UNIVERSITY OF NOVI SAD
TECHNICAL FACULTY "MIHAJLO PUPIN"
ZRENJANIN
REPUBLIC OF SERBIA

VIII INTERNATIONAL CONFERENCE OF

INFORMATION TECHNOLOGY AND DEVELOPMENT OF EDUCATION ITRO 2017

PROCEEDINGS OF PAPERS

VIII MEĐUNARODNA KONFERENCIJA

INFORMACIONE TEHNOLOGIJE I RAZVOJ OBRAZOVANJA ITRO 2017

ZBORNIK RADOVA

ZRENJANIN, JUNE 2017

Publisher and Organiser of the Conference:
University of Novi Sad, Technical faculty „Mihajlo Pupin", Zrenjanin, Republic of Serbia

For publisher:
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Printed by:
Printing office Donat Graf d.o.o, Mike Alasa 52, Beograd

Circulation: **50**
ISBN: 978-86-7672-302-7

By the resolution no. 142-451-2481/2017-01/02, Autonomous Province of Vojvodina, Provincial Secretariat For Science and Technological Development donated financial means for printing this Conference Proceedings.

The Conference is supported by the Autonomous Province of Vojvodina

CIP - Каталогизација у публикацији
Библиотека Матице српске, Нови Сад

37.01:004(082)
37.02(082)

INTERNATIONAL Conference on Information Technology and Development of Education ITRO (8 ; 2017 ; Zrenjanin)
Proceedings of papers / VIII International Conference on Information Technology and Development of Education ITRO 2017 = Zbornik radova = VIII Međunarodna konferencija Informacione tehnologije i razvoj obrazovanja ITRO 2017, June 2017, Zrenjanin. - Zrenjanin : Technical Faculty "Mihajlo Pupin", 2017 (Beograd : Donat graf). - XIII, 290 str. : ilustr. ; 30 cm

Tekst štampan dvostubačno. - Tiraž 50. - Str. VI: Introduction / Dragana Glusac. - Bibliografija uz svaki rad.

ISBN 978-86-7672-302-7

a) Информациона технологија - Образовање - Зборници b) Образовна технологија - Зборници
COBISS.SR-ID *315769095*

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With this publication, the CD with all papers from the International Conference on Information Technology and Development of Education, ITRO 2017 is also published.

Big data analysis and application of experimental research in the higher education process

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Abstract - This paper provides an experimental approach to express a simple and engaging framework for familiarizing students with the process of quality and quantity management in engineering research. In this article, it's illustrated how experiments can be used in the classroom environment by describing a module that is implemented in high educational classrooms. The module familiarized students with how the scientific methods and mathematical methods can be applied to scientific questions and introduced them to basic mathematical concepts for resolving a technical, economical or other social issues. This specific paper can serve as a model for how more complex and rigorous experimental designs can be used to actively engage more advanced (high educational-level) students in the process of research design and statistical analysis.

I. INTRODUCTION

In everyday work, constantly present problem of deciding the next step in the procedure. Making a decision in the past was often based on "experience" and "common sense" rather than scientific grounds. It remains the possibility decision to adopt intuitively (simpler cases or complex problems), relying on experience and common sense, but it is unlikely that such a decision would be best. Taking all this into account it appears that in complex interventions, as well as those who hire large financial and material resources, cannot be permitted without prejudice to such freedom in decision making. Then it is necessary first to carry out calculations and based on it to bring the best i.e. optimal decision. The scientific discipline concerned with the scientific foundations of the decision in the organization and provision of manufacturing operations is called operational research. Greatly contributed to the good survey have and implementation of experiments and analysis of large data and information.

Bo about varietal functions in the field of planning and operative is a new set of problems which are called "problem of execution" and appear in conflict to functional units. In solving these problems, it is necessary to use certain measures or a system of actions that predict and are based on clear principles and have a purpose. The operation we call each of the measures or a system of shares, which are united in one idea, are aimed at achieving a particular goal. Operations are actually measures the management, and they are the work of the human mind. The selection of the parameters that characterize the manner of implementation and organization of the operation depends on the expert. Organization term covers a selection of subjective and technical means into action.

The accepted selection of parameters that depends on man called solution. They can be: positive, negative, reasonable, unreasonable and the like. The solution has the advantage over the other is called an optimal solution. Decision that is best for the organization is called the optimal decision. It is the best in terms of function of a part of the organization is called suboptimal decision.

