Computer modeling and automation of process of cleaning liquids from ferromagnetic impurities

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***Abstract* – Solved model problem type "convection-mass transfer" for the water treatment process in magnetized granular filter material. Mathematical analysis of parameters and models of the magnetic deposition of impurities. Found critical the filter at variable concentrations of magnetic impurities entering the filter. Developed automation system for the continuous purification of water from magnetic impurities, which provides an acceptable concentration of iron impurity at the output of the filter.**

Key words – magnetic deposition, computer modeling, automation of the filtration process.

I. Introduction

Process water systems many industries known to pollution of various kinds of impurities. The problem is acute in thermal and nuclear power (CHP, thermal power plants, nuclear power plants), chemical, steel, glass, alcohol, ceramic, aviation industries. The main reason for the presence of impurities in water technology systems have continuous corrosion technology and communication equipment. At reversible (waste) water dispersed concentration metallurgical production mill scale reaches 100 mg/dm^3, at norm of 10 mg/dm^3 [1]. Such a high concentration mill scale leading to rapid wear technological equipment, deteriorating quality of of products. To remove the ferromagnetic impurities from technological water systems proposed to use the method of deposition magnetic impurities in the magnetized granular filter material. Advantages of the given method is to clearing the water environment with a temperature of 500 °C to, filtration speed of 1000 *m/h*, the ability to purify chemically are aggressive environment. Regeneration of granular ferromagnetic filter media does not require chemical reagents, which makes the method of magnetic filtration is environmentally safe.

One of the least expensive methods that allows to verify its compliance with necessary technical requirements is a computer simulation [2]. When using magnetic filters in water treatment systems there is a need to provide a predetermined concentration of magnetic impurities in a liquid medium. In addition to the efficient use of resources and to ensure that the main function of filter cleaning, it is necessary to investigate the influence of the concentration of contamination entering the system at a critical time of the filter and the differential pressure that is created on it.

The level of automation of heat power engineering is one of the leading places among all industries. Thermal power plants are characterized by the continuity of processes occurring in them. Almost all operations at thermal power plants are mechanized, and the transitional processes they are developing quite quickly.

Automation of water treatment plants to reduce maintenance and increase the reliability of installations, to improve technical and economic performance due to optimization and intensification of technological processes, to provide the water of guaranteed quality. Under automatic control of the filters is achieved by a reduction in the specific and general costs of chemicals and water on its own needs. The introduction of automation control installations water treatment allows 2-3 times to increase the productivity of these plants without additional capital expenditures on equipment and construction, which is the primary factor that determines the feasibility of implementation of automated systems of water treatment.

At the same time, when using a magnetic filter in the cleaning systems to determine the concentration of iron impurities in the liquid medium not developed a universal device that generates a signal change contamination, and the rate is measured empirically, which requires considerable material, labor resources and time, therefore there is a need to automate the process.

II. Analysis of previous studies

Numerous studies have established that the bulk of the impurities are iron with ferromagnetic properties [1,2,4,7]. Deposits of impurities on the surfaces of steam-generating thermal plants in the amount of 200-300 g/m^2, which corresponds to the thickness of the sediments 0.3-0.5 *mm*, causes additional overheating of the tubes at 50-120 °C, which in some cases leads to pipe ruptures.

Experimental studies to determine the influence of the parameters of magnetic cleaning process on the coefficient of magnetic deposition, the concentration of iron impurities, the period filtering [1,2,7], therefore, an urgent task is the mathematical analysis of parameters and simulation of the magnetic deposition of impurities in the purification of multi-concentration and little-concentration water systems and the automation of the corresponding cleaning process.

III. Statement of the problem

As the object of studies the management system of water purification from ferromagnetic impurities, including 2 electromagnetic filters– precipitator and a system of valves that control the water flow and regeneration filters, as well as the controller TSX-Micro3722, which generates control signals for the system, where the subject of research is the process of magnetic filtration of nutrient water from iron impurities.

The research was carried out by means of simulation using the Simulink and M-function pdepe of Matlab environment by converting differential equations into machine code, wherein the control system, according to which will work the controller developed in the software environment of PL7 Pro.

