Skarn-scheelite ores beneficiation stimulation using ultrasonic treatment

Elena Shepeta[1*] and *Luiza* Samatova[1]

[1]Mining Institute of Far eastern branch of Russian Academy of Sciences Khabarovsk, Russia

Abstract. The impact of acoustic vibrations on physical and chemical properties of circulating water, heterogenic systems of pulps of sulphide and scheelite cycles flotations, collectors (IMA-I413p (potassium butyl xanthate), sodium oleate of commercial acid B-115) have been studied on skarn scheelite-quartz-sulphide ore of Vostok-2 deposit. Ultrasonic treatment has been performed using UZDN-2T apparatus. Working frequency 22 kHz, absorbed acoustic power average for radiator Pak = 46 W, sound intensity average I_{us} = 1 W/cm^2 (rated I_{us}= 2-3 W/cm^2). During all experiments, ultrasonic treatment time was constant — 5 minutes, insonation solutions volume — 250-100 ml, solutions heating temperature in the course of insonation — 25-35 °C. The flotation tests patterns, reagent scheme are approximate to process regulation of Primorskaia ore-processing plant processing ores of given deposit. Utmost increment of extraction in case of collctors ultrasonic treatment has been reached on dialkyldithiophosphate (IMA-I413p), the increment of extraction of chalcopyrite into bulk sulphide concentrate 0.98 %. The best results of testing of ultrasonic treatment impact on scheelite ores beneficiation have been obtained in case of ultrasound impact on circulating water. In consequence of stimulation of precious minerals flotation increment of extraction of chalcopyrite into copper concentrate by 1.4 % and scheelite into bulk rough concentrate by 2.5 % has been obtained.

1 Introduction

Despite the fact that ultrasonic treatment of ores and metals spread already in 60-s of the previous century, up to this day it is considered new and advanced method for future development of mineral deposits beneficiation [1-4]. Such state of things is conditioned by the absence of industrial designs of inexpensive high-performance reliable ultrasonic units. Currently, prevailing are ultrasonic baths for items treatment and the acceleration of physical and chemical processes in liquids. Main manufacturers of laboratory ultrasonic units, in domestic industry, are "Aleksandra-Plius", LLC, units have been supplied to Moscow Institute of Steel and Alloys, "Central research geological-prospecting institute of non-ferrous and noble metals" Federal State Unitary Enterprise, "GVINTSVETMET" Federal State Unitary Enterprise, "Uralmekhanobr" OJSC and etc [5]. Industrial jump in modern technologies and equipment development allows suggesting intensive development

* Corresponding author: Elenashepeta56@mail.ru,

as well as in the field of creation of industrial ultrasonic units what actualizes the researches in the field of ore beneficiation using ultrasonic treatment [6].

2 Experimental technique

Testing of ultrasonic treatment impact on efficiency of beneficiation of scheelite and chalcopyrite on ores of Vostok-2 deposit, in given research, was conducted on sample weights of 125 g. Size degradation was carried out in "Pulverisette-5" planetary mill: solid mineral mass/ball load/liquid substance ratio − 1:3.7:0.8, ball diameter — 20 mm, time of size degradation — 7 minutes, content of flotation class in flotation feed — 73 %, distribution of WO_3 − 80.6 % (including sludge 16.5 %), Cu − 84,7 % which correlates to data of size degradation of one kilogram of sample weights in a ball mill.

Ultrasonic treatment of skarn scheelite-sulphide ore was performed using UZDN-2T apparatus, the radiator of which allows ultrasonic treatment of small quantities of mineral media (to 350 ml). Working frequency 22 kHz. Absorbed acoustic power average for radiator Pak = 46 W, sound intensity average I_{us} = 1 W/cm^2 (data obtained based upon performed researches by mineral deposits beneficiation laboratory). Rated approximate values for the device intensity — I_{us}= 2-3 W/cm^2.

