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OPTIMIZING THE REAGENT REGIME DURING THE PHASE OF COARSE PB - ZN FLOTATION IN »ZLETOVO« — MINE PROBIŠTIP

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ОПТИМИРАЊЕ НА РЕАГЕНСНИОТ РЕЖИМ ВО ФАЗАТА НА ГРУБА Pb-Zn ФЛОТАЦИЈА ВО РУДНИКОТ „ЗЛЕТОВО“ — ПРОБИШТИП

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ABSTRACT

Optimizing the reagent regime during the phase of coarse Pb — Zn flotation in „Zletovo“ mine, Probištip is shown in this work supported by the modern investigations and the accomplishment of the mineral flotation.

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ABSTRACT

Optimizing the reagent regime during the phase of coarse Pb - Zn flotation in „Zletovo" mine, Probištip is shown in this work supported by the modern investigations and the accomplishment of the mineral flotation.

Introduction

The success in the selective flotation concentration process as the most important, and in industrial conditions the most common step in the flotation concentration of typical lead- zing ores, is first of all seen, in obtaining qualitative selective lead and zinc concentrations adequate for further metallurgical treatment with high metal recovery in the concentrations.

In order to achieve this, it is necessary to make maximum separation of lead minerals and zinc minerals during the phase of coarse lead flotation. If this is not reached, there will be an increase of zinc content in the lead concentration which has a double negative impact. Firstly, an increased zinc content in the lead concentration lowers its value down, and secondly the presence of zinc in lead concentration at the same time means its loss, because zinc from such concentration can not be efficiently recovered.

Having all this in mind, it is clear that the process of coarse flotation of lead minerals is the most significant segment in the whole process of selective flotation of lead-zinc minerals.

The most important factors which influence the effeciency of separation of lead minerals and zinc minerals during the phase of coarse flotation of lead among others are: the degree of opening of mineral raw material, pH and pulp density, the collector expenditure for zinc minerals and, by all means, the flotation time.

All this factors are more or less well examined for all deposits which are in the process of exploitation.

The aim of this work is optimizing the reagent regime during the phase of coarse Pb - Zn flotation in „Zletovo" - mine - Probištip in fact, to determine the optium collector and depressant expenditures.

In doing this we had in mind that it was not possible to optimize the expenditure of these reagents in a classical way, in other words, by expenditure change of one reagent along the constant change of another because of their mutual influence.

It is clear that in conditions where we have easily flotable sphalerite, and the optimum, collecting of sphalerite will be increased. On the other hand it means that a greater depressant expenditure will be necessary that itself may have a negative influence on collecting of galenite surfaces.

For this reason we made the optimizing of these parameters by the use of full factor plan, gradient of Box and Uilson method and we took the separation efficiency for the target function because the treated parameters mutually influence it.

Full Factor Plan of Experiments for The Two Factors

Changeable factors:

x_1 - collector expenditure KEX

x_2 - Depressant expenditure $ZnSO_4$: NaCN

The target process parameter (parameter that follows the influence of the given factors for the process) will represent the efficiency in the separation of lead minerals and zinc minerals, digitly shown as the difference between lead recovery and the distribution of zinc in the coarse lead concentration (I(%)Pb-R(%) Zn).

The zero regime (initial values for x_1 and x_2)

$x1 = 36$ g/t $\quad$ $x_2 = 100$ g/t $ZnSO4$: 24 g/t NaCN

These values were taken on the basis of the average expenditure of the mentioned factors in the last two years in „Zletovo" - Probištip flotation.

We accept the following variation intervals of changeable factors

$\Delta x_1 =$ g/t; $\quad$ $\Delta x_2 = 20$ g/t : 4 g/t

According to this, +1 and -1 are adequate to the following values of factors:

+1	-1
x_1 max = 42 g/t	x_1 min = 30 g/t
x_2 max = 120 g/t:28 g/t	x_2 min = 80 g/t:20 g/t

Our experimental plan is shown in the following table:

Table 1

Full factor plan of experiments for the two factors:

Number of assay	x_1	x_2
1	+ (42 g/t)	+ (120 : 28 g/t)
2	— (30 g/t)	+ (120 : 28 g/t)
3	+ (42 g/t)	— (80 : 20 g/t)
4	— (30 g/t)	— (80 : 20 g/t)

The dynamics of addition of changeable factors in the assay:
KEX - in the phase of conditioning 80%
- after the fourth minute of flotation 20%
The combination $ZnSO_4$: NaCN was added during the phase of grinding

Other constant conditions during separation of assay:
-fineness of opening in mineral raw material 65% - 0.074mm.
-pulp density - 25%
-conditioning time = 3 min.
-pH=8.6
-flotation time = 10 min.

