MODELLING OF PROCESS IN TWIN-SCREW DOUGH-MIXING MACHINES

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Abstract. *Simulation of the kneading yeast dough kneading machine in continuous operation: To intensify the machining test during mixing, we suggested using a screw as the working part of various modifications, which provide continuous transportation and intensive mechanical impact on the dough during kneading.*

To study the process of kneading proposed design model using software package Flow Vision. Different types of kneading part are investigated: digitalete, spiral, ribbon.

Analysis of the results of modelling allowed us to offer the design a combined work part that provides a three-step process of knead the dough kneading machines in continuous action.

Keywords: dough, knead, screw, mixing.

I. Introduction

A wide application of the advanced dough-making technologies in bread production involves the use of intensive mechanical processing of the semi-finished products. In this regard, double-speed dough-mixing machines of the periodic operation with intensive dough kneading have become a frequent practice in bread making industry resulting a transition from a continuous stream of dough kneading to periodic one because there are no continuous dough-mixing machines of intensive action. The creation of the dough-mixing machines of continuous action is currently important.

The intensification of the mixing process can be performed by increasing the frequency of the body rotation or changing its structure that leads to changes in the structural and mechanical dough properties and provides the reduction of the duration of the dough fermentation.

During fermentation of the dough semi-finished products the change of their structural and mechanical properties occur together with the microbiological processes that determines the state of the surface, the specific volume and porosity structure of the finished products.

Intensive mechanical dough processing while kneading has a positive impact on the quality of the finished products with the use of the advanced dough-making methods. The application of the screw working bodies of various modifications is suggested as the working bodies that provide continuous transportation and intense impact.

Mixing the components occurs in machines with the screw working bodies due to the friction of the mixture on the walls of the screw and trough while moving and sliding. To provide the work of the screw it is necessary that the adhesive force of the mixture with the screw is less than its friction force on the walls of the trough.

Depending on the type and composition of the mixture various types of the screws are used: solid, tape. The mixing effect is higher in the tape working bodies than in the mixers with the solid screws. The redistribution of the particles in the tape mixers is due to the opposite motion of the mixture under the action of the tapes. The highest effect of mixing is reached with the screws that have a perforated surface of the helix, but at the same time they have a lower effect of transportation. Solid screws provide transportation and intensive mechanical dough processing [1].

II. Materials and methods

A calculation model of dough kneading using the software package Flow Vision of the Russian firm “Tesis” is suggested to study a dough kneading process. This package is designed to model hydrodynamic processes in technical and natural conditions and to visualize these processes using the methods of computer graphics. It is based on the analysis of the stress-strain state of the studied material by the finite-element method.

Having analyzed all basic mathematical models that are presented in Flow Vision the model of “incompressible liquid” is used. This model describes the motion of the viscous liquid, gas at small Mach numbers, small and large Reynolds numbers. There may be small changes in density; it means the presence in the dough a gas phase only as the air entrapped during mixing.

A mathematical model of the calculating process of dough kneading is based on the use of a well-known Navier-Stokes equation, energy, transfer convectional, and diffusive shift and viscosity changes of the matter during mixing.

To study different types of the mixing bodies is suggested on the basis of the theoretical studies (Fig. 1) that are placed in pairs in the mixing trough capacity, with the same pitch, the opposite direction of the helices and counter rotation. A combined working body consists of one helix of the solid screw that provides a directed movement of the components into a mixing zone of the tape working bodies; the solid screw delivers the mixed components into a zone of intensive mechanical processing by the screw with the varied pitch.

The components for dough kneading are transported into the receiving pipe and unloading of the kneaded dough is performed through the lattice with openings where the change of the cross-section enables to alter the time and intensity of mechanical processing.

III. Results and discussion

a

b

c

d

Fig.1. Working Bodies of Various Configurations: Pin (a), Helical (b), Tape (c), Compound (d).

Geometric models are built using the software “Compass”, for the compound working body the model is shown in Fig. 2.

