Causal diagram with positive and negative feedbacks of the grain molasses production process

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Abstract. The development and improvement of unique technologies for the production of feed and feed additives is currently an urgent problem, which is formulated at the level of the Government of the Russian Federation. Such technologies include the production of grain molasses in the conditions of agricultural enterprises from raw materials of their own production. To date, the technology for producing molasses from grain has been developed, but there are very few technical means for its implementation. The question of the operation of such installations remains insufficiently disclosed both from a scientific point of view and from a technical point of view, and requires further research. The paper substantiates the design of the plant for the preparation of molasses from grain on the basis of a mental model. When developing the mental model, the installation was considered as a "black box". For maximum consideration of all factors, a mental model of the pumping unit in dynamics is formed. A cause-and-effect diagram with positive and negative feedback on the selection of the pump for installation is formed. The diagram consists of variables and relationships between them with positive or negative effects. It is revealed that the key elements of the diagram are the electric pump and the dispersant, which provide the movement of the suspension. However, the dispersant is more complex, more expensive to manufacture, and has a lower performance compared to an electric pump. Therefore, it follows from the mental scheme that it is possible to achieve an increase in the productivity of the plant due to its technical improvement, taking into account the demand for molasses and focusing on the company's profit from the use of this plant.

1. Introduction

The development and improvement of unique technologies for the production of feed and feed additives is currently an urgent problem, which is formulated at the level of the government of the Russian Federation [1, 2]. Such technologies include the production of grain molasses in the conditions of agricultural enterprises with raw materials of their own production. Scientists have scientifically proved the effectiveness of feeding agricultural animals with grain molasses in terms of their productivity and health [3, 4, 5, 6, 7, 8].

To date, a technology for producing molasses from grain has been developed [9, 10, 11, 12], however, there are very few technical means for its implementation [13, 14, 15, 16]. In general, the plant for the production of grain molasses can be represented in the form of a diagram (figure 1).

The plant for the preparation of grain molasses consists of:
• hydraulic structure (which includes: pumping unit, cavitator, dispersant and structural elements);
• automatic control system;
• heater.

Initially, the grain is mixed in a tank with water and enzymes. By means of a hydraulic circuit, it is fed by gravity to the pump and / or cavitator, and then, under the action of the pump, it is fed to the disperser. After the dispersant, the composition is fed back to the storage tank. The technological cycle is finished. If necessary, use a heater.

![Figure 1](image)

Figure 1. Installation system for the preparation of molasses.

However, the issue of the operation of such installations remains insufficiently disclosed both from a scientific and technical point of view and requires further research.

The purpose of the work is to substantiate the design of the plant for the preparation of molasses from grain on the basis of a mental model.

2. Materials and methods

Deep analysis of the problem and creation of object models allow you to avoid large financial and time losses. At the same time, we consider the installation as a system consisting of several subsystems that are interconnected by cause-and-effect relationships. Further, on the basis of system features, we assign each subsystem the purpose of its functioning [17].

The results are summarized in table 1.

| №  | Goal                                                   | System                      |
|----|--------------------------------------------------------|-----------------------------|
| 1  | The need for a container for placing wort              | Tank                        |
| 2  | Ensure that the grain is crushed to the desired        | Pumping Unit                |
|    | consistency                                           |                             |
| 3  | Movement of grain mass and final product (molasses)    | Dispersant, cavitator       |
| 4  | Installation control and power supply system           | Hydraulic circuit           |
| 5  | Grain molasses heating system                          | Automatic control system     |
When developing a mental model, we consider the installation as a "black box" [18, 19, 20, 21, 22] (figure 2). The input factors are denoted by \(X_i\), and output – \(Y_i\). Among the input factors, based on the analysis of installations and technologies for the preparation of molasses, 8 of the most significant were identified: \(X_1\) – presence of a hydraulic circuit; \(X_2\) – availability of automated control system and SES; \(X_3\) – presence of a heater; \(X_4\) – construction design; \(X_5\) – adaptability; \(X_7\) – working characteristics of the elements; \(X_8\) – cost of elements. The assessment of the installation is carried out through quantitative, energy, and economic parameters: \(Y_1\) – installation of productivity; \(Y_2\) – installation resource; \(Y_3\) – energy expenses; \(Y_4\) – profitability.