All mentioned conditions agree with the conditions that prevail during the phase of initial flotation of lead minerals in „Zletovo" - Probištip flotation.

In the mentioned conditions experimental plan from Table 1 was repeated twice, in other words, two parallel series of four assays each were made in coarse lead mineral flotation and gave the following results:

— **First series of assays:**
E — represents the efficiency of Pb separation in relation to Zn
E' — represents the efficiency of Pb separation in relation to other minerals
E — I (%) Pb — I (%) Zn : E' = I (%) Pb — I (%) OM

Assay -1

Table 2

Prod.	T (%)	Pb (%)	Zn (%)	I (%) Pb	I(%)Zn	I (%) OM	E (%)	E' (%)
Input	100.00	5.73	1.90	100.00	100.00	100.00	47.00	89.91
K-Pb	13.00	42.18	7.13	95.75	48.75	5.84		
Un. flow	87.00	0.28	1.12	4.25	51.25	94.16		

Assay - 2

Table 3

Prod.	T (%)	Pb (%)	Zn (%)	I (%) Pb	I(%)Zn	I (%) OM	E (%)	E' (%)
Input	100.00	6.21	1.93	100.00	100.00	100.00	63.91	89.86
K-Pb	11.33	51.53	5.12	94.00	30.09	4.14		
Un. flow	88.67	0.42	1.52	6.00	69.91	95.86		

Assay - 3

Table 4

Prod.	T (%)	Pb (%)	Zn (%)	I (%) Pb	I(%)Zn	I (%) OM	E (%)	E' (%)
Input	100.00	5.27	1.88	100.00	100.00	100.00	35.32	87.36
K-Pb	13.33	37.13	8.28	93.92	58.59	6.55		
Un. flow	86.67	0.37	0.90	6.08	41.41	93.45		

Assay - 4

Table 5

Prod.	T (%)	Pb (%)	Zn (%)	I (%) Pb	I(%)Zn	I (%) OM	E (%)	E' (%)
Input	100.00	5.91	1.83	100.00	100.00	100.00	57.63	90.26
K-Pb	11.87	47.36	5.78	95.08	37.45	4.82		
Un. flow	88.13	0.33	1.30	4.92	62.55	95.18		

— Second series of assays:
E — represents the efficiency of Pb separation in relation to Zn
E' — represents the efficiency of Pb separation in relation to other minerals
E — I (%) Pb — I (%) Zn : E' = I (%) Pb — I (%) OM

Assay - 5

Table 6

Prod.	T (%)	Pb (%)	Zn (%)	I (%) Pb	I(%)Zn	I (%) OM	E (%)	E' (%)
Input	100.00	6.38	1.85	100.00	100.00	100.00	43.33	88.81
K-Pb	13.00	46.17	7.22	94.00	50.68	5.20		
Un. flow	87.00	0.44	1.05	6.00	49.32	94.80		

Assay - 6

Table 7

Prod.	T (%)	Pb (%)	Zn (%)	I (%) Pb	I(%)Zn	I (%) OM	E (%)	E' (%)
Input	100.00	6.04	1.72	100.00	100.00	100.00	60.93	89.48
K-Pb	11.33	50.05	4.99	93.84	32.91	4.35		
Un. flow	88.67	0.42	1.30	6.16	67.09	95.65		

Assay - 7

Table 8

Prod.	T (%)	Pb (%)	Zn (%)	I (%) Pb	I(%)Zn	I (%) OM	E (%)	E' (%)
Input	100.00	6.14	1.57	100.00	100.00	100.00	35.11	88.07
K-Pb	16.00	37.08	6.03	96.58	61.47	8.51		
Un. flow	84.00	0.25	0.72	3.42	38.53	91.49		

Assay - 8

Table 9

Prod.	T (%)	Pb (%)	Zn (%)	I (%) Pb	I(%)Zn	I (%) OM	E (%)	E' (%)
Input	100.00	5.64	1.87	100.00	100.00	100.00	54.74	89.97
K-Pb	11.20	47.49	6.60	94.33	39.59	4.36		
Un. flow	88.80	0.36	1.27	5.67	60.41	95.64		

As you can see in the first and the second (repeated) series of assays, except efficiency in Pb mineral separation in relation to Zn (E) minerals, which is our target function, we also followed the efficiency in Pb mineral separation in relation to other minerals (E').

