The flotation of Roşia Poieni copper ore in column machine, with non-polar oils addition

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Flotácia medenej rudy z Roşia Poieni v kolóne s prídavkom nepolárneho oleja

The most important natural resource of copper in Romania is the ore deposit of Roşia Poieni. At present, the utilization of Roşia Poieni poorphyry copper ore is possible by extraction in quarry of the mass ore and mineral processing into a technological flux with modest results for the value of metal recovery in concentrate 70-72 % and an average contents of 16,5 % Cu.

Our researches were directed to studies regarding test and utilisation of special procedure of flotation – addition of the non-polar oil – applied to advanced grinding ore with column type machines.

Key words*: non-polar oil, copper, flotation*

Theoretical considerations

The poor copper ores such as the „porphyry copper" type, require processing of huge quantities of very fine grinded material, in order to assure a proper release of mineral components.

For a good processing the mineral associations (heterogeneous and intimate) multistadial grinding – flotation technological schemes are applied, which assure a grinding fineness arround 90-95 % class under 74 microns (sometimes even 90-95 % under 44 microns for a compact mineralization). Practically, the grinding is more advanced as dimenssions of mineral particles of useful species are smaller with the preponderent part of them beeing liberated when valuable minerals begin to be desassociated; so, it is obvious that a smaller level of the minerals' association, determines the grinding conditions.

Hence, in the same time with the grinding-classifying operations, aimed at disassociating gangue minerals and useful minerals or/and the useful minerals, very fine classes are formed (under 10-20 microns) which have a negative influence on the technological results. It is very well known that very fine particles with a low floatability have a negative influence in the flotation process, including the normal particles' flotation.

The clasical flotation of very fine particles provide bad results', caused by the impurification of the flotation concentrates with tailings and by the losing of the useful minerals in the tailings. The main elements which determine the behaviour of the very fine particles in the flotation process (especially of those under 10 microns) are the low mass of the particles, the large specific surface and the presence of the molecular forces weakly compensated on their surfaces.

The particles' dimenssion is a very important factor with a direct effect on the probability of the formation, the adhesion resistance and the raising velocity of the agregates betwen bubbles and mineral particles.

The upper limits of the floatable material are different and depend also on the flotation system conditions. The lower limit is not determined; it is appreciated that the floatability for the particles under 10 microns is very low and the particles of 1-2 microns, are not floatable at all.

In order to improve the separation selectivity of the very fine particles, flotation methods are known the special which remove the main cause of their low floatability: the weak probability of the collision bubbles [1].

The flotation columns, with acounter-current circulation of the air bubbles and the mineral particles assure an increasing of the collision probability, even at very small dimenssions.

In addition, there are many possibilities to improve the flotation results, by adding an nonpolar oil in a mixture with an ionic collector; their beneficial effect consists in the co-adsorbtion to the particles' surface by Van der Vaals forces of the nonpolar part of the ionic collector. This action mechanism has different particularities for extremal dimenssions' particles – (very fine or coarse) – but with benefitial flotation results. This aspect emphasized by the recent experimental research [2,3,4,5].

The efficiency of the mixed colectors' layers relies on has been the formation of some condensed films, with a different function in the flotation process [6].

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The presence of nonpolar oil, causes the increasing of the particles‘ hydrophobicity and simultaneously, the reducing of the induction time, determined by the thining of the hydration layer between the liquid-gas phases.

Derjaguhin [3] showed that the bubble-particle adhesion takes place by "contact lens" or "a capillary meniscus"; when these lens are concave, in their interior appears a suplementary attraction forces between the surfaces with a smaller curvature, accelerating the adhesion.

The thermodynamic study of the adhesion [7], provide a new calculus of the energy of the bubble-particle system, where appears a superficial tension of the oil-liqiud interface (σ_{lu}) and a second contact angle at the same interface (θ_1) :

$$\Delta E = \sigma_{lg} (1 - \cos \theta) + \sigma_{lu} (1 - \cos \theta_l)$$

So, the presence the nonpolar oil increases the adhesion energy, due to real values of the second term, taking into account the contact angle θ_1 whose values are greater than 90^o. On this effect, we based our research to the poor copper ore flotation in a column.