The diagram also shows the environmental impact on the system under consideration. The most important elements of the environment are the qualifications of the service personnel, the temperature and humidity of the air, the degree of dust, and the quality of electricity. However, when drawing up a cause-and-effect diagram, we exclude the impact of these factors, implying their immutability (we assume that the installation is installed in the feed shop).

![Diagram](image)

**Figure 2.** Installation diagram for the preparation of molasses from grain in the form of a "black box".

Molasses preparation is a dynamic process: over time, there is a change in the parameters of the suspension (a mixture of grain, water and enzymes), which leads to a change in the characteristics of the system. Over time, the suspension is heated, which leads to a decrease in its viscosity, and consequently, a decrease in the electricity consumption of the electric motor. At the same time, with an increase in the temperature of the suspension, the heat transfer from the plant elements to the environment increases, which leads to an increase in the heating time. Although the heating of the suspension in the installation is linear [23], it is quite difficult to predict the effect of individual subsystems of the installation on heating. The second point that makes it difficult to understand the behavior of the system is the complexity of understanding the interaction of grains with each other and with the elements of the system. Ultimately, all this affects the operation of the electric motor and causes additional difficulties in its selection.

For maximum consideration of all factors, we form a mental model of the pumping unit in dynamics, which will allow us to predict the operation of the unit and trace the connections between its elements.

3. **Results and discussion**

First, we form a cause-and-effect diagram with positive and negative feedback on the selection of the pump for installation (figure 3).

The diagram consists of variables and relationships between them with positive or negative effects. The structure of the system building subject to the rules of arrangement of polar-ness [17]:

- the more the price of the pump, the greater the capacity of the unit (+);
- the greater the capacity of the plant, the greater the amount of molasses (+);
- the more we get molasses, the more profit (+);
- the greater the profit, the more technologically advanced pump may be used (+);
- more technologically advanced than the pump, the more productivity (+).
Consider the first positive contour (figure 4). The circuit is long-term, its time depends on the time of technical improvement of the electric pump and the installation as a whole, which can be several years. The improvement of the pump and the plant as a whole will lead to greater productivity and, with the demand for molasses, to an increase in profits.

When looking at the diagram, there are several contours with a negative effect:

- the less productive the pump, the more work the installation needs; 
- the more the installation needs to work, the greater the cost of its operation and the greater the loss.

![Figure 3. A cause-and-effect diagram with positive and negative feedback on the selection of the pump for installation.](image)

Figure 3. A cause-and-effect diagram with positive and negative feedback on the selection of the pump for installation.

![Figure 4. Positive contour.](image)

Figure 4. Positive contour.

Contour 2: negative (figure 5). The contour is long-term. A decrease in the performance of the pump and the plant as a whole will lead to a longer operation time and further losses for the enterprise.

![Figure 5. Negative contour.](image)

Figure 5. Negative contour.

Several lower-order positive and negative contours are also shown. For example, the following contour is positive: a decrease in the operator's work with a further increase in the company's profit, and vice versa.

All the contours interact and influence each other, showing the complexity of the functioning and mathematical description of the system.
4. Conclusion
The key elements of the diagram are the electric pump and the dispersant, which ensure the movement of the suspension. However, the dispersant has a more complex design, is more expensive to manufacture and has a lower performance compared to the pump with electric motor. Therefore, it follows from the mental scheme that it is possible to achieve an increase in the productivity of the plant due to its technical improvement, taking into account the demand for molasses and focusing on the company’s profit from the use of this plant.

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