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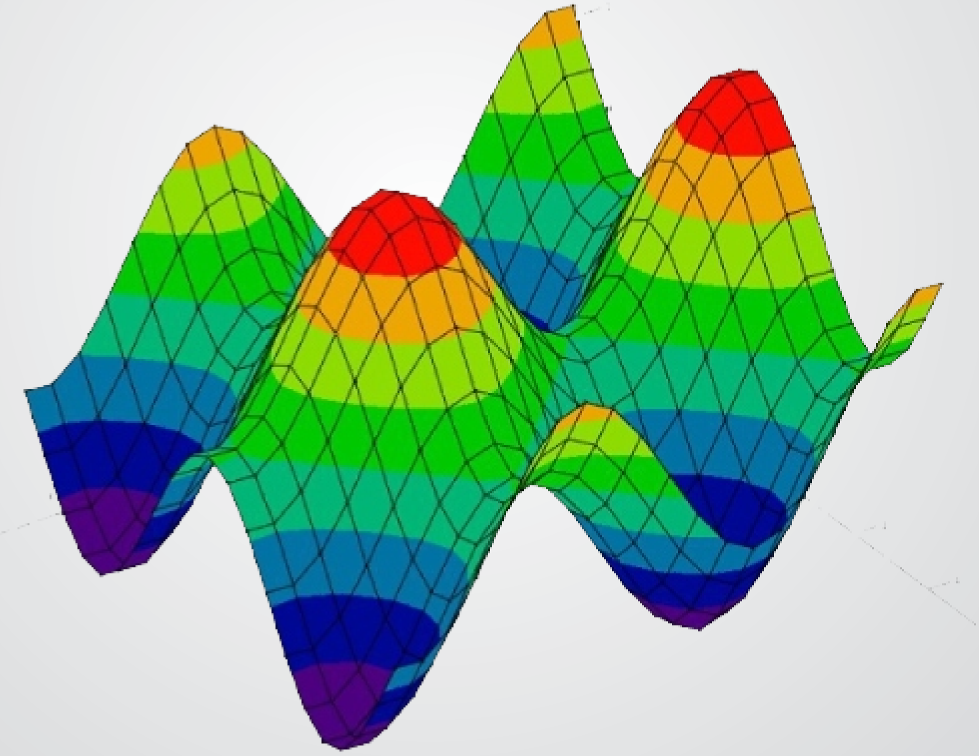

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FEATURES OF TEMPERATURE REGULATION AS A TASK FOR ASSORTMENT OF BREAD BAKING

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Abstract. ***Introduction.*** *In the practice of bread baking in a power oven, where gas is used as fuel, factors related to the effective use of fuel and limitation as ordered by technology. The ordinary control system is not autonomous and requires much more attention from the oven operator, whose usual practice is to do first baking for another assortment.*

Created model of object will be important for temperature control for assortment of bread products.

Materials and methods. *We have experimental information that has been collected from operational bread factories. Specimens have been tested on laboratory ovens for types of dough with different initial moisture. Trend of technological variable had approximated ordinary differential equation; other part of mathematical description was borrowed from famous physical process mass- of temperature exchange.*

Results. *Factors which have strongest effect on baking temperature in oven with circulation of heating gas have been found. Estimate of moisture which is obtained from vapor of dough surface and spreading via recycling composite of heating gas. Different parts of mathematical equation dependent on the condition control point and environment in baking zone. So our recommendation may help the engineer who will be developing a system of controlling baking, guiding the way that heat flow will be adequate to determine the order of baking zones for ordered assortment.*

Keywords: bread, baking, dough, control.

I. Introduction.

The process of pulse-width control for the oven with a gas heating release in the food industry, concerning baking, takes into account the temperature of the baking chamber during the experimental baking, obtaining data from measuring sensors which are mounted there. Since the process of warming up the baking chamber requires raising the temperature of the heating gas to create a temperature gradient, the temperature of the test piece of dough increases due to deviation of temperature, as a consequence of which the surface of dough quickly loses moisture and overheats.

This article is devoted to the effective combination of control methods when changing the assortment of baking products.