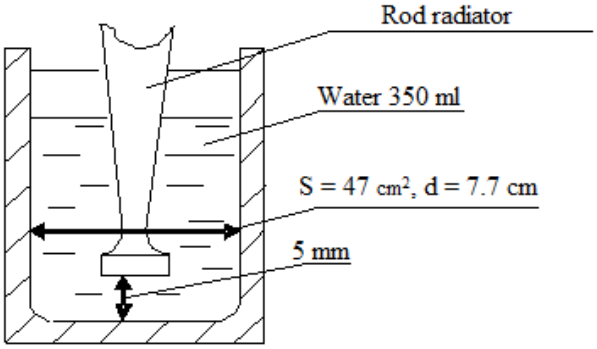

Fig. 1. Exponential rod concentrator (design A)

Exponential rod concentrator with a disc on the end is designed for treatment of media in laboratory breakers with the maximum capacity of 400 ml, ultrasonic vibrations are coupled in the breaker from the top.

During all experiments, ultrasonic treatment time was constant — 5 minutes, insonation solutions volume — 250-100 ml, solutions heating temperature in the course of insonation — 25-35 °C.

Typical pattern of copper-sulphide and scheelite cycles. Main reagent of sulphide cycle: sodium silicate, aeroflot IMA-I413p, pine oil, activated carbon, trisodium phosphate; of scheelite cycle: sodium carbonate, sodium silicate, sodium oleate of commercial acid B-115. The consumption of reagents for bulk cycles were constant in all experiments and corresponding to reagent scheme of Primorskaia ore-processing plant. During finishing cycles, the consumption of reagents was being defined by the quality of rough concentrate.

3 Results and discussion

In case of ore beneficiation, acoustic vibrations obtained most wide spread during treatment of flotation reagents (apolar oils, fatty acids, amines and etc.) which are hardly soluble in water. In production, ultrasound emulsification of oleic acid, tall oil, kerosene, aeroflot, naphthenic acids which allows stimulating the process of reagents dilution in the volume of

pulps in case of decrease in reagents consumption by 11-40 % and increasing in extraction of precious minerals (Dzhezkazganskaia, Balkhashskaia, Almalykskaia, Gaiskaia, Akchatauskaia plants) is used [7-10].

Increase in efficiency of flotation of titanium-zirconic sands, gold from ledge ores, coal, cinnabar, antimonite and selection of lead-pyritic and copper-pyritic concentrates under the impact of ultrasound on heterogenic systems of flotation pulps was noted [11-14]. Insonation of bulk sulphide flotations pulps within 5-20 minutes abruptly decreases flotation response of galena, bornite pyrite, arsenopyrite with retention of flotation of sphalerite, chalcopyrite and pyrrhotite. The difference of kinetics and desorption of collectors from mineral surfaces enables increasing coefficient of minerals selectivity process [13].

Based upon research findings received during the beneficiation of carbonate-fluorite raw materials, ultrasonic treatment of water coming for dilution of froths of cleanings allows reducing the quantity of cleaning operations by means of the growth of selectivity of separation process and increasing fluorite extraction by 7-8 % [15-16].

Based upon theoretical research in this field, main factors influencing flotation process activation were outlined: processes of surface cleaning, cracks opening, splices destruction, structure rupture with caving, microflaws, cavity processes going on in liquid and reinforcing on the boundary of liquid and solid phases, alternation of chemical and phase composition in near-surface layer [17].

Stimulation of beneficiation is one of directions in increasing feasibility of mineral raw materials flotation processing patterns, it is especially important while precious minerals content is decreasing in head ore.

For plant finishing field mining, the increase in feasibility of mining is connected with the stimulation of flotation processes by means of ore feed, reagent schemes, process water treatment.

Goal of research performed: determine main promising trends of ultrasonic treatment application with Vostok-2 field tungsten ores beneficiation.

Results of chalcopyrite beneficiation ability in sulphide cycle in case of ultrasound impact on liquid phase of flotation, process (circulating) water and reagents are represented in Table 1

The best result of chalcopyrite flotation response increase has been obtained with circulating water treated with ultrasound.