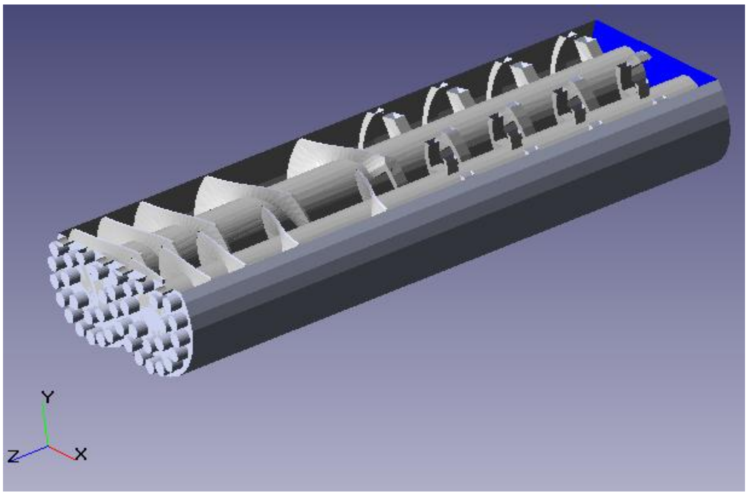
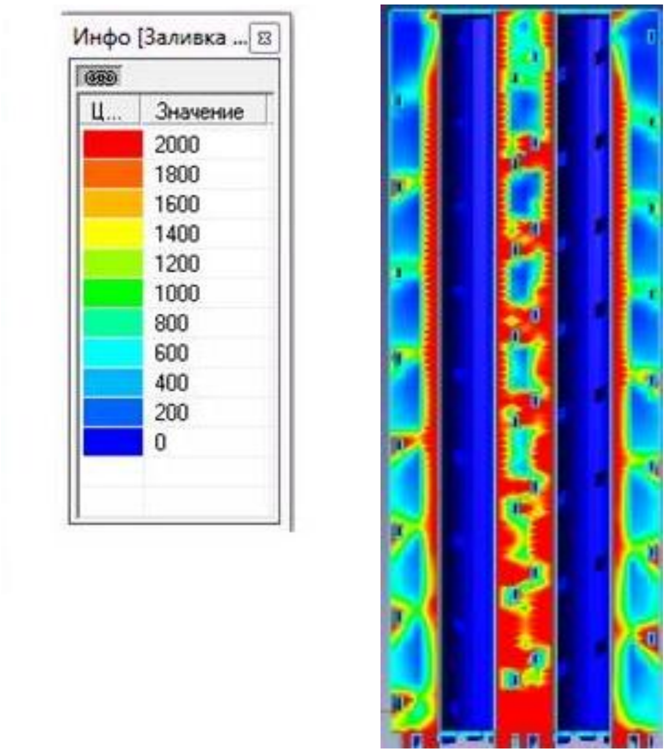


Fig.2 The Calculated Model of the Compound Working Body

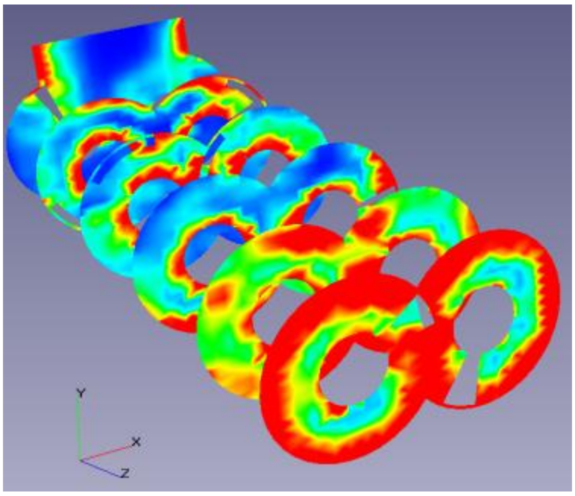
The results of the computational experiment are presented in the horizontal axial section and vertical sections for all investigated working bodies. The potting method enables to estimate the degree of influence of each working body in terms of kinetic energy dissipation.

The spiral working body (Fig. 3) is characterized by an intense equal impact throughout the length of the working body in the area of the flights engagement, and in the end an increase is caused by the resistance of the lattice.

The main energy consumption for internal friction occurs around the shafts of the screws caused by the highest gradient of the dough deformation speed.



