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Differentiation of organic carbon, copper and other metals contents by segregating flotation of final Polish industrial copper concentrates in the presence of dextrin

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Abstract. Existing and new data on production of two copper concentrates differing in copper, organic carbon and other metals contents by reflotation of the final industrial flotation copper concentrates from KGHM Polska Miedz S.A. in the presence of dextrin as a depressing reagent of the mineral particles containing organic carbon are presented in the paper

keywords: flotation, reflotation, segregation flotation, organic carbon, copper, sulfides, dextrin, maltodextrin, industrial concentrates

1. Introduction

The final industrial flotation copper concentrate produced by KGHM Polska Miedz S.A. is a collective product containing several valuable elements such as Cu, Ag, S, Pb, Zn, Ni, Co, V, Mo, Re, Au etc., and unwanted elements including As, Hg, organic carbon (C_{org}) etc. Further processing of the concentrates by smelting is complex and increasing requirements imposed both by technology and environment call for improvements and new methods of copper ore and produced concentrate beneficiation. One of the problems encountered by KGHM at the beginning of this century was the excessive amount of Pb in the final industrial copper concentrates. In response to this demand a new technology was developed, proposed and patented (Drzymala et al., 2000/2001, 2007), which was based on reflotation of the final concentrate in the presence of dextrin (Drzymala et al., 2002) to produce two different copper concentrates. The first copper concentrate, being the froth product of reflotation, was enriched mostly in copper minerals including chalcocite and silver minerals. The second copper concentrate, being the reflotation tailing, also called the cell product, was enriched in C_{org} and, in the case of ZWR Lubin, also in the Pb minerals. Principles of the separation were described in details in a report of investigations commissioned in 2000 by the Polish Ministry of Higher Education, then called the Committee on Scientific Research (KBN), entitled *Modified polysaccharides as selective depressing reagents in flotation of copper material containing lead minerals* (Drzymala et al., 2002). The results of the investigation can be summarized by two figures extracted taken from this report which are shown in Fig. 1. These figures clearly show that reflotation of the final industrial Polish concentrates leads to two concentrates having different compositions, especially of organic carbon and copper.

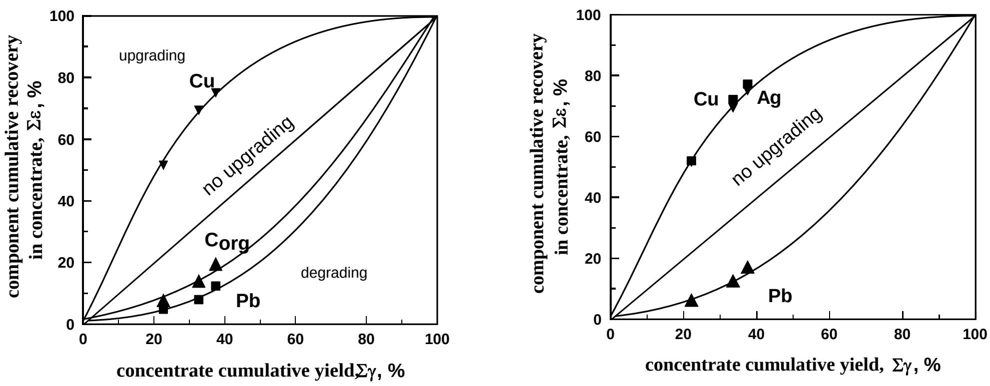

Fig. 1. a) Flotation results (Mayer upgrading curve) of the final industrial copper concentrates from ZWR Lubin in the presence of 50 g/Mg xanthate, 50 g/Mg α-terpineol and 2.5 kg/Mg dextrin prepared from potato starch by roasting at 256°C for 1 hour. Feed: 0.092% Ag, 18.5% Cu and 5.52% Pb (Drzymala et al., 2002), b) in the presence of 5 kg/Mg dextrin of molecular mass about 4 kg/mol and 50 g/Mg of xanthate along with 50 g/Mg of α-terpineol (without pH regulation). Ag minerals float together with Cu compounds. Feed: 7.08% C_{org}, 18.5% Cu and 5.45% Pb) (Drzymala et al., 2002). In this segregation flotation selectivity of dextrin as depressant is utilized

The approach of using dextrin was based on the known, for many years, fact that regulation of hydrophobic particles flotation, including graphite, coal and other naturally hydrophobic materials, can be accomplished by application of dextrin (Miller et al., 1984; Nyamekye and Laskowski, 1991). It is also suitable for the Polish copper concentrates.

