A METHOD FOR CONTROL AND OPTIMIZATION OF TECHNOLOGICAL PARAMETERS AT ORE FLOTATION

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Definite correlation exists among the technological parameters at ore flotation, expressed by a suitable criterion \( E = F(\mathcal{L}, \beta, \gamma, \sigma) \), where:

- \( \mathcal{L} \) - quantity of useful components in the ore (\%)
- \( \beta \) - quantity of useful components in the concentrate (\%)
- \( \sigma \) - quantity of useful components in the waste (\%)
- \( \gamma \) - yield of concentrate (\%)

and the thermodynamic state of the flotation system, expressed in terms of several thermodynamic potentials \( \Delta G, \Delta F, \Delta \mu \), where:

- \( \Delta G \) - free energy as per Gibs
- \( \Delta F \) - free energy as per Helm-Holtz
- \( \Delta \mu \) - chemical potential

\( /1, 2, 3, 4/ \). These correlations provide indirect means for forecasting, control and optimization of the technological parameters by employing some generalizing criteria.

The methods for the control of the flotation process, known so far, are based on the oxidation-reduction potential of the system, used as a generalizing criterion \( /1/ \); the surface tension, the residual concentration of the reagents or the pH-factor of the pulp may be employed as well. \( /6/ \).

The method, proposed in the present paper is based on the thermodynamic laws and the relationship between the technological parameters and the thermodynamic potentials, namely:

\[
\left[ \left( \frac{\partial (\Delta G/1)}{\partial (1/1)} \right) \right]_p = \Delta H
\]

\[
\Delta H = -C \Delta T
\]

\[
E = F(\Delta G)
\]
where:

ΔG - free energy as per Gibbs, isobaric potential (4,1868 KJ/Kmol)

T - absolute temperature (°K)

ΔH - enthalpy, (4,1868 KJ/Kmol)

C - system heat capacity (J/deg)

\[ C = m_1C_1 + m_2C_2 + ... + m_nC_n \]

\( m_n \) - mass of the components (kg)

\( c_n \) - specific heat absorption capacity of the components

(\( J.kg^{-1}.deg^{-1} \))

ΔT - temperature gradient (°K)

E - technological criterion

The enthalpy of the system is experimentally defined through the calorimetric method /8/. The core of the method consists of evaluation of the quantity of heat \( Q \), dissipated or absorbed as a result of the physical-chemical flotation process within the calorimeter, the heat quantity being defined at a constant pressure \( q_p = -(\Delta H)_p \). The magnitude and the sign of the quantity of heat depend on the temperature gradient ΔT of the calorimetric system (e.g. the flotation system):

\[ Q = C \Delta T \quad (J) \tag{4} \]

In case a flotation system is investigated, the heat must be treated as a summation of the heat quantities of the various endothermal and exothermal processes, taking place in the flotation pulp: solution, dilution, mixing, oxireduction, hydration, neutralization, electrolytic dissociation, wetting, adsorption, desorption, evaporation, mechanically generated heat (due to the impeller rotation) etc. The final expression depends and is expressed in terms of the temperature gradient at the end and at the head of the flotation front.

The heat capacity \( C \) is defined by treating the flotation system as a huge opened calorimeter; the mass of the pertaining components is defined (weight of the flotation machine, quantity of minerals, quantity of reagents, quantity of air, water flow rate etc.) and is
multiplied by the specific heat absorption capacities, taken out of reference manuals. After C and T are calculated using equation (2), \( \Delta H \) is defined after substitution. It must be mentioned, that each industrial technological circuitry has its own specific \( \Delta C \) as far as the types of ores, flotation installations and reagents, used in the different factories, have varying characteristics.

After \( \Delta H \) was calculated by (2), using (1) the partial derivative of \( \Delta G/T \) is computed (in terms of the variable \( 1/T \)):

\[
\frac{\Delta G}{T} = \int -G \, dT (1/T) = -C \int \Delta T \, d(1/T) \\
\Delta G = -CT \int \Delta 1d(1/T) = -CT / (T_2 - T_1). 1/T = C(T_2 - T_1) \quad (4)
\]

Substituting (4) into (3) the following relationship is derived:

\[
E = F[\frac{-CT}{-C(T_2 - T_1)}] = F[-C(T_2 - T_1)] = F(-CT) \quad (5)
\]

The technological criterion \( E \) is defined by one of the conventional methods after the technical ratings \( J, J_\beta, \mathcal{E} \) at a preset \( \lambda \) are found.

