International Journal of Engineering & Technology, 7 (3.5) (2018) 28-31

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Bilinear Relational Neighborhood Model of the Stage of Diffusion of Sugar Production Based on the Heat Balance Equation

A.M. Shmyrin[1], **N.M.Mishachev**[2], **A.S. Kanyugina**[3]

** Lipetsk state technical University, Russia*

Abstract

In this paper, the problem of mathematical modeling of the stage of diffusion of sugar production is considered. To build the model, a combined approach is used: the structural identification based on the relational neighborhood scheme is refined with the help of the physical equation of the heat balance and then the parametric identification of the coefficients is performed using standard regression methods. The resulting model is bilinear. The corresponding model, resolved with respect to critically important temperature parameters, is fractional-bilinear. Parametric identification of the model is based on seasonal sampling of production data, the sample size is more than 10000.

Keywords:

1. Introduction

Neighborhood systems or neighborhood models are static or discrete dynamical systems of equations on a graph [1]. The equations of a neighborhood system can correspond to either the vertices of the graph or its edges. In the first case, we call a neighborhood system a vertex-type system, in the second - a relational-type system [2]. The equations of the neighborhood system are structurally identified by the sets of variables entering into them [3,4]: this level of identification is given by the graph. In the problems of managing production processes, such systems arise at the stage of transition from the production scheme (graph) to the mathematical model. The corresponding equations, even under the assumption of linearity, usually contain a large number of parameters. Screening of superfluous parameters can be made on the basis of their statistical significance, but the results of such a formal exception are not always reliable. Quite often simple physical considerations make it possible to reduce the number of model coefficients even before the parametric identification stage. In this article, we apply the described scheme for mathematical modeling of the stage of diffusion of sugar production, while the thermal balance equation is used as a physical component. For parametric identification of the model, a seasonal sampling of the production data of the JV "Borinsky Sugar Plant" is used, the sample size is more than 10000.

2. Technological Diagram for Producing Diffusion Juice

At the stage of diffusion of sugar production, the sugar is extracted from the beet shavings. The final product at this stage of production is diffusion juice [5]. The main units of process equipment at this stage are scalding and diffusion columns. The heater is an auxiliary equipment used to heat the diffusion juice to the specified temperatures. Figure 1 shows a technological block diagram for obtaining the diffusion juice. The arrows indicate the movement of substances. In the separate boxes the parameters on the diagram are placed, which correspond to the control variables for the on the scalding machine, the diffusion column and the heater. The regulation of the temperature of the feed water takes place at a separate stage from the diffusion stage of the water treatment. The temperature of the juice entering the stirrer is heated by means of the returnable steam. The regulation of the expenditure of substances is carried out by varying the degree of opening of the regulating flap.

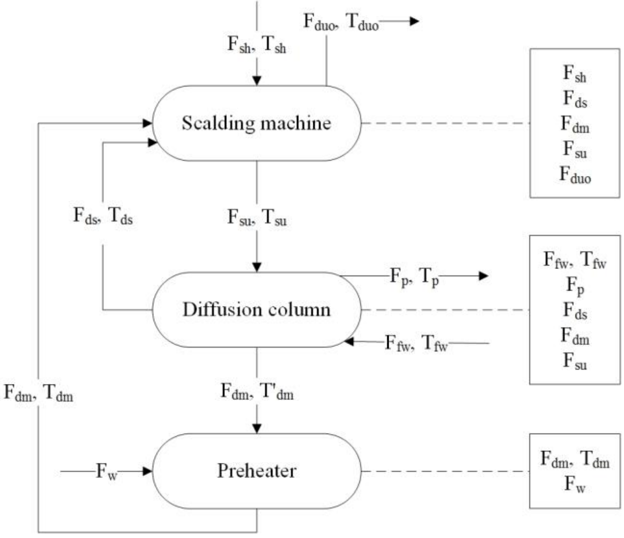

Figure 1. Technological block diagram of obtaining the diffusion juice

where

F_{sh} – shavings consumption;