Description of the column flotation "IPROCELL"

In order to accomplish the experimental task, we used a laboratory scale column flotation installation type IPROCELL, presented in Fig. 1 and made up from:

The floation machine vat, consisting of three cylindrical parts with the dimensions H_{TOTAL} = 2,6 m, $D_{INT.}$ =104 mm. The superior section of the column allows a commutation of the feeding point and the modifying of the height of collecting and washing zones.

The network of pulp feeding is made up from a centrifugal pump (Q_{max} = 2.000 l/h, HR_{max} = 30 m.c.a., HA_{max} = 5 m.c.a.) and a mechanical agitator with a capacity of 100 l. The system assures a recirculation of the pulp (by pass) and so the control of the pulp feeding flow rate.

The system of compressed air feeding has an electric compressor without oil (Q_{max} = 170 l/minut, P_{max} = 8 bar) and a compressed air tank with a capacity of 24 l.

The aerating system has a porous aerating device type IP, from sintering bronze with the pore dimensions between 50-75 microns.

The network of products‘ evacuation consist of collecting the floated product in a circular gutter with a distribution system of washing water by an unsinking single level and the tailings evacuation through a tap with φ = 2,54 mm.

The emulsifying device of nonpolar reagents consists of a porous aerating device type 3P. This device is inserted in the feeding pump with industrial water, ahead the mechanical agitator for an uniform distribution of emulsion in the feeding pulp.

The experimental research

The chemical composition of the copper ore from Roşia Poieni is presented in Tab. 1.; the copper ore has the following mineralogical composition: sulphuroxides and carbonates 10,375 % ($CuSO_4$ = 0,0045, $CuCO_3$ = 0,026), secondary sulphides 37,075 % (CuS, Cu_2S = 0,109) and elementary sulphides 52,551 % ($CuFeS_2$, $CuFeS_4$ = 0,1545).

Tab. 1. The chemical composition of the copper ore from Rosia Poieni

Cu [%]	**S** [%]	**Pb** [%]	**Zn** [%]	**As** [%]	**Fe** [%]	**Al_2O_3** [%]	**SiO_2** [%]	**Bi** [%]	**Au** [g/t]	**Ag** [g/t]
0,294	2,23	0,015	0,022	0,02	3,9	6,98	54,4	0,027	0,019	14,83

The granulometric composition presented in Fig. 2, shows out the weight of the material under 0,074 mm being 83 %, and of the very fine material (-0,045 mm) 83 %.

The experimental research was carried out in the discontinual regime, without recycling of the flotation products.

Taking into account the place of columns in an industrial flotation circuit, trials were carried out in a circuit made up only from a rough and scavenger flotation.

The functional parameters of the flotation column (previously determined [8]) were maintained constant between the experiments, respectively: the pulp flow 8 l/minute; the washing water flow 2 l/minute; the air flow 440 l/hour; the feeding velocity 1,57 cm/s; the washing water velocity 0,4 cm/s; the superficial velocity of air 0,6 bars; the air average content 36,31%.

The flotation trials with the addition of nonpolar reagents were carried out in four series with three trials in which a different consumption of oil was used. The regimes of reagents are presented in Tab. 2.