IV. The main material of the article

Let us consider the spatially one-dimensional process of purification of liquids by filtration in the layer of granular filter material by the thickness (which is identified with the segment axis). Assume [3,5] that contamination particles (impurities) can proceed from one state to another (processes of capture-separation) and, thus, has the opposite effect of the respective concentrations on the characteristics of the considered layer. The process of filtration taking into account reverse influence of process characteristics (the contamination concentration of liquid and trapped particles) on the characteristics of the environment (the coefficients of porosity, filtration, mass transfer, magnetic field strength) by analogy with [2]-[5]) describe the following model:

$$\begin{cases} \dfrac{\partial\left(\sigma(\rho)c(x,t)\right)}{\partial t}+\dfrac{\partial\rho(x,t)}{\partial t}+v\dfrac{\partial c(x,t)}{\partial x}=0, \\ \dfrac{\partial\rho(x,t)}{\partial t}=\beta(H,v,d)c(x,t)-\varepsilon\alpha(\rho)\rho(x,t), \end{cases} \quad (1)$$

$$c\big|_{x=0}=c_*^*(t),\ c\big|_{t=0}=0,\ \rho\big|_{x=0}=0,\ \rho\big|_{t=0}=0, \quad (2)$$

$$v=\kappa(\rho)\cdot grad\ p\ , \quad (3)$$

where $c(x,t)$ – is the concentration of impurities in the fluid that is filtered; $\rho(x,t)$ – the concentration of impurities, precipitated in a granular filter material; β – coefficient, characterizing the mass deposition of impurity particles per unit time ($\beta(H,v,d)=\dfrac{\beta_0 H^{0.75}}{vd^2}$ where β_0 is a free parameter, H – magnetic field strength, v – the rate of filtration d – the diameter of the granules of the filter material [8]), $\alpha(\rho,H)$ – the coefficient, which characterizes the mass volumes detached at the same time from the granules of filter material impurity particles.

$$\alpha(\rho)=\alpha_0+\varepsilon\alpha_*\rho(x,t)\,, \quad (4)$$

$c_*^*(t)$ – the concentration of impurity of particles on filter input; $\sigma(\rho)$ – the porosity of the filter material;(σ_0 – the initial porosity of the filter material)

$$\sigma(\rho)=\sigma_0-\varepsilon\sigma_*\rho(x,t)\,, \quad (5)$$

$\kappa(\rho)$ – filtration coefficient, $\rho_0=\rho(L,\tau_з)$

$$\kappa(\rho)=\begin{cases}\kappa_0-\varepsilon\gamma\rho(x,t),\ \rho<\rho_0, \\ \kappa_0-\varepsilon\gamma\rho(x,\tau_з),\ \rho\geq\rho_0, \end{cases} \quad (6)$$

$\alpha_0,\alpha_*,\sigma_*,\kappa_0,\gamma,\varepsilon$ – hard parameters (they characterize the corresponding coefficients); $\alpha(\rho),\sigma(\rho),\kappa(\rho)$ – variables (are experienced); ε – solid parameters; p - is the pressure. Moreover, we note that unlike [3,5], in the more general case, the pressure $p=p(x,t)$ it would be rational to determine the solution of the equation $\dfrac{\partial}{\partial x}\left(\kappa(\rho)\dfrac{\partial p}{\partial x}\right)=\dfrac{\partial\sigma(\rho)p}{\partial t}$, obtained under the above written equations of motion and the equation of state: $div\ v=\dfrac{\partial\sigma(\rho)p}{\partial t}$ at the boundary $p(0,t)=p_*(t)$, $p(L,t)=p^*(t)$ ($0<t<\infty$) and initial $p(x,0)=p_*^*(x)$ ($0<x<L$) conditions ($p_*(t)$, $p^*(t)$, $p_*^*(x)$ – are given sufficiently smooth and coherent in the corner points of the domain of the function $G=\{(x,t):0<x<L,\,0<t<\infty\}$.

Thus, in the problem-solving process, can determine an appropriate value $grad\ p$, in particular a pressure difference $\Delta P=p^*(t)-p_*(t)$ between input and output filter.