Copyright © 2016 Authors. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

T_{sh} – temperature of the shavings;
F_{su} – consumption of the juice-based mixture;
T_{su} – temperature of the juice-based mixture;
F_p – consumption of the pulp;
T_p – temperature of the pulp;
F_{fw} – feedwater flow rate;
T_{fw} – feedwater temperature;
F_{ds} – supply of diffusion juice to the scalding machine shaft;
T_{ds} – temperature of the diffusion juice;
F_{dm} – supply of diffusion juice to the scalding machine mixer;
T'_{dm} – temperature of the diffusion juice entering the scalding mixer before being fed to
the preheater, $T'_{dm} = T_{ds}$;
T_{dm} – temperature of the diffusion juice entering the scalding mixer after the preheater;
F_w – расход ретурного пара;
F_{duo} – flow of diffusion juice from the scalding machine;
T_{duo} – temperature of the output diffusion juice from the scalding machine.

3. Relational Model and Balance

Critical temperatures T_{su} and F_{ds} should be maintained in certain fairly narrow limits by controlling the remaining variables of the model. The formal relational neighborhood model (metasystem), corresponding to the scheme in Fig. 1, has the form:

$$T_{su} = f(F_{su}, F_{sh}, T_{sh}, F_{dm}, T_{dm}, F_{ds}, T_{ds}, F_{duo}, T_{duo}); \quad (1)$$

$$T_{ds} = g(F_{dm}, F_{su}, T_{su}, F_{fw}, T_{fw}, F_{ds}, T_p). \quad (2)$$

We define the structure of the functions f and g (up to unknown coefficients subject to parametric identification) on the basis of the heat balance equations. The basis for drawing up the heat balance equations are the equations of material balance, which follow from the law of conservation of matter. Below are written the equations of material balance for the technological equipment of the diffusion stage of sugar production: scalding machine (3) and diffusion column (4):

$$F_{sh} + F_{dm} + F_{ds} = F_{su} + F_{duo}; \quad (3)$$

$$F_{su} + F_{fw} = F_{dm} + F_{ds} + F_p. \quad (4)$$

Let us verify the fulfillment of equations (3) and (4) for the sample data. For the scalding machine and the diffusion column, Figures 1 and 2 show diagrams of the deviations of the observed material balance from the theoretical ones, reduced to the average value of the chip consumption. All calculations were carried out, as already mentioned, on the basis of a seasonal samples of more than 10,000 observations. In general, the equations of material balance for sample data are performed with good accuracy. The thermal balance of the technological process is compiled on the basis of the law of conservation of energy. The heat balance equations for the scalding machine (5) and the diffusion column (6) are:

$$F_{sh} T_{sh} C_{sh} + F_{dm} T_{dm} C_{dm} + F_{ds} T_{ds} C_{ds} = F_{su} T_{su} C_{su} + F_{duo} T_{duo} C_{duo} + Q_l \quad (5)$$

$$F_{su} T_{su} C_{su} + F_{fw} T_{fw} C_{fw} = F_{ds} T_{ds} C_{ds} + F_{dm} T_{ds} C_{dm} + F_p T_p C_p + Q_l \quad (6)$$

where $C_{sh}, C_{dm}, C_{su}, C_{duo}, C_{fw}, C_{ds}, C_p$ – specific heats, Q_l – heat losses. For the scalding and the diffusion column, Figures 3 and 4 show diagrams of the deviation of the observed heat balance from the theoretical, reduced to the average value of the heat energy of the juice-grinding mixture. When constructing the diagrams, the chip temperature T_{sh}, the data for which is absent, was assumed to be 20 ° C; the heat losses were not taken into account. Deviations of the calculated heat balance for the sample data are within 20%. Thus, taking into account the unknown heat losses, the heat balance equations for sample data are performed with good accuracy.