It is quite clear that E' has high values in all assays which means that changeable factors x_1 and x_2 by no means influence this size. This situation is quite different when you follow the efficiency of Pb separation in relation to Zn minerals. The value of this size varies from assay to assay very much. This points out the fact that changeable factors x_1 and x_2 have a great influence on the size (E').

Bearing all this in mind, in the following pages we will make modelling of $E = f(x_1, x_2)$ dependence in the form of linear model in order to see the intensity of influence by changeable factors on the target function and to determine the gradient that we will follow in order to obtain its optium values.

Experimental plan with the obtained results is shown in Table 10.

Table 10

Assay number	x_0	x_1	x_2	E_1	E_2	$E_{3r.}$	$E_{r.}$	ΔE
1	+	+	+	47.0	43.3	45.1	44.2	0.9
2	+	—	+	63.9	60.9	62.4	63.3	—0.9
3	+	+	—	35.3	35.1	35.2	36.1	—0.9
4	+	—	—	57.6	54.7	56.1	55.2	0.9

The experimentation plan was repeated twice.

The results of the separation efficiency of Pb in relation to Zn minerals are shown in columns E_1 and E_2. The model was estimated for medium values of Esr as follows:

$$b_0 = 1/4 \,.\, (45.1 + 62.4 + 35.2 + 56.1) = 49.70$$
$$b_1 = 1/4 \,.\, (45.1 - 62.4 + 35.2 - 56.1) = -9.55$$
$$b_2 = 1/4 \,.\, (45.1 + 62.4 - 35.2 - 56.1) = 4.05$$

According to this, the mathematical model of the process of coarse lead flotation expressed through the separation efficiency of Pb and Zn minerals and depending upon the factors x_1 (expenditure KEX) and x_2 (expenditure $ZnSO_1$/NaCN), in conditional units is the following (polynome of first degree):

$$E = 49.70 - 9.55\, x_1 + 4.05\, x_2$$

According to Kohren's, Studen's, Student's and Fisher's criterion we made analysis of model and found as follows:

-coefficients b_0, b_1 and b_2 are considered as important and

-the model is appropriate.

This means that observed process is described correctly by the polynome of first degree and the difference which appears between the experimental and mathimatical results is fortuitous.

Analysis of the Obtained Results

On the basis of the experimental results and the obtanied mathematical model we may come to the following conclusion:

-The efficiency of the process of coarse lead flotation, expressed through the efficiency of the separation of lead and zinc minerals, in relation to the factors x_1 (collector expenditure KEX) and x_2 depressant expenditure $ZnSO_4$/NaCN) in conditional units, can successfully be modelled mathematically by the polynome of first degree:

$$E = 49.70 - 9.55\, x_1 + 4.05\, x_2$$

- Both analysed factors (collector expenditure KEX and depressant expenditure $ZnSO_4/NaCN$) exert an influence on the separation efficiency of Pb and Zn minerals during the coarse flotation phase of lead. Here, the influence of collector expenditure factor is nearly twice as great compared to the depressant expenditure. This is supported by the coefficient values ahead of the mentioned factors in the mathematical model. In fact, the absolute coefficient value b_1 which relates the collector expenditure is 9.55, while the absolute value of coefficient $b_2$which relates to the depressant expenditure is 4.05.

