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DESIGNING THE INFLUENCE OF OPERATING PARAMETERS ON DOUGH DEFORMATION DURING INJECTION

ПРОЄКТУВАННЯ ВПЛИВУ ЕКСПЛУАТАЦІЙНИХ ПАРАМЕТРІВ НА ДЕФОРМАЦІЮ ТІСТА ПРИ НАГНІТАННІ

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Abstract. *The article investigates the current problems of dough rolling - a method of processing dough by plastic deformation, which is the most common method in the bakery and confectionery industry for forming products, namely, the mass of dough in the working chamber of the machine is compressed (compressed) in the gap between the rotating rolls, while it decreases in cross section and increases in length; the process of passing the dough between the rolls is provided by the friction forces of the rotating surfaces of the rolls and the dough. Due to the loose surface of the rollers, the dough moves in the gap between them, deforming at the same time. At the moment of dough tightening by each roll, two forces are exerted: normal force and tangential friction force.*

The purpose of the article is to evaluate the mechanics of the process of developing methods for a sufficiently accurate quantitative description of the processes taking place in the dough during its shape change in the inter-roll gap and after deformation. A comprehensive study of the behavior of dough in the deformation zone during rolling and pressing and the establishment of regularities that link quality parameters to their deformation modes are possible only when using the methods of continuum mechanics. They allow for quantitative assessment of the transformations taking place in the dough. To analyze these processes, it is necessary to take into account the basic rheological properties, conditions on the surface of its contact with the rollers, and other factors.

Key words: dough; deformation; injection; rolls; molding machine.

Introduction.

Reliability of the technological process of rolling and pressing in the production of bagels, drying, gingerbread and other products should ensure minimal dispersion of quantitative characteristics of their quality indicators. Accordingly, new opportunities are created to determine the impact of instability of the initial parameters that arise during the technological change on the quality indicators of the finished product [1-4].

The discrete action of the rolls makes it possible to reduce energy consumption for the process, maintain constant product quality, and simplify control, mechanization, and automation of the process. Maintaining the countercurrent flow and updating the contact surface of the phases between which heat or mass is exchanged contributes to the maximum utilization of coolant energy during heat exchange or maximum mass recovery during mass exchange. During such renewal, fresh elements of the medium come into direct contact. In this case, the driving force of the process increases, the process is accelerated [5-9].

Research methodology.

Technological processes of dough rolling are a complex technological complex, characterized by a high degree of uncertainty, large dimensionality, latency of quality indicators of raw materials and semi-finished products, and multi-purpose behavior, when the priority of goals depends on the situation that arises depending on the circumstances at the control object. Existing control systems for technological processes of dough rolling do not provide an operational comprehensive response to rapid changes in the situational behavior of management objects, which depends on many factors of a technological and organizational nature.

Based on the analysis of the principles of management of complex technological complexes, promising directions for the development of control systems for rolling stages were identified: a scenario approach and the use of knowledge engineering. It is possible to improve the situation by using the mobility of process control in the working chamber with roll working bodies. The mobility is based on the rolling process model, as well as the control of parameters using controlled mechanisms - roll rotation speed, duration of their action, temperature conditions, discrete-pulse impact of the rolls on the environment, and the creation of more advanced roll surfaces. Therefore, the development of multi-purpose technological process control systems for rolling stages, the formation of new roll designs based on the developed approach and design parameters, will help to increase productivity, reduce specific losses and consumption of resources and raw materials, and improve product quality.

Improvement and development of rational designs of machines with rolling working bodies and increase of their efficiency is one of the main tasks of scientists.

Given all of the above, the dough rolling process is promising, as it provides a significant intensification of the process and reduces specific energy consumption [10-14].

Research results.

The purpose of studying the process of dough formation is to ensure full compliance of the processing modes of the structural and mechanical properties of the viscous medium with the structural shapes and parameters of the rolling working bodies.

