электродвигатель 5 и включается лента выдачи товара 6. Лента выдачи товара смещает открытое окно к следующей заполненной кассете, откуда на транспортер попадает товар. Затем покупатель нажимает на дверцу лотка для товара, чтобы получить товар.

Рассмотрим подробнее устройство пластинчатого конвейера и принцип работы (рисунок 2). Конвейер состоит из пластмассовых пластин, соединенных между собой. Часть пластин конвейера сплошные, вторая половина пластин имеют 2 паза для закрепления толкателя в пластине конвейера.

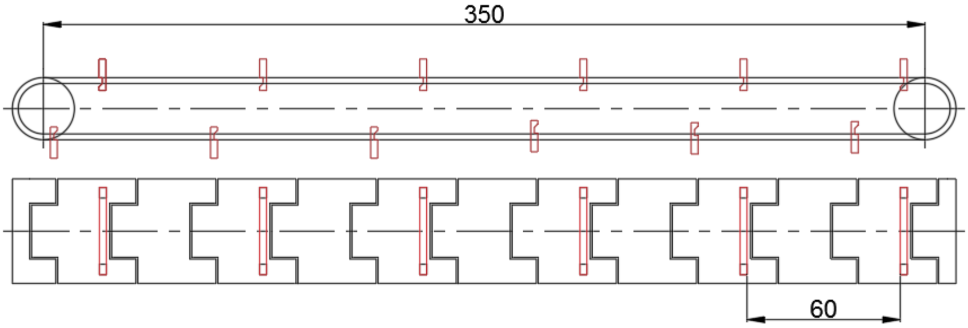

Рисунок 2- Схема пластинчатого конвейера торгового автомата

Товар, расположенный на конвейере, периодически продвигается вперед на заданный шаг за счет толкателя. Толкатели расположены по периметру конвейера с заданным шагом. Толкатель представляет собой пластмассовую пластину, которая устанавливается в пластину конвейера [3].

Использование спроектированного торгового автомата для продажи сувенирной продукции позволяет решить ряд следующих задач: обеспечить высокую скорость выдачи товара покупателю; возможность размещать большое количество товаров, что позволит работать автомату в автономном режиме более длительное время до следующей загрузки; торговый автомат обладает достаточно простой конструкцией и обеспечивает высокую плотность укладки товара; автономность оборудования – автомат работает самостоятельно, не требуются затраты на зарплату продавцу; оборудование занимает небольшую площадь, что сокращает затраты на аренду. возможность изменения внешнего вида автомата для привлечения большего количества клиентов; возможность размещения в местах большого скопления людей (железнодорожные и автобусные вокзалы, аэропорты, торговые центры, вблизи туристических мест и достопримечательностей, на выставках, при проведении различных конференций) [4,5].

Заключение. Таким образом, разработанная модель торгового автомата позволяет с помощью различных устройств и механизмов (конвейерная система выдачи товара с размещением сувенирной продукции в вертикальных кассетах) реализовывать сувенирную продукцию различной формы и размеров с высокой плотностью укладки (например, брелоки, магниты), что позволяет работать автомату в автономном режиме более длительное время до следующей загрузки.

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THE RESEARCH OF MODIFIED CERAMICS AS CONSTRUCTION MATERIAL FOR FOOD EQUIPMENT

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The results of research of technical ceramics in conditions of cavitation wear are presented. The ultrasonic frequencies of 44 kHz were used. The influence of structural constituents of ceramics on the rate of failure is shown. Wear features are noted. The effect of additives on the durability of materials is analyzed. The nature of ceramics wear and its similarity to the mechanism of damage of metals are demonstrated. It is proposed to use the critical destruction power

for the determination of intensity of ceramics wear. On the basis of structural energetic theory, an adapted formula is proposed for comparing the intensity of destruction of ceramics of different types. It was shown that the insertion of ZrO_2 into the α-Al_2O_3 ceramic matrix increases the resistance of ceramics. The nature of dependencies shows a similar pattern of wear of the specimens. The increasing of the content of α-Al_2O_3 in the structure of the material and the addition of the small dispersed ZrO_2 increases the viscosity of ceramics. The results of calculations are correlated with the experimental data. In addition, the proposed approach makes it possible to use for known materials the known dependences of the evaluation of the wear resistance of metals.
Keywords: construction materials, modified ceramics, vibration, wear.

