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RESEARCH ON THE RELATIVE PRODUCTIVITY OF A DRUM MILL TYPE SAG 8.5X5.3

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Abstract. The determination of the optimal operational mode of drum mills can be assessed by different criteria. The most important of them can be formulated as follows: "To be specified and established the values of the mill operational parameters regarding to which it is possible to be provided the user's expected performance at the required quality of the final product and the same to be achieved at minimal energy consumption". For the fulfillment of this condition, there has to be determined the laws of productivity variation, the final product quality and the energy consumption in function of the adequately chosen representative control parameters of the mill. There are obtained mathematical models, describing the most important technological parameters of the machine and are made conclusions about the factors influencing on them.

Mathematical model of the grinding process in a drum ball semi-autogenous mill.

Determination of the objective and the target functions. The first task we face when modeling drum semi-autogenous mills (SAG Mills) is the clear formulation of the target. Considering the poor data on the subject of the study and the high complexity of the study, it is clear that this step is one of the most difficult and at the same time one of the most responsible.

As a step in the modeling process [1], the choice of target function should enable us to apply the methods of mathematical statistics. For this reason, the target function must meet some certain requirements.

The target function must be characterized by quantity, i.e. for each combination of values of input factors to be characterized by a number. The multiple of values that the target function may accept is called an area of its determination. This area can be defined or undefined, continuous or discreet. It is necessary for the target function to be measurable in order to be set. The target function must be singular. In many cases, this requirement is automatically fulfilled [2], as the goal is set strictly and its characteristic is one. Most often functions of this type are the economic target ones (cost, energy consumption, etc.).

The target function must be efficient, i.e. to characterize effectively the SAG Mills operation in accordance with the objective set. Moreover, the efficiency of the target function does not remain constant in the process of research and optimization. For example, when organizing a production in the initial stage, the most efficient target function is the volume of production. When the final possibilities for the production increase are reached, the role of other parameters such as quality, cost of production, etc., is also increasing. Therefore, once the target function is selected, we will not consider it as an invariable parameter. At a certain stage of the study, it may be necessary to replace it with another, more efficient, target function.

The requirement for efficiency is also directly related to the requirement for completeness of the target function. This means that the target function has to characterize in a vast and full manner the targeted objective.

The target function must also be statistically efficient, i.e. with a minimal possible dispersion $\sigma\xi^2$. In practice, this requirement is limited to the selection of a target function that can be measured (calculated with the highest possible accuracy).

Selection of target functions at the investigation of SAG mill type 8.5x5.3. The purpose of this paper is to create a mathematical model of the ore grinding process in a drum ball semi-autogenous mill type SAG 8.5 x 5.3, which to allow the coverage the main phenomena that occur in it. The created mathematical model must serve for the design and the operation of this machine. In the present study as target functions are adopted the relative productivity by class of the final product – q, t/h. This is a quantity of production per unit of time.

For the selected target functions, the following could be said that the relative productivity is an integral criterion for the process, thus satisfying the condition of efficiency of the target function. On the other hand, the productivity meets all of the above mentioned requirements. The relative productivity is a parameter, that characterizes the process in quantitative terms, and this defines its main disadvantage – it is not a sole one.

Statistical survey of the results of the passive experiment of a drum mill type SAG 8.5 x 5.3.

The aim of the present study is to describe by mathematical means the relative productivity upon the final product, the relative energy consumption and the yield of the estimated class of the grinding product. For this purpose, measurements are made on a mill type SAG 8.5x5.3.

The data required for this study is obtained from a system for automatic control and adjustment of the machine. They are comparatively limited in number but this is due to the fact that they are made only for the periods in which is measured the wear of the drum lining and the relatively short period of operation of the machine until the moment of the measurement.

The statistical analysis [2] can be done in two ways. One of them is through mathematically formulated dependencies that have proven the adequacy and others. Another way is by using computer programs that have the theoretical setting, such as Regression from Data Analysis of Excel, Sigma Plot and STATGRAFICS.

Investigation of the relative energy flow of the mill.

The relative productivity of the mill is calculated according to the following formula:

$$Q_1 = Q \cdot K \text{, t/h} \quad (1)$$

where Q, t/h - loading rate of the mill with ore. This parameter is measured by an electronic balance placed on the feed belt of the mill; K, % - yield of the estimatedclass of the final product, - the ratio of the class - 0.08 to the total quantity processed by the mill drum. It is obtained after a sieve analysis of the obtained material at the outlet of the mill.

