Establishment of the Relationship between Productivity and Technological Parameters of the Process of Grinding Ore in Ball Mills

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Annotation. The mining industry is one of the main links in the industry of Azerbaijan and one of the main directions in the non-oil sector. Two companies operate here - Azerbaijan International Mining Company and AzeriGold, which are the determining factors in the country's gold mining.

The article discusses the current state and development prospects of this industry. A regression equation is proposed that allows us to establish a relationship between the performance of ball mills and the technological parameters of the grinding process. It was found that the trajectory of the motion of the balls in a complex manner depends on the parameters studied.

Keywords. mining industry, gold mining, silver, copper, natural resources, technological parameters, minerals.

I. INTRODUCTION.

The Republic of Azerbaijan is a country with rich natural resources. Despite the fact that the main share of mining in Azerbaijan is oil and gas, in recent years, industries such as the extraction of non-ferrous metals and their processing have been successfully developing.

Currently, the country's mining industry is one of the main directions in the non-oil sector and two companies operate here - Azerbaijan International Mining Company (2007) and AzeriGold (2015) [1, 2].

Table 1 shows the level of extraction of gold in 2013-2018.

Table 1 Level of extraction of gold in 2013-2018

Method name	Capacity, in tones	Average annual fineness sample, in g/ton	ounce *, in kg**
2013			
Heap leach	486060	1.26	52063*
Leaching by agitation	357105	3.72	1674.05**
2014			
Heap leach	572127	1.25	60202
Leaching by agitation	618468	2.93	1935.75

2015			
Heap leach	401496	1.47	71673
Leaching by agitation	596626	3.43	2304.69
2016			
Heap leach	419436	1.3	60937
Leaching by agitation	655878	2.77	1959.38
2017			
Heap leach	725494	0.93	52529
Leaching by agitation	708581	1.9	1689.04
2018			
Heap leach	673928	0.9	66294
Leaching by agitation	695608	2.11	2061.74

* Annual gold extraction in ounces;
** Annual gold extraction in kg;;

II. OBJECTIVE.

The aim of this work is to establish a mathematical relationship between the performance of a ball mill and the technological parameters of the grinding process.

The methodology of the experiments. All experimental studies were carried out in accordance with the goal and the requirements of GOST. The experiments were carried out both on special stands (see Fig. 1), and on the AIMC production base (Fig. 2).
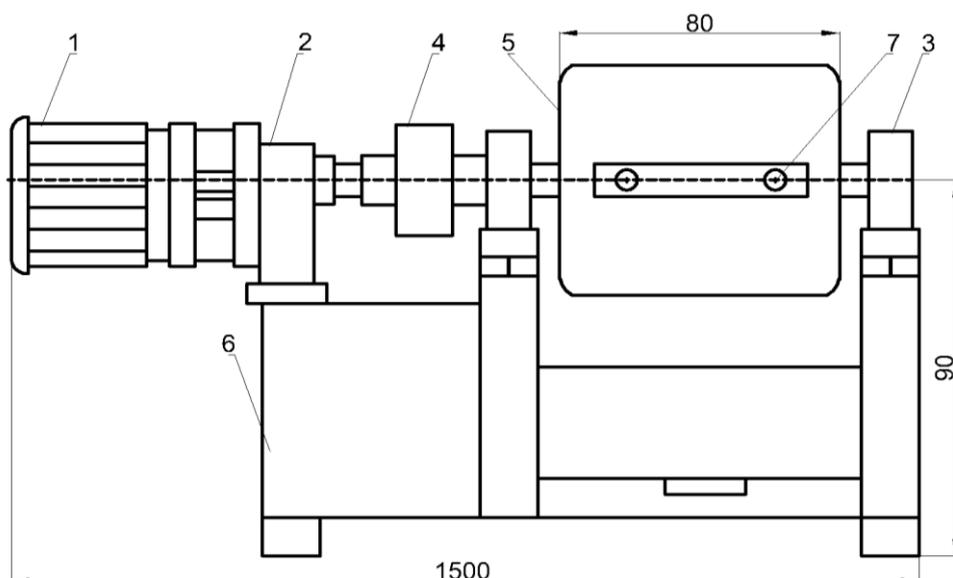
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Fig. 1. Experimental setup: 1 - electric motor; 2, 3 - thrust bearings; 4 - coupling; 5 - mill body; 6 - bed; 7 - housing cover.
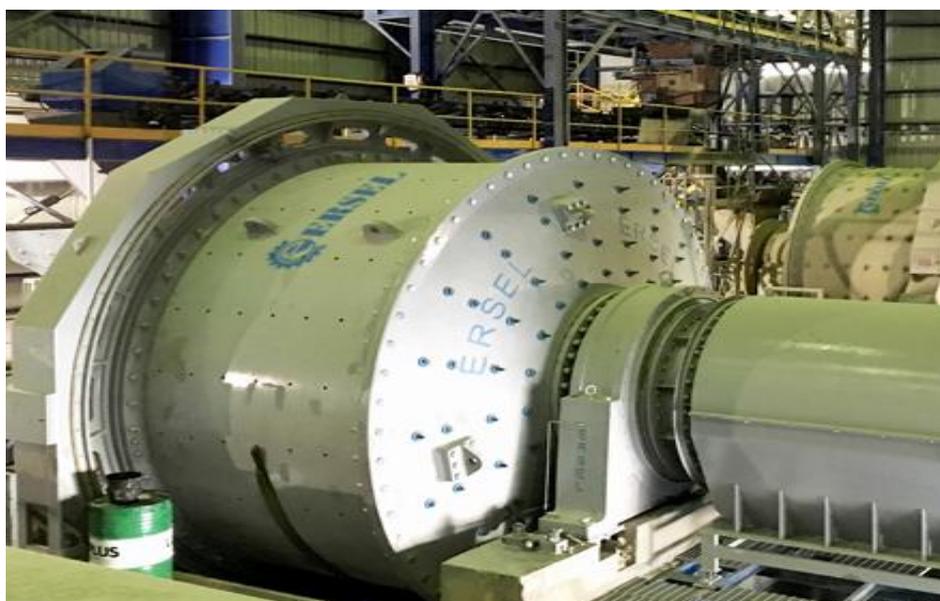