a

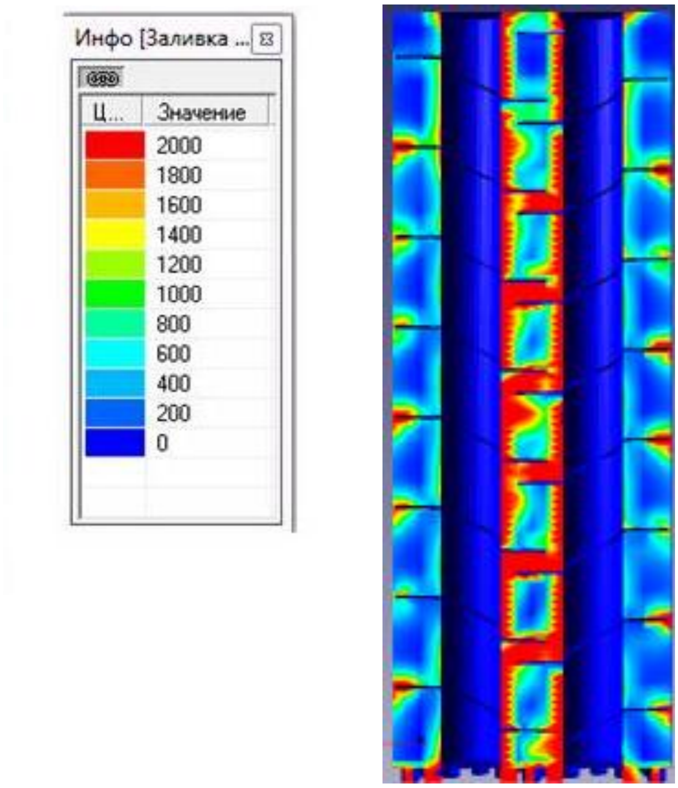


b

Fig.3 The Calculated Result of the Spiral Working Body: a – the Horizontal Axial Section; b – the Vertical Sections.

During the study of the tape working body (Fig. 4) it was revealed that the most intense impact occurs in the area of the flights engagement and on the shafts surface. Such working body is characterized by the transporting function rather than mixing. Installed lattice at the output enhances the impact.

Due to the large total linear velocity of the working bodies at the fixed walls of the container the biggest curling of the product is marked in this area.



a

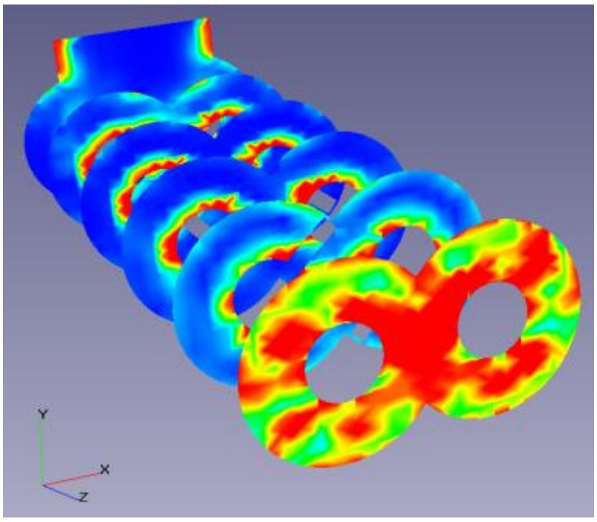


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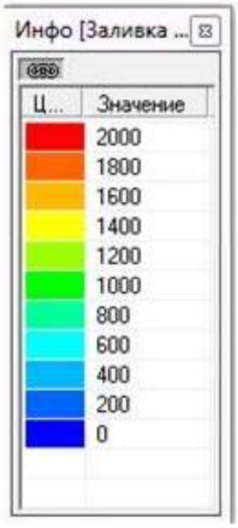
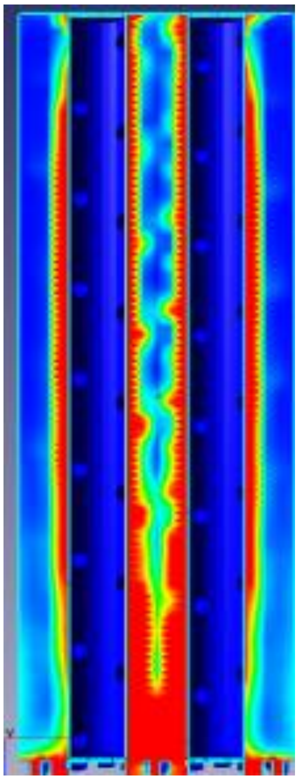
Fig.4. The Calculated Result of the Tape Working Body: a – the Horizontal Axial Section; b – the Vertical Sections.

The pin working body possesses the gentlest impact which is shown in Fig. 5.

The axial velocity component of the product in this case is negligible, so the main energy consumption occurs in the area around the shafts during the mode of almost laminar moving.





