Influence of dextrin on beneficiation of components from copper flotation concentrate

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Abstract. Depressants are one of the most important reagents in flotation process. They are used to improve upgrading selectivity. Natural depressants, especially starch and its derivatives, are one of the most significant polysaccharides used in polymetallic sulphide ores flotation. In the paper influence of dextrin on flotation of copper, organic carbon and mineral components from rougher concentrate was investigated. It has been shown, that dextrin is a good depressant for organic carbon and clay minerals with micas as long as the appropriate collector for sulphides are added. Moreover, significantly better flotation of all copper sulphides and pyrite with marcasite was observed, in comparison with flotation test using collector and frother only. Using dextrin as a single reagent does not affect beneficiation of examined concentrate. However, dextrin had not depressed galena particles. It can suggest that various factors can influence on good flotation of galena, e.g. associations with other sulphides, mineral composition and structure of examined feed.

1. Introduction

The largest European sedimentary copper ore, located at Legnica-Glogow Copper Basin (SW Poland), is processed by three Concentrator Plants which are the part of KGHM Polska Miedz SA [1]. The Concentration Plants process around 33 million tonnes of ore per year [2]. Ore consist of three lithological rock types: sandstone, dolomite and shale. Each of rock type differs mainly in chemical and mineral compositions, physical properties and floatability. The main copper sulphides are chalcocite, bornite, chalcopyrite and covellite. The ore also contains sulphides of other metals like lead (galena), zinc ( sphalerite) and iron (pyrite and marcasite) [3,4].

In the case of the Fore-Sudetic deposit located in Poland, the shale ore is main carrier of organic matter (especially organic carbon). It is the main reason for technological problems in the metallurgical process [5]. However, this rock is quite rich in copper and other accompanying metals. One of the
method to separate organic carbon from useful minerals is the application of depressant for organic matter and flotation of useful sulphides in the presence of appropriate collector with frother.

Depressants are used for increasing upgrading selectivity. This is one of the most important group of flotation reagents. In many processing plants the consumption of depressant is much higher than collector (even 20–30 times) [6]. Usually depressants are classified in two groups: organic and nonorganic. Sodium cyanide, zinc sulphate, sodium sulphide and dichromates have the great significance and the highest consumption amongst nonorganic depressants [7,8]. Sodium cyanide is used in depression of pyrite, arsenopyrite, sphalerite and pyrrhotite [9], zinc sulphate depresses zinc minerals and sodium sulphide – copper and iron sulphide minerals. Dichromates are applied to separate lead and copper minerals [8]. The most important organic depressants are: guar gum, starch and derivatives, especially dextrin. Guaran gum is used in depression of talc and galena [10]. Starch is one of the most important polysaccharide used as depressing reagent in flotation process, especially for iron ores, flotation of muscovite and to separate molybdenite from copper sulphides [11]. Dextrin is received from starch by partial thermal degradation in acidic environment. It can be used to separate micas from sulphides, lead and iron minerals, like galena or pentlandite, from copper minerals, like chalcopyrite [12]. Dextrin and starch can be used in the depression of weathered silicates and carbonaceous matter and assist in depressing the nickel-bearing minerals [8]. According to Liu and Laskowski [13], chalcopyrite can be depressed by dextrin while galena can be floated with xanthate collector in acidic solution. However, in alkaline solutions chalcopyrite minerals are floated while galena is depressed [13].

The paper focuses on the analysis of influence of dextrin on the flotation of copper concentrate obtained after rougher flotation of sedimentary copper ore from Fore-Sudetic Monocline deposits. Three flotation tests with detailed chemical and mineral analysis of products were performed. All experiments were conducted in the presence of an aqueous solutions of industrial reagents. The upgrading selectivity of copper, organic carbon and mineral components was evaluated by mass balance and the plotting of separation curves. Flotation of copper, organic carbon and mineral components were analyzed and described.

