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Mechatronic System's Permeable Materials with Controlled Porosity

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Abstract. Up-to-date directions in the development of modern industry increase the requirements for the quality of technical products. The design and manufacture of competitive process equipment require accuracy, productivity, and efficiency. Therefore, in this article, a new mechatronic system has been designed and developed to help porous, permeable materials with predicted porosity have been produced. The research aims to develop a mechatronic system for technology optimization in manufacturing permeable porous materials with controlled properties. As a result, the method of computer modeling of porous, permeable materials was developed. It allows us to consider the peculiarities of porosity distribution and radial velocity in radial isostatic compression. Additionally, a new mechatronic system for producing permeable materials allows us to determine the porosity distribution and particular characteristics of permeable powder material. The proposed approach allows us to evaluate the impact of technological modes on the main operational characteristics.

Keywords: mechatronic system, porous permeable materials, radial isostatic pressing, industrial wastes, parametric design, modeling, porosity, permeability, manufacturing.

1 Introduction

Industrial development of the technology industry of any industrialized country is impossible without modern mechatronic systems and automation of production. This system is flexible during exploitation, as it allows you to make porous materials of different shapes and sizes by changing the process equipment. The formation of the desired structure of porous products is carried out by radial-isostatic pressing. The existence of traditional technology makes it possible to get new porous permeable materials (PPM). Nevertheless, it is necessary to predict and control the parameters of their structure in the process of manufacturing, which include: granulometric composition of the charge, the shape of particles, the density of the molded workpiece, the quality of the contacts, shaping, porosity, density and their volume of distribution. Today, the development and modeling with using computer-information technologies, mechatronics, and automation of production enable us effectively improve traditional technological processes, introduce low-waste production, improve the quality of manufactured products, save energy, improve production culture and be able to produce porous permeable materials, with controlled porosity and appropriate sizes [1, 2].

Current problems of creating porous technologies are solved due to computer modeling, automation, and modern computer-aided drafting (CAD) systems, which allow optimizing the technology in obtaining porous permeable materials.

2 Literature Review

The progress and success of creating new porous permeable materials is ensured by improving existing or developing new methods of obtaining them according to the domestic and foreign experience of recent decades [3, 4].

However, prediction, optimization, and modeling in powder metallurgy require further improvement of theoretical concepts and their implementation in qualitative methods and algorithms, which are realized with the help of modern computer information technologies.

Today, the optimization of technological processes for obtaining PPM with controlled porosity is solved based on mechatronic systems using computer simulation. This is

due to the significant development of theoretical ideas and considerations in the behavior of the source material (powder) in its processing and use.

Modeling regularities of forming of structure and properties of materials depend on the geometrical factors of the powder particles [5–9].

Literature review of the processing of metal-containing waste products showed a sufficiently large number of technologies for obtaining powder from sludge waste of tool and bearing steels using mechatronic systems [10, 11].

The research aims to develop a mechatronic system for technology optimization in manufacturing permeable porous materials with controlled properties.

3 Research Methodology

3.1 A method for obtaining porous permeable materials

For obtaining porous materials with high permeability, it is necessary to use powders with large particle sizes. It is necessary to use powders of small particle sizes to obtain the high fineness of cleaning. These contradictions lead to the need to find new technological techniques, automated tools, and computer modeling methods to create such structures of porous materials that provide the best possible combination of operational characteristics [12].

For receiving filtering PPMs, a new installation was designed and manufactured. This device is used for pressing the sealing materials of various kinds: metallic and ceramic powders, graphite, fibers, wire, and wire mesh (Fig. 1).

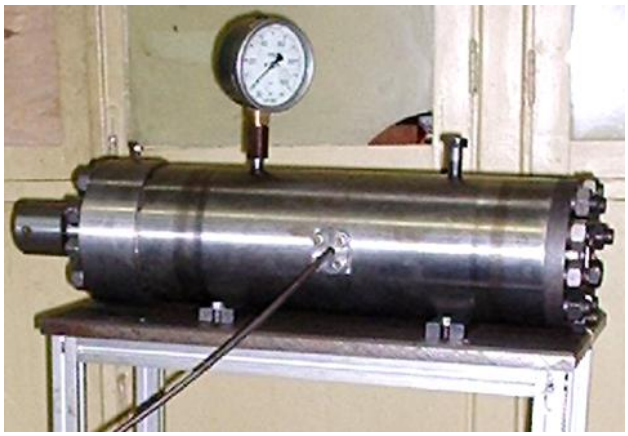

Figure 1 – Photo of the considered device

To expand the range of porous powder products, save raw materials, and reduce expenditures for production, a solid elastic insert (Fig. 2) can be made by forming a set of inner folded inserts [13]. This allows us to get products with a broader range of sizes and improve the technology and the culture of pressing.

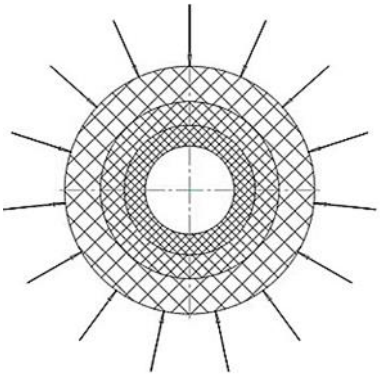

Figure 2 – Scheme of pressing using an elastic insert formed in a set of inner folded inserts

PPMs made with the help of this installation (Fig. 1) meet modern requirements as to the quality of products for this kind.

