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Investigation of the Main Stages in Modeling Spherical Particles of Inhomogeneous Materials

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Abstract. This scientific study deals with the main issues related to the process of filling inhomogeneous materials into a rectangular hopper. The article develops an algorithm for filling particles of structurally inhomogeneous materials. A micrograph of the structure of samples of inhomogeneous materials is presented. It was found that the structure of samples of heterogeneous materials consists of three layers: external, internal and impurities of various grinding aggregates. Based on microstructural analysis, the presence of particles of various shapes and sizes was justified. On the basis of which the main initial conditions for filling the package with spherical particles were described. The basic physical and mechanical properties of structurally inhomogeneous materials were studied using the obtained results. We also constructed an approximate dependence of porosity on the particle diameter of inhomogeneous materials.

1 Introduction

One of the important problems in Ukraine is the problem of the protection of nature and environment [1, 2, 3]. It is also important to establish an optimal balance between resources and processing industries [4, 5, 6]. These problems can partly be solved by powder metallurgy [7], which allows introducing the waste-free production of goods of broad purpose, save energy and materials to reduce labor costs by reducing the number of manufacturing operations, and apply new technologies [8, 9]. These technologies allow going from observing and ascertaining facts to prediction of various properties of materials, products and processes by means of computer and information technologies that have been actively used since 90th years of the last century in the field of materials science [10, 11, 12].

Many scientists are involved in the prediction of material properties worldwide [13, 14]. To the study of the physical and mechanical properties of structurally heterogeneous materials is at one time engaged a fairly large number of researchers [15, 16]. Also in the works of [17, 18, 19] modeling plays an important role, which allows to research without setting expensive and time consuming experiments. The results [20] obtained in these studies have phenomenological nature and the mechanical properties in most cases do not correlate with the structure of materials [2, 21].

The aim of this work is to develop the algorithm of filling particles of structurally inhomogeneous materials. To investigate the dependence of the porosity of the particle diameter and width of a rectangular bunker and to build graphs according to the received dependencies and results.

2 Main Part

Structurally inhomogeneous materials (SIM) are the most common for both natural [22] and artificial materials [23]. They are widely used in many branches of industry and construction [24, 25]. According to the structure of these materials they are very diverse [26], and the properties of these materials are different [27]. So, the approach to the problem of mathematical modeling of structure needs to differentiate each group of structurally heterogeneous materials based on their properties and basic methods of learning [28] which is a form of reflection of reality [29].

Regarding technological processes the following types of modeling are distinguished [30]:

1) mathematical modeling (using mathematical modeling we can build a model by means of mathematics and logic) [31];

2) physical modeling (is carried out through the reproduction of the investigating process of the model that generally has a distinctive feature from the original nature, but has the same mathematical description of the operation process) [32];

3) conceptual design (belongs to one of the most important components of information systems [33, 34]. It contains meta-knowledge and meta data and knowledge about the system, playing a role between future users and developers of the system. The conceptual model is created for an integrated and coordinated design of all other system components [35, 36]. It provides the following basic functions: - provide the means of converting the conceptual model in the realization of the model; - include the following elements, which are sufficient for a complete image of the subject areas and features of the system; - to support the structure and means for displaying knowledge of the interaction of developers and users of the system);

4) structural and functional design (structural modeling is based on specific features of a certain kind of structures that are used as a means of research and development of methods for formal descriptions of systems of specific modeling approaches) [37, 38];

5) imitation (computer) modeling (imitational modeling is a method of solving the problem through the creation and use of a computer model) [39, 40].

The essence of computer simulation is to obtain qualitative and quantitative results for the software model [41]. Qualitative results obtained in the analysis allow detecting the unknown properties of the complex system, its structure, dynamics and development and others. Quantitative findings may have the nature of some future prediction or explanation of past values of the variables that characterize the investigated system.

Materials. We have carried out modeling of structure heterogeneous materials with help of which we have obtained additional information about the processes occurring in the manufacture and maintenance of these heterogeneous materials.

In Fig. 1 structure of inhomogeneous materials samples is presented.

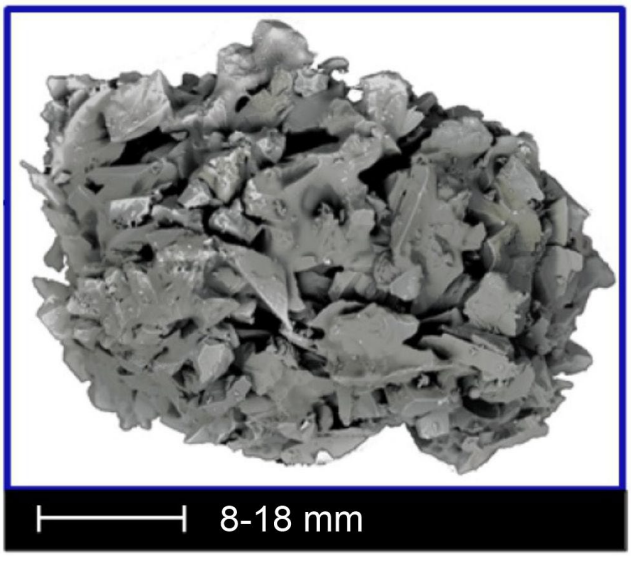

Fig. 1. Structure of inhomogeneous materials samples

An important parameter is the coordination number heterogeneous materials, the number of contacts of particles heterogeneous materials that allows evaluating the quality of materials structure and serves as an anchor point in the construction of approximating dependencies of physical characteristics on porosity. This method of calculating the structural parameters makes it possible to analyze the effects of consolidation when backfilling heterogeneous materials, which appear in the technological processes of manufacture made from powder materials.

