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Relational Neighborhood Model for Diffusion Stage of Sugar Production

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Abstract

A linear relational neighborhood model for the stage of diffusion of sugar production is considered. Parametric identification of the model is based on daily sampling of production data with a time interval of 10 minutes. The dependencies obtained are explained within the framework of the technology of the sugar production.

Keywords: relational neighborhood system, parametric identification, sugar production, diffusion stage

VERTEX AND RELATIONAL NEIGHBORHOOD SYSTEMS

A neighborhood structure (see [1]) is an oriented graph containing *n* vertices (nodes) such that every two vertices can be connected by no more than two oppositely oriented edges. The equations of the *neighborhood system* (see [1]) (associated with the neighborhood structure) correspond to the vertices of the neighborhood structure. Such systems can be called *vertex neighborhood systems*. In [2], the *relational neighborhood systems* were proposed whose equations correspond to the vertices and edges of the graph of the neighborhood structure. A *relational neighborhood system* [2], associated with a neighborhood structure, is the system of equations:

$$X(i) = F_i(U(i), \bar{Y}(*,i))$$
$$Y(i,k) = F_{ik}(X(i), U(i), \bar{Y}(*,i)) \qquad (1)$$

for the states $X(i)$ and outputs $Y(i,k)$ of vertices a_i a of neighborhood structure. Here $\bar{Y}(*,i)$ is the vector of all entrances for the vertex a_i, i.e. " * " runs the numbers of all vertices entering a_i, and $U(i)$ is the control parameter for a_i. Next, the index k runs the numbers of all nodes outgoing of the vertex a_i. If $Y(i,k) = (X(i), U(i))$ for all k than the relational system (1) becomes the vertex neighborhood system

$$X(i) = F_i(U(i), \bar{U}(*), \bar{X}(*)), i = 1,...,n.$$

Equations (1) are, as a rule, linear or non-linear regression models, which are *linear with respect to parameters.* The identification of these parameters is possible if there is a sufficiently large set of experimental data. The relational scheme, in comparison with the vertex, is better suited for the situation when the model describes the movement of any flows from node to node and is convenient for modeling the multi-stage production processes. In this article, we consider the problem of constructing and identifying a relational neighborhood model for the stage of diffusion of sugar production.

THE RELATIONAL NEIGHBORHOOD MODEL FOR DIFFUSION STAGE OF SUGAR PRODUCTION

Figure 1 shows the technological block-diagram for obtaining the diffusive juice, where:

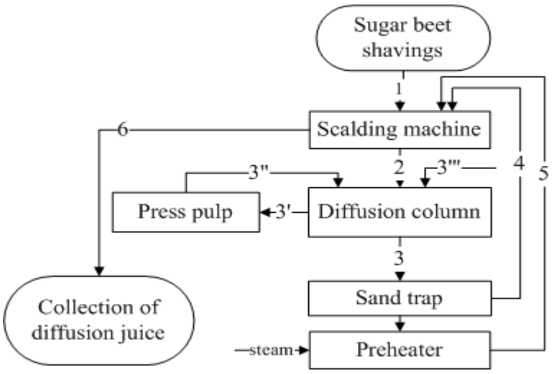

Figure 1. Technological block-diagram for diffusion stage

1 is the sugar beet mixture,

2 is the juice-based mixture,

3 is the diffusion juice,

3' is the desiccated chip,

3'' is the pulp water,

3''' is the feed water,

4 is the diffusion juice,

5 is the diffusion juice heated to a temperature 72 °C ,

6 is the diffusion juice, which enters the collection of diffusion juice.

When constructing a relational neighborhood model, the scalding device (node a_1) and the diffusion column (node a_2) were taken as the vertices of the model (Figure. 2). We consider the diffusion column as a single unit with a sand trap and a preheater. For further work with the model, we supplement the graph of the structure with two additional nodes a_0 (exterior input) and a_∞ (exterior output), see [2]. The node a_0 corresponds to the exterior input, which feeds the beet shavings into the scalding machine and water into the diffusion column. The node a_∞ corresponds to the exterior output, the collector of diffusion juice.