Table 1 – The Fisher-Matrix

№	X_1	X_2	X_3	X_4	X_5	Y_3	Y_2
	I, %	*n*, min^{-1}	Q_w, m^3/h	*Q*, t/h	*M*, t	*K*, %	*q*, t/h
1.	64.555	1062.6	14.3	233	107.3	81.43	189.73
2.	77.591	1067.2	19.86	135	103.5	75.7	102.20
3.	87.016	1087.6	44.86	258.4	99.33	78.66	203.26
4.	99.233	1092.3	35.85	189.97	93.3	80.42	152.77
5.	0.280	1060.2	25.25	238.4	110.5	74.96	178.70
6.	11.475	1004.3	29.53	207.3	114.2	78.34	162.40
7.	25.037	989.3	80.7	248.44	109.33	79.38	197.21
8.	34.078	1013.5	72.36	188.7	108.9	80.34	151.60
9.	40.571	1017.3	30	200.8	80.35	80.25	161.14
10.	50.183	1016.7	40	180.8	106.3	81.2	146.81
11.	65.659	1014	75.3	221.3	96.4	79	174.83
12.	82.569	1118.1	80.25	243.45	90.4	78.73	191.67
13.	0.067	1001.6	65.1	245	112.9	81.2	198.94
14.	19.372	991.6	94.2	252.33	113.1	82.2	207.42
15.	36.870	873.5	35	234	102.7	78.5	183.69
16.	48.404	1000.2	88.2	241.8	113	78.5	189.81
17.	63.621	1035.6	74.9	260.1	107.7	78.8	204.96
18.	81.226	1035.8	93.6	248.9	102.1	81.22	202.16
19.	0.423	1001.2	54.6	274.3	118.1	77.64	212.97
20.	12.921	980.83	60	260	115.8	75.4	196.04
21.	21.283	876.66	50	250.9	110	76.8	192.69
22.	30.625	968.56	70.8	276.1	113.7	75.8	209.28
23.	44.007	956.8	88.5	251.5	111.76	74.57	187.54
24.	57.255	1015.3	169	315.13	110.44	77	242.65
25.	72.969	1051.9	171	334.77	106.5	76.98	257.71
26.	81.853	1058.9	170.47	318.92	106.76	75.56	240.98
27.	87.652	1078.6	206.6	288.1	99.73	75.5	217.52
28.	100.000	1092.1	185.5	318.14	92.3	76.97	244.87
29.	0.000	894.54	160.9	281.2	112.9	79.11	222.46
30.	13.218	941.96	249.6	322.41	112.85	75.87	244.61
31.	26.706	1003.2	265.1	341.39	112.4	76.55	261.33
32.	42.215	1005.3	260	311.1	114.87	76.55	238.15
33.	50.792	1002.1	179.7	315.2	110.4	87.9	277.06
34.	69.197	1033.9	180.4	336.7	104.5	87.9	295.96
35.	78.352	1036.2	245	298.6	102.1	77.1	230.22

The obtained results from the measurements are not given. They are transformed in Fisher-matrix and and given in table1. The mill processing (from the moment of laying new drum linings until the moment of measurement) is represented by the percentage of the lining wear. In this situation, 0 % corresponds to a new lining and 100 % corresponds to a completely worn lining. Data processing from Table 1 is performed through a statistical analysis. In the Table *i*, % is the percentage of wear of the lifters, *n* is oscillation if engine (RPMs), *q* is searched the relative performance. The results of the experiment were statistically processed using the STATGRAPHICS program, trial version. The assessment of the significance of regression coefficients is done according to the Student criterion at a level of significance $\alpha = 0.05$ and at least 8 degrees of freedom. The program estimates the probability of significance of regression coefficients. If this probability is:

$$P - Value < \alpha \tag{2}$$

so the coefficient of regression is significant (α – confidence probability).

Analogically, the adequacy of the equation is evaluated by the significance of the criterion of Fisher. If the significance of the criterion is $P - Value < \alpha$ the equation is adequate.

For the purposes of the practical study of the operational process are searched models and regression, which can be assumed with confidence probability levels of 95 %, and it is expected that acceptable engineering error levels of 5 % are acceptable for technical devices such as drum semi-autogenous mills - type SAG 8,5x5,3.

It can be assessed as a model with high adequacy. The coefficient of multiple correlation is 99.59 % and the adjusted coefficient of multiple correlation is 99.6 %. The value of the confidence probability indicator (P-cvalue) for the model is 0, i.e. it can be accepted that the model is adequate with a confidence probability of over 99 %. Then it is logical the equation of the model with natural variables to be:

$$q = 0.336277 \cdot 10^{-3} \cdot i \cdot n + 6.74063 \cdot 10^{-3} \cdot Q \cdot M \text{, t/h} \tag{3}$$

The model adequacy values are shown in Table 2.

Table 2 – Model adequacy parameter values

Parameter	Estimate	Error	Statistic		*P-Value*
$X_1 . X_2$ (i.n)	0.000336	0.00006349	5.29575		0.0000
$X_4 . X_5$ (Q.M)	0.006740	0.00013292	50.7094		0.0000
Source	Sum of Squares	d.f - degrees of freedom	Mean Square	F-Ratio	*P-Value*
Model	151737E6	3	758687.17	4045.8	0.0000
Residue	6188.3	33	187.524		
Total	152356E6	35			
R^2 =				99.5938 %	
R^2 (adjusted for d.f. degrees of freedom) =				99.5815 %	
Standard Error of Est. =				13.6939	
Mean absolute error =				9.91407	
Durbin-Watson statistic =				1.41806	
Lag 1 residual autocorrelation =				0.290153	

Conclusions from the obtained experimental results. The results obtained from the measurements and the statistical analysis of the relative performance upon finished product show the following:

- the relative yield upon the processed ore is influenced by four parameters, namely: the wear of the drum lining, the mill drum RPMs, the mass of the fill and the ore loading rate of the mill;

- the increase of the mill loading rate with ore results in an increase in the relative productivity of the machine, probably due to the fact that there is more ore in the drum per unit of volume;
- the increase of the amount of mill filling (balls and coarse ore) leads to an increase in relative productivity, possibly due to the fact that each particle is more probable to contact with the grinding media is;
- the increase of drum RPMs also results in increased mill performance due to an improvement of the mill speed mode;
- the increase of the wear of the mill lining, which increases the inner diameter and drum mileage, increases the relative productivity of the machine ,because it increases the volume of the mill drum and improves its speed mode.

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