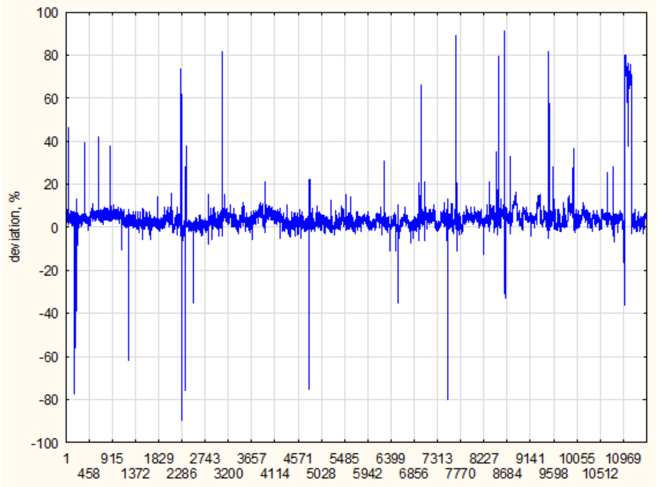

Figure 1. Diagram of deviations of the observed material balance of the scalding machine from

the theoretical one, reduced to the average value of the consumption of chips

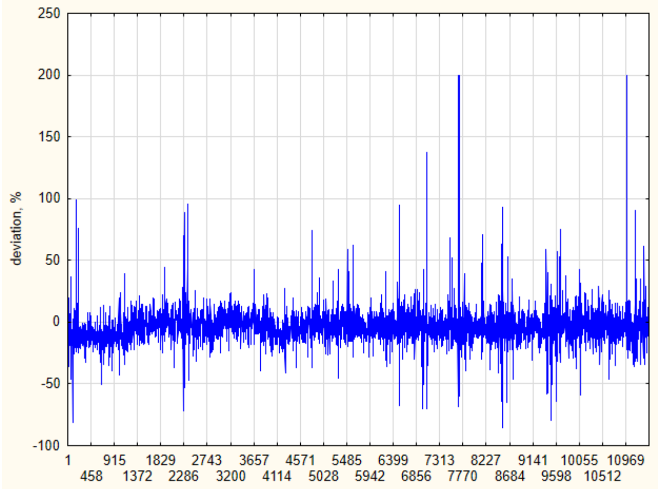

Figure 2. Diagram of deviations of the observed material balance of the diffusion column from

the theoretical one, reduced to the average value of the consumption of chips

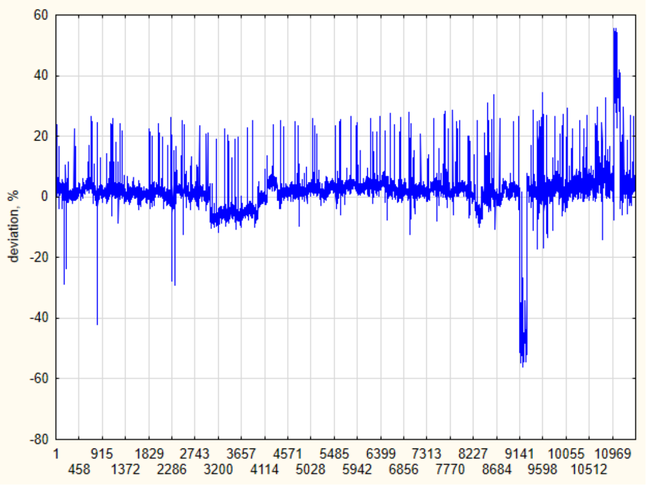

Figure 3. Diagram of deviations of the observed thermal balance of the scalding agent from the theoretical one, reduced to the average value of the thermal energy of the juice-based mixture