It was noted in the previous research that ultrasound impact changes physical and chemical properties of water: pH, electrical conductivity, reduction-oxidation potential, xanthate ions, cyanic compounds and other flotation agents break up, sulphide reagents electrolytic potentials change. With the intensity of acoustic vibrations of 10 W/cm^2 and frequency of 22 kHz and the duration of water treatment of 0.5-10 minutes, the extraction of chalcopyrite increases by 12 % [18].

The dependence of pH change and temperature on time of ultrasonic treatment of tap and process water is given in fig. 2.

In our experiments, insonation of circulating water containing 8.7 g/l of suspended solids, with volume of 250 ml with the intensity of acoustic vibrations of 1.0 W/cm^2 and frequency of 22 kHz within 5 minutes (see fig. 2) led to the reduction of water pH by 0.19 (from 8.19 to 8.0) with insignificant increase in temperature from 20 °C to 26 °C. The clarification of insonated water for a day amounted to 28 %, by initial sample — 36 %. Ultrasonic treatment leads to the enhancement of colloidal solution disability. With the reduction of insonated water volume down to 100 ml, as a consequence of the growth of intensity of impact on water, the reduction of pH by 0.59 and the degree of clarification to 19 % was obtained.

Table 1. Results of chalcopyrite beneficiation in sulphide cycle using ultrasonic treatment of water medium and collectors

Item of insonation	Sulphide concentrate			Sulphide middlings			Sulphide flotation tailings	
	Output %	Copper, %		Output %	Copper, %		Copper, %	
		Content	Extraction		Content	Extraction	Content	Extraction
Without ultrasonic treatment								
H_2O tap water.	14.16	1.32	81.15	8.27	0.30	10.77	0.024	8.08
H_2O circulating water	13.19	1.38	79.43	7.16	0.36	11.21	0.027	9.36
Ultrasonic-treated (volume 250 ml, time of insonation - 5 minutes)								
H_2O tap water.	13.29	1.38	79.76	9.78	0.28	11.89	0.025	8.35
H_2O circulating water.	12.82	1.48	80.84	5.65	0.42	10.31	0.025	8.85
Pulp of flotations	14.47	1.31	82.05	5.84	0.30	7.59	0.030	10.36
IMA-I413p	13.16	1.44	82.13	4.97	0.50	10.78	0.020	7.09
IMA-I413p+potassium butyl xanthate	14.09	1.33	81.66	4.25	0.59	10.86	0.021	7.48
Note: content in ore: WO_3 − 0.72 %, Cu − 0.23 %, As − 0.043 %, S − 4.16 %, Au − 1.0 g/t, Ag − 3.3 g/t.								

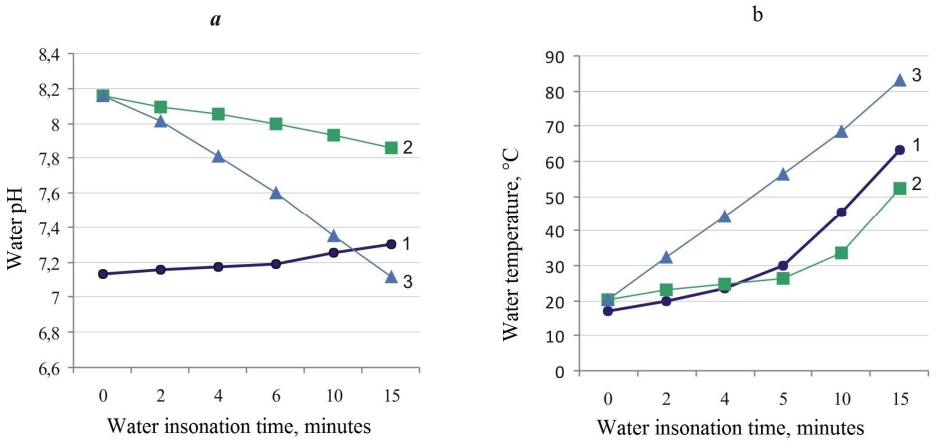

Fig. 2. The dependence of pH (a) and temperature of water (b) on time of ultrasonic treatment: 1 − tap water (250 ml), 2, 3 − circulating water (250 and 100 ml)

