APPLICATION OF DISPERSION ANALYSIS FOR DETERMINING CLASSIFYING SEPARATION SIZE

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ABSTRACT
The paper presents the procedure of mathematical modelling the cut point of copper ore classifying by laboratory hydrocyclone. The application of dispersion analysis and planning with Latin square makes possible significant reduction the number of tests. Tests were carried out by D-100 mm hydrocyclone. Variable parameters are as follows: content of solid in pulp, underflow diameter, overflow diameter and inlet pressure. The cut point is determined by partition curve.

The obtained mathematical model and the values of the coefficients make it possible to find the classifying cut point for variable factors.

1. INTRODUCTION

The commonest method of representing cyclone efficiency is by a performance of partition curve, wich relates the weight fraction, or percentage, of each particle size in the feed which reports to the apex, or underflow, to the particle size. The cut point, or separation size, of the cyclone is often defined as the point on the partition curve which 50% of particles in the feedof that size report to the underflow. Particles of this size have an equal chanse of going with the overflow or underflow. This point is usually referred to as the d_{50} size. Many mathematical models of hydrocyclones include the term "corrected d_{50}" taken from the "corrected classification curve. It is assumed that in all classifiers, solids of all sizes are entrained in the coarse product liquid by short-circuiting in direct proportion to the fraction of feedwater reporting to the underflow.

The effects of changing operating and design parameters in cyclones are very complex. Parameters that may vary with hydrocyclones are: constructive elements (the diameter for underflow and overflow, the relation between lengths of cylindrical and conical parts, angle of conical part) as well as working conditions in hydrocyclone (inlet pressure, capacity and content of solid in pulp).

2. EXPERIMENTAL

The subject of this investigation is the study of the performance of laboratory cyclone D = 100 mm (Figure 1) in classifying of copper ore depending on four variable parameters.

Since with the traditional method of study the total number of tests for four factors at three levels amounts to 81, the authors applied the dispersion analysis which makes possible significant reduction of the number of tests, simultaneous assessment of all factors studied and close optimization of the process.

Tests planning was done according to Greek-Latin square and the factors studied were marked as follows:

- inlet pressure (I-III): I-0,05MPa; II-0.075 MPa; III-0.1 MPa
- content of solid in pulp (1-3): 1-35%; 2-40%; 3-45%
- underflow diameter (A-C): A-13mm; B-15mm; C-17mm
- overflow diameter (α-γ): α- 25mm; β-30mm; γ-35mm.

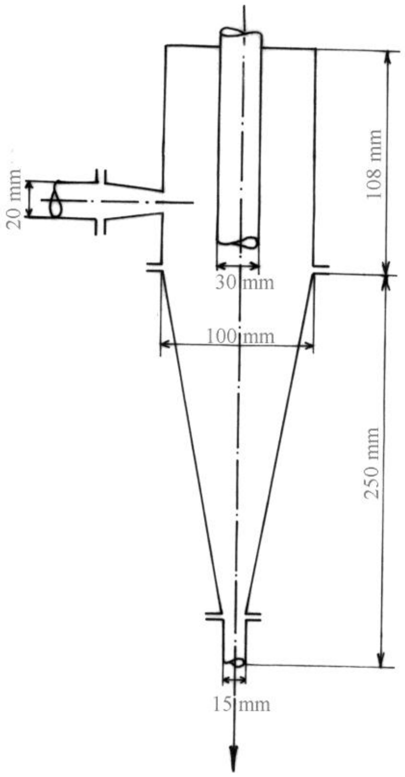

Figure 1. Scheme of the hydrocyclone

The pattern of various systems, according to Greek-Latin square is such that each value of one factor combines with a value of other three factors (Table 1).

Table 1. Tests plan

	I	II	III
1	Bγ	Cα	Aβ
2	Cβ	Aγ	Bα
3	Aα	Bβ	Cγ

Each test was performed twice and the content of each classes in underflow and overflow was determined by screening analysis.

The order and partition curves are shown in Table 2 and Figures 2-10.