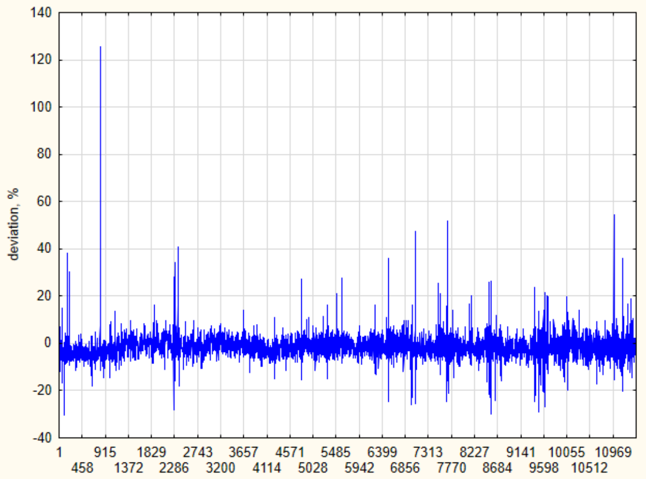

Figure 4. Diagram of deviations of the observed heat balance of the diffusion column from the theoretical one, reduced to the average value of the heat energy of the juice-based mixture

4. Structural and Parametric Identification of the Model

On the basis of equations (5) and (6), the following bilinear realization of the metasystem (1) - (2) can be proposed:

$$F_{su}\mathrm{T}_{su} = \mathrm{a}_0 + \mathrm{a}_1\, F_{sh}\,\mathrm{T}_{sh} + \mathrm{a}_3 F_{dm}\mathrm{T}_{dm} + \mathrm{a}_3 F_{ds}\mathrm{T}_{ds} + \mathrm{a}_4 F_{duo}\mathrm{T}_{duo} \qquad (5)$$

$$F_{dm}\mathrm{T}_{ds} = \mathrm{b}_0 + \mathrm{b}_1\, F_{su}\mathrm{T}_{su} + \mathrm{b}_2 F_{fw}\mathrm{T}_{fw} + \mathrm{b}_3 F_{ds}\mathrm{T}_{ds} + \mathrm{b}_4\, F_p\mathrm{T}_p \qquad (6)$$

Equation (6) contains two terms with temperature T_{ds}; it is necessary to combine these terms for reduction to the form (2) only *after* parametric identification. The results of parametric identification of the model are given below. The equations are written in natural units of measurement, that is, without normalization.

$$F_{su}\mathrm{T}_{su} = 102{,}37 + 3{,}46\, F_{sh}\mathrm{T}_{sh} + 0{,}06\, F_{duo}\mathrm{T}_{duo} + 0{,}75\, F_{dm}\mathrm{T}_{dm} + 0{,}38\, F_{ds}\mathrm{T}_{ds} \qquad (7)$$

$$F_{dm}\mathrm{T}_{ds} = 240{,}07 + 0{,}34\, F_{ds}\mathrm{T}_{ds} + 0{,}85\, F_{su}\mathrm{T}_{su} - 1{,}18\, F_p\mathrm{T}_p - 0{,}03 F_{fw} * \mathrm{T}_{fw} \qquad (8)$$

The coefficients of multiple correlation in both cases turned out to be 0.949. Equations (7) and (8) can be regarded as "regressionally refined" balance equations. To bring them into line with the metasystem (1) - (2), these equations can be rewritten in a fractional bilinear form with T_{su} and T_{ds} on the left. Figures 5 and 6 show graphs of the error function (the difference between the left and right sides) for the pairs of equations (5), (7) and (6), (8). Errors of the initial theoretical thermal balance model are shown in red, the errors of the regression-corrected model are blue. For clarity, the graphs of the errors in the heat balance model are shifted by 5000 upwards. A significant reduction in the error amplitude of the refined model is noticeable in comparison with the initial theoretical model.