In case of using ultrasonic treated circulating water (V − 250 ml, t − 5 minutes) in the process of flotation, the increase in extraction of chalcopyrite into sulphide concentrate by 1.41 % was achieved. The drop of the activity of arsenopyrite flotation in bulk cycle by 4.6 %, pyrrhotite − 3.1 %, was noted.

Saleable concentrate was obtained in copper selection with the increment of extraction by 1.36 %, at that the reduction of losses with copper tailings of selection — 5.96 % which should lead to greater increment of copper extraction in experiments of locked cycle tests.

Insonation of aeroflot IMA-I413p let to reduce losses of chalcopyrite with tailings of bulk cycle by 0.98 %, with treatment of the mixture of aeroflot reagents and butyl xanthate losses reduced by 0.51 % which proves data of partial breaking of xanthate.

Data on ultrasound impact on scheelite flotation are given in Table 2.

Table 2. Values for beneficiation of scheelite from ore using acoustic vibrations

Item of treatment	WO_3 concentrate of basic cycle			Steaming feed			WO_3 flotation tailings	
	Output, %	WO_3, %		Output, %	WO_3, %		WO_3, %	
		Content	Extraction		Content	Extraction	Content	Extraction
Without ultrasonic treatment								
H_2O tap water.	19.59	3.78	94.85	17.95	4.05	93.17	0.050	5.15
H_2O circulating water	27.61	2.62	92.70	16.03	4.35	87.88	0.08	7.30
Ultrasonic-treated								
H_2O tap water.	21.85	3.30	95.01	19.90	3.63	92.61	0.050	5.00
H_2O circulating water	22.35	3.28	95.16	15.45	4.65	93.37	0.048	4.84
Pulp of flotations	20.23	3.65	95.86	10.70	5.32	73.85	0.040	4.14
Sodium oleate	18.57	3.93	94.70	10.45	5.85	79.58	0.050	5.30

Ultrasonic treatment of circulating water led to the stimulation as well as for scheelite flotation. Significant increment of scheelite extraction of 2.46 % was obtained in bulk cycle. Increase in extraction is connected with the reduction of tungsten trioxide content in tailings of scheelite flotation from 0.08 % to 0.048 % with the reduction of rough concentrate output by 5.3 %.

Circulating water insonation let to obtain values of precious minerals extraction close to values on tap water.

Process water ultrasonic treatment is especially important for ore-processing plants during autumn-winter work period when substantial water quality reduction by suspended solids occurs. At Primorskaia ore-processing plant, concentrate is extracted from skarn scheelite-sulphide ore with WO_3 content of 0.56 % in summer (suspended solids in circulating water — 2.9-1.0 g/l) with the extraction of scheelite of 86.9 %, with concentrate quality of 53 % WO_3, with the increase of suspended solids up to 6.0 g/l accordingly 82.6 % and 52.8 % (losses ─ 4.3 %). With the increase of suspended solids in water up to 12 g/l the losses grow up to 6.5 %.

4 Conclusions

As a result of performed testing of skarn scheelite-sulphide ore from Vostok-2 deposit for beneficiation ability in case of ultrasonic treatment impact (working frequency 22 kHz, absorbed acoustic power average for radiator Pak = 46 W, sound intensity average I_{us} = 1 W/cm^2) it has been established that the greatest increment of precious minerals extraction is obtained with circulating water insonation. Increment of extraction of chalcopyrite into copper concentrate amounted to 1.4 % and scheelite into bulk rough concentrate — 2.5 %.

Best results for collectors ultrasonic treatment have been obtained for dialkyldithiophosphates (IMA-I413p), increase in extraction of chalcopyrite into bulk sulphide concentrate amounts to 0.98 %.

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