V. The solution of the problem

The solution of the system (1) under conditions (2) are looking for in the form of asymptotic series [3,4]:

$$c(x,t)=c_0(x,t)+\sum_{i=1}^{n}\varepsilon^i c_i(x,t)+R_c(x,t,\varepsilon)\,,$$

$$\rho(x,t)=\rho_0(x,t)+\sum_{i=1}^{n}\varepsilon^i\rho_i(x,t)+R_\rho(x,t,\varepsilon)\,, \quad (7)$$

where R_c,R_ρ –is the remaining members, $c_i(x,t)$, $\rho_i(x,t)$ ($i=\overline{0,n}$) – members of the regular units of the asymptotes. Similar to [6], after substituting (7) into (1) and the application of standard "procedure of equating" to find functions and c_i i ρ_i ($i=\overline{0,n}$) come to such tasks:

$$\begin{cases}\sigma_0\dfrac{\partial c_0}{\partial t}+v\dfrac{\partial c_0}{\partial x}+\dfrac{\partial\rho_0}{\partial t}=0,\quad \dfrac{\partial\rho_0}{\partial t}=\dfrac{\beta_0 H^{0.75}}{vd^2}c_0, \\ c_0\big|_{x=0}=c_*^*(t),\ c_0\big|_{t=0}=0,\ \rho_0\big|_{x=0}=0,\ \rho_0\big|_{t=0}=0,\end{cases} \quad (8)$$

$$\begin{cases}\sigma_*\rho_{i-1}\dfrac{\partial c_i}{\partial t}+v\dfrac{\partial c_i}{\partial x}+\sigma_*\dfrac{\partial\rho_{i-1}}{\partial t}c_i+\dfrac{\partial\rho_i}{\partial t}=0,\ \dfrac{\partial\rho_i}{\partial t}=\dfrac{\beta_0 H^{0.75}}{vd^2}c_i-g_i, \\ c_i\big|_{x=0}=0,\ c_i\big|_{t=0}=0,\ \rho_i\big|_{x=0}=0,\ \rho_i\big|_{t=0}=0, i=\overline{1,n},\end{cases} \quad (9)$$

where $g_i(x,t)=\sum_{j=1}^{i}\rho_{j-1}\left(\alpha_0+I(i,j)\sum_{j=2}^{i}(\alpha_*\rho_{i-2})\right)$.

Conduct the simulation in the software Matlab, in particular with the use of the M-function pdepe.

As a result of computer simulation (the following input data: $c_*^*(t)=2$ mg/dm^3, $L=1$ m, $v=200$ m/h, $\beta_0=0.9\cdot10^{-9}$ m^2/s, $H=80$ kA/m, $d=5$ mm, coefficient $\alpha_0=0.28\cdot10^{-13}$ m^2/s, $\alpha_*=0.65$, $\varepsilon=0.01$, $\sigma_0=0.5$, $k_0=1$) got the following results (see Fig. 1-4) :