The equation \( E = F(\Delta T) \) may be used to control, optimize and adjust the technological parameters for any preset \( \lambda \) and for any quantitative and qualitative variation of the phases in the flotation system and their components, knowing the temperature gradient \( \Delta T \). Analytical and graphic tables and nomograms can be produced for each ore, presenting sets of calculational and experimental data.

It must be emphasized, that the variations of the thermodynamic potentials of a flotation process are quite small - in the range from \( 10^{-1} \) up to \( 10^{-6} \) kcal/mol. The temperature variations \( \Delta T \), due to various reactions during the flotation process, are quite small either - within the range \( 0.1 - 5 \, ^0K \); nevertheless these small variations are of basic importance for the realization of the flotation process. The temperature variations can be measured with sensitive mercury thermometers, resistive thermometers or thermocouples, calorimetric thermometers. The metastatic Backmann thermometer can
be successfully employed in this specific case, since it provides accurate readings of temperature variations in the range of \( \pm 0.002 \) to \( \pm 0.004 \, {^\circ}K \). Digital thermometers with high resolution may be used as well.

Hereinafter an exemplary application of the proposed method for regression mathematical simulation of the type

\[
E = F(L) \\
E_{\text{Pb}} = F(\Delta T) \\
E_{\text{Zn}} = F(\Delta T) \\
E_{\text{dif}} = F(\Delta T)
\]

is presented, which deals with the specific conditions of the combined flotation installation at the Kirjaly ore dressing works. The models are generated on the base of an industrial experiment. The recorded average values are presented in table 1, and the regression models are given in table 2.

### Table 1  
**AVERAGE VALUES OF THE TECHNOLOGICAL PARAMETERS**

<table>
<thead>
<tr>
<th>Lead (%)</th>
<th>Zinc (%)</th>
<th>Temperature gradient(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L = 2.60 )</td>
<td>( \beta = 19.44 )</td>
<td>( \Delta t = -1.78 )</td>
</tr>
<tr>
<td>( \beta = 13.35 )</td>
<td>( \sigma = 0.10 )</td>
<td></td>
</tr>
<tr>
<td>( \varepsilon = 96.41 )</td>
<td>( \varepsilon = 95.04 )</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2  
**RELATIONSHIP BETWEEN THE TECHNOLOGICAL PARAMETERS AND THE TEMPERATURE VARIATIONS**

<table>
<thead>
<tr>
<th>Relationship</th>
<th>Correlation coeff.</th>
<th>Variations coeff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E_{\text{Pb}} = 90.85 - 6.47\Delta t - 1.65\Delta t^2 )</td>
<td>0.922</td>
<td>0.78</td>
</tr>
<tr>
<td>( E_{\text{Zn}} = 85.64 - 9.86\Delta t - 2.51\Delta t^2 )</td>
<td>0.721</td>
<td>1.26</td>
</tr>
<tr>
<td>( E_{\text{dif}} = 180.243 - 12.606\Delta t - 3.245\Delta t^2 )</td>
<td>0.993</td>
<td>0.73</td>
</tr>
</tbody>
</table>

\[ E = E_{\text{Razumov}} = E_{\text{Pb}} + E_{\text{Zn}} \]
Conclusions

1. The data, given in table 1, permit the express definition of the technological parameters - individual values of $\varphi$ and $E$ correspond to any temperature difference, the dissipation of the results may be found by the average variation coefficient.

2. The data from table 1 are used to construct the regression equations in table 2. Those can be used to control, optimize and forecast the technological parameters after recording the values of $\Delta t$ and substitution in the regression equations.

3. The high values of the correlation coefficients reveal the strong dependence of the technological parameters on the temperature difference.

A calorimetric method to control, forecast and optimize the technological parameters of a flotation process has been devised, employing the thermodynamic laws and the relationship between the thermodynamic potentials of the flotation system and the selected technological criterion. The method provides means for the express and accurate definition of the above-mentioned parameters by measuring the temperature difference at the end and at the head of the flotation front and successive substitution in the regression equations $E = F(\Delta T)$.

References

