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DETERMINATION OF FORCE AND PRESSURE OF END RESISTANCE WHEN FASTENING DOUGH LAYERS

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Abstract
Engineering rheology in the food industry, as an object of study, considers the behavior of raw materials and semi-finished products at the stage of stretching, compression and twisting. The processes of mechanical processing of dough are associated with the interaction of viscous-plastic raw materials (dough) with the working parts of machines, therefore, for effective mechanical processing of dough, it is necessary to take into account its viscosity, plasticity, elasticity and other rheological properties. This will optimize the processes of mixing, rolling, forming and other operations, increasing productivity and quality of the final product. In addition, analysis of the rheological properties of the dough allows you to optimize the choice of equipment, optimal operating parameters (for example, rotation speed of working bodies, pressure and temperature), as well as the development of special processing technologies for various types of dough. In this regard, this work examines the determination of the compression force, the inertial component of the total resistance force, the force and pressure of the end resistance when fastening dough layers using a rotating roller.

Keywords: rheology, dough, food products, raw materials, deformation, stress, compression.

Introduction

The nutritional value of confectionery products is determined by the content of substances necessary for the human body, primarily proteins, essential amino acids, vitamins, minerals, as well as energy value and ability to be absorbed by the human body. Vitamins contained in food raw materials used in the production of confectionery products have high biological activity and play a role in metabolism, regulating certain biochemical and physiological processes. Vitamins do not act as a building material or source of energy. For confectionery products, sources of vitamins are certain types of raw materials. The preservation of vitamins in finished products depends on the technological processing of the initial mixtures of raw materials [1].

This paper examines the rheological aspects of the issue of mechanical processing of dough for flour confectionery products. In particular, the inertial component of the total resistance force when fastening dough layers was determined, and calculations were carried out to determine the force and pressure of the end resistance when fastening dough layers.

To determine the inertial component of the total resistance force when fastening dough layers, we used the diagram shown in Fig. 1. From the diagram we determine the speed of movement of the wedge at the beginning of text compression:

$$U_{н} = U_{1y} = U_0 \cdot \cos\left(\frac{\pi}{2} - \alpha\right) = U_0 \cdot sin\alpha, \quad (1)$$

whereU_{1y} - projection of peripheral speed U_0 per axis OY at the point I; α - the angle of grip of the dough layers by the fastening roller.

From the same diagram it can be seen that the amount of complete lowering of the wedge during compression

$$h_{max} = H_0 - b \quad (2)$$

Substituting expressions (1) and (2) in the formula $P_и = -\frac{mv_н^2}{2h_{max}}$ we get

$$P_и = \frac{m \cdot U_0^2 \cdot sin^2\alpha}{2(H_0 - b)} \quad (3)$$

From Fig. 2 we find

$$cos\alpha = \frac{OB}{OA} = \frac{OD - BD}{OA} = \frac{R + b - H_0}{R} \quad (4)$$

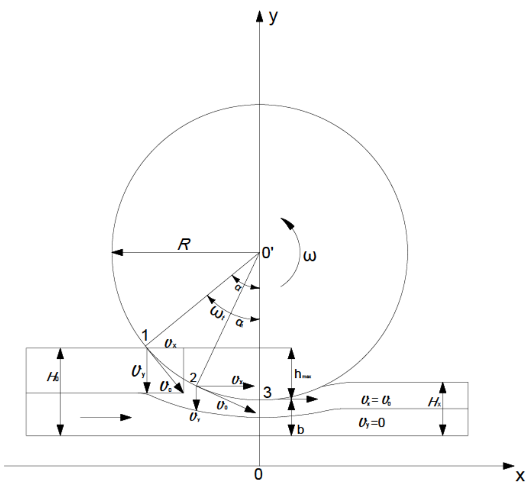

Fig.1. Diagram of speeds of a point on the working surface of a rotating roller.