To achieve this goal, a number of interdependent scientific tasks were solved, namely: a significant number of types of rolling working bodies, rotation frequency, and level of mechanical deformation on the dough were investigated, which allows intensifying the process in order to accelerate its formation while maintaining optimal values of specific work in a correspondingly short time. A characteristic feature of these machines is that under the influence of extreme conditions in the machine chamber, the structural composition of the components partially changes, and the process of these changes depends significantly on the chemical composition of flour and the temperature conditions of the dough entering the molding. They are based on promising impact parameters with the formation of impact conditions under established methods of regulating deformation processes. Therefore, the existing designs of forming and dough dividing machines do not fully meet the quality requirements of the technological process. This effect can be explained by a change in the magnitude of the friction force between the medium and the surface of the rolls, which scientists try to minimize in their works [15-18]. This change leads to an increase in energy consumption.

An analysis of existing methods [19-23] for calculating machines with rolling working bodies made it possible to determine the feed ratio, to establish the influence of design parameters, power consumption, and rheology on the flow of dough mass between the rolls. The data show that their approaches are different. They are associated with the introduction of a large number of experimental coefficients for the ratio of working media. There is a practical absence in determining the operating modes of the roll assembly of the forming machine.

Improving the design of machines with rollers is based on understanding the nuances of the processes that occur when ensuring rational dough flow parameters. Therefore, optimization of the design of the main machine components plays an important functional dependence on quality and energy saving. A detailed study and analysis of the essence of the process based on theoretical views and studies describing changes make it expedient to confirm possible ways to improve the rolling assembly [24-26].

Proceeding from this, the main purpose of this article is to determine the methodology for determining the useful specific power based on torque and pressure in the gap between the rolls, taking into account rheological parameters; to improve the technological process of injection, rolling out the mass of the medium using rolls, provided that the research is optimized, followed by the development of rational designs of machines with rolling working bodies and the prompt implementation of their results in industry.

Therefore, in order to generalize the classification of methods of machines with rolling working bodies, it is necessary to determine those discrete features that characterize their process quality.

To determine the characteristic features of the roll assembly in forming machines that are discrete in nature, we have considered and analyzed possible dough flow structures. It constitutes a mathematical description of the hydrodynamic structure, which provides special opportunities for determining the efficiency of the rolls whose designs we have developed. Taking into account the effect of the rollers on the medium, the following structural flows are possible:

According to the model of ideal extrusion, regardless of the complex real flows of the dough moving to the extrusion zone through the straight processing zone, it does not change. The time spent in the process zone will:

$$t = \frac{V_{in.z}}{V_c} \tag{1}$$

where $Vin.z$ – is the volume of the injection zone; Vc – volumetric capacity of the medium (dough) flow.

The rate of change of the properties of such an ideal flow:

$$\frac{dc}{dt} = -v\left(\frac{dc}{dx}\right), \tag{2}$$

where c – is the parameter under study; v – is the linear velocity of the flow; x – is the displacement coordinate.

According to the model of complete mixing, at all points in the volume of the processing zone, the properties of the medium are the same and equal to their value at the outlet:

$$\frac{dc}{dt} = \left(\frac{V_c}{V_{in}}\right)(C_{in} - C_{ex}), \tag{3}$$

In real cases, the residence time of a mass of medium in a flow is different and differs from the average time that can be determined by Eq. This phenomenon can be described using the diffusion and cellular models.

According to the diffusion model, the mixing of the dough mass in the flow in the direction of its movement is described by an expression formally corresponding to Fick's law of molecular diffusion. By analogy with the coefficient of molecular diffusion in Fick's law, the degree of longitudinal mixing in the diffusion model is characterized by the longitudinal mixing coefficient DL:

$$\frac{dc}{dt} = -v\left(\frac{dc}{dx}\right) + D_L\left(\frac{d_c^2}{dx^2}\right), \tag{4}$$

According to the analysis of the process of injection, rolling, and transportation of a viscous medium, roll machines are the most advanced and promising in terms of energy consumption of work processes, reliability of operation, and conditions of mass processing.

Assuming the congruence of the current lines in relative motion relative to the surface of the working groove on the surface of a cylindrical roll, the value of the radial component of the absolute velocity at the flow point in the area of the smooth surface of the roll along its peripheral radius (Fig. 1) is determined by the expression

$$v_{r2} = (v_{r2})_{\varphi=0} + \omega \frac{dh}{d\varphi}, \quad (5)$$

where $(v_{r2})_{\varphi=0}$ – is the radial component of the absolute velocity in the section 0-0; h – is the current radial gap in the area of a smooth surface (without a groove); φ – is the value of the angle of rotation, which is calculated from the 0-0 section in the direction of rotation of the working roll.

