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Correlation Analysis of Control Parameters of Flotation Process

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Abstract: The dosage of gold-antimony flotation process of 5 main drugs, including Copper Sulfate, Lead Nitrate, Yellow Medicine, No. 2 Oil, Black Medicine, with corresponding visual features of foam images, including Stability, Gray Scale, Mean R, Mean G, Mean B, Mean Average, Dimension and Degree Variance, were recorded. Parameter correlation analysis showed that the correlation among Copper Sulfate, Yellow Medicine, Black Medicine, as well as the correlation among Gray Scale, Mean R, Mean G, Mean B, is strong, and the correlation among Dimension, Gray Scale, Mean R, Mean G, Mean B, as well as the correlation between Stability and each dosing parameter, is week. It also indicated a feasible way to decrease the complexity of flotation control system by reducing some parameters.

Keywords: Visual features, flotation process, correlation analysis.

1 Introduction

The appearance of the bubble directly reflects the quality of the flotation. In actual flotation production, the most important way to judge the working conditions is to observe the visual characteristics of the flotation foam layer. By observing the apparent phenomenon of the bubble layer, experienced flotation operators can mostly judge the flotation conditions and the causes of abnormal working conditions, thereby adjusting the operating parameters of the flotation machine, the dosage of flotation medicine, and the amount of scraping [Zhang, Tang, Ai et al. (2018)].

The appearance characteristics of flotation bubbles include the degree of mineralization, size, color, luster, shape, thickness, stability, fluidity, sound, etc. of the bubbles. These characteristics include mineral type, particle size, quantity, density, pulp concentration, and foaming agent. It is determined by factors such as the amount of inhibitor [Zhao, Peng, Zhao et al. (2015); Lu, Xie, Gui et al. (2018); Xia, Ma, Shen et al. (2018)].

There are many characteristic parameters in the flotation process. Some of the characteristic parameters can be measured in real time, and some can be accurately measured, and some are expensive to measure. In contrast, visual feature information is more easily measured quickly and accurately [Mu, Liu, Gui et al. (2011); Wang, Song, Yang et al. (2018)].

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Many methods, such as k-means [Xiao, Wang, Liu et al. (2018)], morphological clustering [Lezoray and Charrie (2009)], wavelet transformation [Tang, Ling, Yao et al. (2018)], watershed algorithm [Yu, Hou, Wang et al. (2011)], CNNs [Cui, McIntosh and Sun (2018)], etc. are used to analyze the visual feature information from foam images.

2 Control parameter of flotation process

In a flotation factory of gold-antimony located in China, a positive flotation process was built with flotation bubbles as concentrate and bottom stream as tailings. The automatic dosing system has an automatic recording function, which can be used to collect the dosing data. Data sampling is performed every 1225 s, and the sampling results are recorded in the database. A high-definition camera is placed at the appropriate position of each flotation machine for monitoring and collecting the flotation foam image, and the foam image feature calculation is performed every 1225 s, and the calculation result is recorded in the flotation process operation database.

2.1 Bubble shape

The foam image was segmented by the watershed method using the watershed method, and the Mean Average, Dimension, and Degree Variance of the bubbles were defined as average size of bubbles, skewness of bubbles, and variance of bubble size.

2.2 Bubble color

The R component, the G component, and the B component of the RGB color space of the three primary colors of the foam image are respectively extracted, and the average value of the color of each pixel is taken as the feature values Mean R, Mean G, and Mean B. The colorful foam image is converted into a gray image, and the gray scale of each pixel is taken as the Gray Scale feature.

2.3 Bubble Stability

The change of the continuous 2 frames of the foam image is analyzed, and the average value of the corresponding pixel gradation difference is taken as the Stability feature.

2.4 Dosage of drugs

The foam image feature and recording process of the dosing amount are performed simultaneously. Fig. 1 shows the addition records (unit: g) of the five main drugs (Copper Sulfate, Lead Nitrate, Yellow Medicine, No. 2 Oil, Black Medicine). Corresponding foam image feature values (Stability, Gray Scale, Mean R, Mean G, Mean B, Mean Average, Dimension, and Degree Variance). The recording time range is from March 8, 2013 to February 24, 2014.

