ANALYSIS OF THE SPECIAL FEATURES OF THE PROCESS OF KAOLIN’S ENRICHMENT WITH THE PURPOSE OF MODELING

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Abstract. In this work there is studied the increase in the demand of the national economy of the Republic of Uzbekistan for high-quality kaolin for various purposes requires finding new, non-traditional ways of enriching it. The aim of the work is to collect and process existing mathematical models of the kaolin enrichment process, taking into account the features of the modeling object. At the same time, it is necessary to refine the details of the technological regulations, normative and technical documentation, and develop adequate mathematical models of technological processes.

Keywords. Kaolin enrichment, mathematical models, integral level, technological regulations, a mathematical description, construct, the kinetic and hydrodynamic laws, the concentration of intermediate products, kinetic constants.

1. Introduction

The increase in the demand of the national economy of the Republic of Uzbekistan for high-quality kaolin for various purposes requires finding new, non-traditional ways of enriching it [1, 9, 15].

The useful properties of kaolin are determined by their use as raw materials for the production of fine, economically, sanitary, electro and radio ceramics, refractory products, glass and aluminum salt. High dispersion, refractoriness, white color, dielectric properties, chemical inertness, dispersibility, wettability determine the widespread use of kaolin as a universal filler in the manufacture of paper, rubber, cable, plastic and perfumery products [2, 10, 14].

Various attempts to find ways to enrich kaolin are known today. For example, using an electromagnetic separator [3], by separating sand and kaolin particles, followed by precipitation of kaolin aerosol in dust-collecting chambers [2], by treatment with sulfuric acid and ammonium sulfate, by heating to 100 °C, holding at this temperature within 2 hours and subsequent washing [4, 12, 13].

However, these methods do not provide a sufficiently high degree of brightness. It is believed that the well-known technology of kaolin enrichment has exhausted its capabilities and we need new, unconventional methods and approaches for a breakthrough in this area. Therefore, further progress is associated with the widespread use of biotechnology, as well as the introduction of highly efficient control systems using modern methods and computer technology, which will increase the efficiency of the biochemical production of kaolin in general [5-7, 11].

In this case, a complex but necessary task arises of analyzing individual features of the kaolin enrichment process for the purpose of mathematical modeling.

As a result of theoretical and applied research on the analysis of individual features of the kaolin enrichment process, we formulated a goal and set tasks to solve this problem.
The aim of the work is to collect and process existing mathematical models of the kaolin enrichment process, taking into account the features of the modeling object.

In accordance with the goal, it becomes necessary to solve a number of problems in the following sequence: analysis of existing modeling methods and optimal control of the biotechnological process of kaolin enrichment; the formation of a mathematical description of the reaction rate of the transition of ferrous to ferric; development of a mathematical description of the process of separation of iron from enriched kaolin; the formation of a mathematical description of the substrate consumption by bacteria; taking into account active acidity in the development of a mathematical model; identification of patterns between the reaction rate and the concentration of kaolin suspension; identification and mathematical description of the degree of influence of pH and temperature on active acidity; establishing the transition of the amount of enriched kaolin to the target product; accounting for the time spent in the reactor (flow rate); establishing a mathematical description of the density of enriched kaolin.

The possibility of a mathematical approach to the processes under study appeared as a result of mastering the principles used in the analysis of problems of chemical kinetics, when in chemical reactions not every molecule participating in this reaction is considered, but the integral level of their behavior is studied. This approach allows us to describe the dynamics of the process and the kinetic behavior of the system with a very small number of parameters that need to be studied for applying models to real processes.

In this case, the study of the technological process according to its mathematical model includes several successive stages [8, 15]. At first, they make a choice or make up a new mathematical model based on the idea of the process in accordance with the objectives of the proposed study; on the second - the choice of a specific type of mathematical equations that describe the process, the determination of the numerical values of the coefficients included in these equations; on the third - the actual simulation is carried out, i.e. obtaining the desired dependencies as a result of solving mathematical equations. Solutions are most often found using computer calculations by analytical, experimental-statistical or experimental-analytical methods.

Moreover, if you want to ensure the guaranteed quality of biotechnological enriched kaolin, then you need to get the target product with an iron content of not more than 0.4-0.6% per Fe2O3. This means that the iron content must be reduced by 2.5-7 times. The direct application of previously known proposals [2-4, 9] is impossible with the scaling of the process and the transition to large-tonnage production. Therefore, a search for new solutions is required.

One of the typical objects of modeling is the technological scheme of the process of iron removal of kaolin [8, 14].

2. Methods and Results

Compilation of a mathematical description of the kaolin enrichment process is not yet possible. This is because it is difficult to determine for each stage the kinetic and hydrodynamic laws, the concentration of intermediate products, kinetic constants, enzyme activity, etc. Therefore, the content of iron oxide and titanium dioxide, the titer of a solution of iron oxide and titanium, the content of aluminum oxide and hygroscopic moisture in kaolin, we calculated under experimental conditions using the following formulas.