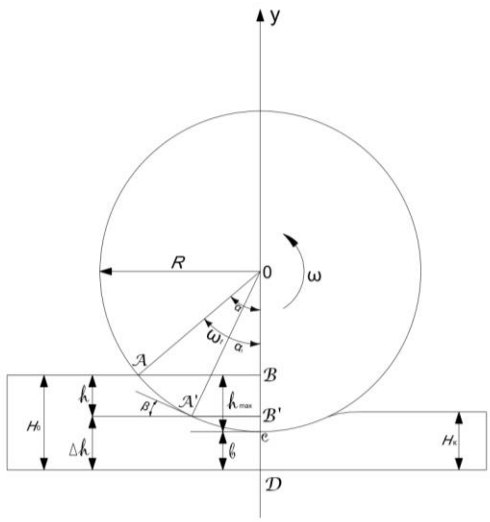

Fig.1. Diagram of speeds of a point on the working surface of a rotating roller.

Where

$$\alpha = arccos\frac{R + b - H_0}{R} \quad (5)$$

Using trigonometric transformations we get

$$sin^2\alpha = 1 - \cos^2\alpha = \frac{(b - H_0) \cdot (H_0 - b - 2R)}{R^2} \quad (6)$$

Considering $U_0 = \omega R$ and substituting expression (6) into equation (3) we obtain a formula for determining the inertial component of the total resistance force when fastening dough layers

$$P_и = \frac{m \cdot \omega^2 (H_0 - b - 2R)}{2} \quad (7)$$

The pressure created by this force during the bonding process is determined by the formula *XOZ*.

$$p_и = \frac{P_и}{S} \quad (8)$$

where S – projection area of the working surface of the fastening roller in the compression zone onto the plane *XOZ*.
From Fig. 2 we find

$$S = L \cdot R \cdot sin\alpha \quad (9)$$

where L – width of the fastening roller collar.
The final formula for determining the pressure created by the inertial resistance force will take the form

$$p_и = \frac{m \cdot \omega^2 (H_0 - b - 2R)}{2L \cdot R \cdot sin\alpha} \quad (10)$$

To determine the end resistance pressure when fastening dough layers, we used the equation given by D. Moore [2] when studying the rolling of a rigid cylinder on a viscous-resistant base. The indicated equation has the form:

$$p_т = E \cdot \frac{h}{H_0} + \frac{\eta}{H_0} \cdot \frac{dh}{dt} \quad (11)$$

where $p_т$ – test end resistance pressure;
E – dough elastic modulus;
η - effective viscosity;
H_0 – total initial thickness of dough layers;
h - magnitude of compressive deformation during fastening;
dh/dt - compressive strain rate.
The first term on the right side of equation (11) characterizes the elastic component of pressure, and the second - the viscous component.
The geometry of the movement of a point on the working surface of the compression test roller during bonding of layers is shown in Fig. 2; after a time t from the beginning of the process, the roller rotates through an angle ωt and point A moves to position A′, the deformation in this case will be h.
As seen

$$h = BB^{'} = OB^{'} - OB \qquad (12)$$

Considering that

$$OB^{'} = R \cdot cos\alpha_{т} \qquad (13)$$

$$\alpha_{т} = \alpha - \omega t \qquad (14)$$

$$OB = R \cdot cos\alpha_{т} \qquad (15)$$

we find

$$h = R[\cos(\alpha - \omega t) - cos\alpha \qquad (16)$$

Differentiating expression (16) with respect to time, we obtain

$$\frac{dh}{dt} = \omega \cdot R \cdot \sin(\alpha - \omega t). \qquad (17)$$

Substituting expressions (16) and (17) into equation (11) we get

$$p_{т} = \frac{R}{H_0}\{E[cos\,(\alpha - \omega t) - cos\alpha] + \omega\eta \cdot \sin(\alpha - \omega t) \qquad (18)$$

The force of the end resistance to an elementary wedge when fastening layers of dough is determined as the product of the pressure of the end resistance and the area of projection of the wedge onto the plane *XOZ*.

$$dP_{т} = p_{т} \cdot dS \qquad (19)$$

Substituting instead dS formula $dS = L \cdot dl \cdot cos\alpha$ we get

$$dP_{т} = p_{т} \cdot L \cdot dl \cdot cos\beta \qquad (20)$$

Considering that $dl - arc\ length, wh$ich the point passes when the fastening roller rotates in time dt with a linear peripheral speed $U_0 = \omega R$, we have

$$dl = \omega \cdot R \cdot dt. \qquad (21)$$

From Fig.2

$$\beta = \alpha_{т} = \alpha - \omega t. \qquad (22)$$

Thus

$$dP_{т} = p_{т} \cdot L \cdot \omega \cdot R \cdot \cos(\alpha - \omega t)\, dt. \qquad (23)$$