- Our former conclusion can also be seen in the results of four assays from the two parallel series. In the first and the assay of both series (assays 1 and 3 and assays 5 and 7), where the collector expenditure is constant and maximum (42 g/t) and the depressant expenditure variable, the decrease of depressant expenditure increases the loss of zinc in the basic lead concentration by tens of percentage units: from 48.75 % (assay 1) to 58.59% (assay 3) or from 50.68% (assay 5) to 61.47 % (assay 7). On the other hand, in the first and the second assay in both series (assay 1 and 2 and assay 5 and 6), where the depressant expenditure is constant and maximum, the decrease in collector expenditure decreases the distribution of zinc in the coarse lead concentration by twenty percentage units: from 48.75 % (assay 1) to 30.10 % (assay 2) or 50.68% (assay 5) to 32.91 % (assay 6). A more explicit relation about the influence of collector or depressant expenditure change is obtained if we observe the second and the fourth (assays 2 and 4 and assays 6 and 8) in the same way in both series. In every assay the lead recovery in basic concentration is very high. All this proves that collector expenditure has twice as greater influence on the efficiency of Pb and Zn mineral separation than the depressant expenditure.

- In order to achieve optimum efficiency in Pb and Zn mineral during the coarse lead flotation a further decrease of collector expenditure is needed, and at the same time a further increase of depressant expenditure.

In this process it is necessary to decrease the collector expenditure from assay to assay by twice as great speed than the increase of depressant expenditure.

DETERMINATION OF OPTIMUM COLLECTOR EXPENDITURE (KEX) AND DEPRESSANT ($ZnSO4/NaCN$)

On the basis of the analysed mathematical model we made another series of four assays. Basides the constant conditions that were equal to those from the first and the second series, in this assay the collector expenditure was decreased from assay to assay and the depressant expenditure was increased.

Collector expenditure KEX and the depressant $ZnSO_4$/NaCN in individual assays was the following:

Assay number	expenditure KEX	expenditure ZnSO4/NaCN
1	24 g/t	130 g/t : 30 g/t
2	18 g/t	140 g/t : 32 g/t
3	15 g/t	150 g/t : 33 g/t
4	12 g/t	150 g/t : 34 g/t

It is clear that the rate of expenditure decrease KEX in relation to the speed of expenditure increase $ZnSO_4$/NaCN from assay to assay was twice as greater.

In Fact, in the first and the second assay KEX expenditure was decreased by 0.5.x_1 value, while the $ZnSO_4$/NaCN expenditure was increased by 0.5.x_2. In the third and the fourth assay Kex expenditure was decreased by 0.5. x_1 value, while $ZnSO_4$/NaCN expenditure was increased by 0.25. x_2. In this way we go along previously determined gradient towards the optimum region.

- Third series of assays:
E — represents the efficiency of Pb separation in relation to Zn
E' — represents the efficiency of Pb separation in relation to other minerals
E — I (%) Pb — I (%) Zn : E' = I (%) Pb — I (%) OM

Assay - 9 **Table 11**

Prod.	T (%)	Pb (%)	Zn (%)	I (%) Pb	I(%)Zn	I (%) OM	E (%)	E' (%)
Input	100.00	5.82	1.71	100.00	100.00	100.00	60.42	90.15
K-Pb	11.67	47.40	5.08	94.99	34.58	4.85		
Un. flow	88.33	0.33	1.27	5.01	65.42	95.15		

Assay - 10 **Table 12**

Prod.	T (%)	Pb (%)	Zn (%)	I (%) Pb	I(%)Zn	I (%) OM	E (%)	E' (%)
Input	100.00	5.78	1.64	100.00	100.00	100.00	65.34	89.08
K-Pb	12.13	45.14	3.97	94.68	29.34	5.60		
Un. flow	87.87	0.35	1.32	5.32	70.66	94.40		

Assay - 11

Table 13

Prod.	T (%)	Pb (%)	Zn (%)	I (%) Pb	I(%)Zn	I (%) OM	E (%)	E' (%)
Input	100.00	5.78	1.71	100.00	100.00	100.00		
K-Pb	12.33	44.45	4.12	94.84	29.72	5.78	65.12	89.07
Un. flow	87.67	0.34	1.37	5.16	70.28	94.22		

Assay - 12

Table 14

Prod.	T (%)	Pb (%)	Zn (%)	I (%) Pb	I(%)Zn	I (%) OM	E (%)	E' (%)
Input	100.00	4.90	1.68	100.00	100.00	100.00		
K-Pb	11.00	40.85	4.41	91.65	28.91	5.54	62.74	86.11
Un. flow	89.00	0.46	1.34	8.35	71.09	94.46		

Analising the results from the third series of assays it is clear that in the second assay we have a signifacant increase of separation efficiency of Pb and Zn minerals in coarse lead flotation in relation to the first assay. In the third assay the value is closely equal to the second, while in the fourth assay it significantly decreases.

