

Quantitative characteristics of area of splicing surfaces of hot-deformed powder materials

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Abstract. This article proposes for consideration the hot-deformed powder materials spliced surfaces area quantitative characteristics' experimental determination. This study analyzes the spliced surfaces' microstructures formation at various stages of obtaining hot-deformed powder materials. The features of the deformation processes during the formation of materials by hot working with pressure are considered. The nature of the splicing surfaces' boundaries on the objects under study, as well as the process of pore healing during the compaction of moldings based on steel from two types of charge based on coarse and fine iron powder with different porosities, is traced. In the course of the work carried out, the selected iron powder particle size certain influence moment on the values of micro- and sub-micropores, surfaces of interparticle adhesion, inter- and intragranular adhesion is observed [1-3].

1 Introduction

Dynamic hot pressing and hot transverse stamping of porous billets in powder metallurgy influences the important processes in the materials production. The study of the factors affecting the structure and properties formation of the powder materials obtained by hot working by pressure of porous workpieces is an important and promising scientific research [3].

For a certain time, researchers, when considering various aspects of interparticle bonding at different stages of the formation of hot-deformed powder materials, used only the qualitative indicators in their calculations. A new stage of such research must inevitably be associated with the introduction and application of quantitative criteria that determine the density of the spliced surfaces in the volume or section of the material being processed. All of the above-mentioned has led to additional scientific research and calculations [1, 2].

2 Main part

One of such quantitative criteria determining the spliced surfaces' density can be the specific splicing surface of hot-deformed powder materials, since it is associated with the number of surface defects in it. The specific area of the splice can be defined as the ratio of the splice total area value to the processed particles volume. For non-porous hot-deformed

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powder materials, this value S_v commensurate with the total particle surface $\sum S_u$, for porous from the latter it is necessary to exclude the value of the total pore surface $\sum S_p$ in the considered $\sum S_u$ scope.

$$\sum S_u = S_v \sum V_u + \sum S_p . \tag{1}$$

An analytical expression for determining the specific surface area of the fusion can be obtained, for example, assuming that all particles have the same size and spherical shape, at different stages of processing their shape is only distorted, while there is no significant change in the surface area, and the volume remains constant. Then

$$S_v = \frac{\sum S_u}{\sum V_u} = \frac{n_u 4\pi r_u^2}{n_u \frac{4}{3}\pi r_u^3} = 3r_u^{-1} = 6d_u^{-1} , \tag{2}$$

where S_u and V_u determine surface and volume of one particle; $\sum V_u$ is the total population n_u defines the processed particles in the considered volume of material; r_u and d_u are the radius and diameter of particles.

Changing the initial shape of particles, its distortion during processing and the use of an ensemble of particles with unequal sizes, that is, the transition to a real powder system, characterized by the average particle size \bar{l} , without changing the nature of dependence (2), it will only lead to a change in the coefficient. In general

$$S_v = k_v \bar{l}^{-1} , \tag{3}$$

where k_v is a proportionality factor to determine S_v .

In logarithmic coordinates, the dependencies are straightened

$$\ln S_v = \ln k_v - \ln d_u . \tag{4}$$

S_v decrease with an increase in the particle size, should lead to a decrease in the total number of surface defects on the particles and, therefore, have a positive effect on the material properties. This allows the use of cheaper coarse powders to produce hot-worked powder materials when compaction is provided by external pressure [4-7].

Another indicator of the splice surfaces' density can be the specific length of the splice boundaries – l_s , measured in a section of a thin section, on the surface of a fractogram or on other objects. For non-porous materials, it is equal to the ratio of the particles' section boundaries total perimeter by the plane of the thin section, or their projections onto the surface of the fractogram (boundaries $\sum l_s = \sum l_u$) to the area of this section, for porous - from this length it is necessary to exclude the value of the pore surfaces sections' total length $\sum l_p$ in the considered section

$$\sum l_s = \sum l_u - \sum l_p . \tag{5}$$

Under the assumptions made in the process of obtaining an analytical expression to determine S_v , it is possible to get the dependence for calculation l_s with the spherical particles

$$l_s = 4 \frac{\sum d_i}{\sum d_i^2} , \tag{6}$$

where d_i is the i -th particle's diameter.

In general, for the particles of arbitrary configuration, it can be written as follows:

$$l_s = 4 \frac{\sum l_u}{\sum S_u} = k_s \frac{\sum l_i}{\sum S_{ri}}, \tag{7}$$

where k_s is a proportionality factor to determine l_s the largest l_i (l_i – the size i -th particle).

Moving on to the average particle size \bar{d} (6), \bar{l} (7) and, assuming that the areas of particles of arbitrary and spherical shapes are the same, and an increase in the perimeter of the first is compensated by an increase in the value of the corresponding coefficient, we obtain

$$l_s = k_s \frac{n_u \bar{l}}{n_u \bar{l}^2} = k_s \bar{l}^{-1} \approx k_s \bar{d}. \tag{8}$$

The relationship between the coefficients k_v and k_s values easily determined for hot-worked powder materials based on spherical particles from the dependencies (2) and (6) $k_v = \frac{3}{8} k_s$. When using powders of other configurations, this ratio is determined experimentally.

Matching the expressions to define S_v and l_s , it can be noted that they have the same dimension (m^{-1}), the same as for the dislocation density. Their numerical values, as a rule, do not coincide, and those that better correlate with the dependences of properties on particle size distribution should be considered reliable [4,5].

