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Analytical and Model Optimization of Kinematic Schemes of Uniform-density Pressing of Powder Materials

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ABSTRACT: The greatest pressure develops at the matrix wall under the pressing punch, and at the ends of the major axis the pressure is higher than at the ends of the minor axis. The lowest pressure develops at the wall of the matrix above the stationary punch, and the pressure at the ends of the major axis of the ellipse is lower than at the ends of the minor axis. The lowest pressure under the pressing punch and the highest pressure above the stationary punch develops in the centers of the corresponding sections. Due to a monotonic change in density caused by a pressure change, the density distribution in the volume of the linings is similar to the pressure distribution described. A quantitative description is given of the uneven distribution of pressures and densities in the volume of linings.

KEY WORDS: ceramic powders, dry pressing, collector mold, uniform density distribution.

I.INTRODUCTION

The development of modern technology imposes increasingly stringent requirements on materials and products operating under conditions of high pressures, speeds, temperatures, corrosive media, etc. Often, it is required to obtain products with physico-mechanical properties, differentiated by volume, such products successfully work in difficult operating conditions, when some surfaces of products are affected by force of action, while others - subject to intense wear in aggressive environments. The most effective use of such products is in the mining and metal-working industries, as well as in mechanical engineering, instrument-making, thermal power engineering and other branches of economic activity.

A variety of different approaches and methods for compacting ceramic powders, including ceramic powders, is due to the specific features of their compaction behavior. The main factor affecting the quality of the compacts obtained by any of the “dry” methods is near-wall friction, the degree of negative influence of which increases with decreasing size of the powder particles. The most studied to date is the method of dry cold uniaxial one-sided pressing of powder materials in closed rigid molds. The compaction during the implementation of this method is carried out by transferring the pressing force through the active forming surfaces of the punches, which move counter to each other relative to the passive forming surface of the die. In this case, due to the loss of the pressing force to overcome the forces of wall friction, a significant density gradient of the pressing along its height occurs.

II. SIGNIFICANCE OF THE SYSTEM

This deficiency is deprived of the collector method of pressing, providing automatic leveling density throughout the entire volume of pressing of any height. A distinctive feature of the collector method of pressing powders is that the mold matrix consists of two multidirectional groups of identical sliders, each of which synchronously moves together with one of the plungers of the plungers during the pressing process. In the present work, an improved version of the collector method is considered, in which the helix-shaped shape is given to the forming sliders. Such a kinematic solution provides an additional component for moving the shaping surfaces that do not coincide with the pressing axis, and, presumably, allows to increase the uniformity of the density distribution over the volume of the powder body. However, any constructive improvement of the compaction schemes and optimization of the geometric dimensions of the molds are associated with expensive field tests. In this regard, the development of an analytical apparatus that would allow an initial assessment of the results of a constructive solution on the final characteristics of a product pressed under given conditions would be relevant.

III. LITERATURE SURVEY

The high cost of raw materials and a wide range of products made from powder materials make the development of process calculation methods an urgent task deformation of such materials with subsequent prediction of properties products. Reliable theoretical basis for constructing design diagrams of technological processes of pressure treatment of powder and porous metals are the mechanics of a continuous medium and the mechanics of a deformable solid body, within which to study the processes in structurally inhomogeneous bodies the continual approach is applied (Druyanov BA. Applied theory of plasticity of porous bodies. - M .: Mashinostroenie, 1989. - 166 p.).

IV. METHODOLOGY

Analytical comparison of compaction schemes. Pressing schemes for a cylindrical body, which is compacted in the usual one-sided way, are shown in Fig. one.

In fig. 2 is a diagram of the balance of forces acting on the surfaces of a cylindrical compact, sealed closed rigid methods of pressing.

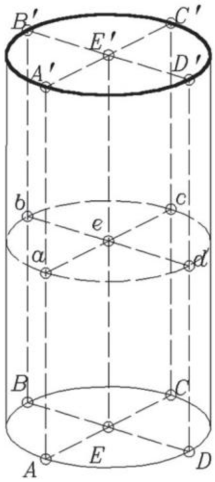

Fig.1. The scheme of compaction of a cylindrical powder body by the method of static uniaxial one-sided pressing.