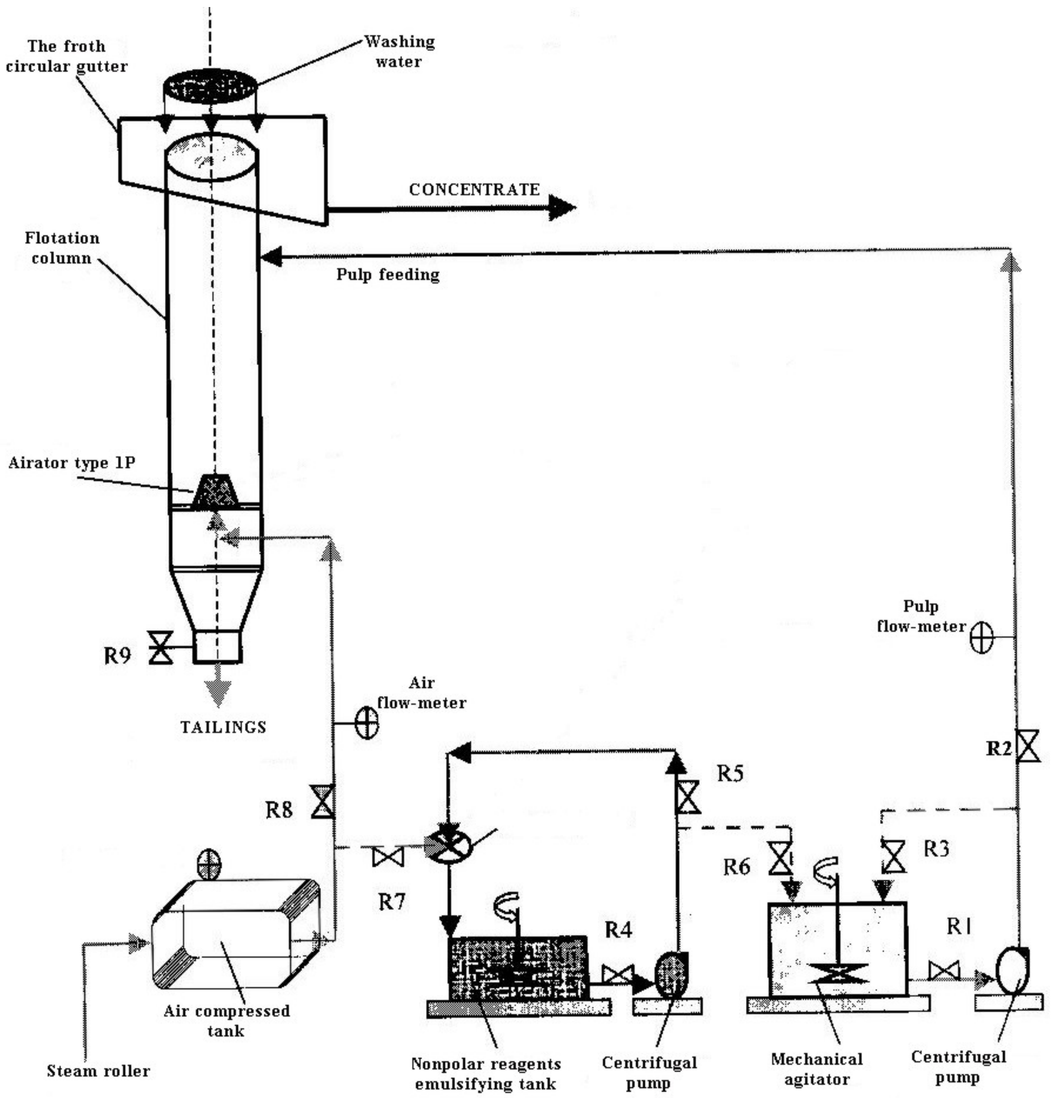


Fig. 1. Column flotation installation, type IPROCELL

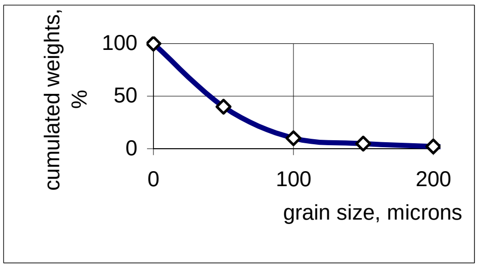


Fig. 2. The granulometric curve

Tab. 2. The quantitative-qualitative regime of reagents

The reagent	Type	Trial number	Specific consumption
Ionic collector	AP404* + RC24** 90 % + 10 %	Trial 1	44 g/t
		Trial 2	46 g/t
		Trail 3	48 g/t
Nonpolar collector	Transformer oil	Serie I	0
		Serie II	400
		Serie III	600
		Serie IV	800
Froth agent	Dawfroth 250	All trials	40 mg/l
pH modificator	lime	All trials	at pH = 11