II. GIVEN EXAMPLE OF REAL INDUSTRIAL PROCESS – EXPERIMENTS TAKEN FROM A COMPLEX

The previous carried out laboratory investigations with application of the new collectors CYTEC and frothers confirmed that there is possibility for significantly improvement of the gold recovery with same copper quality and decreasing of the CaO consumption. The investigations with reagents Aerophine 3404, Aero XD 5002 and frother OP-F49 in the previous period (2010) were very short because of the low quality and variations of the ores. Variations of the ore from 0.15-0.22 % Cu, instability of the flotation and other problems in the flotation process. The combination of the Aerophine 3404, KEX:KBX=

1:1, NaIPX, SKIK Bz 2000, in the different points of the flotation process gave significantly better results that early. The process was prolonged with pH=10.5 and the point of addition of CaO was at the hydro cyclone (70%) and 30 % in the flotation process. The conclusions of these investigations were very heavy for sure confirmation, bur the obtained results were close to the previous results by standard conditions (especially for Au), may be better but not significantly. The Au content in the ore was from 0, 19-0, 29 gr/t, in the concentrate 8-12.3 gr/t, with Au recovery from 45-55 % (some appearances up to 60 %), but the copper recovery in the standard interval. Considering these investigations in laboratory and industrial real conditions may be concluded that:

- The instability and relative short period of investigations in the real conditions have contributed for obtaining the technological parameters closed to the standard conditions,
- As a result of the good regrinding, it was very heavy to clean the rough concentrate Cu/Au,
- Using higher pH, higher than standard in the rougher flotation (elimination of pyrite flotation) by Aerophine 3404, it will be expected higher quality and content of Cu/Au,
- In the existing real conditions of flotation at pH 11.0-11.6 and consumption of Aerophine 3404 (AP3404) from 18-22 gr/t, together with change of adaptive changeable reagent regime by different collectors (the combination from Aerophine 3404, KEX:KBX, NaIPX),
- The prolonged changes of the reagent regime with contemporary addition of new reagents (Bz 2000 = 4-8 gr/t + KEX:KBX=1:1 = 8-4 gr/t, total 12 gr/t) in the grinding cycle, together with addition of NaIPX in the condiotioner with 8-10 gr/t, in the flotation process (rougher and controlled flotation) with 2-4 gr/t, or total addition of 14 gr/t NaIPX,
- The results of the technological parameters of the process in real terms has not suffered significant improvements over conventional conditions.

III. MATERIALS AND METHODS

Based on tests performed in laboratory and industrial conditions in the flotation of copper Mine come to the conclusion that future research should be directed towards the optimization with optimization methods that you get to optimize reagent regime. So, based on industry - zero baseline laboratory values of the collectors in the flotation stages analysis is conducted using optimization technique.

Zero starting values of the collectors in the flotation stages:

- X1 - consumption collector NaIPX = 12 gr/t
- X2 - consumption collector KBX: KEX = 1: 1 = 8 gr/t
- X3 - consumption collector SKIK 2025 = 4 gr/t

Variables collectors in various stages of flotation:

- ΔX1 - consumption collector NaIPX ± 3 gr/t
- ΔX2 - consumption collector KBX: KEX = 1: 1 ± 2 gr/t
- ΔX3 - consumption collector SKIK 2025 ± 1 gr/t

TABLE 1. Tests with a plan experiments

Ex.	X_1	X_2	X_3	I_{Cu}%
1	+	+	+	
2	+	-	+	
3	-	+	+	
4	-	-	+	
5	+	+	-	
6	+	-	-	
7	-	+	-	
8	-	-	-	

TABLE 2. Tests with a plan experiments – Bucim Mine

Ex.	X_o	X_1	X_2	X_3	I_1	I_2	$I_{Cu}\%_{sr}$
1	+	15	10	5	90.13	89.05	89.59
2	+	15	6	5	90.52	87.90	89.21
3	+	9	10	5	89.18	88.80	88.99
4	+	9	6	5	86.66	87.22	86.94
5	+	15	10	3	89.10	87.22	88.16
6	+	15	6	3	88.60	90.48	89.54
7	+	9	10	3	88.90	89.62	89.26
8	+	9	6	3	88.00	87.08	87.54

The remaining operating parameters (pH = 11.72, 55-60 % - 0.074 mm during flotating (12 min) and conditioning (6 min)) as standard in industry. Performed two parallel investigations.