Even though the new process of reflotation in the presence of dextrin was promising, it has never been implemented by KGHM due to improvements in the smelting technology, especially regarding lead. However, increasingly strict requirements imposed by the Huty Miedzi Głogow smelter on organic carbon content in the copper concentrates, which are the feed for the flash furnace, had been forcing the managers of the Mineral Processing Division (Oddział Zakłady Wzbogacania Rud or shortly O/ZWR) of KGHM to look for new and possibly simple technologies of copper concentrates production which would differ in C_{org} content. Investigations on the content of Cu and C_{org} in different size fractions of the final industrial copper concentrates lead to a simple solution based on size classification in HC ϕ350 hydrocyclones (ZWR Rudna, 2002-5). This approach appeared to be successful and was providing elevated contents of C_{org} and reduced content of Cu in the overflow while opposite situation was observed in the underflow stream. However, this technology was also a source of the problems with dewatering of the C_{org}-rich overflow product. The complication originated from the presence of fines which created dewatering difficulties even though flocculants were employed (O/ZWR, 2005). This forced the O/ZWR managers to search again for new solutions.

New investigation presented in the report on *An investigation into the evaluation of an alternative flowsheet and reagent scheme for beneficiation of the Polkowice carbonaceous copper or*e (O/ZWR, 2007) was commissioned by O/ZWR in 2007 at KGHM CUPRUM LTD, which pointed to a possible solution based on production of concentrates with different contents of Cu and C_{org} in the products by reflotation of the final industrial copper concentrates using time as a parameter. It was confirmed by investigation described in the report entitled *Determination of influence of upgradeability of the processed ores on the quality of copper concentrates for the needs of optimization of mining-smelting process of copper production process. Stage III* (O/ZWR, 2009) and performed by AGH in 2009 for O/ZWR. The ability of production of two concentrates having different C_{org} and Cu contents by simple and fast reflotation of the final industrial concentrates was confirmed in an industrial installation at the Rudna Processing Plant (O/ZWR Rudna) put into operation on June 8, 2010. The flotation method of production of copper concentrates differing in Cu and C_{org} content was based on different kinetics of flotation of copper minerals and carbonaceous matter present in the concentrate. It was established that well liberated copper minerals float efficiently and fast. Extending the flotation time leads to flotation of poorly liberated copper minerals forming intergrowths. This reduces copper concentrates quality in terms of Cu content. On the other hand particles containing C_{org} require more time to be transported with bubble to the concentrate. The relation between organic carbon and copper content in the re-floated, in a laboratory flotation machine, final industrial copper concentrate from side A and side B of ZWR Rudna (O/ZWR, 2009), being a result of different kinetics of flotation of C_{org} and Cu is shown in Fig.2.

The industrial reflotation, also referred to as segregation flotation, has been monitored and tested in 2010 within a new project *Elaboration of technology of concentrate production with different caloric values by segregation flotation* (O/ZWR, 2010). It was established that the time needed for separation, based on kinetics of flotation, was very short. Additional laboratory tests revealed that the optimum flotation time was 1 minute while in 2009 it was 6 minutes (O/ZWR, 2010). This complicated the separation process and called for further changes in the operation and construction of the whole reflotation installation. Therefore, adaptation works have been performed to change the processing flowsheet. In the following tests principal parameters, including pulp level in the flotation machine, air flow rate to the flotation machine, flotation time, flotation machine cell volume, feed flow rate, spraying the concentrate froth with water, reagents addition etc. were investigated. The results of one of the series of the industrial segregation flotation trails are presented in Fig. 3.

Figure 3 shows that there is some separation between C_{org} and Cu (Fig. 3a) and no separation between Cu and Pb when the final copper concentrate is subjected to the segregation flotation.