**Aeropromoteur 404; ** Natrium Ethylbuthyldithiophosphate*

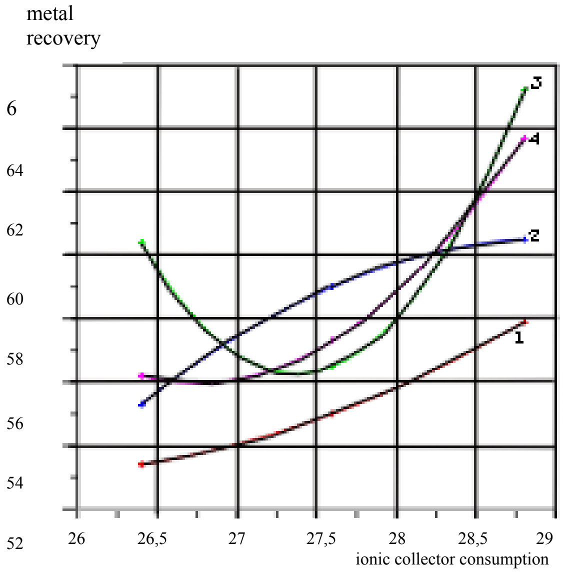
The specific consumptions were dosed 60 % to the rough flotation and 40 % to the scavenger flotation.

Results and discussion

The trials were carried out by using the bifactorial planning matrix of experiments, presented in Tab. 3¸ where x represents the ionic consumption and x' is the nonpolar collector is consumption.

The function "Y" is the metal recovery in the floated product because this parameter points out the influence of both variables and represents general processing index evaluating the flotation results.

The results are presented in Fig. 3. – 6. and represent the copper recoveries with the varying specific consumptions of ionic and nonpolar collectors.



Regression functions:

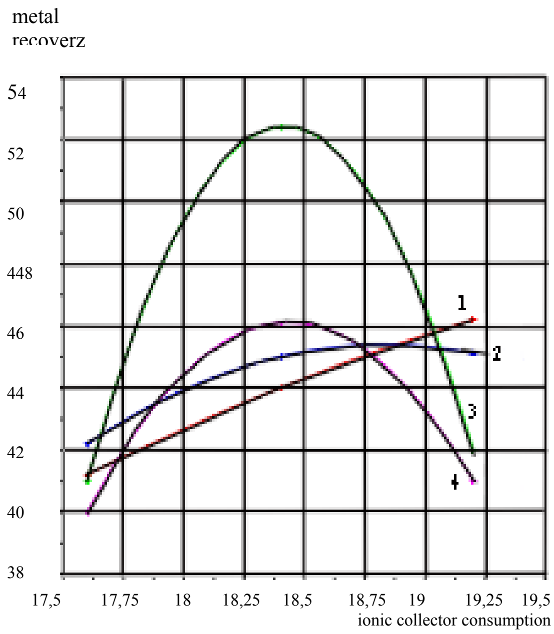
1 $y=347,1-23,042*x+0,451*x^2$

2 $y=582,7+44,333*x-0,764*x^2$

3 $y=3334-239,5*x+4,375*x^2$

4 $y=1372,9-98,458*x+1,840*x^2$

Fig. 3. The variation of the copper recovery with the ionic collector consumption, at different consumptions of unpolar oil (x', g/t) to the rough flotation



Regression functions:

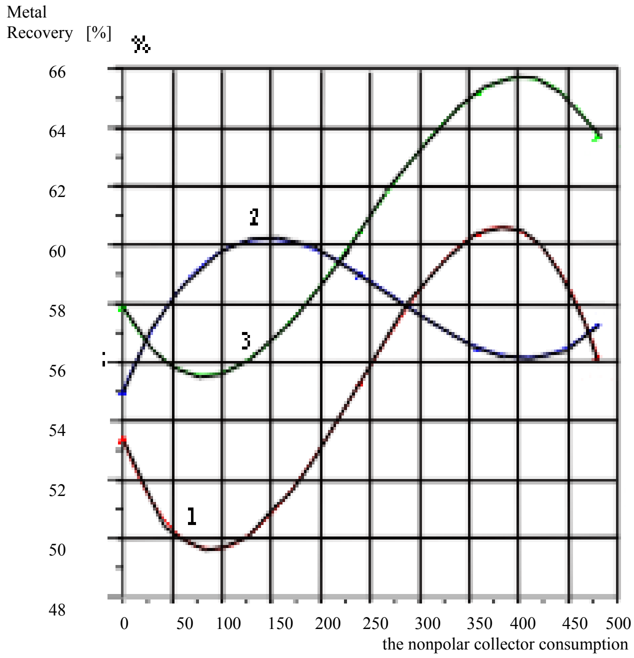
1 $y=172,2-20,375*x-0,469*x^2$

2 $y=702,5+79,438*x-2,109*x^2$

3 $y=-5725,2+627,375*x-17,031*x^2$

4 $y=-2927,8+322,625*x-8,75*x^2$

Fig. 4. The variation of the copper recovery with the consumption of ionic collector, at different consumptions of unpolar oil (x', g/t) in the scavenger flotation



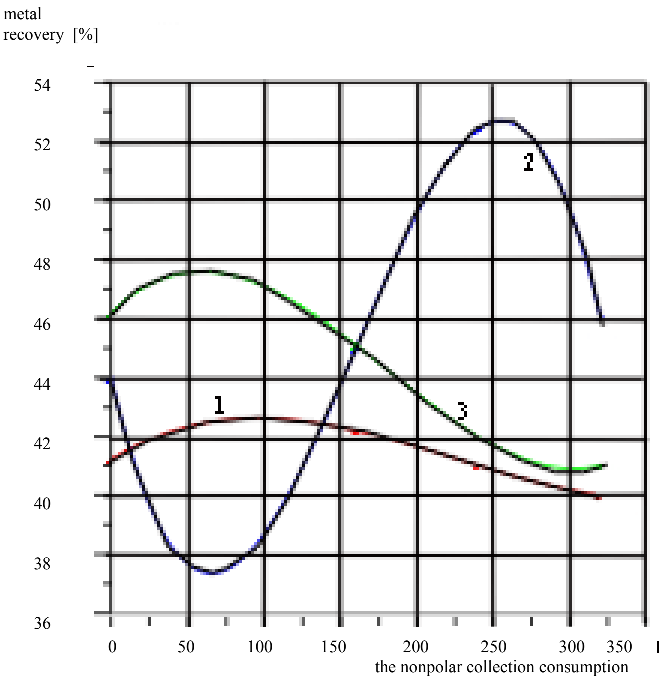
Regression functions:

1 $y=53,4 \ -0,091*x+0,00062*x^2-8,729E^{-7}*x^3$

2 $y=55+0,081*x-0,000378*x^2+4,557E^{-7}*x^3$

3 $y=-57,9-0,061*x+0,000446*x^2-6,125E^{-7}*x^3$

Fig. 5. The variation of the copper recovery with the consumption of nonpolar oil, at different consumptions of ionic collector (x, g/t) in the rough flotation



Regression functions:

1 $y=41,2 \ +0,032*x+0,00021*x^2-3,255E^{-7}*x^3$

2 $y=44-0,2228*x-0,00215*x^2-4,468E^{-7}*x^3$

3 $y=-46,2+0,049*x-0,000504*x^2+9,277E^{-7}*x^3$

Fig. 6. The variation of the copper recovery with the consumption nonpolar oil, at different consumptions of ionic collector (x , g/t) in the scavenger flotation

The metal recoveries obtained in the rough flotation (Fig. 3.) emphasize that all results with ionic and nonpolar collectors are better than those obtained without oil addition; more than that, for this flotation operation, the higher recoveries were obtained for highest collectors‘ consumptions.

The curves from Fig. 4., point out that in the scavenger flotation, the combination of the two collectors is efficient just to a specific consumption of ionic collector of 18,5 g/t; over this consumption, the results are worsening abruptly, as much as the unpolar collector consumption is higher. The explanation could be presence of tailings in the concentrate due to the excess of the collectors (ionic and unpolar).