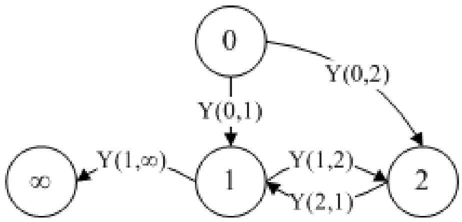

Figure 2. The neighborhood structure of the diffusion stage

The relational neighborhood system here has the form

$$Y(1,2) = F_{1,2}(U(1), Y(0,1), Y(2,1))$$
$$Y(1,\infty) = F_{1,\infty}(U(1), Y(0,1), Y(2,1)) . \qquad (2)$$
$$Y(2,1) = F_{2,1}(U(2), Y(0,2), Y(1,2))$$

All internal parameters are controllable, and therefore there are no variables $X(i)$ and equations for them. Explanation of the notation:

$Y(0,1) = \{Y_1(0,1); Y_2(0,1); Y_3(0,1); Y_4(0,1)\}$ - characteristics of the loaded shavings,

$Y_1(0,1)$ - shavings consumption, m^3 / hr ,

$Y_2(0,1)$ - length of 100 g of shavings, m ,

$Y_3(0,1)$ - % of defective shavings,

$Y_4(0,1)$ - sugar content of the shavings.

$Y(1,\infty) = \{Y_1(1,\infty); Y_2(1,\infty); Y_3(1,\infty); Y_4(1,\infty); Y_5(1,\infty); Y_6(1,\infty)\}$ - characteristics of the obtained juice:

$Y_1(1,\infty)$ - temperature of the diffusion juice from the scalding machine, °C ,

$Y_2(1,\infty)$ - flow of diffusion juice from the scalding machine, m^3 / hr ,

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$Y_3(1,\infty)$ - content of solids in the diffusion juice from the scalding machine, %,

$Y_4(1,\infty)$ - sugar content of the diffusion juice, %,

$Y_5(1,\infty)$ - the purity of the diffusion juice, %,

$Y_6(1,\infty)$ - acidity of the diffusion juice, %.

$U(1) = \{U_1(1); U_2(1)\}$ - internal parameters of the scalding machine:

$U_1(1)$ - level in the scalding machine shaft before the screen, %,

$U_2(1)$ - level in the scalding machine mixer in front of the screen,%.

$Y(1,2) = \{Y_1(1,2); Y_2(1,2)\}$ - characteristics of the juice-grinding mixture supplied to the diffusion column:

$Y_1(1,2)$ - temperature of the juice-grinding mixture , $^\circ C$,

$Y_2(1,2)$ - consumption of the juice-based mixture, m^3 / hr.

$Y(0,2) = \{Y_1(0,2); Y_2(0,2); Y_3(0,2); Y_4(0,2); Y_5(0,2)\}$ - characteristics of water supplied to the diffusion column:

$Y_1(0,2)$ - consumption of pressurized water, m^3 / hr,

$Y_2(0,2)$ - temperature of pressurized water, $^\circ C$,

$Y_3(0,2)$ - feedwater flow rate, m^3 / hr,

$Y_4(0,2)$ - feedwater temperature, $^\circ C$,

$Y_5(0,2)$ - acidity of feed water, %.

$Y(2,1) = \{Y_1(2,1); Y_2(2,1); Y_3(2,1) Y_4(2,1); Y_5(2,1)\}$ - characteristics of the diffusion juice coming from the diffusion column into the scalding machine:

$Y_1(2,1)$ - consumption of diffusion juice from the diffusion column, m^3 / hr,

$Y_2(2,1)$ - temperature at the bottom of the column, $^\circ C$,

$Y_3(2,1)$ - consumption of diffusion juice in the scalding machine shaft, m^3 / hr,

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$Y_4(2,1)$ - consumption of diffusion juice in the scalding machine mixer, m^3 / hr,

$Y_5(2,1)$ - the temperature of the juice in the scalding mixer after the preheater, $°C$.

$U(2) = \{U_1(2); U_2(2); U_3(2)\}$ - internal parameters of the diffusion column:

$U_1(2)$ - temperature at the bottom of the column, $°C$,

$U_2(2)$ - temperature in the middle part of the column, $°C$,

$U_3(2)$ - temperature at the top of the column , $°C$.

PARAMETRIC IDENTIFICATION OF LINEAR RELATIONAL NEIGHBORHOOD MODEL FOR DIFFUSION STAGE OF SUGAR PRODUCTION

Parametric identification of the relational neighborhood model (2) was carried out on the basis of a sample of production data from 00:00 to 23:50 hours with a time interval of 10 minutes. The calculations were carried out in the package Statistica 10. We considered a relational neighborhood model, linear not only in terms of parameters, but also in all variables, that is, all equations of the system (2) were assumed to be linear with respect to all variables. Studies have shown that adding bilinear dependencies (products of variables) to the model does not lead to an improvement in the quality of the model.