The coefficients of the linear model of values for the use of copper in concentrate ICu % are:

b_0= 1/n [89.59+89.21+88.99+86.94+88.16+89.54+89.26+87.54] = 88.65
b_1= 1/n [89.59-89.21+88.99-86.94+88.16-89.54+89.26-87.54] = 0.346
b_2= 1/n [89.59+89.21-88.99-86.94+88.16+89.54-89.26-87.54] = 0.47
b_3= 1/n [89.59+89.21+88.99+86.94-88.16-89.54-89.26-87.54] = 0.03
b_{12}= 1/n [89.59-89.21-88.99+86.94+88.16-89.54-89.26+87.54] = - 0.596
b_{13}= 1/n [89.59-89.21+88.99-86.94-88.16+89.54-89.26+87.54] = 0.26
b_{23}= 1/n [89.59+89.21-88.99-86.94-88.16-89.54+89.26+87.54] = 0.24
b_{123}= 1/n [89.59-89.21-88.99+86.94-88.16+89.54+89.26-87.54] = 0.18

(1)

According to the above tables and results (n = 1/8), a mathematical model of the process of chalcopyrite flotating expressed by using copper concentrate ICu %, depending on the x_1 (consumption collector NaIPX), x_2 (consumption collector KBX: KEX = 1: 1) and x_3 (consumption collector SKIK 2025), in arbitrary units has the following view (first order polynomial):

$$ICu\% = 88.65+0.346x1+0.47x2+0.03x3-0.596x1x2+0.26x1x3+0.24x2x3+0.18x1x2x3 \quad (2)$$

IV. CHECK THE SIGNIFICANCE OF THE MODEL COEFFICIENTS

The error reproducibility of the model coefficients is:

$$S_{bj} = \frac{S_{rIsr.}}{\sqrt{n}} \frac{0{,}514}{\sqrt{8}} = \frac{0{,}514}{2{,}8284} = 0{,}18 \quad (3)$$

Border significant value of the coefficients is:

$$\left|b_j\right|_g = t \cdot S_{bj} = 2{,}306 \cdot 0{,}18 = 0{,}41 \quad (4)$$

where is:
t – criterion Student p = 95 %; t = 2.306
Considering the limit of the coefficients (0.41), the linear model would have shown below formula with coefficients b_0, b_2 and b_{12}. However, if we consider process in real terms (b_1 = 0.346 or 84.4 % of the absolute limit of 0.41), you should take this as an important factor in the equation.

$$Icu\ \% = 88.65 + 0.47x_2-0.596x_1x_2 \quad (5)$$

Given the resulting linear model and significance of x1 and x2 parameters for the conduct of the process of flotating as influential factors coefficient before x1 which is below the limit value of 0.41 is taken as an important factor and therefore definitive view of mathematical model of the process serious flotating copper, expressed through the exploitation of minerals of copper, arbitrary units are as follows:

$$ICu\ \% = 88.65 + 0.346x_1 + 0.47x_2-0.596x_1x_2 \quad (6)$$

V. FULL FACTORIAL PLAN OF EXPERIMENTS FOR THREE FACTORS IN BUCIM MINE

The plan of experiments is carried out for existing regent regime in the flotation plant in Bucim mine. The obtained result are given in the following table 3:

TABLE 3. Tests with a plan experiments

Ex.	X_o	X_1	X_2	X_3	I_1	I_2	$I_{Cu}\%_{sr}$	I_{pres}	ΔI
1	+	15	10	5	90.13	89.05	89.59	88.87	0.72
2	+	15	6	5	90.52	87.90	89.21	87.93	1.28
3	+	9	10	5	89.18	88.80	88.99	88.18	0.81
4	+	9	6	5	86.66	87.22	86.94	87.24	-0.30
5	+	15	10	3	89.10	87.22	88.16	90.06	-1.90
6	+	15	6	3	88.60	90.48	89.54	89.12	0.42
7	+	9	10	3	88.90	89.62	89.26	89.37	-0.11
8	+	9	6	3	88.00	87.08	87.54	88.43	-0.89

