Fuzzy-logic system for regulating the temperature regime of a bioreactor in the process of bacterial oxidation

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Abstract. In this article, a simulation model of an intelligent control system for a bioreactor used in the bacterial oxidation process of sulfide deposits with complex, gold-enriched content is developed using the functional blocks from the Fuzzy Logic Toolbox library in the MATLAB software package. Furthermore, the mathematical model of the bioreactor is represented through its transfer function in the significant adjustment channel. A rule base is established to regulate the variation of input and output parameters for the fuzzy control system. The study reveals that employing a fuzzy controller for bioreactor systems is an effective method for system adjustment.

1 Introduction

Based on the analysis of the dynamic characteristics of the bioreactor, the main requirements for the parameters of its operating mode were developed and the fuzzy adjuster for the control system was improved . Here, the main requirement is to keep the temperature in the bioreactor stable with high accuracy, taking into account the continuous change of temperature. According to the control issue, the temperature of the biocake at the outlet of the bioreactor and the temperature of the cooling water at the inlet were taken as the main adjustable quantities. As an input quantity, the consumption of cooling water supplied to the bioreactor was taken.

Tasks to solve the problem is carried out:

1. A model of the control object, its input, output parameters and inclusion of turbulent effects.
2. Selection of decision-making algorithms based on fuzzy logic representing the conditions of the bacterial oxidation process.
3. Synthesis of a fuzzy adjuster that provides the necessary qualitative and quantitative indicators of the control of the temperature regime of the bioreactor in the presence of various turbulent effects.

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2 Materials and methods

The concentrate coming to the bioreactor can be kept stable at the value given in the technological regulation by introducing an additional fuzzy adjuster. Therefore, it is necessary to keep the temperature of the cooling water stable in accordance with the technological regulation. The dynamic characteristics of the control object are used in the construction of the automated adjustment system for this given quantity. In this case, the dynamic characteristic of the tuning device - the channel of the tuning quantity is obtained. The dynamic characteristics of the adjustment channel are necessary for the selection of the control algorithm and the calculation of its parameters [1-5].

According to the data obtained on the basis of experimental experiments, the transfer function of the tuning channel, which is significant, was determined:

$$W_{22} = \frac{0.98p + 0.1506}{p^2 + 0.13p + 0.045} \tag{1}$$

The structure of the fuzzy adjuster and the selection of its adjustment parameters mainly consist of two steps. That is, linear typical adjustment laws are determined and the values of the parameters of the adjuster are found. According to the analysis, it was proposed to use a fuzzy PID-adjuster to adjust the significant control channel. Because one of the requirements for the object is to ensure accuracy and speed.

It should be noted that the control system of the bacterial oxidation process is a complex object, and it is a non-stationary process. To control such systems, the expressed PID - adjuster was used [6-9].

Bacterial oxidation of the process imitative model to build for MATLAB practical from the Fuzzy Logic Toolbox package was used. This software tool using vague, expert , adaptive, hybrid neuron network manage systems to build opportunity there is.

In the development of the intelligent control system of the bioreactor, it is desirable to use the fuzzy adjuster and to form a rule base for its operation. For this purpose, using the SIMULINK library in the MATLAB software package [10-13], the following intelligent control system of the bioreactor control based on the fuzzy adjuster was built. A bioreactor used in the process of bacterial oxidation was taken as an object in this constructed structural scheme. The transfer function of the object on the channel taken as the important adjustment channel of the bioreactor intelligent control system was obtained.