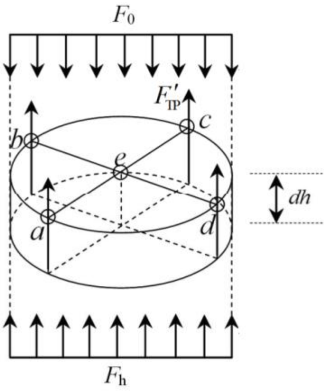

Fig.2. The balance of forces in a thin layer of a cylindrical uniaxial pressing scheme.

It is known from the theory of pressing powder materials in closed rigid molds that, due to wall friction, density drops across the height of the pressing in its central part (Fig. 1) along the [EeE '] axis are always less than the walls (along the [AaA'] line) , and the average density along any of its vertical is the same at any moment of pressing.

In the transition to the values of pressure, which in cylindrical compacts of constant hydraulic section are proportional to the values of the acting forces, the equation for the pressure loss of pressing due to wall friction.

Consider the problem of the stressed state of the powder material when it is pressed into cylindrical molds with an arbitrary contour in plan. The force action from the tool on the powder billet according to the one-sided pressing scheme turns this billet into the desired cylindrical shape.

As is well known, in the process of manufacturing a ceramic product, the pressing stage is one of the most important, predetermining many essential properties of the product, since possible defects arising during pressing can often not be corrected by subsequent sintering. The formation of these defects is usually associated with an inhomogeneous density distribution in the briquette; therefore, the study of such a distribution at the final pressing moment is of considerable interest.

Suppose that the cross section of a briquette is a simply connected or doubly connected region. Then it is natural to use the orthogonal curvilinear coordinates α, β, ζ chosen so that the outer and inner contours of the cross section are located along the coordinate lines α - const and (or) β - const. The coordinates α, β, ζ are related to the Cartesian coordinates x y, z by the relations.

Consider the function of a complex variable

$$x + iy = \exp(\alpha + i\beta) \tag{1}$$

Defining real and imaginary parts in (1), we arrive at relations (2)

$$x = x(\alpha,\beta), y = y(\alpha,\beta), z = \zeta \tag{2}$$

$$x = e^{\alpha} cos\beta, y = e^{\alpha} cos\beta \tag{3}$$

The distribution of pressures in the volume of the powder blank in the form of a circular cylinder of radius R is approximated by dependence.

$$p(r,\zeta) = p_o + \sum_{n=1}^{N} C_{n1} J_0(i v_n r) sh\frac{n\zeta}{Nh} \tag{4}$$

Take the following numeric data

$$\xi = 0{,}4,\ \ \mu = 0{,}25,\ \ h = R \tag{5}$$

Making this result in (4), we obtain

$$p(r,\zeta) = p_0 \left[1 + 0{,}144 J_0\left(\frac{1.581 r}{R} i\right) sh\frac{\zeta}{h}\right] \tag{6}$$

and according to the formula (6) we calculate the pressure in the characteristic points of the ceramic linings:

$$p(0,h) = 1{,}169 p_0, \qquad p\left(\frac{R}{2},h\right) = 1{,}195 p_0, \qquad p(R,h) = 1{,}293 p_0, \qquad p(0,-h) = 0{,}831 p_0,$$

$$p\left(\frac{R}{2},-h\right) = 0{,}805 p_0, \qquad p(R,-h) = 0{,}707 p_0, \qquad p(r,0) = p_0, \qquad \forall r \in [0,R]$$

Pressure plots calculated by the formula (6) are shown in Fig.3 and 4

According to $p(\alpha,\beta,\zeta) = p_k \sqrt[m]{\frac{p(\alpha,\beta,\zeta)}{p_{max}}}$, the ratio of the greatest p_{max} and the smallest p_{min} densities is

$$\frac{p_{max}}{p_{min}} = \sqrt[m]{\frac{p(R,h)}{p(R,-h)}} = \sqrt[m]{1{,}829}$$

which, for example, with m = 4.9 gives

$$p_{max} = 1{,}131 p_{min}$$

Those. the highest density is 13.1% higher than the lowest density.

