Control system for a process of fermentation unit based on a fuzzy controller

E A Muravyova and F F Abdrafiкова
Ufa State Petroleum Technological University, Branch in Sterlitamak, 2 October Avenue, Sterlitamak, 453118, Russian Federation

E-mail: muraveva_ea@mail.ru

Abstract. We have developed control system for a fermentation unit process based on a fuzzy controller. The objects under control are fermentation tanks located at “Bashspirt” Joint-Stock Company. The process of saccharified wort fermentation is carried out by yeast. The task was to improve the process of fermentation of saccharified wort by yeast and replace the outdated control system with a newer and more modern one. In this regard, a fuzzy controller system has been designed to control the process of fermentation unit capable of controlling the following twelve output parameters: valve position for supplying wort to six fermentation tanks and for supplying yeast to six fermentation tanks. Twelve control output parameters control the following seven input parameters: the fill level of the prefermenter, the fill level of six fermentation tanks. The output parameters are controlled on the base of the information obtained from the wort and yeast input level sensors. The introduction of an automatic control system that takes into account the basic parameters of a multi-connected object and is capable of controlling the entire process of the fermentation unit allowed to solve the following problem: stabilization of the input parameters and the output process parameters control.

Alcohol production is one of the largest technologically advanced industries. The fermentation unit is characterized by technological processes proceeding according to the continuous-flow method. The fermentation unit is designed to carry out the fermentation of saccharified wort by yeast in fermentation tanks [1]. This is due to their complexity, high sensitivity to violation of the regime and working conditions. Fermentation tanks application allows to produce a fermented wash, which is necessary in the production of ethyl alcohol. The study of the technological process, the determination of factors influencing the process, the establishment of new ways to use the processes of fermentation in industrial conditions continues to this day. Many factors are not yet understood, and the details need to be polished [2]. The priority tasks are to improve the fermentation process and make production process most profitable, with the least energy consumption and maximum output. In this case, it is necessary to take into account various factors affecting the quantity and quality of the products of fermentation tanks: maintaining, monitoring and controlling the input and output parameters of this unit. The object of control is fermentation tank located on the territory of the “Bashspirt” joint-stock company, where the process of fermentation of saccharified wort is carried out by yeast. Currently, correct operation of the fermentation unit is continuously monitored by the operator. The main goal of the control system (CS) of the process is to maintain the optimal level of wort and yeast of a certain size within the limits set by the operator. In this regard, it is necessary to replace the outdated CS with
a newer and modern one, which will improve product quality, lead to lower production costs and also ensure the safety.

Yeast from the yeast department is fed to the prefermenter, which is located in the fermentation unit. The volume of the prefermenter is 120 m³, the actual filling volume is 80 m³. Yeast must be fed into each fermentation tank. The prefermenter is filled with yeast for each subsequent fermentation tank while the previous fermentation tank is filled with wort. The following procedure for filling the fermentation tanks is established in the fermentation unit (figure 1):

- Open the valve (Fs1) on the first tank (2) and start filling it with wort.
- After filling the cone of the first tank (2) with a wort, open the valve (Fd1) and rinse the wort and the entire volume of yeast from the prefermenter (1) (Lv).
- After filling (Lch1) the first tank (2), close the valve (Fs1), open the valve (Fs2) for the supply of wort to the next second tank (3). After filling the cone of the second tank (3), open the valve (Fd2) and rinse the wort and the entire volume of production yeast from the prefermenter (1) (Lv).
- Filling the next four remaining tanks (4, 5, 6, 7) is carried out similarly to the previous two tanks (2, 3).

However, if any of the valves (Fs1-Fs6, Fd1-Fd6) is opened early, the process failures. It can lead to emergency situations and the fermentation tank failure. In order to support smooth and continuous operation of the fermentation unit, it is necessary to maintain constant filling level of the fermentation tanks, to control the opening of the valves for the supply of wort (Fs1-Fs6) and production yeast (Fd1-Fd6). Classical PID-controllers, which are most often used for process control, are not designed to control a multiply connected control system that takes into account the interconnections of process parameters. To solve this problem, we set a task to develop a multidimensional control system that takes into account the interconnections of technological parameters using fuzzy logic.

Figure 1 shows the graphic screen of the control system (CS) of the fermentation unit.
The conceptual model of the fuzzy controller (FC1) that controls the process of filling the first fermentation tank in the fermentation unit is shown in figure 2.

The conceptual model of the fuzzy controller (FC2) that controls the process of filling the second fermentation tank in the fermentation unit is shown in figure 3. The conceptual model for the third - sixth fermentation tanks is similar to the conceptual model of the second fermentation tank.

**Figure 2.** A conceptual model of the control system of the first fermentation tank based on a fuzzy controller.

**Figure 3.** A conceptual model of the control system of the second fermentation tank based on a fuzzy controller.

It is necessary to take into account the following input and output variables of the technological process of filling the fermentation tank for control system of this process:

**Input Variables:**
- the level of the prefermenter - \( L_v \), 0 \( \div \) 100%.
- the filling level of the first - sixth fermentation tanks is \( L_{c1} \) - \( L_{c6} \), 0 \( \div \) 100%.