The content of iron oxide \( G_i^o \) and titanium dioxide \( G_t^o \) in percent calculated by the formulas:

\[
G_i^o = \frac{m_i^o V_i^o a}{V_{ao} m_{ao} b}
\]  
\[
G_t^o = \frac{m_t^o V_t^o a}{V_{ao} m_{ao} b}
\]
where \( m^0 \), \( m^b \) - respectively, the mass of iron oxide and titanium, \( g \); \( V^0 \) - the volume of the main solution, ml; \( m_{ak} \) - mass of a sample of kaolin, \( g \); \( a \), \( b \) - const.

The titer of a standard solution of iron oxide is calculated by the formula:

\[
G_{ri} = \frac{m}{c} \tag{3}
\]

where \( m \) is the mass of calcined sediment, \( g \); \( c \) is the const volume of a standard solution taken for precipitation of iron hydroxide, ml.

The titer of a standard solution of titanium \( G_{rt} \) is calculated by the formula:

\[
G_{rt} = \frac{m^0_{pr}}{V^r} \tag{4}
\]

where \( m^0_{pr} \) is the mass of the calcined precipitate, \( g \); \( V^r \) - the volume of a standard solution taken for the precipitation of titanium hydroxide, ml.

The percentage of aluminum oxide \( G^a \) is calculated by the formula:

\[
G^a = \frac{\left( V^r_{tr} - V^r_{ul} \right) N^a_{ul} V_{ul} a}{V^a_{ul} m_{ak}} - K^p_{fi} - K^p_{ji} G^o \tag{5}
\]

where \( V^r_{tr} \) is the volume of trilon B solution, ml; \( V^r_{ul} \) - the volume of a solution of zinc acetate, spent on titration, ml; \( R^a_{ul} \) - the ratio between the solutions of trilon B and zinc acetate; \( N^a_{ul} \) is the titer of trilon B solution calculated from alumina; \( V_{ul} \) - the volume of the main solution, ml; \( m_{ak} \) - mass of a sample sample of kaolin, g; \( V^a_{ul} \) - the volume of an aliquot of the main solution ml; \( K^p_{fi} \) - conversion factor of iron oxide (in kaolin) to aluminum oxide; \( K^p_{ji} \) is the conversion factor of titanium oxide to aluminum oxide; \( G^o \) - the content of iron oxide in kaolin; \( G^i \) - the content of titanium oxide in kaolin; \( a \) - const.

The hygroscopic moisture content in kaolin \( W^b \) in percent is calculated by the formula:

\[
W^b = \frac{(m_1 - m_2) d}{m_{ak}} \tag{6}
\]

where \( m_1 \) is the mass of the vessel with kaolin before drying, g; \( m_2 \) - the mass of the vessel with kaolin after drying, g; \( m_{ak} \) - the mass of a sample of kaolin, g; \( d \) is const.

Based on studies, it was found that these formulas do not take into account other main technological factors that have a significant impact on the process of obtaining enriched kaolin. These include factors such as time, pH, and density.

In the process of fermentation of the reaction mixture, starting from two days, part of the suspension is selected and analyzed for the content of iron oxide, which can be represented as:

\[
y = y_0 \left[ 1 - e^{- \frac{2}{T} \left( \cos w_j + \sin \frac{w_j}{T_w} \right)} \right] \tag{7}
\]

it is shown that the density is directly proportional to the concentration of iron content. With a constant substrate and time, the speed of the process, depending on the concentration of iron content, can be expressed by the formula:

\[
v = K[x] \tag{8}
\]

and depict the straight line, because it is directly proportional to the concentration of kaolin.

The speed of the biochemical process reaches its maximum value only at certain \( pH \) values. The effect of \( pH \) on the rate of oxidation of iron can be established experimentally.
Experimental data showed that at initial $pH = 2.2 - 2.3$, the culture is able to oxidize ferrous iron in a wide pH range, but the optimum $pH$ is in the range of 2.2-2.5. At higher and lower $pHS$, bacterial oxidation is less active.

The mathematical description of the dependence of the rate of the enzymatic reaction on $pH$ has the form:

$$V = \frac{V_n}{1 + \frac{[H^+]}{K_1} + \frac{[H^+]}{K_2}}$$

where $K_1$, $K_2$ are the ionization constants of the complex, $[H^+]$ is the concentration of hydrogen ions. This equation has not found wide application because of the complexity of determining these constants.

Thus, the analysis of individual features of the technological process of kaolin enrichment showed that they belong to the class of multidimensional complex systems. Undeveloped methods for modeling such classes of objects remain. Therefore, with the aim of constructing a mathematical model of such classes of objects, we have identified the main technological factors and individual features of the biotechnological process of kaolin enrichment, which subsequently together will make it possible to obtain enriched kaolin that meets the requirements of various industries. At the same time, it is necessary to refine the details of the technological regulations, normative and technical documentation, and develop adequate mathematical models of technological processes.

3. Conclusion

As a result of theoretical and applied research on the analysis of individual features of the kaolin enrichment process, we formulated a goal and set tasks to solve this problem. Thus, the analysis of individual features of the technological process of kaolin enrichment showed that they belong to the class of multidimensional complex systems. Based on studies, it was found that these formulas do not take into account other main technological factors that have a significant impact on the process of obtaining enriched kaolin.

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