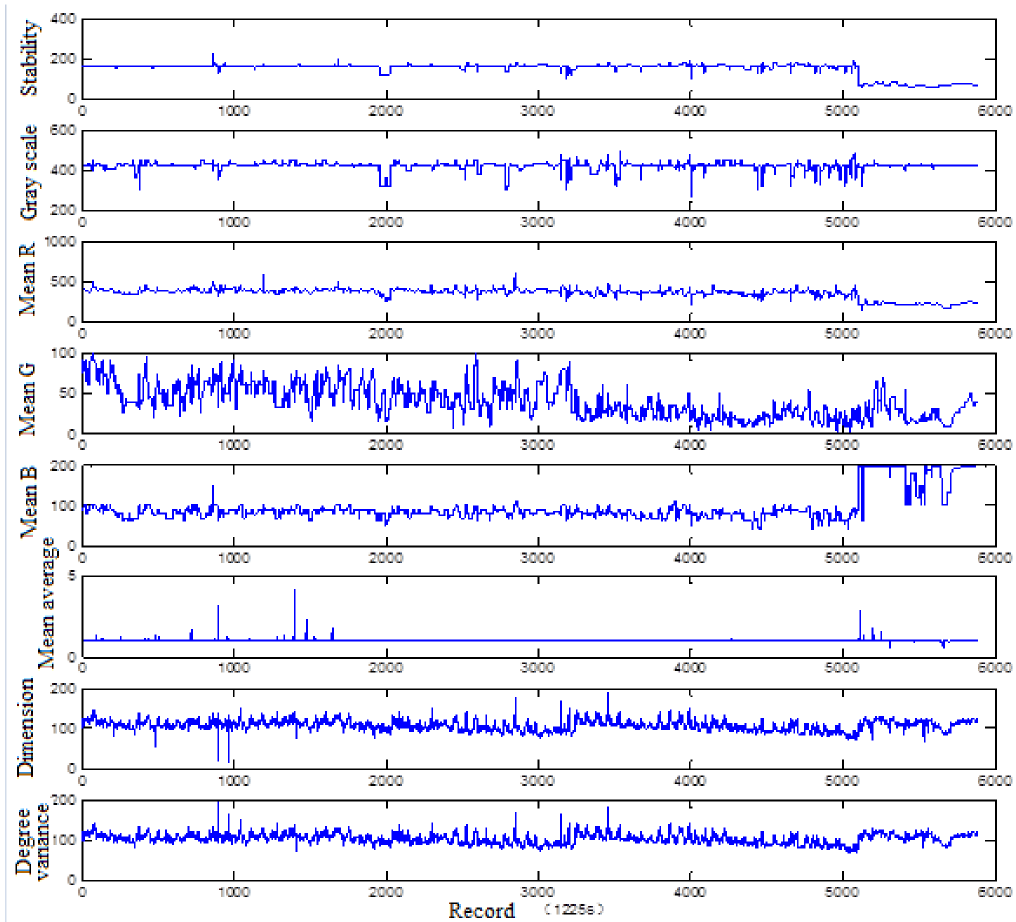

Figure 1: Flotation record (5964)

3 Parameter correlation analyses

The interdependence of phenomena can be roughly divided into two types: functional relations and related relationships. Variables with functional relationships can be expressed as correlations due to measurement errors and interference from various random factors. After a deep understanding of the variables of the correlation, the correlation may be transformed into or described by functional relationships.

Under linear conditions, the statistical indicator used to reflect the closeness of the linear correlation between the two variables, denoted by:

$$r=\frac{S^2_{xy}}{S_xS_y}=\frac{\sum\left(x-\bar{x}\right)\left(y-\bar{y}\right)/n}{\sqrt{\sum\left(x-\bar{x}\right)^2/n}\cdot\sqrt{\sum\left(y-\bar{y}\right)^2/n}}=\frac{n\sum xy-\sum x\sum y}{\sqrt{n\sum x^2-\left(\sum x\right)^2}\sqrt{n\sum y^2-(\sum y)^2}} \tag{1}$$

In formula (1), -1≤r≤1. r>0 means positive correlation. r<0 means negative correlation. |r|=0 means no linear relationship. |r|=1 means complete linear correlation. |r|≤0.3 means no linear correlation. $0.3<|r|\leqslant 0.5$ means a low linear correlation. $0.5<|r|\leqslant 0.8$ means a significant linear correlation. $|r|>0.8$ means a highly linear correlation.

Judgment coefficient is expressed as the square of the correlation coefficient, which is used to measure the degree of interpretation of y by the regression equation. The range of the decision coefficient is $0 \leq r^2 \leq 1$.

The judgment coefficient refers to the proportion of the total variation of the dependent variable that can be interpreted by the independent variable, which can explain the degree of influence of the factor.

The larger the coefficient of judgment,

$$r^2 = \frac{U}{L_{yy}} = \frac{\sum\left(\hat{y} - \bar{y}\right)^2}{\sum\left(y - \bar{y}\right)^2} = 1 - \frac{Q}{L_{yy}} \tag{2}$$

The relationship between the coefficient of determination and the correlation coefficient can be used to determine the linear correlation between the two variables.

$$r^2 = \frac{(n\sum xy - \sum x\sum y)^2}{\left[n\sum x^2 - (\sum x)^2\right]\left[n\sum y^2 - (\sum y)^2\right]} \tag{3}$$

The estimated standard error is the average degree of difference between the actual value of the dependent variable and its estimated value, indicating the representative strength of the estimated value for each actual value, which can reflect the fitness between the pros and cons in the model.