II. Materials and methods.

The result of the analysis of industrial ovens established that baking in ovens primarily uses heat which is accumulated by the fillers and armature of the oven. The process of baking in the oven starts with products that have the highest baking temperature followed by those with a gradual decrease of temperature; the next challenge of baking is only to maintain the temperature zones.

The process of burning fuel in the furnace of the over chamber takes place using the algorithm of modulation required by the amount of heat. In the mixing chamber is an active mixture of burning products with air. The share of flue gases is regulated by the inflow dampers opening for zones (B2, fig. 1) of the oven, with an adjustment damper being made for each assortment of bread, which is baked subsequently without reconfiguring the flow of gases warming the oven.

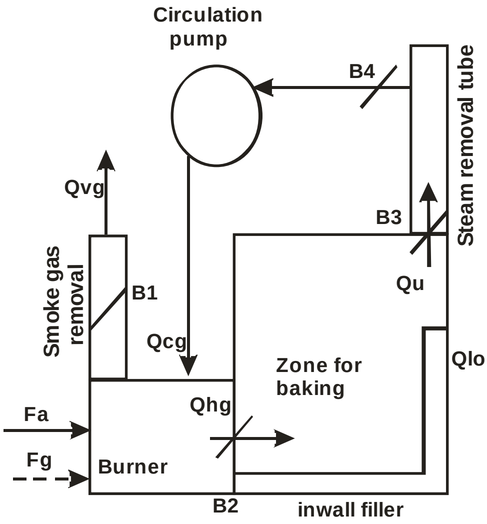

Fig.1.*Common scheme of baking oven*

III. Result and discussion.

The temperature of the heating gas depends on the configuration of the power gas burner from the portion of utilization of the circulating gas mixture. In general, the heat balance of the baking zone of the oven is:

$$Q_{hg} + Q_{if} - Q_{wp} - Q_u - Q_{loss} = 0 \qquad (1)$$

as heating zones occur by means of/with the help of recirculating mixture

$$Q_{hg} = Q_{bg} + aQ_u , \qquad (2)$$

aQ_u - the accumulated heat which returns to the heating of the zone,

Q_{wp} - heat which takes away the moisture of the test piece,

Q_{loss} - heat is not returned to the disposal of the heating gas and heating armature of oven.

In the general case Q_{wp} can be seen as a physical model of the porous structure in which the pore diameter is the value of dynamic and nonlinear dependence on temperature.

Dynamics of porosity which is formed as gas as provenance is extremely complex and chaotic, as related to the tempo of fermentation of organic compounds of dough. However, during the process of baking bread, the impact to the structure is more dynamic. The test piece of dough created during the time of proofing gains the temperature of 120 ºC during 3 – 15 minutes while remaining in the oven, when creating the shape of the bread. After further time, the shell receives moisture, where the speed of obtaining moisture is also limited and decreases due to dynamics. Therefore, the effect of gas generation into the hydrodynamic structure of bread during baking with decreasing temperature is not significant.

Readiness of the bread is determined by the temperature in the center of the crumb, so the task is to promote the baking temperature by capillary movement of steam and feeding structure. The formed shell is a structure of a certain minimum porosity, which is a result of the high temperature in the first baking zone of the oven, in the baking procedure, or toasting procedure in the case of making dark bread.

Thus promoting the formation of the rate of advance of temperature can be consisted of two periods:

- Raising the temperature of the outer shell;
- Feeding the outer shell by means of internal moisture.

Now we have a detailed look at the formation of the heat flow to maintain the temperature in the zone of the oven. The regulation damper responsible for updating the speed of air in the baking zone forms the temperature profile and is limited only by the power of the burner.

The power burner creates the necessary heat flux, characterized by balance (2). The resulting flow leads to effective change of the gas mixture, but as the number of temperature zones on one burner can be from 4 to 8, this is counting upper and lower zone heating of a tunnel type oven. Temperature control by means of power burners is not used, because this introduces a significant perturbation of temperature zones.

The structure of parametric connections of baking oven should link:

- change of the heat flow through the damper position;
- discharge heat flow from adjacent baking zones;
- use of the resource of heat created by the combustion gases and recirculated air.

