Upgrading of the process of technological pulp separation in modern pressure filters

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Filtration is one of the main technological processes determining the efficiency of hydrometallurgical circuit of non-ferrous metallurgical factory, chemical, beneficating and other industries. Nowadays, modern high-technology filters are generally used in production of non-ferrous metals all over the world. Increase of filter capacity and efficiency is one of priority problems. However, this problem solution needs not only increasing the filter size but also the process intensification: separation with the maximal rate, providing output product with a given quality.
Modern filter is a complex machine with many functions and operating modes. Such filter setting and operation control of all it's subsystems is a difficult task. Certainly, this problem should be solved not by responsible staff, but by automatic control system, which is part of the filter.
This paper pays great attention to suspension filtration process at constant differential pressure with sediment formation. Practically such process is the most widespread.
The problem of increased filtration efficiency is solved in several stages. The first stage is a mathematical filtering model, while the second stage is the experimental study, using the laboratory periodic nutsche filter. Finally stage is the development of mathematical filtration models in MatLab program.

Key words: filtration, pressure filter, modeling, automatic control system, mathematical model.

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Filtration process is considered on the example of filtration of technological pulps at non-ferrous metal metallurgical factories. Generally, concentrates of different metals have much moisture after multistage grinding and flotation processes. Before the convection drying, requiring a high cost of energy, is often conducted the filtration process for removing of the main liquid mass. Installed filter efficiency is important not only for the quality and quantity of products, but also for the cost of subsequent drying if it necessary. Consequently intensification of various filters [1] operation is one of the main problems.

One of the most successful examples of connection of filtration process and automatic control system is automatic vertical pressure filter. This type of filter has a number of advantages:

– high capacity;

– advanced filtration surface at small occupying area of filter;

– possibility of regulation thickness and sediment wetness (the main output filter characteristic);

– insignificant time requiring for auxiliary operations such as filter partition washing and cake removing;

– filtering cloth regeneration without stopping;

– full automatic of filtration process.

Technological pulps filtration is difficult for exact mathematical description due to the fluid movement through the porous material depending on a large number of factors characterizing the properties of material and substances involving in process. Nevertheless, dependences based on the Kozeni – Karmar equation, [1] are able to describe the process with sufficient accuracy for industrial filters calculate.

A great attention is paid to suspension filtration process at constant differential pressure with sediment formation. Practically this is the most widespread process.

The main filtration equation is based on the Darcy's law [2] and shows the change of filtrate consumption depending on differential pressure before and after filter partition and resistivity of this partition.

$$\frac{dV}{dt} = \frac{\Delta p A}{\mu \alpha_{sp}\left[\frac{C_W \rho}{(1 - C_W m)}\right]\frac{V}{A} + \mu R_r}, \quad (1)$$

V — filtrate volume, m^3; t — time, s; Δp — differential pressure before and after filter partition, Pa; A — filter partition area, m^2; μ — dynamic viscosity of fluid phase of suspension, Pa·s; α_{sp} — specific resistance of sediment, $m \cdot kg^{-1}$; C_W — mass fraction of solid in suspension; ρ — fluid phase density in suspension, $kg \cdot m^3$; m – sediment wetness after filtration; R_r — filter partition resistance, m^{-1};

After the integration of equation (1) at a constant differential pressure (Δp = const), the main equation of filtration the following form:

$$\frac{t}{V} = \frac{\mu\alpha_{sp}}{2A^2\Delta p}\left[\frac{C_W\rho}{(1 - C_W m)}\right]V + \frac{\mu R_r}{A\Delta p} = aV + b, \quad (2)$$

a and b — constants, using the same filter with a constant differential pressure at filtration constant at mass composition of suspension.

The following equation is used for subsequent modeling to determine of filtrate volume depending on time:

$$V = \frac{-b + \sqrt{b^2 + 4at}}{2a}. \quad (3)$$

The height formed sediment on the filtration partition is directly proportional to filtrate passing through a filtrate partition [3]. Consequently, the following equation is used for sediment height determination depending on time:

$$L = \frac{VC_W[\rho_s(m - 1) + \rho]}{A\rho_s(1 - mC_W)}, \quad (4)$$

ρ_s — solid phase density in suspension, $kg \cdot m^3$.

Wetness of sediment after filtration can be assessed defining average value of porousness and densities of solid and fluid phases of suspension:

$$m = 1 + \frac{\rho\varepsilon}{\rho_s(1 - \varepsilon)}, \quad (5)$$

ε —average value of sediment porousness.

Differential pressure at filtration effect on properties formed the sediment with changing average value of resistivity and porousness [3, 4]. The sediment is called compressible and incompressible if this effect has large and small influence, respectively. may be using The following equations are used to evaluate the effect of pressure on the sediment properties:

$$\alpha_{sp} = \alpha_0(\Delta_p)^n, \quad (6)$$

$$\varepsilon = \varepsilon_0(\Delta_p)^{-\lambda}, \quad (7)$$

α_0, n, ε_0 and λ — constants for this suspension which are determined during the experiment.

Experiment used the suspension, consisting of a mixture of iron particle concentrate (Fe_3O_4) and water. Baseline suspension characteristics are:

– solid phase density in suspension ρ_s = 3947.25 kg/m^3;

– fluid phase density in suspension ρ = 987.45 kg/m^3;

– dynamic viscosity of fluid phase (t = 18.2 °C) μ = = 0.0286 Pa·s;

– mass fraction of solid in suspension C_W = 0.38.