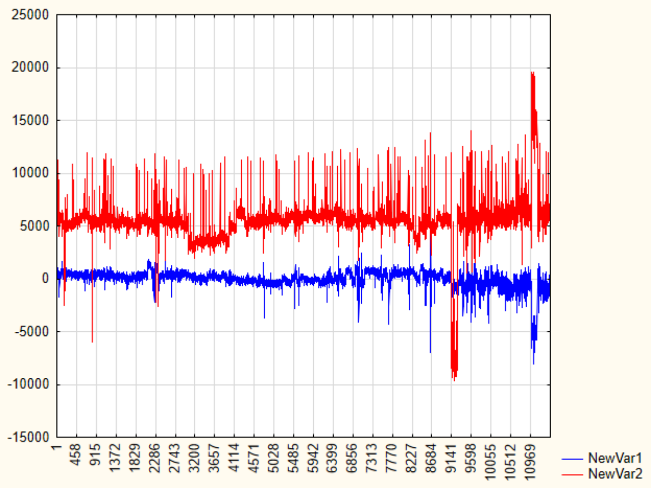

Figure 5. Graphs of errors of the initial theoretical heat balance model (5) and the refined regression model (7) for scalding. The errors of the model (5) are shifted by 5000 up

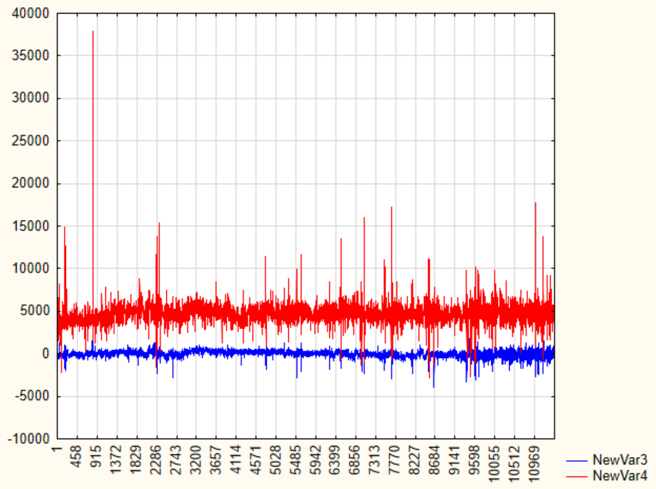

Figure 6. Graphs of errors of the original theoretical heat balance model (6) and refined regression model (8) for scalding. The errors of the model (6) are shifted by 5000 upwards

5. Conclusion

The problem of mathematical modeling of the stage of diffusion of sugar production is considered. Structural identification of the model was carried out on the basis of the heat balance equations for scalding machine and diffusion columns. For further parametric identification, a samples of data for a season of volume greater than 10,000 was used. The error of the refined regression model is on the average 3-4 times less than the error of the initial theoretical heat balance model.

Acknowledgments

The work is supported by the Russian Fund for Basic Research (project 16-07-00854 a).

References

[1] Blyumin S.L., Shmyrin A.M, (2005), Neighborhood system. Lipetsk: LEGI.
[2] Shmyrin A.M., Kanyugina A.S, Kuznetsov A.P, (2017), Relational Neighborhood Model for Diffusion, Stage of Sugar Production, International Journal of Applied Engineering Research, Vol.12, No. 12, pp. 3151-3156.
[3] Shmyrin, A.M., Mishachev, N.M., Kosareva, A.S, 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.
[4] Shmyrin A.M., Mishachev N.M., Kanyugina A.S., Kanyugin A.A., Bogatyrev V.O, (2017), Parametric identification of linear block-regression neighborhood model for diffusion stage of sugar production, Modern informatization problems in the technological and telecommunication systems analysis and synthesis: Proceedings of the XXII-th International, Open Science Conference (Yelm, WA, USA, January 2017), pp. 360-365.
[5] Sapronov, A.R, (1983), "Sugar technology", Moscow, Light and Food industry, p. 232.