Tab. 3. The matrix of bifactorial flotation trials of Y_{ij} is metal recovery in the floated product, corresponding to the i test and j trial; x_{ij} is the ionic collector consumption, corresponding to the i test and j trial; x'_{ij} is the unpolar collector consumption, corresponding to the i test and j trial.

Series	Rough flotation		Scavenger flotation	
	Y	**x, x'**	**Y**	**X, x'**
I.	$Y_{11} = 53,4$	$x_{11} = 26,4$ / $x'_{11} = 0$	$Y_{11} = 41,2$	$x_{11} = 17,6$ / $x'_{11} = 0$
	$Y_{12} = 55,0$	$x_{12} = 27,6$ / $x'_{12} = 0$	$Y_{12} = 44,0$	$x_{12} = 18,4$ / $x'_{12} = 0$
	$Y_{13} = 57,9$	$x_{13} = 28,8$ / $x'_{13} = 0$	$Y_{13} = 46,2$	$x_{13} = 19,2$ / $x'_{13} = 0$
II.	$Y_{21} = 55,3$	$x_{21} = 26,4$ / $x'_{21} = 240$	$Y_{21} = 42,2$	$x_{21} = 17,6$ / $x'_{21} = 160$
	$Y_{22} = 59,0$	$x_{22} = 27,6$ / $x'_{22} = 240$	$Y_{22} = 45,0$	$x_{22} = 18,4$ / $x'_{22} = 160$
	$Y_{23} = 60,5$	$x_{23} = 28,8$ / $x'_{23} = 240$	$Y_{23} = 45,1$	$x_{23} = 19,2$ / $x'_{23} = 160$
III.	$Y_{31} = 60,4$	$x_{31} = 26,4$ / $x'_{31} = 360$	$Y_{31} = 41,0$	$x_{31} = 17,6$ / $x'_{31} = 240$
	$Y_{32} = 56,5$	$x_{32} = 27,6$ / $x'_{32} = 360$	$Y_{32} = 52,4$	$x_{32} = 18,4$ / $x'_{32} = 240$
	$Y_{33} = 65,2$	$x_{33} = 28,8$ / $x'_{33} = 360$	$Y_{33} = 42,0$	$x_{33} = 19,2$ / $x'_{33} = 240$
IV.	$Y_{41} = 56,2$	$x_{41} = 26,4$ / $x'_{41} = 480$	$Y_{41} = 40,0$	$x_{41} = 26,4$ / $x'_{41} = 320$
	$Y_{42} = 57,3$	$x_{42} = 27,6$ / $x'_{42} = 480$	$Y_{42} = 46,1$	$x_{42} = 27,6$ / $x'_{42} = 320$
	$Y_{43} = 63,7$	$x_{43} = 28,8$ / $x'_{43} = 480$	$Y_{43} = 41,0$	$x_{43} = 28,8$ / $x'_{43} = 320$

The metal recoveries obtained in the rough flotation at the different unpolar collector consumption, mean that an increase of the consumption represent a better flotation results for any consumptions of the ionic collector, but only to a point (maximum), after that, the recoveries decrease.

The sinusoidal variantion is quite unusual but this aspect was maintained in all trials. This could represent a necessity of exact adjusting of both collectors in order to obtain a maximum effect on the metal recovery.

In the scavenger flotation, the results present the same variations and, also in this case, better results are obtained at lover unpolar consumptions.

Conclusions

1. The advantages of flotation columns recommend them to be used forpoor ores as those from Roşia Poieni, taking into account the advanced grinding fineness. The new installation IPROCELL type assures a very fine air bubbles formation, so useful for the very fine particles flotation.
2. The results in flotation columns, comparatively with those obtained in classical machines (the rough flotation), are better and indicate an increasing of the metal recoveries by 5-8 %.
3. The utilization of transformer oil as an nonpolar collector has a very good influence on the flotation results. Is is important to underline that in this stage of our research we can not establish if the positive effect of unpolar addition is caused by the particles hydrophobisation or by the formation of flocculation centers (as in the special flotation method by agglomeration).

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