Fig. 1 shows diagrams illustrating the spliced surfaces' formation process at various stages of obtaining hot-deformed powder materials from a charge based on fine and coarse powder.

When using coarse powder, in all cases, the unit values of the sizes of micro- and sub-micropores, interparticle contact surfaces, inter- and intragranular coalescence increase. At the same time, the relative values of all these parameters decrease, and in the case of interparticle splice surfaces' migration, the number of defects on its former boundary.

The size and shape of pores depend on the particle size distribution of the powder and, in general, it can be assumed that with an increase in the particles' size and a decrease in the range of their variation, the pores become larger, the relationship between the volumes of particles and pores can be found from the expression for determining the porosity [8-10].

$$P = \frac{\sum V_p}{\sum V_u + \sum V_p}, \tag{9}$$

where V_p is pore volume, $\sum V_p$ is the total pore volume of the molding in which the particles occupy the volume $\sum V_u$.

Assuming that the number of particles n_u and pore n_p forming the same, we get:

$$V_p = V_u \frac{P}{1-P}. \tag{10}$$

The errors introduced by the indicated assumption are reduced when the particles acquire a spherical shape and the same size.

Analyzing the formula (10), we can conclude that the volume of a single pore is determined by the particle size and decreases with decreasing porosity. In addition, they determine the features of the deformation processes during the hot-deformed powder materials' formation, the deformation uniformity degree, the ratio of the areas of the splicing surface arising at different process stages.

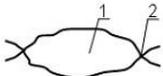
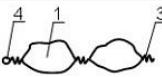
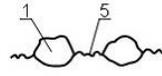
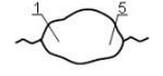
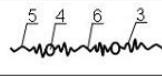
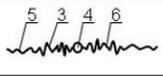
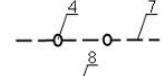
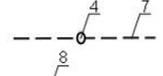
Stages of production of hot-deformed powder materials	Type of powder	
	Small	Large
1. Bulk state		
2. Cold pressing		
3. Sintering		
4. Hot pressure treatment		
5. Hot pressure treatment or post heat treatment		

Fig. 1. Diagrams illustrating the formation of spliced surfaces at various stages of obtaining hot-deformed powder materials: 1 – micropore; 2 – point contact in the poured powder; 3 – physical interparticle contact; 4 – sub-micropore; 5 – intragranular splicing; 6 – intergranular splicing; 7 – former border of splicing; 8 – boundary of the migrated splice surface

The diagrams illustrating the process of pore healing during the compaction of moldings based on powders with different particle sizes are shown in Fig. 2. They indicate the participation in healing the large pores of a much larger volume of particles than in healing the small pores. When using a mixed powder, the pore can be filled with fine powder particles without their significant structural deformation, which is accompanied by pore fragmentation.

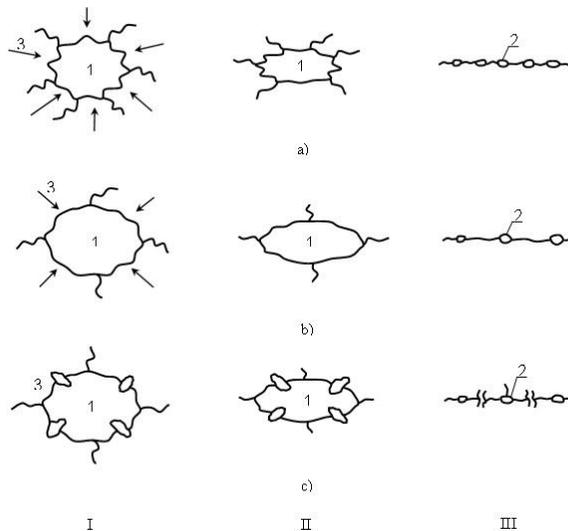


Fig. 2. Diagrams illustrating the process of pore healing during compaction of moldings based on fine (a), coarse (b) and mixed powder (c). 1 – micropore; 2 – sub-micropore; 3 – particle; the state of forming after: I – cold pressing; II – sintering; III – hot pressing

3 Conclusion

The studies carried out prove the fundamental influence of technological factors on the splicing processes, the formation of a certain microstructure and properties of hot-deformed powder materials. In the presented work, analytical expressions were used to determine the quantitative characteristics of the spliced surfaces in the calculations.

In the course of experiments, it was revealed that a change in the initial shape of particles, the use of particles of unequal sizes will only lead to a change in the numerical coefficient. A decrease in the specific surface area of the splicing with an increase in the particle size has a positive effect on the material properties, which makes it possible to use cheaper coarse-grained powders in production.

It was found that when using coarse-grained powder at all the stages considered, the unit values of the micro- and sub-micropores sizes, surfaces of interparticle contact, inter- and intragranular splicing increase.

As a result of the studies carried out on sintered powder blanks, it was proved that the size and shape of the pores depend on the granulometric composition of the powder; with an increase in the size of particles and a decrease in the range of their variation, the pores become larger. With an increase in the particle size in the zones immediately adjacent to the pores, the deformation degree of the material increases and the coalescence is activated. As the distance from the pore increases, the conditions for its flow deteriorate; however, this can be compensated for by conducting preliminary sintering and, at the same time, ensuring adhesions on surfaces remote from the pores.

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