Change of heat flux:

$$Q_{hg} = Q_{bg} + \sum_{n=1}^{i} Q_{u\_i} - Q_{loss\_u} , \qquad (3)$$

Q_{loss_u} - common loss of heat utilization heating gas from oven,

Q_{u_i} - utilization of gas from i-zone of oven.

Warming gases are further distributed according to the established resistance of oven dampers β_i where the opportunity to obtain a certain quantity of heat generated from the total determinate by pressure difference ΔP before and after the damper, while the change in pressure in the mixing chamber prior to the distribution of the zones can be defined by Bernoulli’s Law [1].

$$\Delta P = \frac{\nu^2 \rho}{2} \sum_{i=1}^{n} \beta_i ,$$

$$\nu = \sqrt{\frac{2\Delta P}{\rho \sum_{i=1}^{n} \beta_i}} , \qquad (4)$$

where: ν - the air velocity in the channel heating ρ - density environment.

And so the quantity of heat that spreads by gas mixture is:

$$Q = c\rho V \Delta T = c\rho \nu S \Delta T ,$$

$$Q = c\rho S \Delta T \sqrt{\frac{2\Delta P}{\rho \sum_{i=1}^{n} \beta_i}} , \qquad (5)$$

where: *c* - the heat of the gas mixture; *S* -sectional area of the channel movement gas mixture.

We can assume that the pressure in the baking zone P_{zone} corresponds to the atmospheric pressure, because areas are not closed tightly. The latter causes heat transfer between adjacent zones of the oven. So as the pressure difference created by the fan is a constant and is the magnitude of the pressure in the area of the baking, the air flow may be placed in accordance with the existing damper valves local resistance. Adjusting the damper on the utilization of circulating gases should only be done with power adjustment of the burner, as it is expected to increase the proportion of dioxide for circulating gas.

In the mixing chamber, increasing the quantity of the gas mixture at constant aerodynamic parameters of chimney the motion of heating gases leads to an increase in the gas flow for heating the baking area.

Change in the speed of movement of gases may change the position of dampers’ recirculated gases, while in the mixing chamber pressure drop changes:

$$P_{m\_ch} = P_{zone} - \Delta P_u - \Delta P_{u\_dam} + \Delta P_{fan} + \Delta P_{dam\_zone}\,, \tag{6}$$

$$\Delta P_{dam\_zone} = \frac{\rho \sum_{i=1}^{n} \beta_i \nu^2{}_{hg}}{2}\,, \tag{7}$$

which in turn leads to reducing

$$\Delta P = P_{zone} - P_{bz}\,,$$

whereas having all other fixed parameters velocity of heating gas decreases into every separated heating area:

$$\nu_{ug} = \sqrt{\frac{2\Delta P}{\rho \beta_i}}\,, \tag{8}$$

according to the resistance β_i generated by the damper area.

In the case of rotary butterfly-type damper

$$\beta = \varsigma_i \cdot (1 - \sin^2 \alpha) = \varsigma_i \cdot \cos^2 \alpha\,, \tag{9}$$

where: α - angle relative to the direction of flow dampers, ς_i - aerodynamic resistance of the material dampers on its location perpendicular to the flow.

When applying slide damper, given the mechanism of movement through the opening we obtain:

$$\beta = \varsigma_i \cdot (1 - l)\,, \tag{10}$$

where: l - share of slide dampers, length that covers the box heating gases.

As the temperature and composition of the gas mixture at constant power differed little during the heating zone, the above function has been simplified to account for the aerodynamic resistance for unchanging environmental conditions.