Introduction. In food industry, it is important to use physical and mechanical effects, for example, hydrodynamic cavitation, to intensify the processes of processing of liquid-phase media. Microbubbles that arise during the decay of cavitation caverns have an intense impact effect on the components of the medium. Such conditions accelerate the mass-exchange reactions [1,2]. Technological equipment for food industry in various industries implements the processing of products mainly in a liquid-phase state. At the same time, special conditions of flow appear in the equipment units (fittings, pump seals, diffusers, confuser, Venturi nozzles). These conditions include cavitation. It causes the intensive wearing of equipment. Its reliability and durability are reduced under such conditions. Thus, a rational choice of appropriate materials is relevant. Ceramics is one of these materials.

Researches of its erosion resistance and patterns of wearing are of great practical importance. Physics, mechanical, chemical and operational properties of technical ceramics based on aluminum oxide are determined by:

- content of α-Al2O3 and ratio of phase components, impurities and binders;
- the ratio of the defining crystalline phases;
- size, shape and nature of the distribution of phase components;
- structure and porosity of the specimen;
- pore size and its density, their shape and placement;
- nature, properties and temperature of the environment.

The plastic deformation is completely absent in brittle materials. The fragile nature of its destruction is the most typical. Ceramics relate to such materials. Hooke's law is fair for most ceramic materials. They are evaluated by the value of the bending strength, modulus of elasticity, shear and separate other indicators, which are characteristic for researches of metallic materials. The behavior of ceramic materials during cavitation wearing is similar to metal structural materials.

Main part. The manufacturing of structural elements from practically pure α-Al_2O_3 for food equipment is known from [3,4]. Ceramics is used for valves of homogenizers [4] and valves for transporting corrosive-active media with a solids content up to 20% [5] and loaded small parts [5] (Fig.1a, 1b).

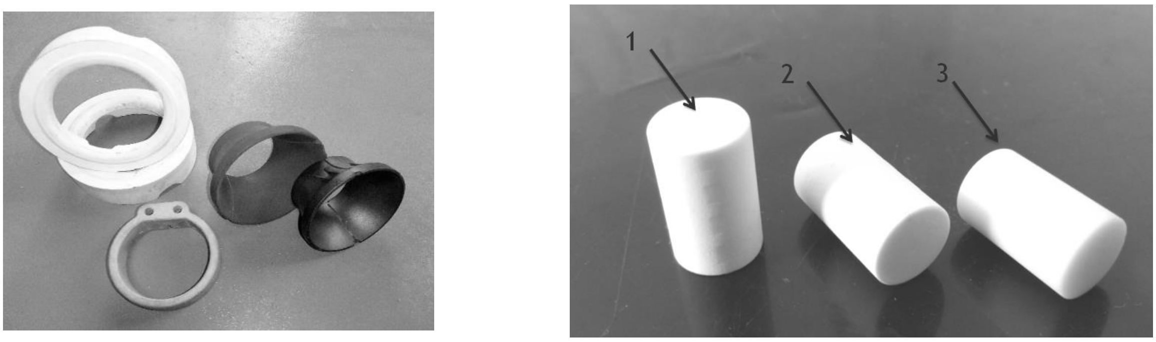

Fig. 1. a) small parts of food equipment; b) specimens of ceramic products: 1 - technical porcelain; 2 - ZrO_2; 3 – α-Al_2O_3

Ceramics is comparable by durability with corrosion resistant steels. However, the operational properties of ceramics can be improved. This is achieved by introducing of modifying components into its composition, for example, ZrO_2. The addition of chemically inert ZrO_2 in ceramics inhibits the growth of corundum crystals. For example, the addition of 0.5 ... 1.0% ZrO_2 contributes to the formation of crystals no more than 15 µm [6]. Submicron ZrO_2 and α-Al_2O_3 interlayers appear at the corundum grain boundaries. The crystals have a smaller size and are more perfect isometrically at the same time. Insertion to the composition of ceramics of modifying additives changes not only its operational characteristics. This may change its cavitation resistance.

