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NUMERICAL MODELING OF POWDERED MACHINE PARTS MANUFACTURING FOR FOOD INDUSTRY EQUIPMENT

The powder forming process of stamping powder machine parts for food industry machines and devices is consider. The computer simulation method for such products design is proposed. The blank shape changing during deformation as well as the density and equivalent plastic deformations distributions are determinate.

The analysis of stamping blanks of two types there is conducted. It is shown that the presence of material radial flow leads to accumulated plastic deformations increasing level and as a result, it allows obtaining products with increased exploitation characteristics.

***Keywords**: numerical modeling, powdered machine parts, the mathematical model*

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ЧИСЕЛЬНЕ МОДЕЛЮВАННЯ ПРОЦЕСУ ВИРОБНИЦТВА ПОРОШКОВИХ ДЕТАЛЕЙ ДЛЯ ОБЛАДНАННЯ ХАРЧОВОЇ ПРОМИСЛОВОСТІ

Методом комп'ютерного моделювання імітується процес штампування порошкових деталей, що застосовуються в машинах і апаратах харчової промисловості. Визначено зміну форми заготовки в процесі деформування, а також розподіл щільності і еквівалентних пластичних деформацій по її об'єму. Проведено аналіз штампування заготовок двох типів. Показано, що наявність радіальної течії призводить до підвищення рівня накопичених пластичних деформацій матеріалу і, в результаті, дозволяє отримувати вироби з підвищеними експлуатаційними характеристиками.

***Ключові слова**: чисельне моделювання, порошкові деталі машин, математична модель*

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ЧИСЛЕННОЕ МОДЕЛИРОВАНИЕ ПРОЦЕССА ПРОИЗВОДСТВА ПОРОШКОВЫХ ДЕТАЛЕЙ ДЛЯ ОБОРУДОВАНИЯ ПИЩЕВОЙ ПРОМЫШЛЕННОСТИ

Методом компьютерного моделирования имитируется процесс штамповки порошковых деталей, применяемых в машинах и аппаратах пищевой промышленности. Определено изменение формы заготовки в процессе деформирования, а также распределение плотности и эквивалентных пластических деформаций по ее объему. Проведен анализ штамповки заготовок двух типов. Показано, что наличие радиального течения приводит к повышению уровня накопленных пластических деформаций материала и, в результате, позволяет получать изделия с повышенными эксплуатационными характеристиками.

***Ключевые слова**: численное моделирование, порошковые детали машин, математическая модель*

Introduction. **Formulation of the problem.** Ensuring of high-tech equipment working possibility for the food industry (diffusion equipment, transport systems, extruders, etc.) substantially depends on the availability of sufficient spare parts [1]. To such details it is possible to carry bronze loose leaves of internal supports and external bearings of standard and repair sizes, bronze labyrinth seals of internal supports and etc. (Fig.1 a, b).

a

b

Fig. 1. **Bronze inserts (a) and seals (b)**

Therefore, there is an important problem high exploitation resource-saving technologies design for a wide range of products manufacturing with specified technical requirements.

At present days, one of the perspective methods products manufacturing is the powder stamping blank. The porosity presence is the main characteristic feature of such products. At the same time, one of the rational variants for the blank selection is expedient to consider sintered powder specimen. Such specimen can be able to with-stand tensile stresses. Therefore, they can be processed with more complex deformation schemes using, for example – in unclosed volumes. The using of such processing schemes makes it possible to realize maximum shear deformations, which in order a practically non-porous material obtaining with high operational properties [2].

The other finite parameters of material products also depend on the deformation scheme such as microstructure, ductility and toughness. The shear deformations presence leads to the material properties improvement. This is due to the minimum porosity, favorable orientation of metallic grains, non-metallic inclusions and pores, the texture appearance. We have the variant without texture forming – postpressing scheme (without significant material flow).

The effective deformation schemes design and optimal technological powder specimen parameters determination is possible on the base of preliminary computer modeling.

The mathematical model construction of porous specimen pressing process. We are considering the porous material as a two-phase dispersed system with a gas dispersion medium. This leads to the assumption that the relative motion of these phases is absent. For such environments it is expedient to use the assumption that the separation between phases is neglected by averaging the characteristics of the disperse medium (density, velocity, stress) [2].

Thus, upon the averaging technology, the safely motion amount equation for disperse material takes the form [3]:

$$\rho \frac{du}{dt} + grad(pu \cdot u) - grad\sigma - pg = 0 \tag{1}$$

where ρ is the average density of the mixture; σ – stress tensor in the mixture; u – displacements vector of mixture points; g – gravitation acceleration vector.

The constitutive relations formulating that connect the stress on a material and deformation parameters at the, we assume that the deformation rate is represented as:

$$\varepsilon_{ik} = \varepsilon_{ik}^{e} + \varepsilon_{ik}^{i} \tag{2}$$

where $\varepsilon_{ik}^{e}, \varepsilon_{ik}^{i}$ respectively, the elastic and inelastic parts of the strain rate tensor.

