Influence of foam height on salt flotation of copper-bearing shale

To cite this article: T Ratajczak 2018 IOP Conf. Ser.: Mater. Sci. Eng. 427 012007

View the article online for updates and enhancements.
Influence of foam height on salt flotation of copper-bearing shale

T Ratajczak

Wroclaw University of Science and Technology, Faculty of Geoengineering, Mining and Geology, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland
tomasz.ratajczak@pwr.edu.pl

Abstract. Influence of height of foam on salt flotation of copper-bearing shale, having different Cu and organic carbon contents, was investigated. It was found that the yield of flotation of copper-bearing shale in the presence of NaCl is directly dependent on the content of organic carbon and height of foam produced during flotation. It has been shown that the height of flotation froth $h$ depends on type of shale, and its variation can be described by formula $h/h_{\text{max}} = 1/(t+1)^n$, where $t$ is the time of flotation and $n$ is a constant.

1. Introduction

Flotation of mineral particles in aqueous salt solutions without additional chemical reagents is referred to as salt flotation [1-2]. Inorganic salts may act as foaming agents [1-7], and their effectiveness in flotation depends on the type and concentration of salt [2, 8].

Copper-bearing shale from the sedimentary deposits of the Legnica-Głogów Copper District is characterized by a different lithological structure, mainly due to its diverse chemical and mineralogical composition. For this reason, shales from the LGOM area are classified as clayey, dolomitic, clayey-dolomitic with varying content of copper (Cu) and organic carbon (Corg). The most valuable is the shale with increased content of organic carbon due to the higher content of copper. An important factor of the shale is Corg content, because its high content adversely affects the copper metallurgical processes. For the separation of carbonaceous substances from copper ore preflotation is used, which consists in flotation of ore in the presence of only froth agents. It is indicated that differentiated organic carbon content in shale can affect their floatability in the presence of foaming agents [11].

The purpose of paper, based on the results of Kurkiewicz [9] as well as Kurkiewicz and Ratajczak [10], was to determine the effect of foam height on salt flotation of copper-bearing shale having different content of copper and organic carbon.

2. Flotation of copper-bearing shale in presence of NaCl

The tests were performed using copper-bearing materials denoted as shale L, Ps and Pd [9, 10, 11]. They originated from LGOM [11]. Their Cu and C$_{\text{org}}$ were determined in the Mineral Processing Laboratory WGGG PWR content is given in table 1. The size of particle was below 0.1 mm.
Table 1. Characteristics of shale [10, 11].

| Shale symbol | Type of shale                      | Cu, % | C_{org}, % |
|--------------|------------------------------------|-------|------------|
| L            | loamy-dolomite shale               | 1.13  | 7.45       |
|              | high-carbon and medium-copper      |       |            |
| Pd           | dolomite-loamy shale               | 0.83  | 5.34       |
|              | medium-carbon and high-copper      |       |            |
| Ps           | dolomite shale                     | 0.58  | 0.57       |
|              | low-carbon and low-copper          |       |            |

Flotation of copper-bearing shale was carried out in a Mechanobr flotation machine with cell having capacity of 0.25 dm³ and an air flow of 50 dm³/h. The tests were performed in aqueous NaCl solutions at concentrations of 0.25M; 0.50M; 1.00M; and 2.00M. The flotation time was 30 minutes. The height of the flotation froth was measured at the beginning of collecting each flotation product, i.e. 1; 4; 10; 15 and 30 minutes of flotation. A more detailed research methodology is given in the work of Kurkiewicz and Ratajczak [10] and Kurkiewicz [9]. Figure 1 presents a summary of the results of flotation of investigated copper-bearing shales. Figures 1a-c refer to flotation yield, described by the 1st order kinetics in the work of Kurkiewicz and Ratajczak [10], while figures 1a'-c' the height of foam during flotation of the L, Pd, Ps shales.

Figure 1 shows that copper-bearing shale L, Pd, Ps flotation depends on concentration of NaCl solution and type of shale. Additionally figure 2 presents a dependence of the maximum yield as a function of froth height measured during flotation (t = 30 min). Larger yields and higher froth were obtained for flotation of L shale, which was characterized by a higher content of organic carbon, in comparison to shale Ps (table 1).
3. Evaluation of copper-bearing shale flotation performed in the presence of NaCl

In order to plot curves which characterize the influence of flotation time on froth height for the studied copper-bearing shale, an approximation of results collected in fig. 1 a’-c’ was carried out. Figure 3 shows a dependence of the height ratio of foam ($h$) and its maximum height ($h_{\text{max}}$) on time ($t$) of shale flotation. The waveforms relation, which is shown in figure 3, can be approximated with an exponential or polynomial curve, but the latter would lead to a multiparameter function, which is not beneficial when flotation results are used for comparison.

