THE METALLURGICAL PROCESSES EFFICIENCY EVALUATION: THE PROCESS ROBUSTNESS MEASUREMENT OF THE SHAFT RETRACTIVE MELTING

Dosmukhamedov N.K.

The Kazakh National Technical University after K.E. Satpaev, e-mail: nurdos@bk.ru

The efficiency evaluation technique of the metallurgical processes, on the mine retractive melting of the lead production example has been developed in this work. The basic principles of the theory G. Taguti have been laid into the methodology basis. Also, it has been shown, that the copper content of the lead bullion and the lead and the arsenic content in the matte are the main factors (e.g. «the noise»), having affected the process efficiency (e.g. the signal») at the mine retractive melting. It, moreover, has been found, that the process maximum efficiency can be achieved, by measuring and maintaining at the optimum level, the selected values, as the independent parameters «the noise».

Keywords: process efficiency, copper instruction into matte, independent parameters

The detailed analysis procedure of the economic – technologically indicators and corresponding them data on the process conditions technological regime and the parameters, that are determined the process final indicators is used in place to be created the mathematical model of the every metallurgical technology [1–3]. However, the direct data transfer of the existing technology to the new process is quite flawed, and it can be led to the significant errors, with the considerable change in the raw materials composition. This approach is particular relevant and is acquired the specific urgency for the processes, where two or more metals are extracted, in result of the raw materials complex composition processing to the desired products. So, to one of these processes, can be attributed the shaft retractive melting of the middlings and the industrial products separate processing, circulating and the other copper–, the lead – containing materials of the lead production with the following copper and the lead extraction to the desired products – the matte and the lead bullion, respectively. By the technology, the two desired products – the copper – lead matte and the lead bullion are obtained in the process, which are directed further, respectively, for the conversion and the refinement. This process is characterized by the low technological parameters: the copper extraction in the matte is at the level only ~85 %, and the lead in the lead bullion is hardly reached up to 45 %. However, in view of the alternative processing technologies absence of the middlings and the industrial products, circulating and the other copper–, the lead – containing materials of the lead production, the existing process is being still applied today. From the perspective of the above – mentioned, the challenge study of the shaft retractive melting process efficiency is certainly presented the fundamental and the significant one.

Thus, the present work purpose – is the metallurgical processes efficiency evaluation with the common positions, by the robustness measurement, on the mine retractive melting process example.

Materials and methods of research

The daily pair data on the products compositions of the heats – the mattes, the slags, and the lead bullion, having obtained at the shaft retractive melting, in the period from January to June, 2011, have been used by us in the work. The homogeneous data sets, which were indicated the average operating conditions of the process, had been selected. So, the non – typical results of the mattes and the slags compositions, evidently having distinguished from the total sample, have already been discarded, and they were not subjected to the necessary processing. Thus, the input data number, having accepted to the analysis, had been made up 185 paired samples of the mattes and the slags, and the lead bullion compositions, which was quite sufficient for the significant dependences between the single function and the independent parameters identification.

The approach, having developed in the paper [4], which was given the every process efficiency evaluation methodology, having consisted in the «signal–to–noise» ratio measurement (e.g. the theory of G. Taguti), had been used in the work. So, the theory essence is, that often, when, in practice, it is quite impossible to be known all the factors and the conditions of the process working, it is necessary to strive to be ensured, that the process would be maximum stable and the most robust to the uncontrollable factors variations, that have the greatest impact on the quality index variations (e.g. the process efficiency). This understanding the authors are called the robustness, and are, moreover, their approaches for its measurement. So, in their opinion, it is quite necessary to be measured only one value – the «signal–to–noise» ratio for the robustness measurement of the every process. The process quality can be improved only by the functional relationship study between the process input and output parameters, what, in fact, the «signal–to–noise» ratio study approach is.

Results of research and their discussion

The copper extraction in the matte has already been selected for the shaft retractive melting process, as the ideal single function *Y*, having reacted to changes in the «single – to – noise» ratio.

As a result of the preliminary mathematical processing of the statistically industrial data, it

had been found, that, as the «the noise » (e.g. the vibrations) independent parameters, having affected the copper extraction, the most significant and important ones were the following parameters: the temperature (T), the partial pressure of the oxygen (P_{O2}), the slag composition (the CaO, SiO_2, $Fe_{com.}$ Compositions), the Pb, As compositions in the matte, and the Cu in the lead bullion. Having taken into account, that in the melting processes such independent parameters, as the slag composition, and the closely related with it T и P_{O2} [5], for the total duration of the process they are maintained at the constant level (e.g. the minor fluctuations of the slag composition can be ignored), the further consideration on the final function impact was considered from the Cu composition in the lead bullion (x_3) and also from the Pb (x_4), As (x_7) compositions in the matte. Thus, the process efficiency evaluation has been to be measured the variations in the selected parameters (e.g. «the noise») and also to be determined the effect of each from them on the final function Y – the copper extraction in the matte (e.g. «the signal»).

Thus, the parameters sample data x_3, x_4 и x_7, have been taken from the average monthly total set products' compositions of the heats, are given in the Table.

For the values calculating of the copper extraction in the matte, it has been used the procedure for the copper amount calculation in the starting material and in the matte, with the copper composition using of such products and their obtained volumes, having produced by the factory data. The variations evaluation procedure of the $\boldsymbol{x_i}$ independent parameters and their impact determination on the process efficiency has been resulted in for the $Y = f(Y/x_i)$ type graphical dependencies building for all the common data set. Then, the obtained results have been shown in the Figure.