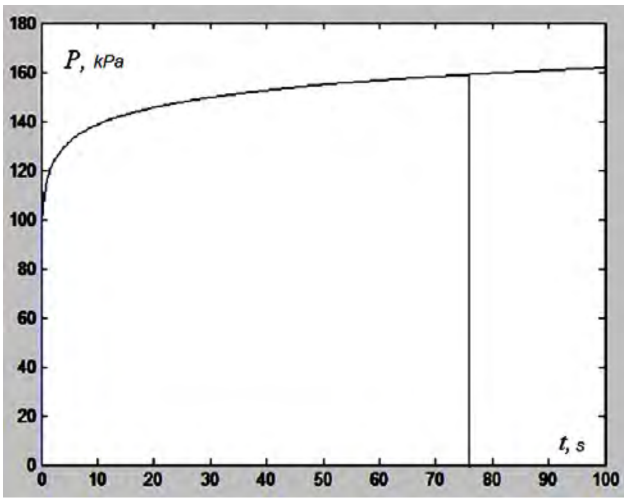

Fig. 1. The change in the pressure difference

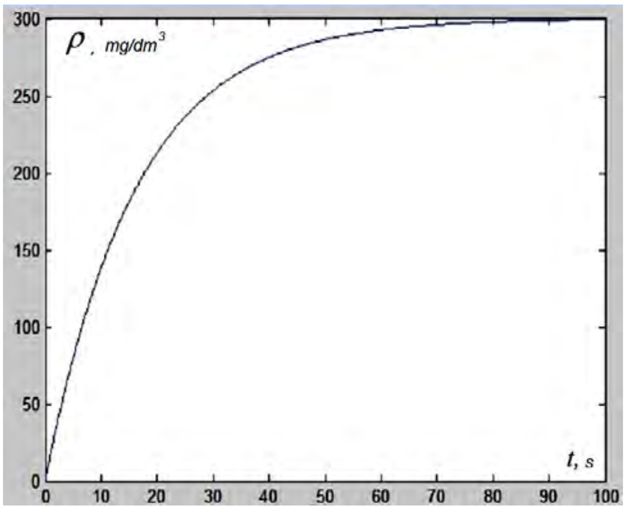

Fig. 2. The change in the concentration of particles, became interested in the filter

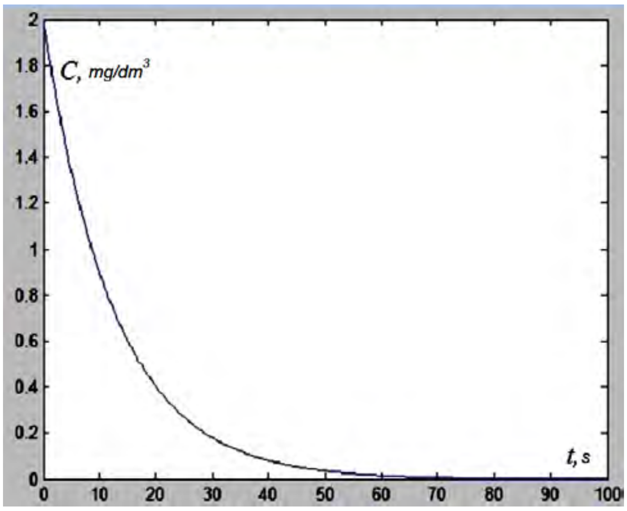

Fig. 3. The change in the concentration of particles in solution

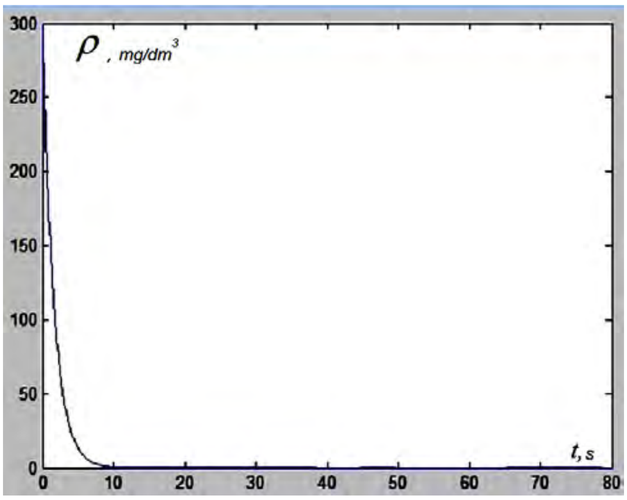

Fig. 4. The change in the concentration of particles at cleaning the air filter

To automate the process of magnetic water treatment developed functional scheme of automation (figure 5), according to which the function is controlled by a transfer flow of the filtering fluid between the two filters. During filtration, the filter work another "dirty" automatically performs regeneration.

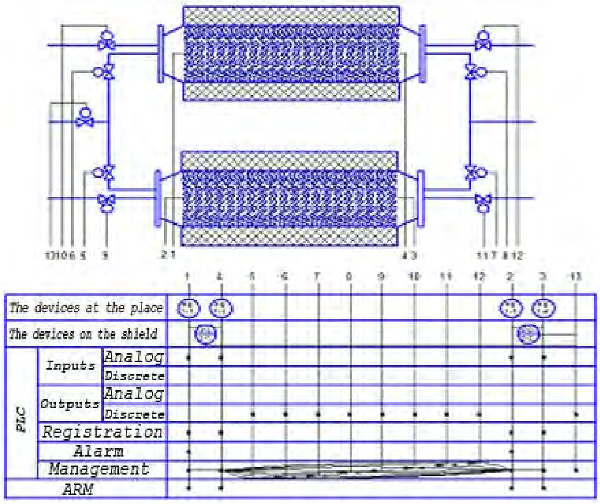

Fig. 5. Functional scheme of automation

Given system is would have 2 regulation outlines that provide at the appropriate level such technological parameters:

1. The concentration of contaminants in the liquid environment.
2. Pressure at the output of process water from the system.