Experiment used the laboratory periodic nutsche filter with the surface of filtration partition A = 0.0022 m^2 (Lappeenranta University of Technology). Processes occurring in laboratory periodic nutsche filter are similar to the processes in industrial filters. Consequently, model developing can use the laboratory equipment [5, 6]. Appearance and schematic image of filter are presented on Fig. 1.

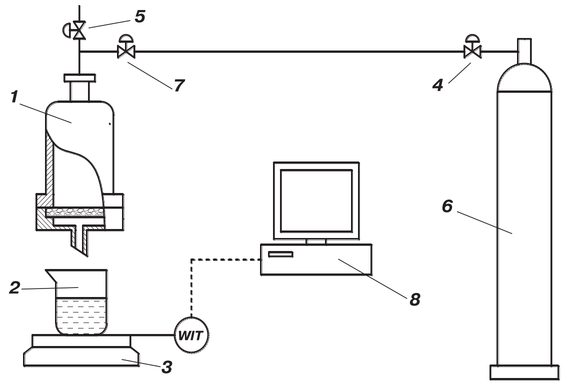

Fig. 1. Schematic image of laboratory filter:
1 — filter; *2* — tank to filtrate; *3* — scales; *4* — valve to adjust the pressure supply; *5* — input branch pipe for suspension; *6* — nitrogen bottle for pressure supply; *7* — valve for pressure supply; *8* — computer for data gathering

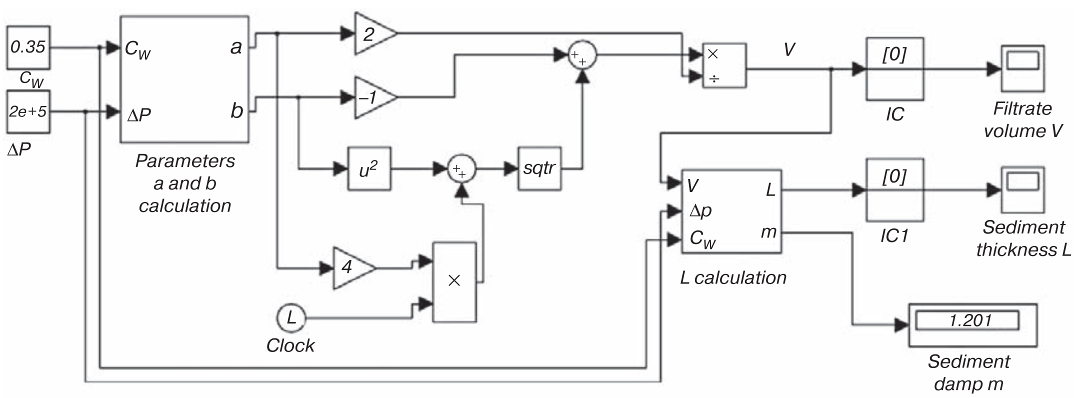

Fig. 2. Filtration model in Simulink program (Δp = 2 bar)

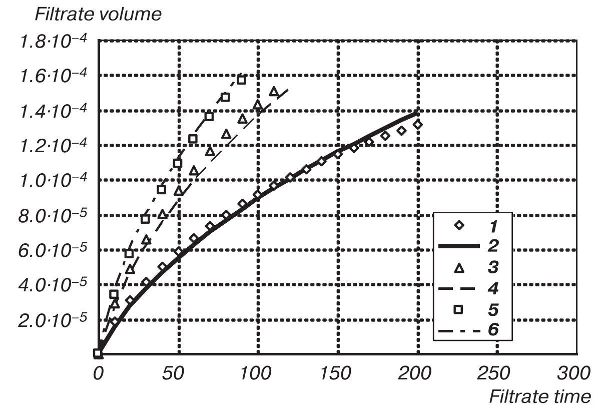

Fig. 3. Experimental results from laboratory filter and data of modelling process from Simulink program:
1 — 2 bar (exp.); *2* — 2 bar (mod.); *3* — 4 bar (exp.); *4* — 4 bar (mod.); *5* — 6 bar (exp.); *6* – 6 bar (mod.)

Experiments were performed at three different differential pressures Δp ($2{\cdot}10^5$, $4{\cdot}10^5$ and $6{\cdot}10^5$ Pa), while the resulting filtrate weight was fixed in real time. On the basis of the experiments, there were established the following sediment characteristics (depending on differential pressure) and filter partition:

$$\alpha_{sp} = 1.791{\cdot}10^{10}(\Delta p)^{0.154} \text{ m/kg},$$

$$\varepsilon = 0.628(\Delta p)^{-0.497},$$

$$R_r = 2.5{\cdot}10^{11} \text{ 1/m}.$$

Mathematical model of filtration process at constant differential pressure was implemented on the basis of the formulas (3)–(5) and dependences of specific resistance and average sediment porousness from pressure in Simulink program [7, 8]. Taking into account the forming sediment compressibility this model is presented on Fig. 2.

Fig. 3 shows the change filter costs depending on time for experimentally obtained different differential pressure and by the process modeling.

The model, shown in the Fig. 3 exactly describes the change of filtrate volume depending on time. Besides, this model complies to experimental results obtained in similar pressure filter [9, 10]. As shown, small deviations of experimental results from simulation data are shown in some times of filtration. It depends inconstant pressure during the filtering process [11, 12].

The proposed model can be used in automatic control system. This will optimize technological processes in the installation and change its easily in accordance with the industrial problem [13]. Also this model can be used for search of optimal conditions filtration process in different industries observing the cost reduction and increase the capacity of industrial filters [14].

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