This means that between the second and the third assay we obtain maximum value in the separation efficiency of Pb and Zn minerals. After that, during the fourth assay, there is a decline because of the significant decrease in lead recovery in coarse Pb concentration, although zinc recovery in the same product decreases further on. This shows that collector concentration in the pulp in the fourth assay was below the minimum necessary in order to achieve collecting of all mineral grains of lead bearers.

Bearing this in mind we may come to the conclusion that the optium KEX collector expenditure in the coarse Pb flotation is 18 g/t, and the optium expenditure of $ZnSO_4/NaCN$ depressant is 140 g/t : 32 g/t.

CONCLUSION

Considering the completed laboratory examinations and the obtained mathematical model for coarse lead mineral flotation expressed by the efficiency of Pb and Zn mineral separation ($E = 49.70 - 9.55x_1 + 4.05x_2$) it follows that:

- Collector expenditure (KEX) has almost twice as great an influence on the efficiency of lead and zinc mineral separation than the depressant expenditure for zinc minerals ($ZnSO_4/NaCN$).

This leads to the fact that even a small increase in collector expenditure in the pulp above the optium causes collecting of zinc mineral surfaces (sphalerite). This is supported by the modern investigations according to which for the mineral flotation, in this case it is galenite, a small or „practical" xanthate concentration is necessary because its surplus remains in the pulp and may cause undesirable effect during the selective flotation process;

- Optimum collector expenditure (KEX) in the coarse lead mineral flotation of Pb - Zn ore from „Zletovo" mine - Probištip is about 18 g/t. The collector expenditure has been checked in process conditions of the plant flotation and the obtained results point out the significant improvement in lead mineral and zinc mineral separation during the phase of coarse lead mineral flotation;

- Optium depressant expenditure ($ZnSO_4$/NaCN) of zinc minerals (sphalerite), during the process of coarse lead mineral flotation from the same raw material is about 140 g/t : 32 g/t.

РЕЗИМЕ

ОПТИМИРАЊЕ НА РЕАГЕНСНИОТ РЕЖИМ ВО ФАЗАТА НА ГРУБА Pb-Zn ФЛОТАЦИЈА ВО РУДНИКОТ „ЗЛЕТОВО" - ПРОБИШТИП

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Ефикасноста на процесот на селективна флотациска концентрација, како најзначајна и, во индустриски услови, најприсутна постапка за валоризација на типичните оловно-цинкови руди, се огледа пред сè, во добивањето на квалитетни селективни концентрати на олово и цинк погодни за натамошна металуршка преработка, со високо искористување на металите во тие концентрати. За да се постигне ова, неопходно е, покрај другото да се изврши максимална сепарација (раздвојување) на оловните и цинковите минерали во фазата на груба и оловна флотација. Ако ова не се направи, ќе дојде до зголемување на содржината на цинк во оловниот концентрат, што ќе предизвика двоен негативен ефект. Прво, зголемената содржина на цинк во оловниот концентрат ја намалува неговата вредност и, второ, присуството на цинк во оловниот концентрат претставува истовремено и негова загуба, бидејќи цинкот од ваквиот концентрат не може ефикасно да се искористи. Имајќи го сетоова предвид, јасно е дека процесот на грубо флотирање на оловото претставува најзначаен сегмент во целокупниот процес на селективно флотирање на типичните оловно- цинкови руди.

Во рамките на овој труд, со помош на полн факторски план на експерименти на флотирање (градиентна метода на Boks и Uilson), извршено е математичко моделирање, со полином од прв ред, на зависноста на ефикасноста на сепарацијата (раздвојувањето) на оловните и цинковите минерали од потрошувачката на колектор KEX и потрошувачката на деприматор за цинковите минерали ZnSO4/NaCN. Врз основа на добиениот математички модел, со додатна серија на опити, извршено е оптимирање на потрошувачката на колектор KEX и деприматор (за цинковите минерали) ZnSO4/NaCN. На овој начин определени се оптималните количини од овие реагенси што треба да се додаваат во фазата на грубо флотирање на Pb-Zn-минералите, за да се постигне нивно максимално раздвојување, односно да се добие груб оловен концентрат со што помала содржина на цинк во него.

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