From this study, it was found that the structure of samples of heterogeneous materials consists of three layers. The outer layer has a normal structure and mainly consists of grains of a larger shape of 15-18 mm. The inner layer consisted mainly of particles with a diameter of 10 mm. The third layer was characterized by impurities of various grinding aggregates. It should be noted that the outer edges of the lobes were bevelled and ranged in size from 15 to 18 mm. The bevel of the particles indicates that the materials were crushed in the usual way and processed with an aggregate tool. And the inner layer of the samples had a mostly cylindrical particle shape and allowed fixing particles of more than the same size with a diameter of 10 mm.

Due to the fact that the initial stage technology of powder metallurgy is filling - package of fairly low density, it is important to modeling the process of forming loose packing of particles of spherical form (Fig. 2).

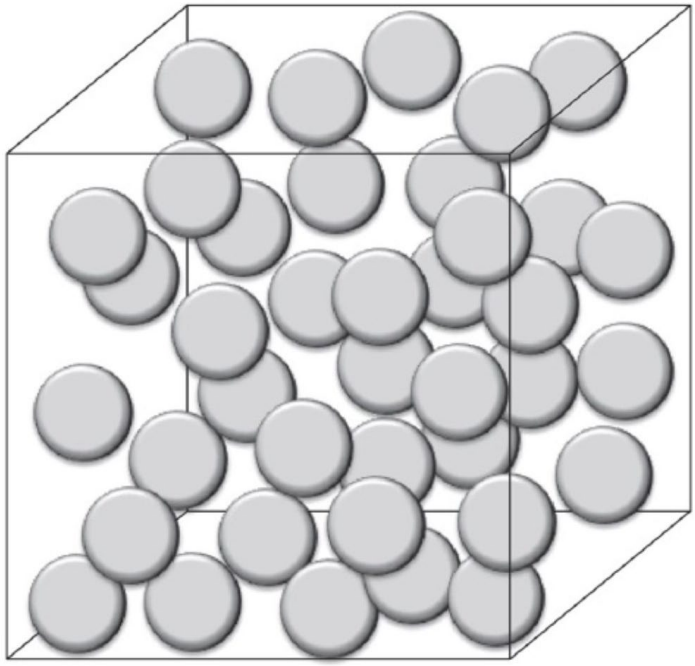

Fig. 2. View the window of filling of particles

Based on the materials submitted by the algorithm of filling particles of structure heterogeneous materials (Fig. 3).

The proposed packaging process a spherical particles is finished when three conditions a basic are fulfilled:

1) considerable number of spherical particles (packed particles) is reached;
2) container (bunker) is filled completely;
3) at the request by the user.

Tests. With the proposed algorithm of work of particles heterogeneous materials a number of back fillings using a described computer model was made. In this case there was investigated backfilling of round particles with diameter varied from 8 to 18 mm in a rectangular bunker size of 800 by 800 pixels. Angle was 8-10 degrees. In order to reduce the error for each set of values there were held five backfilling and counted average value of porosity. The results are given in Tables 1.