Figure 4 shows the relation between height of froth and time of flotation of the copper-bearing shale samples in NaCl solutions approximated with equation (1):

$$\frac{h}{h_{\text{max}}} = \frac{1}{(t+1)^n},$$  \hspace{1cm} (1)

where: $h$ - height of foam during salt flotation of copper-bearing shale, cm; $h_{\text{max}}$ - maximum height of foam during salt flotation of copper-bearing shale, cm; $t$ - flotation time, min; $n$ - foam height indicator.

Figure 4 shows that the height of froth depends on the type of shale, and its height, characterized by index $n$, is directly dependent on the organic carbon content in the shale (table 1), and thus hydrophobicity of shale [10, 14]. However, the dependence of $n$ and $C_{\text{org}}$ has a minimum at the carbon content of approximately 5%. After that the value of the index describing the height of foam $n$ begins to increase, which may indicate the parabolic nature of dependence of $n$ and $C_{\text{org}}$. Research in this area...
should be continued, because basing on 3 experimental points it is difficult to clearly know the course of the dependence.

Figure 4. Froth height limit curves for flotation of copper-bearing shales in the presence of NaCl.

4. Summary
As a result of the conducted research, the influence of froth height on flotation yield of copper-bearing shale in presence of NaCl was presented. It was noted that height on froth flotation increases with increasing salt concentration and is highest at the beginning of each flotation of studied shale. During further flotation (1-15 min), froth height decreases and becomes constant for about 15 minutes. The initial increase in froth height may indicate that the particles of shale rapidly move to the surface of the froth, which increases the volume (froth height), and the gradual reduction in the particles concentration can cause a decrease of the froth height. In addition, it was shown that for L shale characterized by a higher content of organic carbon in relation to the content of Corg in shale Ps, the outflow and the flotation foam is higher (fig. 1a-a’, c-c’; fig. 2). It was also found that the height of the froth during copper-bearing shale flotation depends on concentration of salt and type of copper-bearing shale, and its course can be described by equation 

\[
\frac{h}{h_{\text{max}}} = \left( \frac{1}{t+1} \right)^n
\]

The presented research results may be a basis for further work on the effectiveness of flotation measured by the recovery of Cu or Corg content in relation to changes in the froth height over time.

Acknowledgements
This work was partially financed by the Polish Statutory Research Grant 0401/0129/17.

References
[1] Laskowski J 1965 J. Colliery Guardian 211 pp 361-6
[2] Ratajczak T and Drzymała J 2003 Flotacja solna (Oficyna Wydawnicza Politechniki Wrocławskiej: Wrocław)
[3] Pugh R J, Weissenborn P and Paulson O 1997 Int. J. Miner. Process. 51 pp 125-38
[4] Grabowski B and Drzymała J 2008 Annales Universitatis Mariae Curie-Skłodowska, Lublin-Polonia, Sectio AA, Vol. LXIII 6 pp 68-72
[5] Lipniarski M, Ratajczak T and Drzymała J 2015 III Polski Kongres Górnicy, Mineralurgia i wykorzystanie surowców mineralnych (WGGG PWr: Wrocław) pp 35–9
[6] Smólska M and Ratajczak T 2017 Lupek miedzionośny III (WGGG PWr: Wrocław) pp 97-102
[7] Witan J and Ratajczak T 2017 Lupek miedzionośny III (WGGG PWr: Wrocław) pp 138-45
[8] Ratajczak T 2017 Mineral Engineering Conference MEC2017 EDP Sciences art. 01028 pp 1-3
[9] Kurkiewicz S 2017 *Flotometryczna hydrofobowość łupka miedzionośnego w obecności soli* Praca dyplomowa, niepublikowana (WGGG PWr: Wrocław)

[10] Kurkiewicz S and Ratajczak T 2017 *Łupek miedzionośny III* (WGGG PWr: Wrocław) pp 103-9

[11] Drzymała J, Karwowski P, Borowski K, Pązik P and Kowalczyk P B 2017 *Łupek miedzionośny III* (WGGG PWr: Wrocław) doi: 10.5277/lupek1702 pp 52-58

[12] Ratajczak T, Drzymała J and Kowalczyk P B 2016 *Mineral Engineering Conference MEC2016* EDP Sciences art. 01033 pp 1-5

[13] Drzymała J, Ratajczak T and Kowalczyk P B 2017 *Physicochem. Probl. Miner. Process.* **53(2)**, pp 983–95

[14] Kubiak B and Drzymała J 2017 *Łupek miedzionośny III* (WGGG PWr: Wrocław) pp 64-68