Taking into account equation (18), equation (23) will take the form

$$dP_{т} = \frac{L\omega R^2}{H_0}\{E[cos\,(\alpha - \omega t) - cos\alpha] + \omega\eta \cdot \sin(\alpha - \omega t)\}cos(\alpha - \omega t)dt \qquad (24)$$

To simplify the process of fastening layers of dough, we consider it as simultaneous compression by an infinitely large number of elementary wedges having the same width and located at different heights. These wedges, when compressing the dough, sequentially pass through the same positions, lagging behind each other for an infinitesimal period of time *dt*. Therefore, the total simultaneous force of the end resistance of the test for all wedges can be taken equal to the sum of the efforts of the end resistance of the test for one wedge in all its positions when passing through the compression zone in a time equal to $t_{ст} = \alpha/\omega$.

Therefore, the total end resistance force of the test is determined by integrating $dP_{т}$ by time from 0 before α/ω, т.е.

$$P_т = \int_0^{\alpha/\omega} d[P_т \cdot (t)]. \qquad (25)$$

Substituting equation (24) into formula (25), integrating and after simplifications we obtain

$$P_т = \frac{L \cdot R^2}{2H_0}[E\left(\alpha - \frac{sin2\alpha}{2}\right) + \frac{\omega\eta}{2}(1 - cos2\alpha)] \qquad (26)$$

Substituting equations (7) and (26) into Eq. $P = P_и + P_т$ we obtain a formula for determining the compression force when fastening dough layers.

$$P = \frac{m\omega^2(H_0 - b - 2R)}{2} + \frac{LR^2}{2H_0}[E\left(\alpha - \frac{sin2\alpha}{2}\right) + \frac{\omega\eta}{2}(1 - cos2\alpha)] \qquad (27)$$

In accordance with the accepted physical model of the process, the total compression pressure of the dough layers during bonding consists of the pressures determined by equations (10) and (18), i.e.

$$p = \frac{m\omega^2(H_0 - b - 2R)}{2LRsin\alpha} + \frac{R}{H_0}\{E[cos\,(\alpha - \omega t) - cos\alpha] + \omega\eta sin(\alpha - \omega t)\} \quad (28)$$

The result of the experiments is the following: it was revealed that the fastening of two layers of dough with the shoulders of a rotating roller is a process of constant compression of these layers along the vertical axis. As a physical model of the process of fastening dough layers, a scheme of gradual compression of an elastic-viscous mass by a vertically descending wedge can be adopted. Increased compression when fastening dough layers is spent on overcoming the forces of inertia and the end resistance of the wedge. Equations (7) and (10) make it possible to determine the inertial component of the total resistance force and the pressure created by this force when fastening the dough layers. The force and pressure of the end resistance when bonding the layers are determined by the elastic and viscous characteristics of the dough. Equations (18) and (26) allow us to determine the pressure and force of the end resistance of the dough during the bonding process. Equations (27) and (28) allow you to calculate the force and compression pressure when fastening dough layers using a rotating roller. To check the degree of approximation of the proposed model to the real process, it is necessary to carry out an experimental test, the results of which are compared with formulas obtained theoretically. For the practical use of the obtained dependencies (27) and (28), it is necessary to know the rheological properties of the dough for national flour products with filling and the mass of the equivalent load that ensures compression of the dough layers by a wedge.

REFERENCES:

1. Тошев А.Д. Кондитерские изделия без сахара в питании диабетиков / А.Д. Тошев, К.М. Персецкая // Молодой ученый. – 2018. - №52 (238). С.23-27. – URL. https: //moluch.ru/archive/238/54698/
2. Копченков В.Г. Трение и изнашивание эластомеров в условиях контактно-динамического нагружения / Дисс...докт.техн.наук, Ставрополь, 2004. – 424 с.