In turn, the value of the gap h at the initial stage of drawing the mass of the medium into the space of its compression by the rollers is determined by the geometric relation in the form

$$h = \sqrt{R^2} + e^2 - 2 \cdot R \cdot e \cdot \cos\varphi - r_2, \quad (6)$$

where R – is the radius of the inner surface of the cylindrical roller; e – eccentricity formed by the mass of dough; r_2 – is the peripheral radius of the working roll with dough.

Having differentiated equation (6), we have

$$\frac{dh}{d\varphi} = \frac{e \cdot R \cdot \sin\varphi}{\sqrt{R^2 + e^2 - 2 \cdot e \cdot R \cdot \cos\varphi}}, \quad (7)$$

Taking into account the condition $(v_{r2})_{\varphi=0} = 0$, we obtain:

$$v_{r2} = \frac{\omega \cdot e \cdot R \cdot \sin\alpha}{\sqrt{R^2 + e^2 - 2 \cdot e \cdot R \cdot \cos\alpha}}, \quad (8)$$

Equation (8) shows that the radial component of the flow arising at the initial stage of tightening by the roll surface from the side of the fixed contour of the mass of the medium is subject to a sinusoidal condition. This condition leads to a change in the stationarity of the angle of rotation of the entire mass at the absolute velocity of the medium.

From the equations obtained, we see that the position of the inner surface of the medium for a fixed value of the angle of rotation is determined by the following dimensionless parameters: relative to the resulting eccentricity $\vec{e}$ and $\overrightarrow{e_R}$; the relative radius of the inner surface in the 0-0 section $\vec{\varphi}_0$; the relative radius of the roll $\vec{R}$; the coefficient of influence of the geometric parameters of the working roll α. Thus, these five parameters should be decisive in any experimental studies of rolls [27-30].

Conclusions.

Observations have shown that the results of experimental studies, combined with theoretical generalizations, expand the completeness of the assessment of physical processes and allow predicting the practical implementation of the obtained provisions and create opportunities for mathematical formalizations of the elements of the studied dough injection technologies.

In addition, the presence of a gas phase in the media of the systems, which are spontaneously or forcedly formed in the form of dispersed phases, was chosen as a unifying feature of theoretical and experimental studies.

Based on the results obtained, it can be argued that the development of enzymatic processes during roll injection is clearly associated with the influence of different types of deformation, which determines the impact on the change in the quality indicators of bagels; possible structures of dough flows are considered and analyzed; characteristic features of the roll assembly in forming machines that are discrete in nature are determined.

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Анотація. *У статті досліджуються актуальні проблеми нагнітання тіста валками – це спосіб обробки тіста пластичною деформацією, що є найбільш поширеним методом в хлібопекарській та кондитерській промисловості при формуванні виробів, а саме маса тіста в робочій камері машини обжимається (стискується) в зазорі між обертовими валками, при цьому, воно зменшується в поперечному перетині і збільшується по довжині; процес проходження тіста між валками забезпечується силами тертя обертових поверхонь валів та тіста. Завдяки рихлевій поверхні валків тісто переміщається в зазорі між ними, одночасно деформуючись. В момент затягування тіста кожним валком, відбувається вплив двох сил: нормальної сили і дотичної сили тертя.*

Метою статті є оцінка механіки процесу розробки методів достатньо точного кількісного опису процесів, що проходять в тісті при його формозміні в міжвалковому зазорі і після деформації. Всебічнє дослідження поведінки тіста в зоні деформування при розкачуванні і нагнітанні та встановленні закономірностей , що звязують параметри якості *з режимами їх деформації, можливі лише при використанні методів механіки суцільного середовища. Вони дозволяють проводити кількісні оцінки перетворень, що проходять в тісті. Для аналізу цих процесів необхідно врахувати основні реологічні властивості, умови на поверхні його контакту з валками та інші фактори.*

Ключові слова: *тісто; деформація; нагнітання; валки; формувальна машина.*

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