Considering the obtained results will be carried out analysis of the obtained linear model, establishing his adequate. As the model is obtained based on the mean values of recoveries, then the productivity error for the mean values will be:

$$\overline{S}^2_{rIsr.} = \frac{\begin{bmatrix} (90{,}13-89{,}05)^2 + (90{,}52-87{,}90)^2 + (89{,}18-88{,}80)^2 + (86{,}66-87{,}22)^2 \\ + (89{,}10-87{,}22)^2 + (88{,}60-90{,}48)^2 + (88{,}90-89{,}62)^2 + (88{,}00-87{,}08)^2 \end{bmatrix}}{64}$$

$$\overline{S}^2_{rIsr.} = 0{,}264; \text{ or } \overline{S}_{rIsr.} = \sqrt{0{,}264} = 0{,}514 \quad (7)$$

VI. ADEQUATE MODEL CHECKING

After the estimation of the investigated model, it needed to calculate the mean result of each test, and instead x_j in the mentioned model we will put appropriate conditioned units of the test (± 1):

$I_{pres.1}$ = *88.65 +0.346 (+1) + 0.47 (+1) – 0.596 (+1) = 88.87*
$I_{pres.2}$ = *88.65 +0.346 (+1) + 0.47 (-1) – 0.596 (+1) = 87.93*
$I_{pres.3}$ = *88.65 +0.346 (-1) + 0.47 (+1) – 0.596 (+1) = 88.18*
$I_{pres.4}$ = *88.65 +0.346 (-1) + 0.47 (-1) – 0.596 (+1) = 87.24*
$I_{pres.5}$ = *88.65 +0.346 (+1) + 0.47 (+1) – 0.596 (-1) = 90.06*
$I_{pres.6}$ = *88.65 +0.346 (+1) + 0.47 (-1) – 0.596 (-1) = 89.12*
$I_{pres.7}$ = *88.65 +0.346 (-1) + 0.47 (+1) – 0.596 (-1) = 89.37*
$I_{pres.8}$ = *88.65 +0.346 (-1) + 0.47 (-1) – 0.596 (-1) = 88.43*

(8)

In the above table are given errors $\Delta I = I_{sr.} - I_{pres.}$, and the model adequate may be checked by Fischer criteria:

$$F = \frac{\left[\sum_{i=1}^{N} I_{sr.i}^2 - N \cdot \sum_{i=0}^{k} b_i^2\right]}{(N-k-1)\cdot S_{rIsr.}} \tag{9}$$

Where: k – number of linear members in the mentioned model. In our case, we will have:

$$F = [89.59^2 + 89.21^2 + 88.99^2 + 86.94^2 + 88.16^2 + 89.54^2 + 89.26^2 + 87.54^2] - 8[88.65^2 + (0.346)^2 + 0.47^2 + (0.03)^2 + (-0.596)^2 + 0.26^2 + 0.24^2 + 0.18^2] / 5 * 0.514;$$
$$F = 2.157 \tag{10}$$

For $f_b = 8-2-1 = 5$ and $f_r = 8(2-1) = 8$, for confidential level p = 95 % =3.69, and Student = 2.306, Fischer criteria:

$$F^* = f_r + p + t = 8 + 3.69 + 2.306 = 13.996. \tag{11}$$

As $F << F^*$, the model is adequate. It means that investigated process is correct described by means of polynomial of the first order and the difference which is appeared between experimented and estimated results is accidental.

VII. THE DETERMINATION OF THE OBTAINED LINEAR MODEL GRADIENT FOR REAGENT REGIME IN THE FLOTATION PLANT IN BUCIM MINE

The gradient method is based on the fact that biggest degree of improvement for a function is achieved if the progressive by the length of the gradient. As this direction is direction of the steeper gradient, then we are talking about for maximum, or the direction of the steeper fall. In fact, the gradient is vector for a point of the n-dimensional space. This one is determined by the determination of the first derivations of the aim function in the relationship of their changeable factors. It is important to note that the gradient direction is a local, not a global property. If we suppose that the function $y(x_1, x_2,)$ which has had continuous partial derivations, then there is the point (x_1, x_2), around which for a little small change in the every one direction will be obtained the following estimation.

