STRENGTH CHARACTERISTICS OF FOOD PRODUCTS

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The article covers experimental study of knives with different sharpening angles to determine the strength properties of molded half-finished product and associated energy consumption for cutting. Determination of the values of the limiting shear stress of products depending on moisture content of the dough and the radius of rounding of the knife.

Keywords: cutting, strength properties, impact strength, blade knife, dough moisture, Fisher's value, knife blade, slip coefficient, blade rounding radius.

The main problems of the food industry are the intensification and optimization of technological processes, the introduction of new progressive types of equipment for rational processing modes that ensure increased production efficiency, reduced energy costs and raw material losses, and improved product quality.

Cutting is a technological method of machining various materials. Due to the difference in the physical and mechanical properties of this or that material, which affects the cutting process, various requirements are imposed on the modes and methods of cutting, as well as on cutting tools.

For products and half-finished products of the food industry, mainly blade cutting and its variation, called sliding cutting, are used. This type of cutting is also widely used in various sectors of the national economy like agricultural production, light industry, etc.

The interaction of knives with macaroni tubes is associated with specific geometric characteristics of the cutting tool, i.e. radius of curvature of the blade, sharpening angle, parameters of the longitudinal microrelief, etc.

The interaction itself has a shock (impulse) character. Hence, it is obvious that it is necessary to study the strength characteristics of the cutting object in combination with the above parameters [1].

In our case, by analogy with dynamic testing of metals and plastics, impact strength is taken as the main criterion characterizing the strength properties of the object under study. Taking into account the specifics of the section, a plate knife was used as a working medium, and the parameter obtained experimentally, as shown in the works of can be called the specific work of cutting A_o, J/m^2

Installation for the study of the strength properties of macaroni tubes is developed on the basis of a pendulum plant and consists of a frame, a pendulum, a knife holder, a plate knife, a device for holding a sample, a scale and an arrow.

The work of the installation is as follows. The pendulum with a knife is fixed with a trigger in the raised position; the tube bundle is installed in the holder. After that, lifting the trigger, release the pendulum. The kinetic energy is spent on cutting the beam, and the rest makes the pendulum rise in the opposite direction by a certain angle.

The cutting work is determined by the formula:

$$A = Gl(\cos\varphi - \cos\varphi_0)\ (J) \qquad (1)$$

where: G is the gravity of the pendulum, N; l is the length of the pendulum (the distance from its axis to the center of gravity), m; φ and φ_0 are the lifting angles of the pendulum, respectively, before and after the destruction of the sample, degree.

Specific cutting work was determined by the formula:

$$A_0 = \frac{A}{F}, \quad \left[\frac{j}{м^2}\right] \qquad (2)$$

where: A is total work of cutting, J; F is the area of the cut section of the cassette, m^2.

In the experiments, we used lamellar knives with a straight cutting edge made of 9KS steel with a hardness of HRC = 58 units. The taper angle of the cutting edge ranged from 0.2 to 1.0 mm. The knives were set at different angles to the longitudinal axis of the pendulum: the angle was changed from 0° to 60°. The cut quality was assessed by the K_I index, which characterizes the degree of preservation of the cross-section of the macaroni tubes when cutting the circular shape. Macaroni tubes 40 mm long and 5 mm outer diameter were tightly packed into a cylindrical cassette Ø30 mm with a slot in the central part for the passage of a plate knife fixed to a pendulum. The cassette is installed on the head frame so that its longitudinal axis is perpendicular to the cutting plane.

The parameters of the microgeometry of the cutting edge are the most important characteristics that determine the cutting ability of knives, the level of energy consumption and the quality of the formed surface. The edge-rounding radius is one of the main parameters of microgeometry. On the other hand, the dominant factor in the formation of the structural and mechanical properties of a half-finished product is its moisture content. Therefore, it seems appropriate in the initial series of the experiment to find out the degree of mutual influence of these factors on the value of the specific work of cutting [2]

The results of the experiments were expressed by the value of the specific work A_0 J/m^2. This series of experiments was carried out with a plate knife thickness δ= 0.2 mm; angle of installation equal to 0°; sharpening angle equal to 15°. Strong baking flour was used for kneading.

The first factor (x_1) is the moisture content of the dough varied from 28% to 32%. The second factor (x_2) is the radius of the blade rounding, and is from $3.5x10^{-3}$ mm to $20.5x10^{-3}$ mm.
The use of the central compositional company of the second-order time planning allows obtaining a curvilinear dependence of the output parameter (in our case, the specific cutting work) on variable factors: dough moisture and rounding radius, as well as to evaluate the effects of the interaction of factors.
After processing the experimental data, we obtain the following regression equations:

$$y=0{,}292-0{,}055x_1+0{,}0455x_2+0{,}0165x_1^2+0{,}011x_2^2–0{,}015x_1 \cdot x^2. \quad (2)$$

The value of the Fisher criterion, calculated on a computer, is $F_p = 4.17$.
To check the adequacy of the obtained regression equation, the calculated value of the Fisher test was compared with its tabular values.
Fisher table value was determined for a significance level of 0.05 according to the number of degrees of freedom when determining the variance of adequacy

$$f_1 = (n - n_0) - n^1 \quad (3)$$

and repeatability dispersion:

$$f_2 = n_0 - 1 \quad (4)$$

where: n is the number of experiments; n^1 is the number of significant coefficients of the regression equation; n_0 is the number of experiments at the central point; K is the number of factors.
The tabular value of the Fisher criterion at f_1=3 and f_2=4 for a 5% significance level is $F_{0.05}$ = 6.5914. Thus, the calculated F_p value is less than the tabular value, i.e. at the accepted level of significance (0.05), then the resulting equation adequately describes the process under study.
To use the obtained equation when finding the values of the varied factors, we will decoding the variables included in the equation. Then the equation takes the form:

$$У=3{,}5510-0{,}1551W-0{,}0332\rho_л+0{,}0018W^2+0.0003\rho_л^2–0{,}0008W\rho_л, \quad (5)$$

where: W is the moisture content of the dough,%.
The obtained equation is valid only for the experimentally investigated values of moisture content and the radius of rounding of the blade and can be used to determine a rational combination of the recipe for kneading macaroni dough and the parameters of sharpening the blade.
The reason for this is that an increase in humidity leads to an increase in the plasticity of the half-finished product. This, in turn, causes the localization of the breaking stresses σ max directly under the blade and a decrease in the part of the cutting work spent on deformation of the bundle of macaroni tubes.
The strength characteristics, as known, are not a constant of the material, but depend on the loading conditions of the object under study [3]. Therefore, in relation to the tasks set, in the

future, the influence of the geometric characteristics of the cutting tool (knife thickness, sharpening angle, angle of installation) on the main indicator, the specific work of cutting, was studied.

Structural-mechanical and strength properties of a layer of raw macaroni tubes depend on the complex of technological rheological properties of macaroni dough, molding conditions, features of the geometric shape of the half-finished product and the density of their packing in the layer.

References

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