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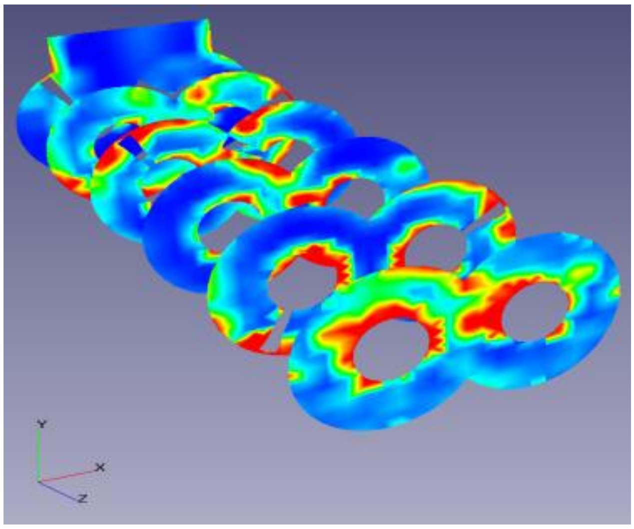
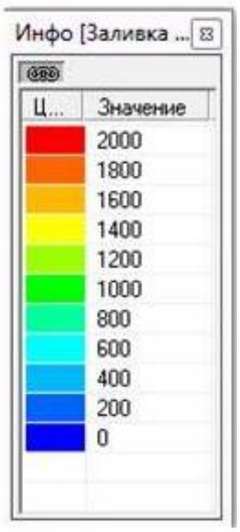


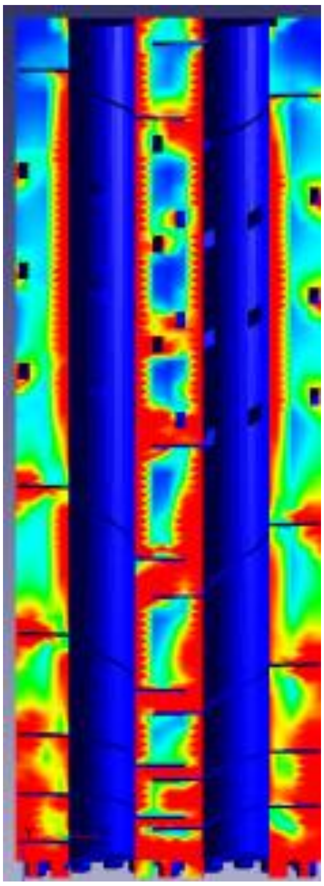
a

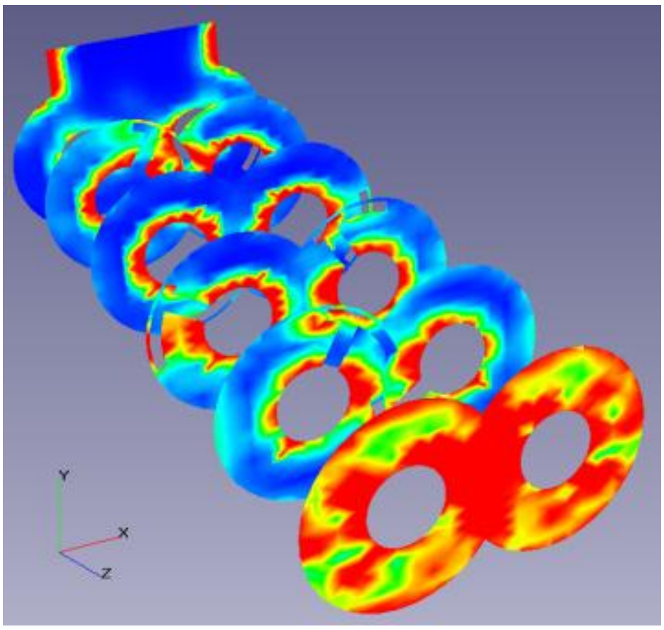
Fig.5. The Calculated Result of the Pin Working Body: a – the Horizontal Axial Section; b – the Vertical Sections.

The increase of the impact in front of the lattice in engagement area occurs probably due to the low transporting capacity of the pin working body.

The construction of the compound working body and its calculations are suggested on the basis of the theoretical and experimental studies (Fig. 5).







b

Fig.6. The Calculated Result of the Compound Working Body: a – the Horizontal Axial Section; b – the Vertical Sections.

a

One solid tape flight to supply the raw materials into the mixing zone of the components by the spiral working body is set to enhance the transporting function of the compound working body, then the set solid tape flights that provide dough transportation into the third zone, while the second stage of kneading is carried out. The third stage – plasticizing – is carried out by the solid tape working body with a reducing pitch. Pitch reducing between the flights contributes to intensive mechanical impact of the dough mass throughout the volume of the camera, as in the area of the flights engagement, and in the near-wall layer.

The dissipation of kinetic energy into heat happens more frequently in the places of the impact on dough of the working body; the greatest impact has a screw working body with a reduced pitch.

IV. Conclusions

Thus, modelling of the dough kneading process for different constructions of the working bodies of continuous action is suggested using the software package Flow Vision. Data analysis enables to suggest a construction of the compound working body that provides a three-stage process of dough kneading in the dough-mixing machines of continuous action.

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