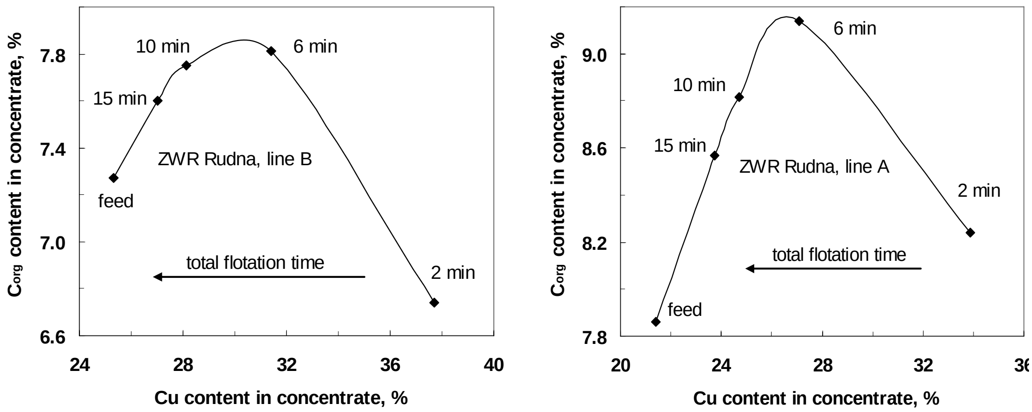

Fig. 2. Relation between organic carbon and copper content in the refloated in a laboratory flotation machine final industrial copper concentrate from side A and side B of ZWR Rudna (O/ZWR, 2009)

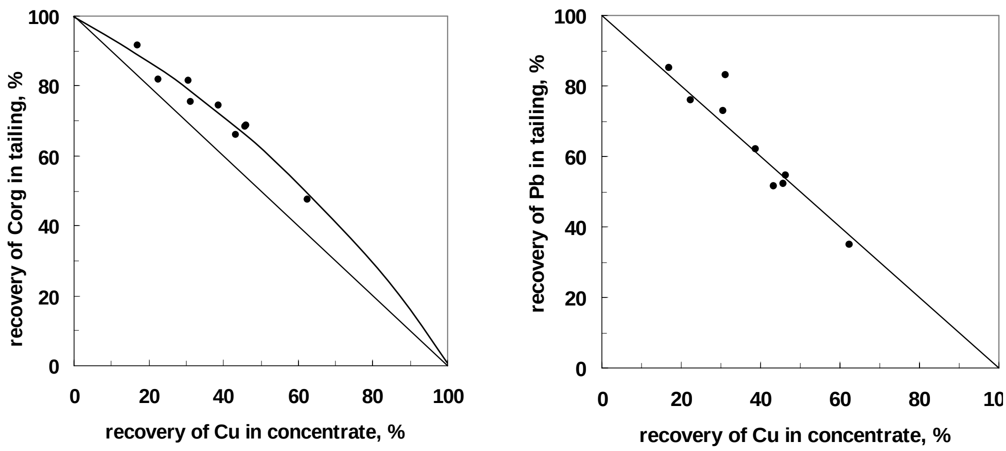

Fig. 3. Results of reagent free reflotation of the final industrial flotation copper concentrates leading to different Cu and Corg recoveries in the two products of the process at ZWR Rudna (O/ZWR, 2010, series I). Reflotation performed with industrial flotation machines MF011 and MF013. Different data points were obtained by varying flotation conditions. Separation results from different kinetics of Cu and Corg flotation (Fig. a). No separation between Cu and Pb is observed (Fig. b)

Since the results of segregation flotation were still unsatisfactory, a new effort was undertaken (O/ZWR, 2010) to use different depressants, including dextrin, which confirmed previous findings (Drzymala et al., 2002) that dextrin can be an efficient reagent leading to reduction of the C_{org} content in the froth product obtained by reflotation of the final industrial flotation copper concentrate from KGHM.

The results of laboratory and industrial tests involving segregation flotation of the final industrial flotation copper concentrates from ZWR Rudna in the presence of dextrin to get two copper concentrates differing in Cu and C_{org} contents are presented in this paper.