Table2. Order of tests

Test No	Solid [%]	$d_{underflow}$ [mm]	$d_{overflow}$ [mm]	P [MPa]
1	35	15	35	0.050
2	35	17	25	0.075
3	35	13	30	0.100
4	40	17	30	0.050
5	40	13	35	0.075
6	40	15	25	0.100
7	45	13	25	0.050
8	45	15	30	0.075
9	45	17	35	0.100

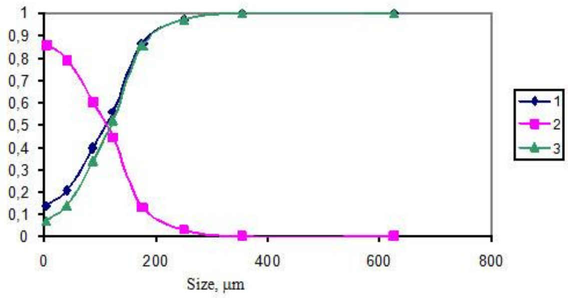

Figure 2. Uncorrected-1 and corrected-3 curve for test 1

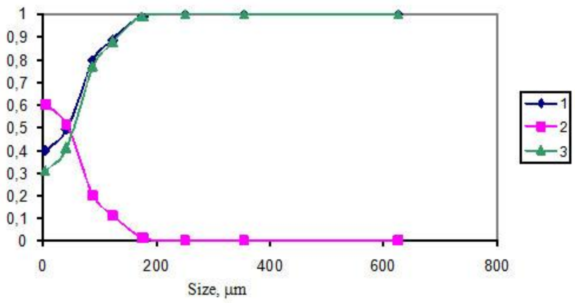

Figure 3. Uncorrected-1 and corrected-3 curve for test 2

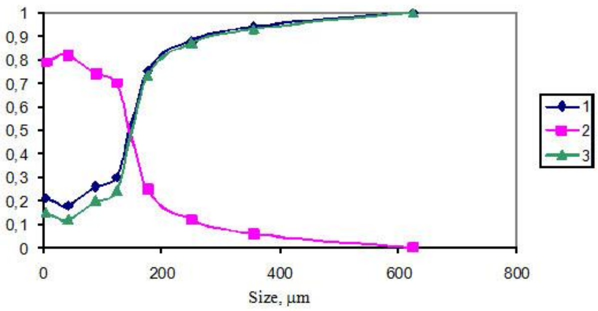

Figure 4. Uncorrected-1 and corrected-3 curve for test 3

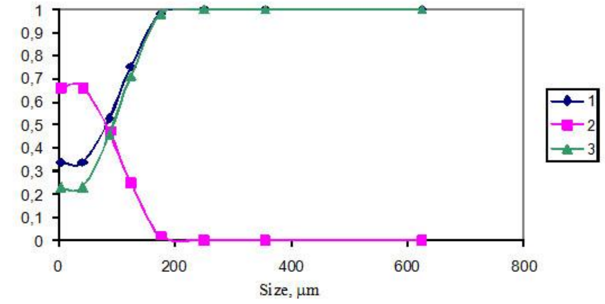

Figure 5. Uncorrected-1 and corrected-3 curve for test 4

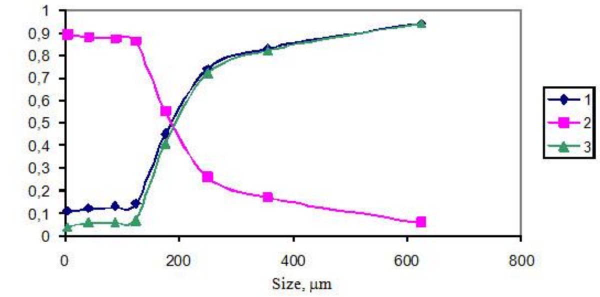

Figure 6. Uncorrected-1 and corrected-3 curve for test 5

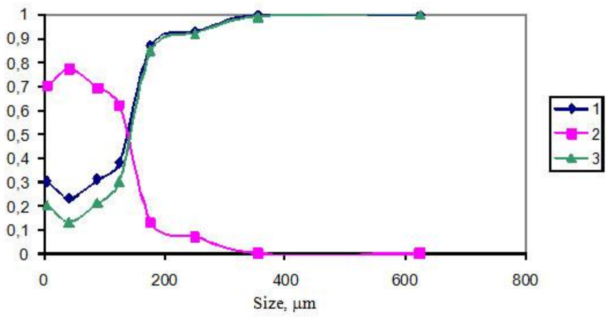