Wearing of different types of based on α-Al_2O_3 ceramics under cavitation conditions was researched in [1,2,7]. It has been revealed, that elastic deformations occur in ceramic materials due to the mechanical action of cavitation. They lead to the formation of surface cracks and their growth. The concentration of stresses leads to the cleavage of the microscopic volumes of the material, and the process of mechanical action repeats cyclically. The cavitation resistance of the modified ceramic materials was actively investigated in [8]. Information about the ceramic cavitation wear at various intensities of mechanical shock is limited. That's why the research for new scientific and practical results must be continuous.

The information on cavitation resistance of ceramics is limited. To researching above property of ceramics, there were carried out experimental research using a magnetostrictive vibrator with the frequency of vibration 44 kHz. The intensity of wear was determined by the weight method by loss of sample mass at fixed time intervals. The main characteristics of specimens are presented in table 1.

Table 1 – Main properties of ceramic materials

Properties	Number of specimen		
	1	2	3
Content of ZrO_2, α-Al_2O_3, % mas	65	92	96
Density, g/sm^3	2,2	3,4	3,5
Elastic modulus, $E \cdot 10^2$, MPa	0,6	2,2	2,4
Impact strength, кJ/m^3	1,8	4,0	4,90

The results of the researching are illustrated by the figures, which show the changes in the mass of the specimens at frequency of vibration of the magnetostrictive vibrator of 44 kHz (Fig. 2) and the rate of loss of theirs mass (Fig. 3). Equally evident is the graph for the rate of mass loss (Fig. 2), which characterizes the cyclic nature of the process, when the kinetic energy of the impact of cavitation bubbles accumulated in surface layers of the specimen contributes to the brittle fracture of its microvolumes.

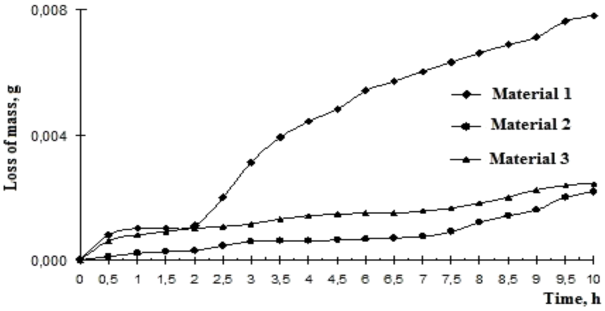

Fig. 2. Change in mass loss of material at frequency of vibrations of the magnetostrictive vibrator.

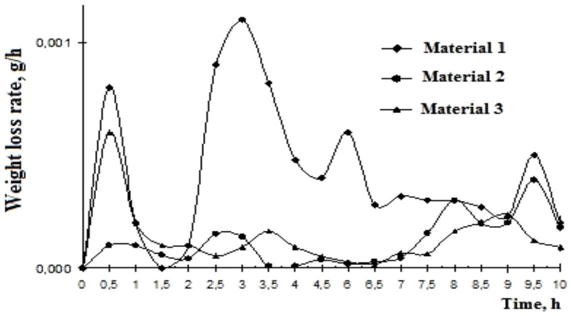

Fig. 3. Mass losses rate of specimens at the frequency of magnetostrictive vibrator.

Microscopic analysis showed that the destruction of specimens occurs precisely over the vitreous phase, which is contained along the grain boundaries of aluminum oxide. Specimens also contain other inclusions that affect their physical and mechanical properties and the mechanism of destruction. In addition, ceramic materials possess structural defects (pores, cracks), caused by the composition and technology of their manufacture. When researching the size of α-Al_2O_3 grains, it was found that sizes up to 150 mkm are optimal, which determine the resistance of the material to the propagation of cracks, their number and determines the dependence of the energy of fracture on the grain size. Most defects of microcracks type occur during the sintering and subsequent cooling of the specimens. These microcracks will increase even under low loads and, according to the theory of A. Griffiths, their presence on the outer surface and inside the specimens contributes to the increasing of stress concentrations. This leads to the increase of the size of cracks and to subsequent destruction of specimen. It is established that the most reliable criteria for the wear resistance of structural materials is the critical strain power density W_{cr}* and the accumulation period of cyclic accumulation of damages. Upon reaching W_{cr}*, visible erosion products are formed, and after the accumulation period, the wear rate sharply increases.