2. Experimental

2.1. Laboratory experiments

In the reflotation experiments involving polysaccharides, a relatively high molecular weight dextrin, having the so-called dextrose equivalent (DE) equal to 6-8 and labeled as maltodextrin was used. I can be noticed that on the DE scale starch has 0 value while glucose/dextrose has the value of 100. Both selection and dose of the dextrin were based on the results described in the patent (Drzymala et al, 2007), other published data (Drzymala and Kozlowski, 2004) and availability of this dextrin on the market.

The feed (15 dm^3 of slurry) for the laboratory experiments was the same as the feed for the industrial segregation flotation performed in the two MF011 and MF033 flotation machines. The laboratory test were performed in a Mechanobr type flotation machine working at 2450 rpm and air flow rate equal to 120 dm^3/h. It was equipped with a 1 dm^3 cell in volume.

2.2. Industrial trials

The industrial scale reflotation tests were carried out in the presence of dextrin. The conditions of the tests with dextrin, to determine its influence on separation of C_{org} and Cu, was based on laboratory investigation tests and patent PL 195693 (Drzymala et al., 2000/1; 2007). The industrial trial was carried out at predetermined dose of maltodextrin DE 6-8 as the dextrin equal to about 2 kg per one megagram of dry mass (2 kg/Mg) of the final industrial copper concentrate. Since the production was about 7000 Mg per shift and reflotation concentrate yield was about 7%, an addition of 120 kg of dextrin per hour was necessary. A dose of 60 kg of dextrin, having a low DE6-8 dextrose equivalent, was used as 10% aqueous solution. The results obtained in the absence of the reagent on October 12, 2010 between 5:30 am to 12:30 pm were compared with those obtained in the presence of dextrin conducted between 12:30 and 13:00 pm. The reagent was added to the concentrate trough of the MF09 flotation machine. Taking into account the capacity of side A of ZWR Rudna for the industrial final copper concentrate and flotation kinetics, the samples of reflotation products were collected with a 6 minutes delay. Frequency of sampling in the course of regent addition was 3 minutes due to a short time of the industrial test.

3. Results and discussion

3.1. Reflotation of the final industrial flotation copper concentrates in the presence and absence of dextrin

The results of separation of Cu from C_{org} by reflotation are presented in Tables 1-2. Table 1 shows contents of Cu and C_{org} in the feed and in the products of separation while Table 2 gives calculated upgrading parameters such as yield and recovery as well as separation factor *a*. The separation factor, reflecting upgrading of Cu in relation to C_{org} is defined as (Drzymala and Ahmed, 2005)

$$\varepsilon_{Cu} = a\frac{100-\varepsilon_{C_{org}}}{a-\varepsilon_{C_{org}}} \tag{1}$$

where

ε_{Cu} – recovery of copper in the froth product

ε_{Corg} – recovery of organic carbon in the cell product

a – separation (selectivity) factor (100 for ideal separation and ~1000 for no separation). The value of *a* can be based on individual data points or the whole upgrading curve plotted as the Fuerstenau upgrading curve.

Table 1. Cu and C_{org} contents in the feed and products of reflotation (segregation flotation) in industrial flotation machines MF011 and MF033 in the presence of maltodextrin (DE 6-8)

Date/shift, time		Dextrin	Feed		Froth product		Cell product	
			Cu	C_{org}	Cu	C_{org}	Cu	C_{org}
12.10.10 shift I	5:30 am to 12:30 pm	absent	26.02	8.59	26.40	8.74	32.99	9.49
	12:30 pm to 13:30 pm	present	24.39	9.14	21.48	9.68	38.57	6.68

In addition to Tables 1 and 2 Figure 4 presents the results of Cu and C_{org} separation by reflotation in the presence and absence of dextrin.

A significant obstacle in analysis of the reflotation results was erroneous determination of Cu and C_{org} in the feed and the cell product in the absence of dextrin. Despite this shortcoming, it was possible to established that dextrin applied in the reflotation of the final industrial copper concentrate leads to new copper concentrate having reduced amount of C_{org} (6.68% in the presence of dextrin and 9.49% in the absence) and elevated content of Cu (38.57% in the presence of dextrin and 32.99% in the absence). It proves that applied dextrin and reflotation procedure provide two copper concentrates differing in organic carbon content.