The elastic component in equation (2) is presented in the form of Hooke's law:

$$\varepsilon_{ik}^{e} = \frac{1+\nu}{E}(\sigma_{ik}^{e} + \frac{\nu}{1+\nu}\sigma_{ik}\delta_{ik}) \tag{3}$$

where E is the Young modulus, ϑ – the Poisson coefficient, δ_{ik} – the Kronecker delta.

The inelastic component is represented as [3]:

$$\varepsilon_{ik}^{i} = \mu(\Phi)\frac{\partial \Phi}{\partial \sigma_{ik}} \tag{4}$$

The isotropic disperses material of deformation masses transition from the reverse to the irreversible states can be represented by potential Φ [4]:

$$F = \frac{(p - p_0)^2}{\psi} + \frac{\tau^2}{\varphi} - {\tau_s}^2 = 0 \tag{5}$$

where p_0 is the spherical component of the stress tensor at which the volume does not change. The semiaxis size of the ellipsoidal contour is assumed:

$$\begin{cases} \psi = \psi_1 & \text{at} \quad p \le p_0 \\ \psi = \psi_2 & \quad\quad p \ge p_0 \end{cases} \tag{6}$$

The material functions values, φ, ψ and p_0 are determinate by [4, 5]:

$$\varphi = \frac{1}{(1+m)^2} \cdot (1-\theta)^3 \cdot \left(1 - \left|2 \cdot a - 1\right|\right)^2 \tag{7}$$

$$\psi_1 = \frac{8}{3} \cdot \frac{(1-\theta)^4}{\theta} \cdot \frac{(1-a)^2}{(1+m)^2} \tag{8}$$

$$\psi_2 = \frac{8}{3} \cdot \frac{(1-\theta)^4}{\theta} \cdot \frac{a^2}{(1+m)^2} \tag{9}$$

$$p_0 = \sqrt{\frac{2}{3}} \cdot \tau_s \cdot \frac{(1-\theta)^2}{\sqrt{\theta}} \cdot \left(\frac{1-m-2 \cdot a}{1+m}\right) \tag{10}$$

where, besides, the porosity θ and the material solid phase yield point stress τ_s, $0 \le a \le 1$, $0 \le m \le 1$. Parameter a characterizes the fragility of the porous material particles, m is the quality of the contacts between the particles. The loading surface contour is shown at Fig. 2.

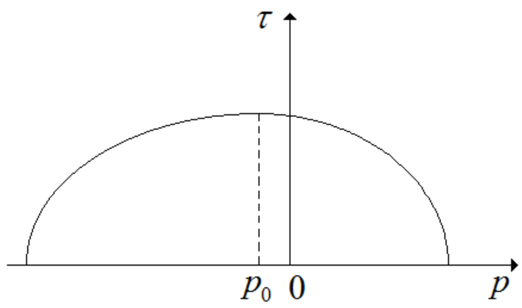


Fig. 2. **The loading surface contour**

Calculation scheme and simulation results. Let's consider two schemes the annular shape product stamping (Fig. 3).

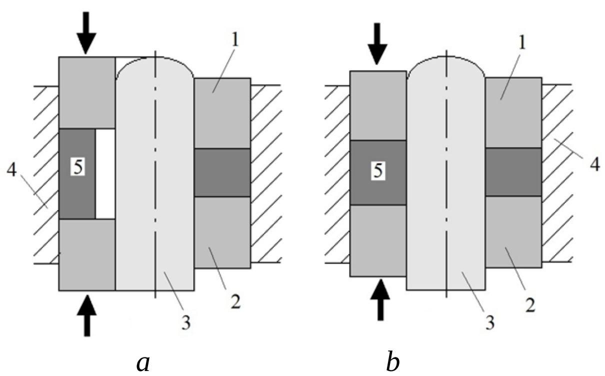


Fig. 3. **Stamping schemes: a - with radial flow to the center; b - second compaction: 1 - upper punch, 2 - lower punch, 3 - mandrel, 4 - matrix, 5 - powder blank**

The first example is corresponded to the case when a blank inner diameter is larger than the diameter of the mandrel (Fig. 3a). In this case, there is the possibility of material flow in radial direction to the center. In the second case (Fig. 3b), the blank inner diameter is equal to the mandrel diameter (postpressing scheme). The masses of both blanks are equal, their initial porosity is 0.2. The upper and lower punches move towards each other at the same speed. The friction coefficient between the blank and the tool was assumed to be 0.15.

The results of computer simulation are shown in Fig. 4-6. By virtue of symmetry, the right half of the axial section of the stamped blank is considered.

At the initial stage deformation of the first type blank takes place a radial material flow to the center. Its internal surface, as a result of friction, acquires a convex ("barrel-like") shape. The porosity (Fig. 4, a) and equivalent plastic deformation distribution (Fig. 5, a) are unevenly across the blank section. The smallest porosity and the largest equivalent deformation takes place in the area of the blank ends near its inner surface, as well as in the center. Correspondingly, the max porosity and the min equivalent deformation are in the area of the blank convex inner surface, near the central part of its ends and near the matrix in the middle part of the blank height.