Fig. 2. General view of the mill type SAGMill

Changes in the mill drum speed were carried out by an ATV71HU55N4 brand converter. As grinding media, metal balls made according to the technology proposed by us were used [3].

Mining ores delivered from the Gadir, Gadabay and Ugur deposits of the Republic of Azerbaijan were used as grinding material. In the course of research work, the MillTraj simulation program was used in parallel to compare the results.

The studies were carried out on the basis of the plan of a complete factorial experiment of type 24 [4, 5]. The advantage of this plan is that when applied, all possible combinations of factors can be analyzed at all levels 24 selected for the study [6].

Based on the results of preliminary experimental data, a regression relationship was sought as follows.

$$M = a_0 + \sum_{i=1}^{n} a_i \cdot x_i + \sum_{\substack{i=1, \\ j \neq i}}^{n} a_{ij} \cdot x_i x_j + \sum_{i=1}^{n} a_{ii} x_{ii}^2$$

where M - is the productivity of the mill;

xi, xj - levels of variation of factors;

ai - is the coefficient of the linear interaction effect;

aij - is the coefficient for the pair interaction effect;

aii - is the coefficient of the quadratic interaction effect.

The significance of the regression coefficients and the adequacy were determined by calculating, respectively, the Student and Fisher criteria.

Discussion of the results of the study.

At present, the AIMC processes ore with Moos hardness which varies over a rather wide range [7].

Each time they are processed, the operating parameters are optimized (drum load factor — X_1, rotation speed —X_2, resolution angle of elevators — X_3 and hardness —X_4).

Ore processing is performed at SAGMills type with overall dimensions D x B = 5 x 2 meters.

Based on the experience and recommendations of the manufacturer, the following parameters were selected as operating parameters (Table 2):

Table 2 Operating parameters values

Factors	Mark	Change intervals				
		-2	-1	0	1	2
Drum load factor, %	X_1	15	17,5	20	22,5	25
Rotation speed, %	X_2	67.4	68.9	70.5	72.0	73.6
Resolution angle of elevators, degree	X_3	52	58	64	70	76
Ore hardness, according to the Mohs scale	X_4	3	4	5	6	7

To numerically solve the obtained data, the MATLAB and MICROSOFT EXCEL software packages were used.

The results of the studies established a correlation between capacity and operational parameters:

$M = 20.31 + 0.594 \cdot X_1 + 1.214 \cdot X_2 + 0.091 \cdot X_3 - 9.582 \cdot X_4 + 0.001 \cdot X_2 \cdot X_3 + 0.002 \cdot X_1 \cdot X_3 - 0.021 \cdot X_1 \cdot X_4 - 0.011 \cdot X_3 \cdot X_4$

As can be seen from the regression equation, the influence of ore hardness (X4) has a significant impact on the grinding process capacity. The influence of other factors is implemented in the following sequence – X_2, X_1 и X_3.

It was established that the trajectory of the movement of the balls comprehensively depends on the controlled factors, the optimal values of which are indicated in Table 4. Moreover, the discrepancy between the experimental and calculated indicators is about 5.0%

Table 3 The relationship between the trajectory of the balls and the capacity of the mill

Factors names	Trajectory of the balls				
	1.0	0.92	0.8	0.56	0.42
X_1	22.5	20	17.5	25	15
X_2	73.3	72.05	70.5	68.95	67.4
X_3	64	70	58	76	52
X_4	3	4	5	6	7
Y, Experimental	105.4	94.6	79.54	70.57	46.82
Estimated	103.98	90.56	74.57	70.12	47.38

III.   CONCLUSION.

Thus, the following main conclusions can be drawn:

- the mining industry of Azerbaijan is one of the main, dynamically developing and promising areas of industry and AIMC is a determining factor in this industry;

- the resulting correlation equation allows you to adequately assess the influence of regime factors on the performance of the grinding process.

- the main factor influencing the ore grinding performance is hardness (X4), other factors are implemented with the sequence - rotation speed (X2), drum loading coefficient (X1) and elevator placement angle (X3).

-this correlation equation can be used to determine the relationship between the operating parameters and the productivity of all types of ball mills.

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