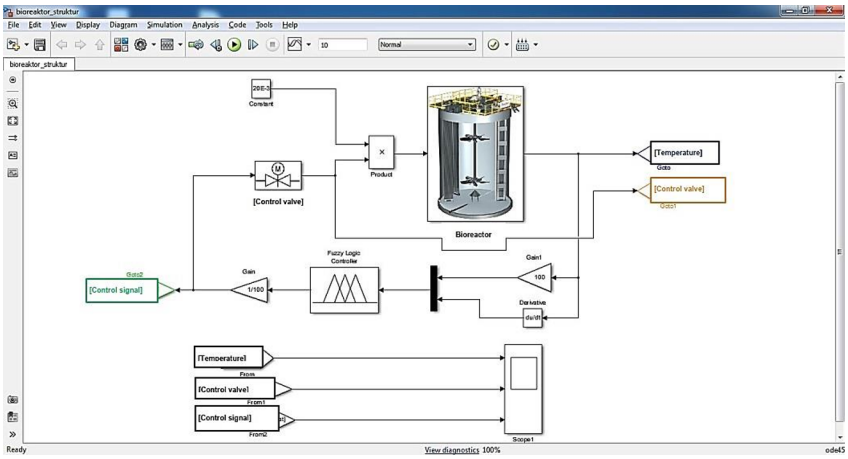

Fig. 1. Structural diagram of the intelligent control system of the bioreactor.

A control system was created depending on the temperature change in the bioreactor, depending on the degree of opening or closing of the adjusting valve installed in the pipe from which the cooling water comes.

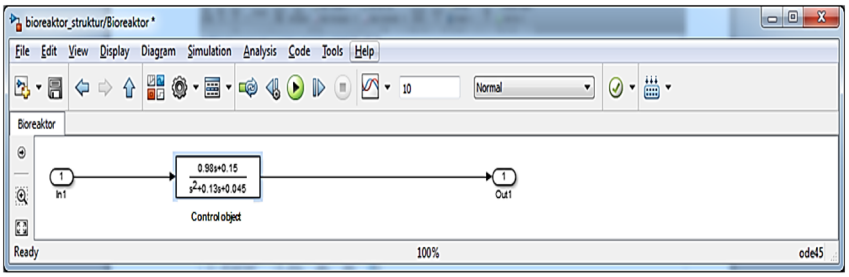

Fig. 2. A simulation model of a bioreactor.

Create a simulation model of the bioreactor, the transfer function of the object (1) was entered using the transfer function block in the SIMULINK library in the MATLAB environment, and a Subsystem was created. From this except in the pipeline installed corrector of the valve imitative model in the Subsystem view given.

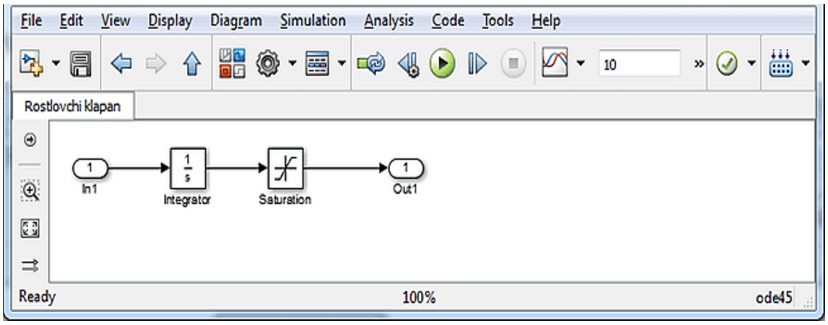

Fig. 3. A simulated model of a control valve.

To express the temperature of the bacterial oxidation process, the linguistic variables "very cold", "cold", "normal", "hot" and "very hot" are defined, where the minimum temperature starts from $0\ ^0C$ *and* reaches a maximum of $+70\ ^0C$. is and there are relevance functions corresponding to these linguistic variables. With this in mind, the set of fuzzy variables is defined by the expression [14, 15]:

$$< T, [0, 70], \mu_{VC}(x), \mu_C(x), \mu_N(x), \mu_H(x), \mu_{VH}(x) > \quad (2)$$