Figure 7. Uncorrected-1 and corrected-3 curve for test 6

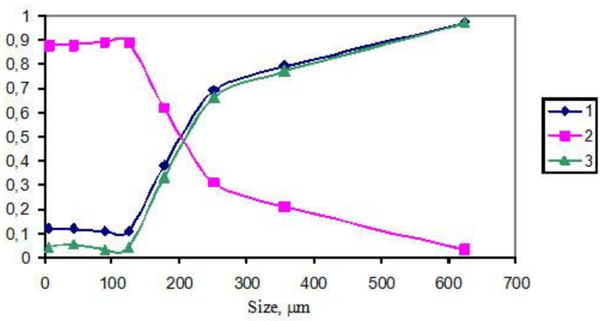

Figure 8. Uncorrected-1 and corrected-3 curve for test 7

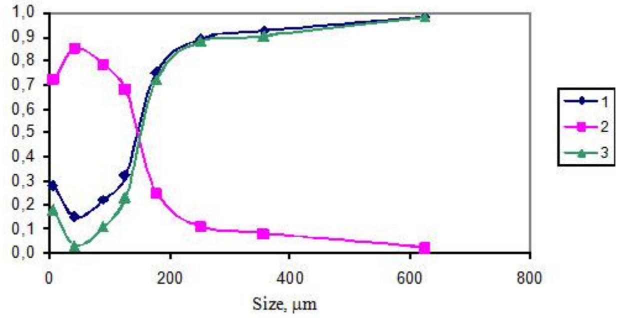

Figure 9. Uncorrected-1 and corrected-3 curve for test 8

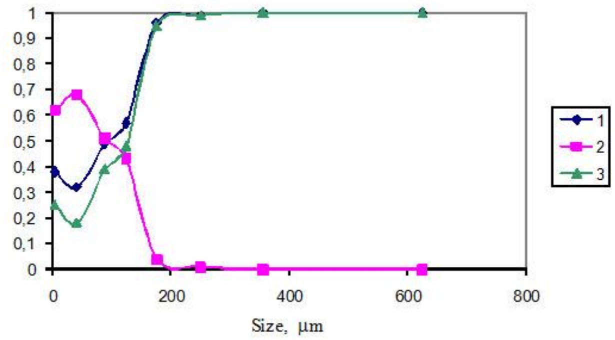

Figure 10. Uncorrected-1 and corrected-3 curve for test 9

3. RESULTS AND DISCUSSION

The results for the cut points are written in Table 3 with the tests plan.

Table 3. Results for corrected cut poin

125	60	150
115	62	149
97	199	142
100	196	139
202	155	119
200	153	118

1. Calculation of sums for individual group of factors Y_i ... $Y\gamma$ and general Y.

Y(I) = 839 Y(II) = 825 Y(III) = 817
Y(1) = 661 Y(2) = 873 Y(3) = 947
Y(A) = 1096 Y(B) = 829 Y(C) = 556
Y(α) = 805 Y(β) = 804 Y(γ) = 872
Y(gen)= 2481