Table 2. Upgrading results parameters and separation factor *a* of separation Cu from C_{org} in the presence of maltodextrin (DE 6-8)

Data/shift, time		Cu		Corg		C_{org} recovery for balance based on Cu	separation factor (Cu from Corg) (*a*)
		froth product yield	froth product recovery	froth product yield	cell product recovery		
12.10.10 shift I	from 5:30 am to 12:30 pm	30.0*	38.0	-20.0	122.1	71.2	292.6
	from 12:30 pm to 13:30 pm	17.0	26.9	18.0	86.8	87.9	159.9

* - froth product yield was assumed as for shift III on 11.10.2010 due to imbalance of Cu in the flotation products

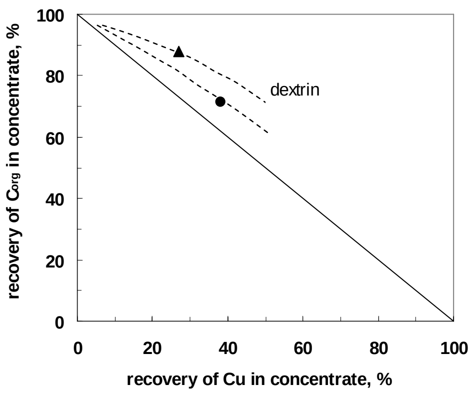

Fig. 4. The Fuerstenau upgrading curve showing relation between recovery of C_{org} in the cell product and Cu recovery in the froth product for industrial trial of reflotation in the absence and presence of maltodextrin DE 6-8 at the dose of 1.93 kg/Mg. The throughput was 7640 Mg per shift, concentrate yield 6,84%

3.2. Laboratory reflotation tests

The laboratory flotation tests were carried out to supplement the industrial trail results obtained in the presence of maltodextrin DE 6-8. The sample for tests was the final industrial copper concentrate collected on October 12, 2010 during shift I between 5:30 am and 12:30 pm. It was the so-called balanced sample prepared by the Center for Quality Investigations (CBJ) after removing the so-called balance determination sample. The following samples were investigated: 1) flotation for the collected sample at the original solids density (flotation F0) in the absence of dextrin, and 2) flotation of the sample collected in the presence of maltodextrin (flotation F1). Figure 5 shows the change of the Cu content in the reflotation froth products. It results from the data on the Cu content in the froth products, collected after indicated in the figure flotation times, that as expected, the dextrin addition does not depress flotation of copper minerals while it depresses C_{org} flotation. This leads to a beneficial differentiation of the flotation products in respect to the Cu and C_{org} assay.

The content of C_{org} in the froth products collected after different time intervals (Fig. 5) indicates that dextrin significantly reduces the kinetics of C_{org} flotation leading to a reduction of C_{org} grade in the froth concentrate and increased C_{org} content in the cell product.

Figure 6 shows separation of C_{org} from Cu in terms of separation factor *a* calculated separately for each product of segregation flotation and flotation time. It confirms very efficient (low *a* values) and persisting depression of C_{org} and its separation from Cu in the presence of dextrin and poor separation (high *a* values) of C_{org} from Cu in the absence of dextrin.

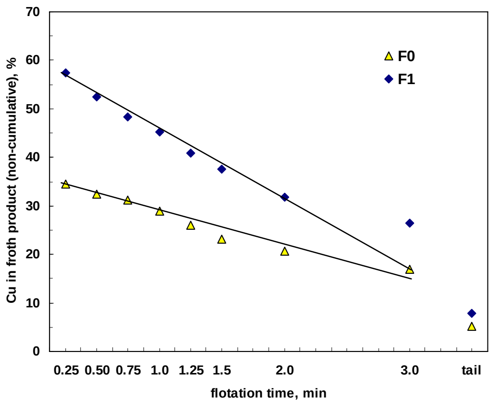

Fig. 5. Results of laboratory batch tests on reflotation of final industrial copper concentrates performed in the absence (F0) and presence (F1) of dextrin, shown as Cu content in the froth product as a function of flotation time