Based on the results of conducted experiments, it is possible to assume the validity of application of the critical strain power density index for comparison of wear of ceramic materials. Depending on the properties of materials, the power density reaches critical value at a certain velocity of impact V_{cr}.

Since $V_{cr} = f\,(W_{cr}^*)$, the criterion of wear resistance for brittle fracture of the surface layer of a material can be determined from the simplified Pogodaev – Nekoz formula [1]:

$$W_{cr}^* = \frac{\sigma_v^2 / 2E}{3} \cdot C_M \tag{1}$$

where – σ_v^2 the ultimate strength, E is the elastic modulus, C_M is the velocity of propagation of shock waves in the material under load.

This makes it possible to compare the wear resistance of materials. The values in formula (1) can be simply determined experimentally. It adapts well to the results of experimental data and makes it possible to quantify the rate of destruction of materials and to predict their durability [2]. On the basis of the proposed approach to the evaluation of wear resistance of ceramic materials, comparative wear resistance is presented in the table 2. Calculations show the legitimacy of using the proposed approach to comparing the wear resistance of various types of ceramic materials, which is determined by their physical-mechanical properties, in particular, hardness.

Table 2 – The critical strain power density W_{cr}* of the specimens

W_{cr}*	Number of specimen		
	1	2	3

	75,6	762,3	901,6

Conclusion. The obtained values of the critical strain power density W_{cr}* for the investigated specimens are in a good agreement with the results of experiments that establish the dependence of the cavitation-erosion resistance of technical ceramics on the content of aluminum oxide. The introduction of the modifier of ZrO_2 into the α-Al_2O_3 ceramic matrix allows the significant increasing of its wear resistance. Wear of materials is determined by the intensity of the cavitation effect and the phase ratio of components. The mechanism of wear of ceramics has a cyclical nature, which is similar to hydro-abrasive wear of metals. To assess the wear of ceramics it is possible to use the approach similar to that one used for the assessment of wear of metals. The using of modified ceramics is recommended for elements of food equipment that are operated under cavitation and waterjet wearing conditions. The chemical ceramics inertness is useful for working in aggressive technological environments of food industry.

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MODELING OF THE MIXING PROCESS

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The kneading of wheat yeast dough by cam working elements is investigated. Mathematical modeling was performed using the Flow Vision software package based on the simulation of three-dimensional motion of liquids and gases in technical structures, as well as for the visualization of flow curves by computer graphics. Physical modeling was performed via experimental setup with cam kneading elements. The distance between the cams is 2–4–6–8–10 mm, the rotation speed is 20–100 rpm.

Keywords: mathematical, modeling, dough, kneading, cam

Introduction. Imitation modeling aims to calculate the values of certain characteristics of a process that develop over time, by reproducing the flow of this process on a computer via its mathematical model [1-2]. During projecting of the process of dough mixing, there is a range of issues related to the type of working elements is supposed to be chosen. On the basis of theoretical searches and obtained experimental results, after comparative analysis of working elements, it was decided to simulate the process of kneading yeast wheat dough using cam working elements [3-4].

Dough kneading is a complex process that involves creating a homogeneous capillary-porous mass of flour, water, yeast, salt, and other components. The formation of dough during kneading occurs as a result of a number of processes, of which the most important are: physico-mechanical, colloidal and biochemical processes [5-6].

Main part. Mathematical modeling of the yeast dough kneading process was performed via the Flow Vision software package, which is designed to model the three-dimensional motion of liquids and gases in technical and natural objects, as well as to visualize flow curves by computer graphics.

Based on the results, after parametric modeling of the kneading process by the cam working elements, a linear dependence of the speed of movement of the dough in the working chamber was obtained (Fig. 1).