$$\frac{df}{dx_1}(x_1, x_2) = \frac{df(88.65 + 0.346\,x_1 + 0.47x_2 - 0.596x_1x_2)}{dx_1} = -4.422$$

$$\frac{df}{dx_2}(x_1, x_2) = \frac{df(88.65 + 0.346\,x_1 + 0.47x_2 - 0.596x_1x_2)}{dx_2} = -6.68$$

$$m_1 = \frac{\frac{df}{dx_1}(x_1)}{\sqrt{(\frac{df(x)}{dx_1})^2 + (\frac{df(x)}{dx_2})^2}} = \frac{-4.422}{8.012} = -0.55$$

$$m_2 = \frac{\frac{df}{dx_1}(x_2)}{\sqrt{(\frac{df(x)}{dx_1})^2 + (\frac{df(x)}{dx_2})^2}} = \frac{-6.682}{8.012} = -0.83 \tag{12}$$

The direction will be shown as a vector φ marked with n numbers $(m_1, m_2 \ldots m_n)$.

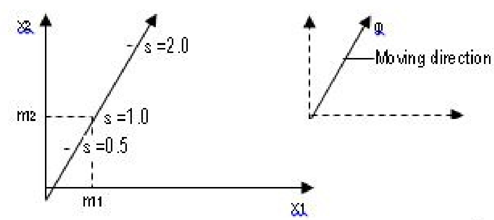

Figure 1. Direction of search

$$\frac{m_1}{m_2} = \frac{-0.55}{-0.83} = 0.663$$
$$m_1 \cdot \Delta x_1 = -0.55 \cdot 3 = -1.65$$
$$m_2 \cdot \Delta x_2 = -0.83 \cdot 2 = -1.66 \tag{13}$$

Obviously, we are in the direction of the gradient and the variable x_1 and x_2 should be set moderately to one another, because b12 interaction coefficient with its sign shows it.

Standard deviation $\boldsymbol{\sigma} = \sqrt{\frac{\sum \Delta I^2}{7}} = \mathbf{1.03}$

By the analysis of the linear model of polynomial of the first order for copper recovery from the chalcopyrite ore, above mentioned equations for carried out investigations by decreasing of the collector (x_1– NaIPX) and with increasing of the (x_2– KEX:KBX=1:1), we'll be obtained following results in table 4.

TABLE 4. Tests with a plan experiments

I_1	I_2	$I_{Cu}\%_{sr}$	I_{pres}	ΔI	ΔI^2	$\Delta I^2/7$
90.13	89.05	89.59	88.87	0.72	0.52	
90.52	87.90	89.21	87.93	1.28	1.64	
89.18	88.80	88.99	88.18	0.81	0.65	
86.66	87.22	86.94	87.24	-0.30	0.09	**1.07**
89.10	87.22	88.16	90.06	-1.90	3.61	
88.60	90.48	89.54	89.12	0.42	0.17	
88.90	89.62	89.26	89.37	-0.11	0.01	
88.00	87.08	87.54	88.43	-0.89	0.79	

TABLE 5. Tests with a plan experiments

Exam	X_1	X_2	I_1	I_2	$I_{Cu}\%_{sr}$
1	11.5	10.5	90.0	89.2	89.6
2	11.5	9.5	90.4	90.0	90.2
3	9.5	10.5	90.1	89.3	89.7
4	9.5	9.5	89.7	89.3	89.5
5	11.5	10.5	89.2	89.2	89.2
6	11.5	9.5	89.2	90.0	89.6
7	10	10.5	90.4	90.2	90.2
8	9.5	9.5	88.7	88.3	88.5

The other working parameters (pH=11.72, 55÷60 % - 0.074 mm, flotation time 12 min and time of conditioning 6 min and X3 = 4÷6 gr/t) are standard as in the real industrial conditions. The copper recovery in the ICu %sr is optimal or need minimum decreasing of collector consumption of NaIPX = 10-11.5, and increasing of KBX: KEX=1:1 = 9.5÷10.5 gr/t, according to the influence of the feed ore quality, bigger content of copper in the feed, bigger consumption of the collectors.

VIII. Conclusion

In this paper is shown optimization techniques with formatting the mathematical model and adequate model for carried out investigations. Obtained tabular results and figures will show the optimal quantity in reagent regime (collectors), particle size, flotation time for rougher flotation, conditioning time etc.

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