Changing the amount of heat formed by mixing chamber after muffle:

$$\frac{dQ_{hg}}{dt} = c_{bg} \rho_{bg} \Delta T_{bg} \frac{dV_{bg}}{dt} + c_u \rho_u \Delta T_u \frac{dV_u}{dt}\,. \tag{11}$$

On the right side of equation (11), all the component factors relating to burning gases are determined by the power of the burner, and therefore remain constant during its operation. For routine baking temperatures (210-280 ºC), saturated low-pressure steam enters into the baking area, where the cooling armature zone converts into a superheated steam, which falls into the recirculation loop and is removed through the tube. Since the change of content of the gas mixture occurs under constant pressure and stable content of the evaporated substance, the density of the medium will also decrease. At constant conditions of heating, dynamic of change of temperature in the chamber can be correlated with the dynamics of change of heat capacity of air recirculation. For an invariable position of dampers in the box of recirculation air utilization

$$\Delta T_u = \frac{1}{c_u \rho_u \nu_{u\_c} S}\,, \tag{12}$$

where: $\varDelta T_U$ - change of temperature as a result of variables consisting of mixture of gas from baking zone, C_{U} - the heat capacity of the gas mixture ρ_U - the density of the heat-transfer agent in the gas mixture, $\nu_{U.C}$ - capacity of heating mass which circulates via burner chamber.

Thus, in the circuit of distribution of the heating gas, temperature changes will occur due to changes in the channels of damper resistance and changes in the flow of heating gas for heating baking zones which mix burner gases or occur due to changes in heat capacity:

$$Q_{hg} = Q_{u\_c} + Q_{bg}\,, \tag{13}$$

$$\frac{dQ_{bg}}{dt} = const\,,$$

where: $Q_{U.C}$ - heat which returns with circulation of utilized gas.

Distribution of air recirculation:

$$Q_{u\_c} = Q_u - Q_{loss\_u}\,,$$

where: Q_{loss_u} - loss of utilized gas from oven.

It is agreed that change of damper position will be the only established mode of burner, when burner is working and the oven is empty. Since medium Q_u heat capacity of recirculated air is a constant during the movement of dampers, as well as the temperature of utilized gas from baking zone, as utilization tube is open and capacity of warming zone hasn’t closed $\rho_u = const$, change of Q_{loss_u}

$$\frac{dQ_{loss\_u}}{dt} = \frac{dV}{dt} c_u \rho_u \Delta T\,, \tag{14}$$

$$\frac{dV}{dt} = F = S \cdot \nu_{loss\_u}\,.$$

As in general cases, the effect of the released water should be considered as an influential factor, while the resistance generated by capillaries of dough does not reach a dimension where motion is significantly limited of moisture which feeds the outer shell, and the evaporated moisture will reach higher than consists in the circulating air. The supplied heat flow of baking zones used for the extraction of water from the surface of the test piece of dough, as the moisture removed had converted to a saturated steam, continues to be mixed with the circulating gas which has heat capacity lower than had been obtained by steam heat [2]. So the failure in temperature that typically occurs when loading the baking oven correlates with the mixing of fluids of different heat capacity:

$$\frac{dQ_{zone}}{dt} = c_{bg}\rho_{bg}\Delta T_{bg}\frac{dV_{bg}}{dt} + c_w \Delta T_d \frac{dM_{u\_c}}{dt} + Q_{arm}, \qquad (15)$$

where: C_w - heat capacity of water which has been included in circulation steam,

ΔT_d - difference in temperature between outer shell of dough and gas of baking chamber,

M_{u_c} - mass of test piece of dough.

Since the mechanism of heat Q_{arm} from the oven armatures requires detailed consideration and hasn’t included in this paper, the heat which is spent for a test piece of dough will be referred to as the heat coming from the heating gas flow furnace chamber:

$$c_{bg}\rho_{bg}\Delta T_{zone}V_{bg} = c_{bg}\rho_{bg}\Delta T_{bg}\frac{dV_{bg}}{dt} + c_w \Delta T_d \frac{dM_{u\_c}}{dt} + Q_{arm}, \qquad (16)$$

where the amount of moisture that adds to the content of circulating gas is determined by loss of mass of the test piece during baking.

IV. Conclusions

In further studies, one should look at the possibility of regulating the power of the burner, which can accelerate the process of heating and reveal possibilities to optimize costs when used to power ovens. As the test piece of dough is a complex porous structure, with capillaries that decrease in diameter, it can be analogized with a large number of capillaries with different water content and different diameters.

For each type of baking it is appropriate to approximate the characteristics of release of moisture from the dough for different values of the temperature gradient. Thus the actual process will research the release of moisture from a test piece of dough for different temperature gradients between the surface of the test piece and the air baking chamber.

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