The results of parametric identification are given below. Everywhere further, R is the coefficient of multiple correlation, p is the significance level of the corresponding predictor. All predictors that are not significant ($p > 0.05$) were successively removed from the multiple regression equation with the equation recalculated at each step. All equations are written in natural units of measurement, that is, without normalization.

THE EQUATION FOR LEAVING THE SCALDING AGENT IN THE DIFFUSION COLUMN.

1. For the diffusion process, the beet shavings must be heated to the denaturing temperature of the protoplasm of the shavings cells. To do this, the beet shavings in the scalding machine are heat treated stepwise by two streams of diffusion juice to obtain a juice-containing mixture: first it is heated to 34-35°C with a diffusion juice at a temperature equal to the juice temperature at the outlet of the diffusion column (70-72 ° C), and then finally up to 72-74°C by juice, heated in the preheater to 76°C. As a result, the temperature of the juice-based mixture depends on the temperature of the heat carriers of these two streams, namely, the temperature of the bottom of the column and the temperature of the juice after the preheater. The results of identification:

$$Y_1(1,2) = 0.603 * Y_2(2,1) + 0.267 * Y_5(2,1) - 23.089;$$

$R = 0.661$; $p(Y_2(2,1)) = 0.000000$;

$p(Y_5(2,1)) = 0.000043$.

2. The juice-based mixture is obtained as a result of mixing with a diffusion juice heated in a shaft of scrapers of beet shavings with a diffusion juice fed into the scalding mixer. In order to efficiently proceed with the diffusion process, it is necessary to keep the temperature in the lower part of the column at a level of 70-72 ° C, with the proper expenditure of the diffusion juice for scalding. The results of identification:

$$Y_2(1,2) = 0.486 * Y_1(0,1) + 0.114 * Y_2(2,1) + 0.476 * Y_3(2,1) + 0.506 * Y_4(2,1) - 122.008;$$

$R = 0.943$; $p(Y_1(0,1)) = 0.000000$; $p(Y_2(2,1)) = 0.001234$; $p(Y_3(2,1)) = 0.000000$; $p(Y_4(2,1)) = 0.000000$.

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THE EQUATIONS FOR RELEASING OF DIFFUSION JUICE.

1. Before the release of the diffusion juice from the scalding agent, it comes into direct contact with the beet shavings entering the scalding machine. Therefore, the temperature of the diffusion juice at the outlet from the scalding agent depends on the quality parameters of the beets and beet shavings, and hence on the quality of the heat exchange of the shavings and diffusion juice. Calculation showed that when the necessary temperature parameters of the denaturation of the juice-based mixture are reached, the juice consumption for heating also influences the temperature of the diffusion juice at the outlet of the scalding machine. The results of identification:

$$Y_1(1,\infty) = -0.44 * Y_2(0,1) - 0.33 * Y_3(0,1) - 0.43 * Y_4(0,1) - 0.35 * Y_4(2,1) + 77.971;$$

$R = 0.670$; $p(Y_2(0,1)) = 0.000000$; $p(Y_3(0,1)) = 0.000005$; $p(Y_4(0,1)) = 0.000000$; $p(Y_4(2,1)) = 0.000002$.

$$Y_2(1,\infty) = 0.294 * Y_2(2,1) + 0.338 * Y_3(2,1) - 128.730;$$

$R = 0.542$; $p(Y_2(2,1)) = 0.000347$; $p(Y_3(2,1)) = 0.000044$.

2. The quality of the resulting diffusion juice ($Y_3(1,\infty)$; $Y_4(1,\infty)$; $Y_5(1,\infty)$; $Y_6(1,\infty)$) depends on the quality of the beet shavings, as well as on the quality of the diffusion process itself and the observance of temperature conditions. The results of identification:

$$Y_3(1,\infty) = -0.37 * Y_2(0,1) + 0.254 * Y_3(0,1) - 0.36 * Y_2(2,1) + 0.246 * Y_4(2,1) + 40.078;$$

$R = 0.597$; $p(Y_2(0,1)) = 0.000001$; $p(Y_3(0,1)) = 0.001695$; $p(Y_2(2,1)) = 0.000004$; $p(Y_4(2,1)) = 0.001444$.