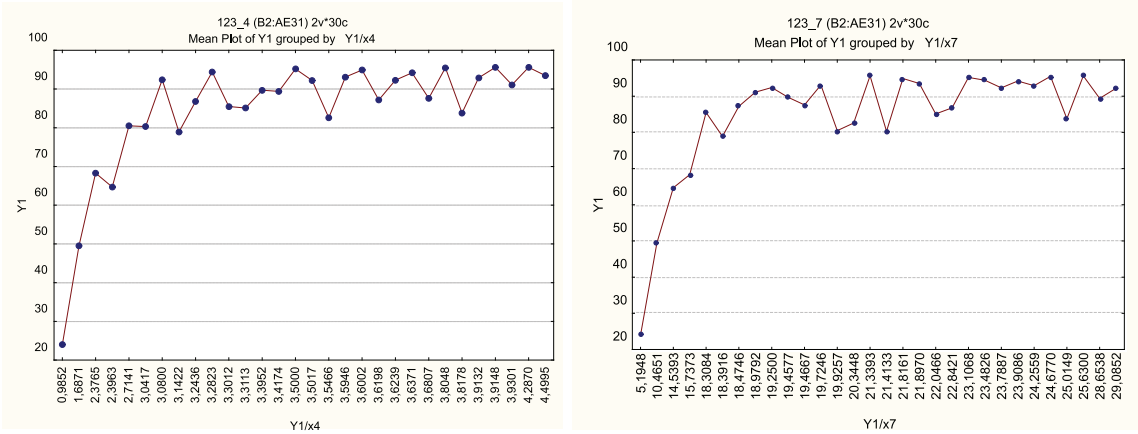
So, it is clearly seen in the Figure, a, b, c, that the variations limits x_3, x_4 и x_7 and their impact on the y value are expressed quite distinctly and clearly (including the Y/x_i high ratios areas) with the further increase in the Y/x_3, Y/x_4 и Y/x_7 ratio. For all this, the underlying trend, which must be observed by the theory G. Taguti, – the «signal – to – noise» ratio increase is practically reduced the process actual variation around the planned function features – it is not done so explicitly. Therefore, the measurement and the maintenance at the optimum level of the copper composition in the lead bullion and the lead and the arsenic compositions in the matte is the necessary and the sufficient condition for the process high efficiency provision.

The x_i optimum values have already been determined, according to the built dependencies, by means of the calculation, which are ensured the maximum copper extraction in the matte, and, consequently, the process maximum efficiency of the shaft retractive melting. The optimum values of the copper composition in the lead bullion and the lead, the arsenic compositions in the matte, having provided the maximum copper extraction in the matte, is equal to 95,6%, are made up 2,15; 21,2 and 3,28%, respectively. In practice, at the average copper extraction in the matte, which is equal to 83,7%, the similar parameters values are corresponded to 3,07; 27,8 and 4,25%, respectively.

Thus, the data obtained are agreed rather well with the work's results [6], where the similar challenge has been solved, by means of the process mathematical modeling classical method using of the shaft retractive melting, with the same sample of the set using, as in the present work. This is practically demonstrated the theory of G. Taguti applicability to be evaluated the metallurgical processes efficiency.

The Metals Compositions in the Melting Products (e.g. Sample) and the Copper Extraction Calculated Values in the Matte

Number	Cu in lead bullion, %	The content in the matte, %		Removing Cu in matte, %
		Pb	As	
	x_3	x_4	x_7	Y
1	3,55	26,33	3,17	92,2
2	3,90	29,34	4,73	49,5
3	3,43	24,36	4,62	24,0
4	3,31	26,16	3,12	89,4
5	3,10	28,74	4,34	68,3
6	3,30	29,66	4,04	80,5
17	3,42	23,18	4,80	91,1
18	3,17	23,74	3,83	92,9
19	2,73	26,40	3,75	80,3
20	3,02	25,90	4,72	93,1
21	3,10	24,86	4,67	85,5
22	3,97	27,20	4,12	95,2
23	3,02	25,10	3,87	95,5
24	2,41	30,00	4,80	92,4
25	3,36	27,00	4,45	64,7
26	2,38	25,70	3,86	85,1
27	3,17	23,80	4,50	87,6
28	3,52	22,30	4,48	95,6
29	2,49	21,95	3,35	83,8
30	2,95	20,78	4,27	93,5



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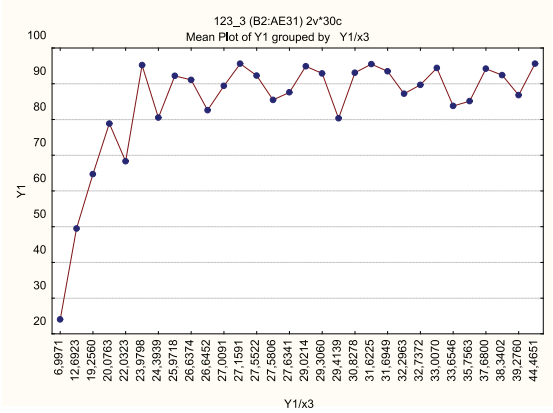

c

The Variation Effect of the x_i Independent Parameters on the Copper Extraction in the Matte (Y)

Conclusions

The method to be evaluated the metallurgical processes efficiency for the shaft retractive melting example of the lead production has been developed. The theory of G. Taguti applicability to be assessed the technological processes efficiency of the non – ferrous metallurgy has been shown. It has been found, that the copper composition measurement in the lead bullion and the lead, the arsenic compositions in the matte (e.g. «the noise») is the necessary and the sufficient condition, in order to be achieved the process maximum efficiency. It is necessary the measured independent parameters maintenance at the level of their optimum values for the process maximum efficiency provision. Their values increase above the optimum level will be led to the dramatic reduction of the copper extraction in the matte (e.g. «the signal»).

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