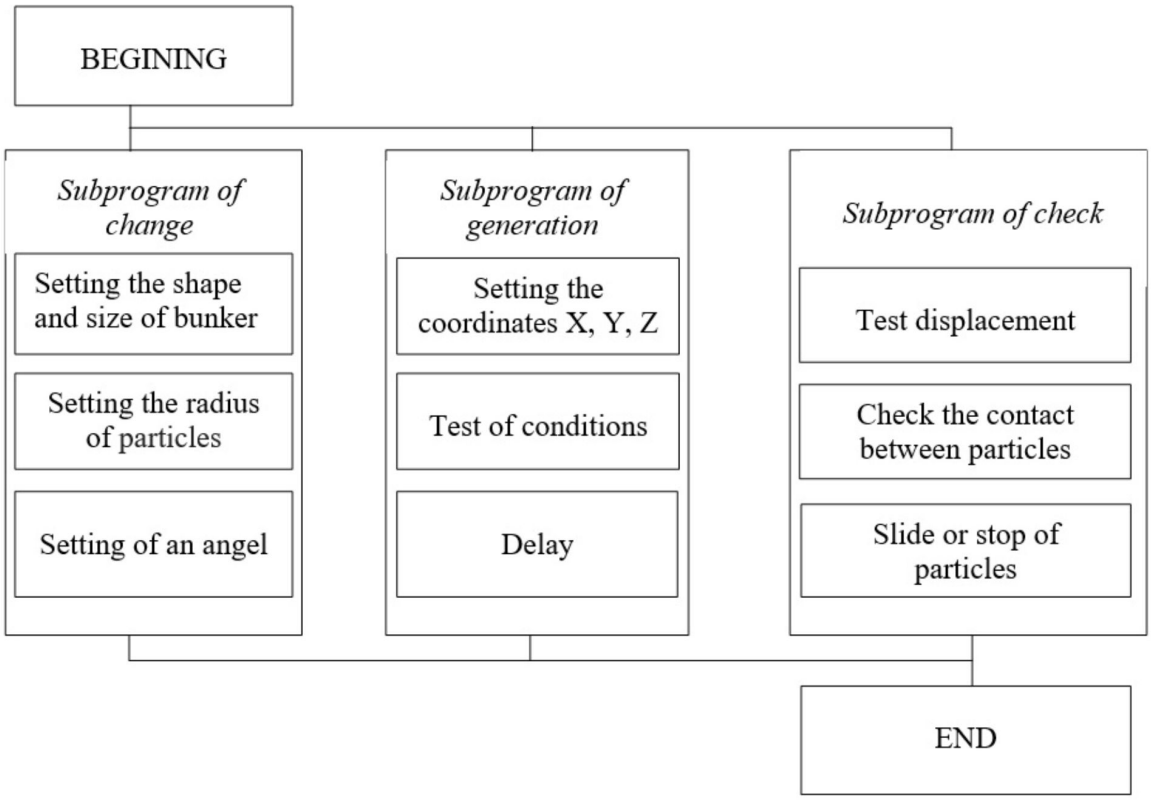

Fig. 3. The algorithm of work of particles filling

Table 1. The dependence of the porosity on diameter of particles

Diameter, D [mm]	The average porosity for a given diameter, [%]
8	10-12.8
10	13.2
12	12.8-14.3
14	15
16	16.2
18	19.1

In Fig. 4 the dependence of the porosity on diameter of particles of inhomogeneous materials is presented.

From the graph of the obtained dependence of the porosity on the diameter of particles inhomogeneous materials can be concluded that the obtained values of porosity with increase of particle materials size increase. Thus, the described model of particles materials backfilling for this case adequately reflects the porosity of the package.

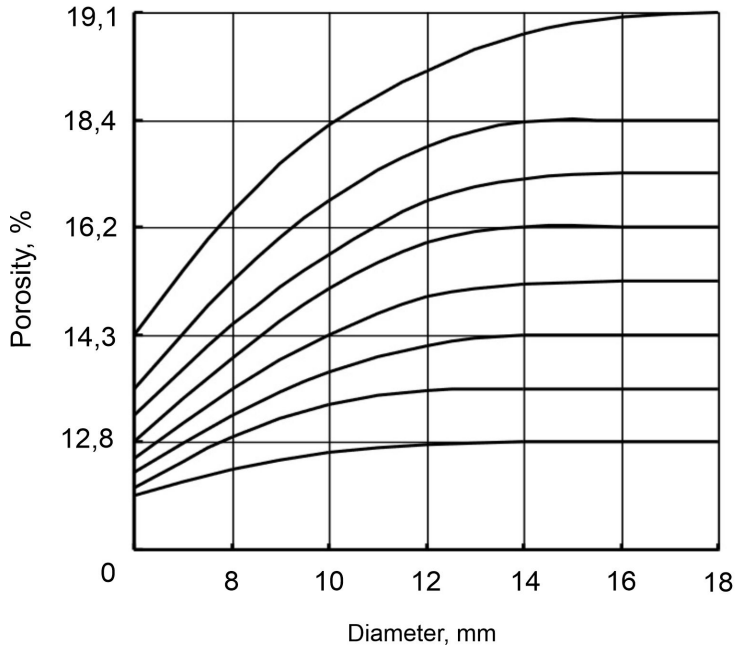

Fig. 4. The dependence of the porosity on diameter of particles

3 Conclusion

Based on computer and simulation modelling of the backfill-packaging process of inhomogeneous materials, the influence on the porosity of structurally inhomogeneous materials, their size, particle shape and internal interaction (ratio) in the charge is estimated.

It should also be noted that the proposed modelling complex has wide opportunities for studying the properties of samples made of powder and heterogeneous materials. It can also be used in various fields of science for various tests and performance testing of various composites.

It should also be noted that the complex of this proposed modelling allows us to form the most important scientific and practical results, which include the following range of three main studies:

1) evaluation of the main parameters of the backfill-packaging process of heterogeneous materials;

2) using computer metallographic analysis methods to investigate correlation and internal relationships between components of structurally inhomogeneous materials;

3) reliable prediction of the results of approximating porosity dependencies, taking into account the shape and size of grains (particles).

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