For the second forming scheme (postpressing) there is no material radial flow. The porosity (Fig. 4, b) and the equivalent deformation distributions are presented at Fig. 5, b. They are also unevenly distributed, but the nature of this distribution is different. The smallest porosity and the largest equivalent strain are at the blank ends in the contact blank areas with the matrix and the mandrel. The max porosity and the min equivalent deformation are also in the areas of blank contact with the matrix and the mandrel in the middle part of the blank height, which is due to the influence of friction.

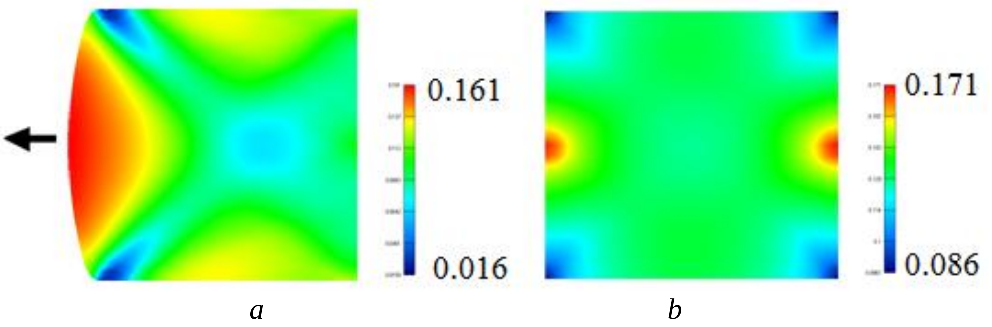


Fig. 4. **Porosity distribution: a – forming with a mandrel radial flow to the center; b – postpressing compaction**

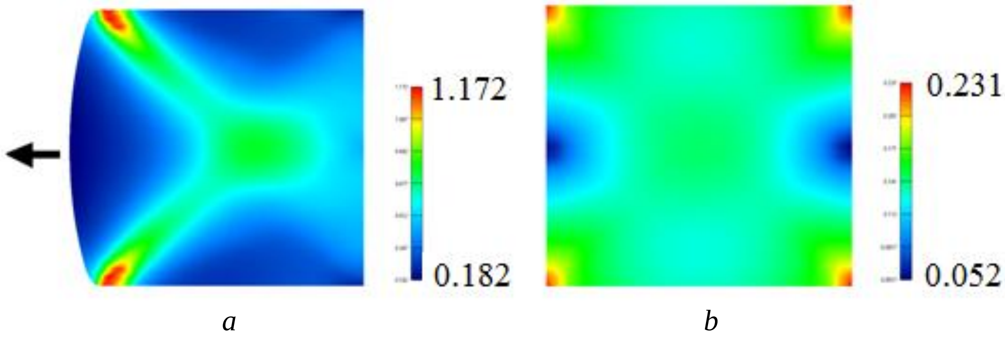
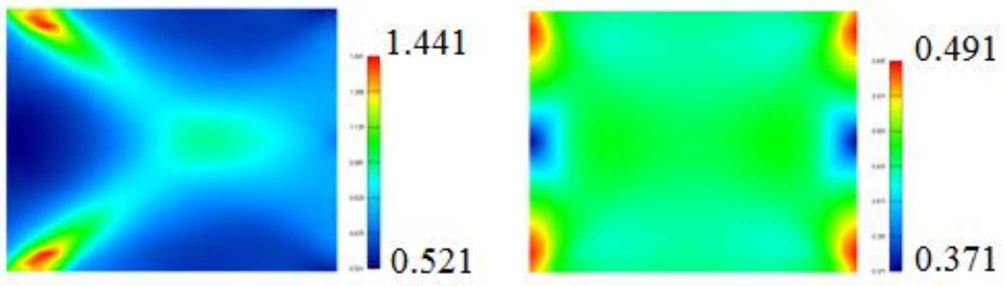


Fig. 5. **Equivalent plastic deformation distribution: a – forming with a material radial flow to the center; b – postpressing compaction**

At the final forming stage the internal surface of the first type blank resorts against the mandrel. In this way further compressing takes place according to the postpressing scheme. The porosity at the final forming stage is near 0.01 and its difference across the blank section is insignificant. The porosity distribution for the second type blank deformation is analogous.

At the same time, it should be noted the difference in the equivalent plastic deformation level distribution (Fig. 6).

The equivalent plastic deformation value is much higher for the first blank type when the material radial flow takes place. These fact can leads to the high exploitation products properties obtaining.



a *b*

Fig. 6. **The equivalent plastic deformation distribution: a – forming with a material radial flow to the center; b – postpressing compaction**

Conclusions.

For the annual shape product examples of powder metallurgy process the computer modeling possibility is shown. The process sintered powder blanks stamping is considered. Computer modeling allows determining the blank shape changing and the density, stresses and deformations distribution.

Analysis of modeling stamping results for the two types blanks showed that the of material radial flow leads to an increase of accumulated plastic deformations level and, as a result, it allows obtaining products with high exploitation characteristics.

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