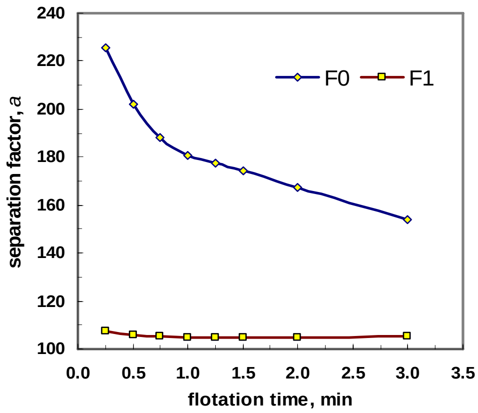

Fig. 6. Relation between separation factor *a*, reflecting separation of Cu and C_{org} during fractionated batch laboratory flotation, and flotation time. Results in the presence (F1) and in the absence (F0) of dextrin

The same results plotted as the Fuerstenau upgrading curve (Fig. 7) prove again a good efficiency of separation of Cu from C_{org} in the presence of dextrin. According to Fig. 7. it is possible, for instance, to obtain froth product with Cu recovery equal to 50-60% with only 10% recovery of C_{org} in that product, that is 90% recovery of C_{org} in the cell product. Thus, it is feasible to separate the final industrial copper concentrate into two copper concentrates: the froth product enriched in Cu and the cell product enriched in C_{org}.

The laboratory experiments conducted to enriched the industrial tests show that segregation flotation (reflotation) of the final industrial flotation copper concentrates in the absence and presence of dextrin is very efficient.

An important element in a further creation of technology for production of two concentrates having different caloric values by segregation flotation in the presence of dextrin will be the determination of the dose and other parameters influencing the process.

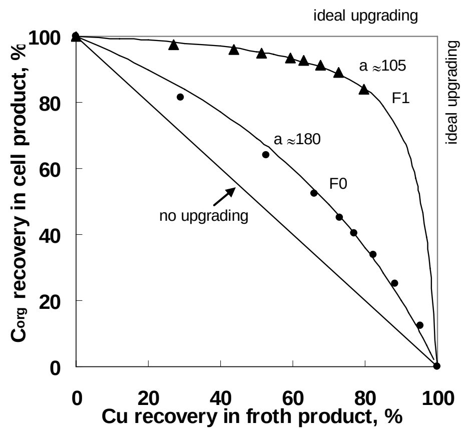

Fig. 7. Separation curve for laboratory batch tests on reflotation of final industrial copper concentrates performed in the absence (F0) and presence (F1) of dextrin in the form of the Fuerstenau upgrading curve

4. Conclusions

Both industrial and laboratory flotation results presented and discussed in this paper confirmed previous data that dextrin is an effective C_{org} depressant for splitting, by reflotation also called segregation flotation, the final industrial flotation copper concentrate into two copper concentrates differing in Cu and C_{org} contents. The reflotation provides the froth product enriched in Cu and depleted in C_{org} while the cell product with elevated amount of C_{org} and reduced assay of Cu. A final decision on application of dextrin for production of the two industrial copper concentrates should be based on optimization of reagent dose in combination with economical analysis.

It becomes now necessary to evaluate the possible benefits of smelting of the new concentrates from the Cu and C_{org} content points of view. It would allow to determine the optimal dose of the dextrin in the process.

Acknowledgements

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W pracy przedstawiono znane oraz nowe dane dotyczące produkcji dwóch koncentratów miedziowych o zróżnicowanych zawartościach miedzi i węgla organicznego na drodze ponownej flotacji przemysłowgo końcowego koncentratu miedziowego z KGHM Polska Miedź S.A. przy użyciu dekstryny jako odczynnika depresującego ziarna mineralne zawierające węgiel organiczny.

słowa kluczowe: flotacja, reflotacja, flotacja segregująca, węgiel organiczny, miedź, siarczki miedzi, dextryna, maltodextryna, koncentraty przemysłowe