2. Materials and methods
For the purpose of conducting the depression tests, a sample of shale-dolomitic copper ore was collected from the Rudna Concentrator Plant of KGHM Polska Miedz S.A. in Poland. Three rougher flotation experiments in the presence of collector and frother were conducted. A mixture of sodium ethyl and isobutyl xanthate with sodium O,O-diethyl dithiophosphate was used as the collector, while a mixture of polyglycol ethers was utilized as the frothing reagent. Both reagents were prepared directly before flotation test. From each flotation test one concentrate was collected after 30 minutes. These samples were used as a feed in depression tests. Chemical and mineralogical analyses of each rougher concentrate sample were conducted. The contents of copper and organic carbon were found to be about 7.4% and 8.8%, respectively. The content of all copper sulphides was about 8.9%, consisting of 4.5% chalcocite, 2.6% bornite, 0.9% chalcopyrite, and lower contents of covellite and enargite. Moreover, the concentrate samples contained about 1.4% pyrite and/or marcasite, 0.4% galena and 0.2% sphalerite. In table 1 the particle size distribution of rougher concentrate is presented.

| Particle size, mm | Yield, % |
|------------------|----------|
| 0–0.020          | 37.4     |
| 0.020–0.040      | 27.7     |
| 0.040–0.071      | 22.8     |
| 0.071–0.100      | 7.9      |
| >0.100           | 4.2      |

Three flotation tests of rougher concentrate samples were conducted. All conditions of performed tests are presented in table 2. In the course of each test one concentrate and tailings were collected.
Table 2. Conditions of performed flotation tests.

| Flotation number | Dextrin dose, g/Mg | Collector dose, g/Mg | Frother dose, g/Mg | Comments |
|------------------|-------------------|---------------------|-------------------|----------|
| 1                | –                 | 20                  | –                 | –        |
| 2                | 2 000             | 80                  | 5                 | –        |
| 3                | 2 000             | –                   | –                 | Before depression test, the feed was purified with distilled water to remove all collector |

All experiments were conducted in a Denver D12 laboratory flotation machine using flotation cell with capacity of 1.5 dm³. The density of the flotation suspension was 300 g/dm³. In each test technological water from Rudna Concentrator Plant was used. Dextrin was used as an organic carbon depressant next to standard reagents applied as the collecting and frothing reagents. During each experiment, the air flow rate was kept constant at 20 dm³/h. Flotation tests were conducted at stirrer speeds between 700 and 850 rpm. The concentrates were collected after 20 minutes. All flotation tests were conducted in natural pH (between 7.8–8.0). It should also be pointed out that dextrin solution was added before collector and frother in the second flotation. The suspension was mixing with depressant for 10 minutes, with collector 3 minutes and 1 minute with frother.

After the flotation all products were washed in distilled water to remove all soluble compounds. Clear samples were dried at 65 ºC for 24 hours and weighed. After that, the representative samples from each product were collected to perform chemical and mineral analysis. Mineralogical investigation of each sample was performed using QEMSCAN® system with advanced procedure that was created and developed based on Polish copper ores and products of their processing [14]. Mineral library dedicated for this type of material have been previously used in another research related to the final concentrates and tailings from three different Concentration plants in Poland [15]. Data obtained for each sample contain such information as mineral composition and particle size distribution. The contents of copper and organic carbon in each flotation product were determined by using iodometric titration and spectrometric method, respectively. All obtained data were recalculated and balanced.

3. Results
The results of flotation were evaluated by the mass balance of components and products of separation, as well as by plotting recovery-recovery and grade-recovery separation curves (figures 1-5). Obtained results allow for comparison of the upgrading selectivities of copper, organic carbon and all mineral components. Moreover, in figure 6 the upgrading results of particle size in each flotation test are presented.
Figure 1. Upgrading curves as a relationship between recovery of copper (a) and organic carbon (b) in the concentrate and recovery of remaining components in tailing for all performed flotation experiments.

Figure 2. Upgrading curves as a relationship between recovery of copper (a) and organic carbon (b) in the concentrate and content of this component for all performed flotation experiments.

As it is presented in figures 1 and 2, the best results of upgrading of copper were obtained in the presence of dextrin, collector and frother as reagents. In this experiment the best quality of flotation concentrate was obtained: the content of copper equals to 17% with recovery of this metal at the level of 53%. The addition of organic depressant in the presence of sulphides collector significantly improves the copper selectivity (figures 1a and 2a) and decreases the flotation of organic carbon (figures 1b and 2b). The content of this component in concentrate was reduced from about 9% to 4.5% while the recovery of organic carbon in concentrate decreased from about 65% to 12%. Furthermore, addition of dextrin as a single reagent (without collector) results in the lack of upgrading of copper and organic carbon in the concentrate. It indicates that to depress the organic carbon the presence of dextrin with sulphide collector is essential.