$$Y_4(1,\infty) = -0.33 * Y_2(0,1) - 0.26 * Y_4(0,1) - 0.24 * Y_2(2,1) + 0.765 * Y_4(2,1) + 25.448;$$

$R = 0.869$; $p(Y_2(0,1)) = 0.000000$; $p(Y_4(0,1)) = 0.000000$; $p(Y_2(2,1)) = 0.000000$; $p(Y_4(2,1)) = 0.000000$.

$$Y_5(1,\infty) = -0.25 * Y_2(0,1) - 0.26 * Y_4(0,1) - 0.23 * Y_2(2,1) + 0.803 * Y_4(2,1) + 109.225;$$

$R = 0.869$; $p(Y_2(0,1)) = 0.000001$; $p(Y_4(0,1)) = 0.000000$; $p(Y_2(2,1)) = 0.000001$; $p(Y_4(2,1)) = 0.000000$.

$$Y_6(1,\infty) = -0.85 * Y_4(2,1) + 14.582;$$

$R = 0.848$; $p(Y_2(0,1)) = 0.000000$.

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THE EQUATION FOR THE EXIT FROM THE DIFFUSION COLUMN TO THE SCALDING MACHINE.

1. The amount of produced diffusion juice depends on the amount of shavings coming into the diffusion column. The results of identification:

$$Y_1(2,1) = 0.817 * Y_2(1,2) + 26.289;$$

$$R = 0.817; \; p(Y_2(1,2)) = 0.000000$$

2. The temperature in the lower part of the column depends not only on the temperature of the juice-grinding mixture, but also on the temperature of the feed water and the temperature in the middle part of the column, since not only the diffusion process takes place, but also the heat exchange process. The results of identification:

$$Y_2(2,1) = -0.30 * U_2(2) + 0.358 * Y_3(0,2) + 0.420 * Y_1(1,2) + 131.278;$$

$$R = 0.722; \; p(U_2(2)) = 0.000003; \; p(Y_3(0,2)) = 0.000015;$$

$$p(Y_1(1,2)) = 0.000000.$$

3. The following dependence shows how the flow of diffusion juice into the scalding machine is related to the temperature regime in the diffusion column, namely, a certain amount of diffusion juice with an appropriate temperature is necessary to preheat the chips and the juice-containing mixture. The results of identification:

$$Y_3(2,1) = 0.246 * U_1(2) + 0.269 * Y_3(0,2) + 0.621 * Y_2(1,2) - 153.447;$$

$$R = 0.781; \quad p(U_1(2)) = 0.000082; \quad p(Y_3(0,2)) = 0.000015;$$

$$p(Y_2(1,2)) = 0.000000;$$

$$Y_4(2,1) = -0.28 * U_1(2) - 0.23 * U_2(2) + 0.667 * Y_2(1,2) + 999.225;$$

$$R = 0.767; \quad p(U_1(2)) = 0.000003; \quad p(U_2(2)) = 0.000386;$$

$$p(Y_2(1,2)) = 0.000000.$$

4. When stepwise heating the juice-containing mixture to the temperature at which diffusion takes place, it is necessary to maintain a certain temperature of the diffusion juice by heating it in the preheater. The results of identification:

$$Y_5(2,1) = 0.271 * Y_1(1,2) + 65.163;$$

$$R = 0.271; \; p(Y_1(1,2)) = 0.001028.$$

CONCLUSION

The results of parametric identification of a linear relational neighborhood model for the stage of diffusion of sugar production are presented in the article. The dependencies obtained are explained within the framework of the technology of the sugar process.

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REFERENCES

[1] Shmyrin, A.M., Mishachev, N.M., and Kosareva, A.S., 2016, "Clustering Neighbor structure", Vestnik Tambov University. Ser. Natural and technical sciencesб T. 21. Vol. 2, pp.457-462.

[2] Shmyrin, A.M., Mishachev, N.M., and Kosareva, A.S., 2016, "Block-neighborhood regression model stage diffusion of sugar production", Modern techniques of applied mathematics, control theory and computer technology: Sat. tr. IX Intern. Conf. "PMTUKT 2016", Voronezh, Publishing house "Science Book", pp. 406-409.

[3] Sapronov, A.R., 1983, "Sugar technology", Moscow, Light and Food industry, 232 p.