculated according to the relation $\Delta x = t_{\alpha, f} = Sx/\sqrt{n}$. Sx is the standard deviation of the measured value x , n is the number of measurements, t is the critical value of the Student test at $\alpha = 0.05$ and $f = n - 1$ are degrees. If the variation of the results of two parallel experiments was such that Fe content exceeded $2\Delta x = 0.1$, the experiment was repeated. Similarly, when the difference of weight yields in two parallel experiments exceeded $2\Delta x = 3$, the experiment was also repeated.

Separation on a Shaking Table

The verification experiments were carried out using < 1 mm grain size. Since this material was not hydraulically pre-classified into equally settling grain sizes, the experiment was such that the equally-settling sizes, subsequently individually separated, were formed at the basic stage. The parameters of the shaking table were as follows: slope: 3° , speed: 110 rpm, stroke: 10 mm. There were 10 sampling canisters on the longitudinal side and the head of the shaking table. In the experiments, the first three sampling canisters were considered to represent the concentrate, next five the middlings and the remaining two were the tailings.

By separating the material at given conditions, the following products have been obtained:

	weight yield (%)	Fe content (%)
tailing+pyrite	9.3	8.4
middlings	16.6	3.1
concentrate	74.1	2.4

The total error of the experiment determined from the results of the verification experiments was $\pm 3\%$ rel.

On the strength of the verification results we decided to carry out next experiments with < 0.15 mm grain size in order to liberate the grains. Coarser

grain sizes did not render satisfactory results. Similarly, in this case we used a previously non-classified material and hence in the basic stage it was hydraulically classified into three equally settling sizes and pyrite. The experiment was performed according to flowsheet 1.

Fig. 1 Flowsheet 1: collection of the shaking table separation products.

By comminution Fe is concentrated in finer grain size, as follows:

Grain size [mm]	Weight yield [%]	Fe content [%]
+0.8	24	2.48
0.15–0.8	36	2.83
–0.15	40	3.64

By separating the material the following products were obtained:

	Weight yield [5]	Fe content [%]
Pyrite	4.0	12.70
Middlings	19.5	2.93
Concentrate	70.1	2.19

In conclusion of this part, it should be stated that separation on the shaking table, under the given conditions, does not provide feldspar concentrates having the content of Fe less than 2%.

Magnetic Separation

For separation in a magnetic field, the entire spectrum of grain sizes of the material was used. Size fractions -0.15 mm, $-0.8+0.15$ mm and $+0.8$ mm were separated with a high-intensity magnetic separator 138 T-SEM and size $-2+0.8$ mm and $-2+1$ mm size fractions were separated with a disc electromagnetic separator.

The results are given in Tables 1, 2 and 3. Statistical evaluation of the experiments shows that the variation of Fe in the feed does not exceed limits of the confidence interval for the mean value. It follows from the calculation of the basic statistical characteristics:

$$\bar{x} = 2.51$$

$$S_x = 0.034, n = 4, f = 3,$$

$$\bar{x} \pm t_{\alpha, f} S_x \sqrt{n} = 2.51 \pm 3.182 \times 0.034 \sqrt{4} = 2.51 \pm 0.05\% \text{ Fe}$$

It was not desirable to separate -0.15 mm size fraction at a higher intensity of the magnetic field because there was no qualitative difference between the separation products. $-2+1$ mm size fraction was separated by using the disc magnetic separator according to flowsheet 2 shown in Figure 2. The results of these experiments are given in Table 4.

Table 1 The separation results for +0.8 mm grain size

Product	2A		4A		6A		8A	
	w.y. %	% Fe	w.y. %	% Fe	w.y. %	% Fe	w.y. %	% Fe
Non-magnetic	76,27	2,11	68,21	2,14	68,31	2,14	68,19	2,20
magnetic	23,73	3,65	31,79	3,28	31,69	3,30	31,81	3,32
Feed	100	2,48	100	2,50	100	2,51	100	2,56