Fuzzy Inference System Editor using, bacterial oxidation in the process applied Intelligent control system of reactor based on fuzzy logic incoming and outgoing sizes is entered. In this Membership Function Editor through each one incoming and outgoing of sizes belonging of functions arguments and numerous values are also entered. Bioreactor unclear manage system based on manage for the rules base formation to the goal according to is considered In this the rules base Mamdani algorithm based on input in the form of the following formula given [16, 18]:

$$\begin{aligned} &IF\ Temperature\ is\ A_1,\ THEN\ Control\ valve\ is\ B_1 \\ &IF\ Temperature\ is\ A_2,\ THEN\ Control\ valve\ is\ B_2 \\ &\ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \\ &IF\ Temperature\ is\ A_n,\ THEN\ Control\ valve\ is\ B_n \end{aligned} \quad (3)$$

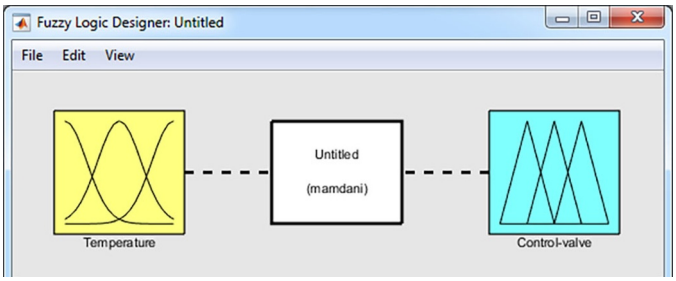

Fig. 4. Intelligent control system of bioreactor based on fuzzy logic.

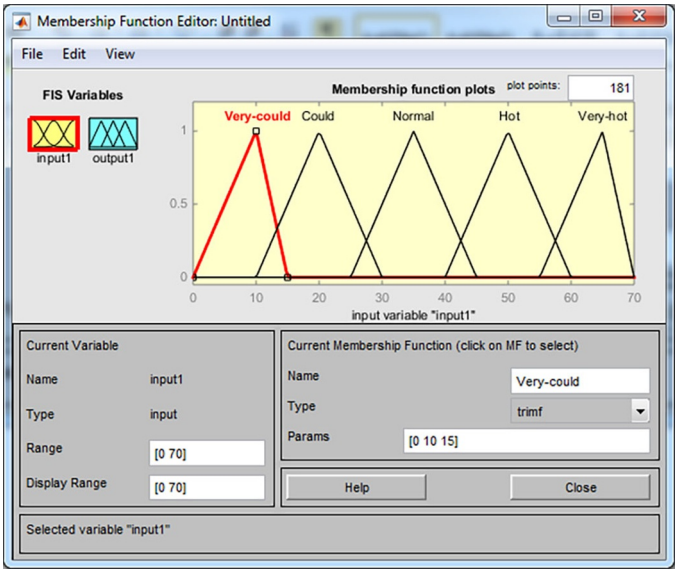

Fig. 5. Graph of the relevance function or sine of the temperature change in the bioreactor.

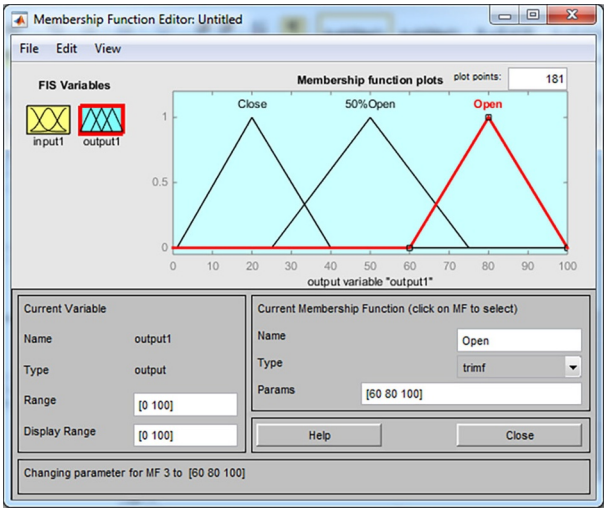

Fig. 6. The graph of the function of the degree of opening or closing of the adjusting valve.

Figure 7 below shows the 7-rule base of the intelligent temperature control system in the bioreactor.