To estimated standard error,

$$S_e = \sqrt{\frac{\sum(y - \hat{y})^2}{n - 2}} = \sqrt{\frac{\sum y^2 - a\sum y - b\sum xy}{n - 2}} \tag{4}$$

Under large sample conditions, the formula can be used to calculate

$$S_e = \sqrt{\frac{\sum(y - \hat{y})^2}{n}} = \sqrt{\frac{\sum y^2 - a\sum y - b\sum xy}{n}} \tag{5}$$

The relationship between the decision coefficient and the estimated standard error is

$$r^2 = 1 - \frac{Q}{L_{yy}} = 1 - \frac{\sum(y - \hat{y})^2}{\sum(y - \bar{y})^2} \tag{6}$$

or

$$r^2 = 1 - \frac{S_e^2}{S_y^2} \tag{7}$$

In which $S_e^2 = \frac{\sum(y-\hat{y})^2}{n-2}$, $S_y^2 = \frac{\sum(y-\bar{y})^2}{n-1}$.

4 Experiments

The correlation between the flotation process parameters is analyzed respectively, and the parameter correlation of the significance level of 0.95 is calculated. The results are shown in Tab. 1.

Table 1: Result of parameter correlation analysis

	CS	LN	YM	N2	BM	St	GS	MR	MG	MB	MA	Dm	DV
CS	1.00	0.12	0.92	0.29	0.86	0.12	0.11	0.16	0.13	0.13	0.37	0.17	0.29
LN	0.12	1.00	0.18	0.15	0.06	0.04	0.15	0.15	0.15	0.15	0.11	0.03	0.09
YM	0.92	0.18	1.00	0.51	0.71	0.13	0.06	0.01	0.05	0.03	0.46	0.22	0.35
N2	0.29	0.15	0.51	1.00	0.05	0.05	0.34	0.32	0.33	0.30	0.30	0.18	0.21
BM	0.86	0.06	0.71	0.05	1.00	0.07	0.28	0.32	0.30	0.31	0.19	0.09	0.16
St	0.12	0.04	0.13	0.05	0.07	1.00	0.11	0.12	0.13	0.12	0.14	0.02	0.12
GS	0.11	0.15	0.06	0.34	0.28	0.11	1.00	0.98	0.98	0.98	0.39	0.07	0.31
MR	0.16	0.15	0.01	0.32	0.32	0.12	0.98	1.00	1.00	0.99	0.35	0.02	0.29
MG	0.13	0.15	0.05	0.33	0.30	0.13	0.98	1.00	1.00	0.99	0.38	0.03	0.32
MB	0.13	0.15	0.03	0.30	0.31	0.12	0.98	0.99	0.99	1.00	0.39	0.07	0.30
MA	0.37	0.11	0.46	0.30	0.19	0.14	0.39	0.35	0.38	0.39	1.00	0.07	0.91
Dm	0.17	0.03	0.22	0.18	0.09	0.02	0.07	0.02	0.03	0.07	0.07	1.00	0.28
DV	0.29	0.09	0.35	0.21	0.16	0.12	0.31	0.29	0.32	0.30	0.91	0.28	1.00

Comments: CS: Copper Sulfate, LN: Lead Nitrate, YM: Yellow Medicine, N2: No. 2 Oil, BM: Black Medicine, St: Stability, GS: Gray Scale, MR: Mean R, MG: Mean G, MB: Mean B, MA: Mean Average, Dm: Dimension, DV: Degree Variance.

As can be seen from Tab. 1:

(1) Among the dosing parameters, there is a strong correlation between Copper Sulfate, Yellow Medicine and Black Medicine, indicating that these three drugs are in strong linkage in production control.

(2) In the characteristic parameters of the foam image, the correlation between Gray Scale, Mean R, Mean G and Mean B is close to 1, which means a strong correlation. There is also a strong correlation between Mean Average and Degree Variance.

(3) There is a weak correlation among Dimension, Gray Scale, Mean R, Mean G, and Mean B, which means that the bubbles' color and the bubbles' skewness are independent to each other.

(4) Among the foam image characteristic parameters and the dosing parameters, the correlation between Stability and each dosing parameter is mostly less than 0.1, and there is almost no correlation between Mean Average and Degree Variance.

(5) There is a weak correlation or a medium correlation among Gray Scale, Dimension and dosing amount. That is to say, when considering the dosing amount, Mean Average, Degree Variance, Gray Scale, Dimension are valuable, and Stability is almost worthless.

5 Conclusion

Using the automatic dosing system of flotation factory, the five main drugs (Copper Sulfate, Lead Nitrate, Yellow Medicine, No. 2 Oil, Black Medicine) and corresponding foam image feature values (Stability, Gray Scale, Mean R, Mean G, Mean B, Mean Average, Dimension, Degree Variance) were recorded. Correlation analysis showed that there are many obvious correlations among flotation control parameters, including a strong correlation among Copper Sulfate, Yellow Medicine, Black Medicine, a strong correlation among Gray Scale, Mean R, Mean G, Mean B, a weak correlation among Dimension, Gray Scale, Mean R, Mean G, and Mean B, a week correlation between Stability and each dosing parameter, rarely no correlation between Mean Average and Degree Variance, and a weak correlation or a medium correlation between Gray Scale or Dimension and dosing amount. That is to say, Mean Average, Degree Variance, Gray Scale, Dimension have certain reference value, and Stability has almost no reference value. It also indicates a feasible way to decrease the complexity of flotation system by reducing some control parameters.

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