Find the force P applied to the pressing punch:

$$P = 2\pi \int_0^R p(r,h) r dr = 2\pi \left[p_0\, R^2/2 + C_n sh1 \int_0^R J_0(i v_1 r) r dr\right] = \pi R^2 p_0 \left(1 + 2 \cdot 0{,}144 \cdot 1{,}1752 \cdot \frac{1{,}0636}{1{,}581}\right)$$
$$= 3{,}857 R^2 p_0$$

for specific effort we get

$$P_{y\partial} = \frac{P}{F} = \frac{3{,}857 R^2 p_0}{\pi R^2} = 1{,}228 p_0$$

Calculate the reaction of the P * fixed punch

$$P_* = 2\pi \int_0^R p(r,-h) r dr = 2{,}425 R^2 p_0$$

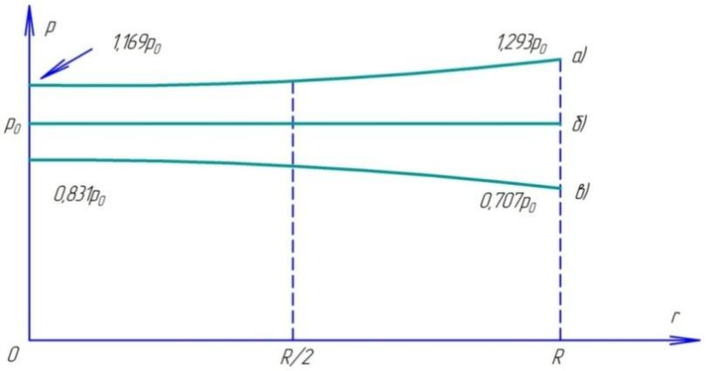

Fig.3. Pressure diagrams in sections of a circular cylinder:
a) under the pressing punch, b) in the middle section, c) above the stationary punch.

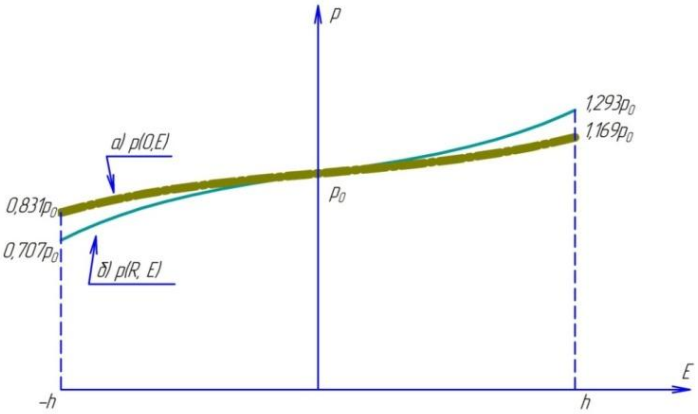

Fig.4. Diagrams of pressure along the height of a porous circular cylinder along its a) axis and b) forming.

The resultant friction force on the side surface of the mold, equal to the difference of the forces P and P *, is $1{,}432R^2p_0$.

V. EXPERIMENTAL RESULTS

As a result of solving the problem of one-sided pressing of powder briquette in the form of cylindrical ceramic linings, the following qualitative features of the distribution of pressures and densities were established:
a) the greatest pressure develops at the matrix wall under the pressing punch, and at the ends of the major axis the pressure is higher than at the ends of the minor axis;
b) the lowest pressure develops at the wall of the matrix above the stationary punch, and the pressure at the ends of the major axis of the ellipse is lower than at the ends of the minor axis;
c) the lowest pressure under the pressing punch and the highest pressure above the stationary punch develops in the centers of the corresponding sections;
d) due to a monotonic change in density caused by a pressure change, the density distribution in the volume of the linings is similar to the pressure distribution described in a), b), and c).
e) a quantitative description is given of the uneven distribution of pressures and densities in the volume of linings.

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