Also supervises such technological parameters:
1. Pressure of contaminated water at input filter 1.
2. Pressure of contaminated water at input filter 2.

Order to identify deviations in the technological process in the case of deviation of critical parameters to implement an emergency stop of the process by means overlapping filing of contaminated water shut-off valve in the system.

The contour of regulation of pressure technological water at the outlet of the pipe (PC 2-1, PC 2-2). The given contour of maintains a specified pressure of technological water at the outlet of the cleaning system by changing the costs of polluted substance at input in the appropriate filter.

The main disturbance is the concentration of particulate contamination, that remained in the corresponding filter. With increasing particles that linger in the corresponding filter bandwidth of the filter is reduced and reduced the pressure that is perceived the pressure sensor PE 1-2 or PE 1-4.

The signal from the sensor goes to the microprocessor system. The managing microprocessor system produces an electrical signal which fed to the corresponding executive mechanism and control flap opening filing of contaminated water. As a result of opening regulating flap is increased filing of the liquid medium, the pressure at input to the filter increases, resulting in an increase of water pressure at the outlet of the purification systems and its stabilization, but the change of pressure on logon happens to a certain critical value, which is perceived by the relevant sensor the pressure PE 1-1 or PE 1-3, after reaching the value a given transfer happens of fluid flow to the other filter.

The contour of regulation concentration of contamination at the output of the system**.** The major perturbation of a given of the technological parameter is the concentration of perturbation on logon and feed rate of contaminated water. The settlement of a given technological parameter occurs along of pressure drop at the inlet and the outlet of the corresponding filter.

When increasing the of particles that delayed in the corresponding filter bandwidth of the filter is reduced and reduces the pressure at the outlet of the filter, perceived the pressure sensor PE 1-2 or PE 1-4 and the system begins to augment expenditure of contaminated substances, thus begins to grow and the system pressure pollution delayed are beginning to not at start of the filter, and in certain coordinate. The given a sequence of actions takes place till the time for the present the difference between the respective of differential pressure sensors the pressure not achieve defined value and program management in the microcontroller does not translate the fluid flow to another filter by supplying control signals to the corresponding outputs.

Develop a program to control the operation of continuous filters for water purification from iron impurities. For writing the program use the language of diagrams (Ladder Language LD). To display the progress of the process developed graphical presentation software PL7 PRO. The mnemonic process has the form shown in figure 6.

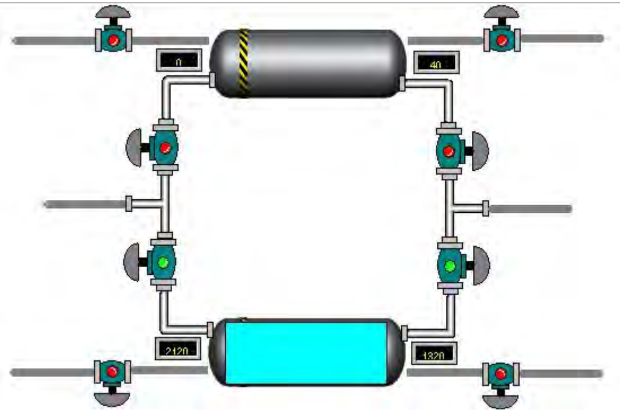

Fig. 6. The mnemonic of the technological process by means of software PL7 PRO

Conclusions

As a result, the solution of the model problem process of purification of aqueous media in magnetized granular filter material held automation systems for continuous water purification taking into account the changes of flow parameters, which controls two filters with the permanent transfer of the fluid stream and the regeneration of the pre-filter and also identifies the days of efficient cleaning and regeneration of the filter.

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