**Output Variables:**
- the position of the valve for feeding the wort to the first - sixth fermentation tanks - \( F_{s1} \) - \( F_{s6} \), (0; 1);
- valve position for supplying production yeast to the first - sixth fermentation tanks - \( F_{d1} \) - \( F_{d6} \), (0;1)

To determine the position of the valves for the supply of wort and production yeast to the fermentation tanks, you need to know: the position of the valves of all tanks for the supply of wort and production yeast, the filling level in the prefermenter and the filling level in all fermentation tanks. To do this, it is necessary to send a signal to the control system from level sensors located on each of the tanks 2-7 and on the prefermenter 1.

A conceptual model of a system of fuzzy controllers (FC1-FC6) that control the process in the fermentation unit is shown in figure 4.
The values of these variables are used to control the process in the fermentation unit. We will describe the algorithm for controlling the process of filling fermentation tanks and taking into account the dependence of process variables on the base of production rules using linguistic variables.

In this article we designed a system of fuzzy controllers to control the technological process of the fermentation unit. This system allows to control the position of the valve for supplying the wort to the first fermentation tank, the position of the valve for supplying the production yeast to the first fermentation tank, the position of the valve for supplying the wort to the second fermentation tank, valve position for supplying production yeast to the second fermentation tank, valve position for supplying wort to the third fermentation tank, valve position for supplying production yeast to the third fermentation tank, valve position for supplying the wort to the fourth fermentation tank, valve position for supplying the production yeast to the fourth fermentation tank, valve position for supplying the wort to the fifth fermentation tank, valve position for supplying the production yeast to the fifth fermentation tank, valve position for supplying the wort to the sixth fermentation tank, and the position of the valve for supplying production yeast to the sixth fermentation tank, depending on the prefermenter’s filling level, filling level of the first to sixth fermentation tanks. The fuzzy algorithm was implemented in MATLAB, Unity Pro and Vijeo Citect. A multidimensional control system was set up. The fuzzy controller takes into account the mutual influence of the input parameters: the level of wort and production yeast on the output parameters: the position of the valve for supplying the wort to the first fermentation tank, the position of the valve for supplying the production yeast to the first fermentation tank, the position of the valve for supplying the wort to the second fermentation tank, the valve position for supplying production yeast to the second fermentation tank, valve position for supplying the wort to the third fermentation tank, valve position for supplying production yeast to the third fermentation tank, valve position for supplying the wort to the fourth fermentation tank, valve position for supplying the production yeast to the fourth fermentation tank, valve position for supplying the wort to the fifth fermentation tank, valve position for supplying the production yeast to the fifth fermentation tank, valve position for supplying the wort to the sixth fermentation tank, valve position for supplying production yeast to the sixth fermentation tank, valve position for supplying the wort to the third fermentation tank, valve position for supplying production yeast to the third fermentation tank, valve position for supplying the wort to the fourth fermentation tank, valve position for supplying the production yeast to the fourth fermentation tank, valve position for supplying the wort to the fifth fermentation tank, valve position for supplying the production yeast to the fifth fermentation tank, valve position for supplying the wort to the sixth fermentation tank, and valve position for supplying production yeast to the sixth fermentation tank. The introduction of an automatic control system that takes into account the main parameters of a multidimensional object and is able to control the entire process of the fermentation unit made it possible to solve the next problem: stabilization of the input parameters and control of the output parameters of the process.

References
[1] 2015 Operating procedure of fermentation unit of the Sterlitamak Alcohol Distillery Plant Bashspirt p 7
[2] Yarovenko V L 2009 Production technology of alcohol (M.: Kolos) p 428
[3] Fedotiev N N, Alabyshew A F, Roginyan A L, Vyacheslavov N M, Zhivotinsky P B and Galnbek A A 1962 Applied Electrochemistry p 405
[4] Muravyova E A and Bogdanov A V 2018 Software Implementation of The Accurate Regulators a Three-Dimensional Object Heating Chamber Evaporator Heater Steam Boiler International Multi-Conference on Industrial Engineering and Modern Technologies
[5] Muravyova E A, Sharipov M I and Bondarev A V 2018 Method for Increasing the Speed and Reducing the Error of Multidimensional Precise Logic Controller International Multi-Conference on Industrial Engineering and Modern Technologies
[6] Muravyova E A and Gabitov R F 2018 Economic Features to Optimize the Catalyst Calcinations Process International Multi-Conference on Industrial Engineering and Modern Technologies
[7] Muravyova E A and Sharipov M I 2018 SCADA-System Based on Multidimensional Precise Logic Controller for the Control of a Cement Kiln International Multi-Conference on Industrial Engineering and Modern Technologies
[8] Muravyova E A and Uspenskaya N N 2018 Optical Memory and Neural Networks 27 297-307
[9] Muravyova E A, Bondarev A V, Sharipov M I, Galiaskarova G R and Kubryak A I 2018 IOP
Conference Series Materials Science and Engineering 327 (2) 022072
[10] 2015 Master Production Instructions of the Sterlitamak Alcohol Distillery Plant Bashspirt p 85