Table 2 The separation results for -0.8+0.15 mm grain size

Product	1A		2A		4A		6A	
	w.y. %	% Fe	w.y. %	% Fe	w.y. %	% Fe	w.y. %	% Fe
Non-magnetic	77,91	2,34	72,12	2,36	62,77	2,24	59,73	2,22
magnetic	22,09	4,51	27,88	4,13	37,23	4,05	40,27	3,88
Feed	100	2,82	100	2,85	100	2,91	100	2,89

Table 3 The separation results for 0.15 mm grain size

Product	1A		2A	
	w.y. %	% Fe	w.y. %	% Fe
Non-magnetic	33,64	3,35	26,32	3,41
magnetic	66,36	3,78	37,68	3,70
Feed	100	3,64	100	3,62

Table 4 Results of magnetic separation of -2+1 mm grain size

Product	4A		6A		8A	
	w.y. %	% Fe	w.y. %	% Fe	w.y. %	% Fe
Non-magnetic	92,21		88,11		85,18	2,35
magnetic	7,79	5,61	4,1	3,48	2,93	2,75
Feed	100		92,21		88,11

Fig. 2 Magnetic separation flowsheet using the disc separator

Combination of Magnetic and Gravity Separation

In order to reduce the Fe content in the concentrate, experiments were carried out using magnetic pre-treatment in combination with the shaking table separation, after comminution of the non-magnetic product below 0.15 mm. The experiment proceeded as follows: $-2+0.8$ mm size fraction was separated with the disc magnetic separator at the electric current of 8 A. We obtained:

- (i) the non-magnetic product with the weight yield 72.81% and 2.26% Fe, and
- (ii) the magnetic product with the weight yield 27.19% and 3.46% Fe.

The non-magnetic product was comminuted to the fineness of -0.15 mm by the a friction mill. Using the separation of the shaking table and collecting samples according flowsheet 3 shown in Figure 3, we obtained the following results:

	Weight yield [%]	Fe content [%]
Pyrite	4.5	12.01
Tailings	12.2	2.17
Middlings	12.2	2.19
Concentrate	71.1	1.67

Fig. 3 Flowsheet 3: shaking table separation at the combined treatment

Electrostatic Separation

For separation in electrostatic field, laboratory high-voltage electrostatic separator Sturtevant type OH was used. The separation was carried out with $-0.8+0.15$ mm size fraction. The first valve was set so that, without voltage, all the material fell into the first container, as can be seen in Figure 4. The second

Fig. 4 Laboratory high-voltage electrostatic separator Sturtevant

valve was in a vertical position and so only dust particles being wiped from the drum and representing only a small fraction (0.5%) entered the third container. By analysing the powder after finishing all the experiments, 2.5% Fe content was found. The results given in Table 5 do not reflect this fact.

The attained separation results and technical parameters are listed in Table 5. These results show the separation in electrostatic field to be more problematic than that in the magnetic field.

Table 5 Electrostatic separation results

No.	Parameters of experiments	Product			
		1.		2.	
		w.y. %	% Fe	w.y. %	% Fe
Wire electrode - min.					
1.	26 μ A 8000 V	22,0	3,2	78,0	2,80
2.	40 μ A 15000 V	5,7	3,8	94,3	2,63
Wire electrode - max.					
3.	15 μ A 10000 V	64,5	2,8	35,5	3,08
4.	40 μ A 22000 V	30,5	2,9	69,5	2,90
5.	70 μ A 26500 V	10,7	3,5	89,3	2,83

CONCLUSION

The conducted experiments were centered on verification of possibilities of physical methods of treating a raw material of a given type to the final form of the feldspar concentrate, or as a pre-treatment method prior to flotation. The obtained results confirmed that by using the applied physical methods it is not possible to reduce the Fe content below 1.6%. When starting from the requirements for the Fe_2O_3 content in the feldspar concentrates [2] and the ceramics manufacture [1], we can conclude that the concentrate of the raw material from the combined treatment is suitable for the production of industrial ceramics.

In conclusion we can state that magnetic separation, under determined conditions, can be included in a technological cycle of a raw material pre-treatment prior to flotation, if the results of the flotation treatment enable the required parameters of the feldspar concentrate to be rendered.

REFERENCES

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