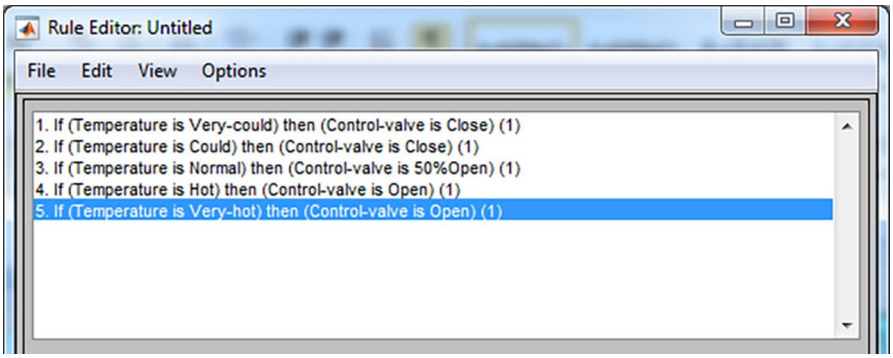

Fig. 7. A rule base developed for the intelligent control system of the bioreactor.

3 Results and discussion

Based on the simulation modeling results, theoretical conclusions can be drawn, i.e., the automatic control system with a fuzzy adjuster synthesized under conditions of uncertainty of changes in the external environment affecting the bacterial oxidation process ensures stable maintenance of the bioreactor temperature at the desired value, and the object parameters can be adjusted in a wide range. It allows quality management of the technological process even when it changes. The temperature change in the bireactor provided for in the created control system, the change graph of the control signal and the output signal from the check valve are presented in Figure 8 below.

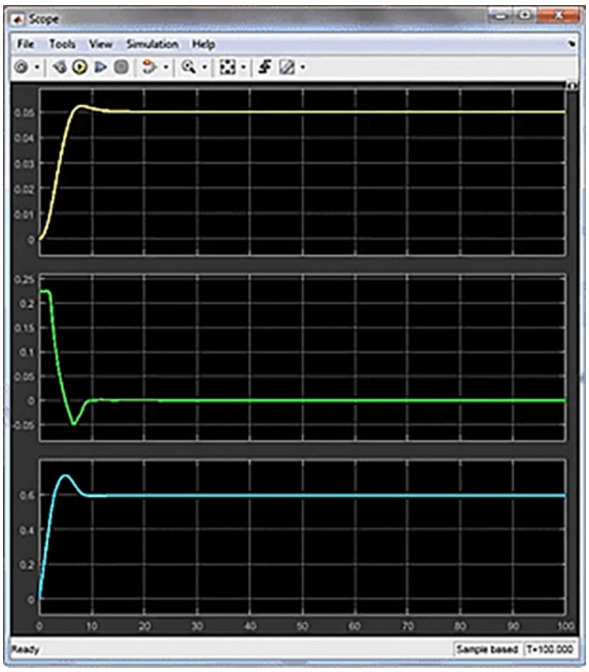

Fig. 8. Transient processes in the intelligent control system of the bioreactor.

4 Conclusion

According to the results of simulated modeling, the fuzzy logic controller developed in the conditions of uncertainty of changes in external influences affecting the process of bacterial oxidation of sulfide ores with complex enriched gold content stabilizes the temperature of the bioreactor at the required value, and the parameters of the technological process enables quality management of the object even when it changes. This proposed method includes software modules, which are the main components of a hierarchical technical and software system, designed to intelligently control the oxidation of iron or the cultivation of bacteria in a continuous mixing bioreactor during mineral processing. The control system used continuously operating sensors and transducers to determine the state of the bioreactor and process parameters. Based on the fact that the bacterial oxidation process is isothermal, a fuzzy logic adjustment system was developed using Fuzzy Toolbox Control to stabilize the temperature of the bioreactor. According to the results of the research, when the proposed control system is introduced, according to the standards of the enterprise, due to the reduction of cooling water consumption by 4.3%, the service life of the water transfer pumps will be further increased. Also, since the water transfer pumps do not work in the load mode, i.e., after adjusting the rotation speed according to the consumption of cooling water, electricity consumption is saved.

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