In figures 3-5 the upgrading results of copper, lead and iron sulphides are presented. Additionally, the results for useless components: clay minerals with micas, carbonates and quartz are shown. As it is presented, the best upgrading results for each copper sulphide in the presence of dextrin, collector and frother are obtained. The best results were observed for chalcopyrite while the lower upgrading selectivity was obtained for covellite. For bornite and chalcocite quite similar results were achieved. It confirmed, that the addition of depressant reagent improves the upgrading of each copper sulphide, especially the easiest floating mineral – chalcopyrite. As it can be seen that, when only collector and
frother was used, the upgrading results for copper sulphides are quite comparable (similar curves courses). Application of dextrin as a single reagent results in the lack of copper sulphides flotation, with the exception of covellite. For this mineral low flotation level is observed. Similar results were achieved for galena and pyrite/marcasite flotation (figure 4). Moreover, the addition of dextrin (in the presence of collector and frother) does not reduce the flotation of the main lead-bearing mineral – galena. This sulphide floats similar in test with collector, frother and dextrin and also in the test using only collector with frother. It means that the dextrin does not depress galena. Furthermore, the addition of dextrin into flotation in the presence of collector significantly increases the upgrading selectivity of pyrite/marcasite.

**Figure 3.** Upgrading curves as a relationship between recovery of chalcocite/bornite/chalcopyrite in the concentrate and recovery of remaining components in tailings for all performed flotation experiments.

**Figure 4.** Upgrading curves as a relationship between recovery of covellite/galena/pyrite+marcasite in the concentrate and recovery of remaining components in tailings for all performed flotation experiments.

Application of dextrin with collector as a flotation reagents results in worse flotation of clay minerals with micas – the main organic matter carrier (figure 5). For the rest of analyzed components – rock-forming minerals (calcium and magnesium carbonates and quartz) a bit better flotation was achieved in the presence of depressant with collector. No effect of dextrin usage (without collector addition) during the flotation of all rock-forming components was observed.
Figure 5. Upgrading curves as a relationship between recovery of clay minerals+micas/carbonates/quartz in the concentrate and recovery of remaining components in tailings for all performed flotation experiments.

The analysis of influence of dextrin on the particle size flotation was conducted. As it can be seen in figure 6, the presence of collector with frother as flotation reagents give similar flotation of each analyzed size fraction. The addition of dextrin give better flotation of all particles, with the exception of the smallest one (below 0.020 mm). This fraction markedly floats worse than the rest. Definitely it is connected with the depression of fine and very fine clay minerals, which are major carrier of organic matter. The most interesting results were obtained in the experiment with dextrin without collector addition. There is no upgrading into concentrate particles coarser than 0.020 mm. Moreover, a low flotation of these fractions into tailings are observed. Only for the smallest particles (below 0.020 mm) a weak flotation into concentrate was observed. Probably, this observation explains the reason of quite good flotation of covellite in this test. This mineral usually occurs as fine and very fine grains and forms a lot of outgrowths with other sulphides [16]. Small size of covellite effects in a weak flotation of this mineral in concentrate with the presence of dextrin and without using collector.

Figure 6. Upgrading curves as a relationship between recovery of particle size in the concentrate and recovery of remaining particle sizes in tailings for all performed flotation experiments.

4. Conclusions
Three flotation tests were conducted in the presence of dextrin and/or collector and frother. Chemical and mineralogical analyses of all upgrading products were performed.

According to presented results, dextrin is a good depressant for organic carbon and clay minerals with micas as long as the appropriate collector for sulphides is added. Significantly better upgrading of
each copper sulphide and pyrite/marcasite is observed, in comparison with flotation test in which only collector and frother were used. Using dextrin as a single reagent does not affect beneficiation of examined feed. The addition of dextrin improves a bit flotation of useless minerals such as carbonates and quartz. In the presence of dextrin with sulphide collector, flotation of very fine particles reduces substantially. Certainly it is connected with depressing effect of dextrin on the clay minerals, which usually form fine and very fine grains. It is quite interesting that dextrin does not depress main lead-bearing mineral – galena. According to available worldwide literature, in the presence of polysaccharides (starch or dextrin) and xanthate collector at a neutral or slightly alkaline pH, copper sulphides (like chalcopyrite or chalcocite) are depressed while galena floats well [11,13,17,18]. Markedly different results were obtained in the paper and other research carried out in Authors department. There may be several reasons for the described phenomenon that can relate to mineralization, composition and/or structure of examined material. Received results can indicate galena particles that occur in strongly associations with copper sulphides and float with copper-bearing minerals in the presence of sulphide (usually xanthate) collector. Moreover the methodology can significantly influence on the flotation of galena. This research has potential for further investigation.

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