2. Calculation of the sums of squares in lines, columns and letters:

$$\sum I-III = \sum_{j}^{k}\left(\frac{Y_j^2}{n}\right) - \frac{Y^2}{N} = 41{,}33$$

$$\sum 1-3 = \sum_{i}^{n}\left(\frac{Y_i^2}{k}\right) - \frac{Y^2}{N} = 7345.333$$

$$\sum A-C = \sum_{l}^{p}\left(\frac{Y_l^2}{p}\right) - \frac{Y^2}{N} = 24301.0$$

$$\sum \alpha-\gamma = \sum_{m}^{r}\left(\frac{Y_m^2}{r}\right) - \frac{Y^2}{N} = 506.333$$

$$\sum gen = \sum_{ij}^{N} Y_{ij}^2 - \frac{Y^2}{N} = 32264.5$$

3. Calculation of sum of the error for reproductivity:

$$\sum rep = 70.500$$

4. Degree of freedom for group of factors:

$f_{I-III} = 3-1 = 2$ $f_{1-3} = 2$ $f_{A-C} = 2$ $f_{\alpha-\gamma} = 2$

5. Degree of freedom for general dispersion:

$f_{gen} = N - 1 = 18-1 = 17$

6. Degree of freedom for general reproductivity:

$f_{rep.} = f_{gen} - f_{I-III} - f_{1-3} - f_{A-C} - f_{\alpha-\gamma} = 9$

7. Dispersion of reproductivity is:

$$S_{rep} = \frac{\sum rep}{f_{rep}} = 7.833$$

8. Dispersion of the influence of groups is:

$$S_{I-III}^2 = \frac{\sum I-III}{f_{I-III}} = 20.667$$

$$S_{1-3}^2 = \frac{\sum 1-3}{f_{1-3}} = 3672.667$$

$$S_{A-C}^2 = \frac{\sum A-C}{f_{A-C}} = 12150.5$$

$$S_{\alpha-\gamma}^2 = \frac{\sum \alpha-\gamma}{f_{\alpha-\gamma}} = 253.167$$

9. Assessment of the influence of factors according to Fischer's criterion calculated is:

$$F_{I-III} = \frac{S_{I-III}^2}{S_{rep}^2} = 2.638$$

$$F_{1-3} = \frac{S_{1-3}^2}{S_{rep}^2} = 468.851$$

$$F_{A-C} = \frac{S_{A-C}^2}{S_{rep}^2} = 1551.128$$

$$F_{\alpha-\gamma} = \frac{S_{\alpha-\gamma}^2}{S_{rep}^2} = 32.319$$

For the level of probability p = 95%, Fischer's criterion amounts to $F_{tab} = 3.9$. Since $F_{tab} < F_{ass,}$ it follows that the influence of all factors examined is significant for the cut point except inlet pressure. The influence of the underflow diameter and the content of solid in inlet pulp are the largest.

10. Determination of coefficients of the model:

$\bar{y} = Y/N$; $a_j = Y_j/n - \bar{y}$; $b_i = Y_i/k - \bar{y}$; $c_l = Y_l/p - \bar{y}$;

$\bar{y} = Y/N = 2481/18 = 137.83$

$a_I = 2.003$; $a_{II} = -0.333$; $a_{III} = -1.667$

$b_1 = -27.667$; $b_2 = 7.667$; $b_3 = 20.000$

$c_A = 44.833$ $c_B = 0.333$; $c_C = -45.167$

$d_\alpha = -3.667$; $d_\beta = -3.833$; $d_\gamma = 7.500$

11. Model of classifying efficiency.

Taking in consideration that according to tabular values for the criterion of Student at f=2 and the level of probability 90-95%, t = 2.92 and $S_{rep.} = \sqrt{7.833} = 2.79$ the model for corrected cut point will be:

$$d_{50C} = 137.833 + a_j + b_i + c_l + d_r \pm 8.15$$

The obtained mathematical model and the values of the coefficients make it possible to find the classifying cut point for variable factors.

4. CONCLUSION

The application of dispersion analysis makes possible significant reduction of the number of tests, simultaneous assessment for all factors tested and close optimization of the process. Tests planning in the paper is done based on Latin square so that the total number of tests for four factors at three levels amounts to nine.

The mathematical model obtained and the values of the coefficients make it possible to find out the optimum conditions for the work of the hydrocyclone for variable factors.

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