In the developed object-oriented Computer-aided design (CAD), the parameterization mechanism is implemented by the use of the parametric drawing and modeling system Pro/ENGINEER, which became the basis for the development of a system for modeling the parametric design of installations for the dry radial-isostatic pressing (Fig. 3).

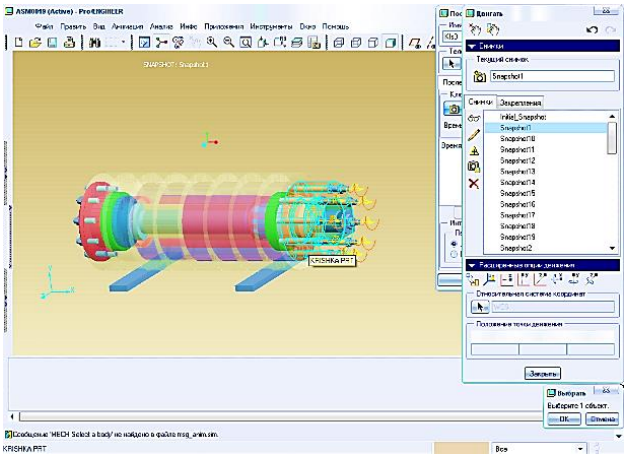

Figure 3 – Design scheme of the developed mechatronic system

One of the essential aspects of the installation design for dry radial isostatic pressing of porous permeable materials is calculating the forces and voltage in detail (Fig. 4).

Modern materials processing technology for pressure and powder metallurgy is required to obtain a wide range of products.

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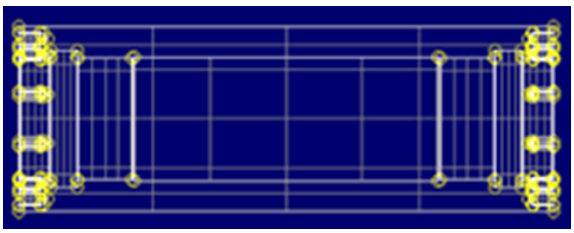
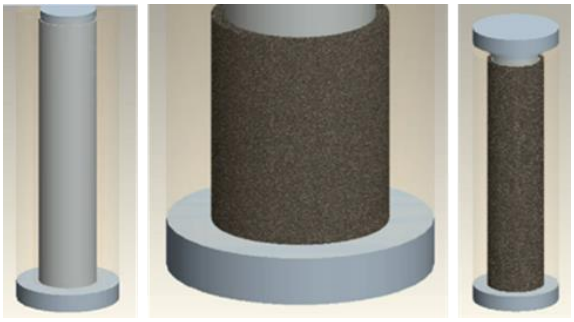
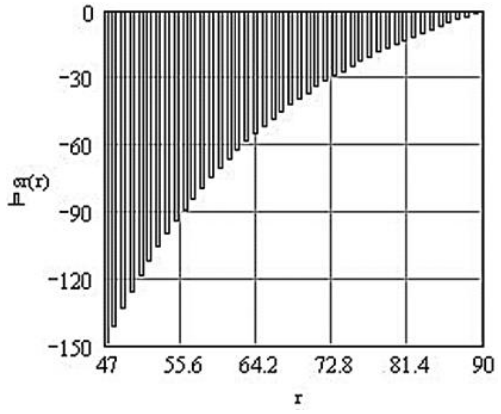


a

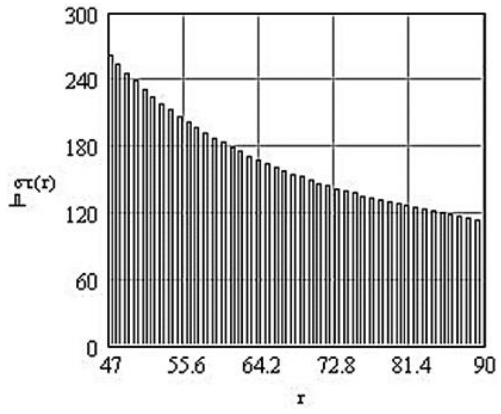


b

Figure 4 – System of calculation of forces and voltage in details of the design of the installation model for dry radial isostatic pressing of porous permeable materials based (a) and modeling of powder filling process in the form of radial isostatic pressing (b) by using Pro/ENGINEER



a



b

Figure 5 – The curves of radial (a) and tangential (b) stresses variation on the thickness of the isostatic cylinder for pressing

The progress in powder metallurgy and the treatment of materials by pressure is mainly determined by improving pressing processes. They relate to the main phase of production and determine the size, shape, range, power consumption, and effect on properties of the finished product essentially.

Developed and existing technologies do not solve manufacturing PPM products with the optimal combination of structural characteristics and physical and chemical properties. It is essential to control the quality of products, mechanize and automate the pressing, equipment, and tools processes by predicting their properties at the initial stage of formation.

Using the ABAQUS software, a reliable porosity model has been developed (Fig. 6).

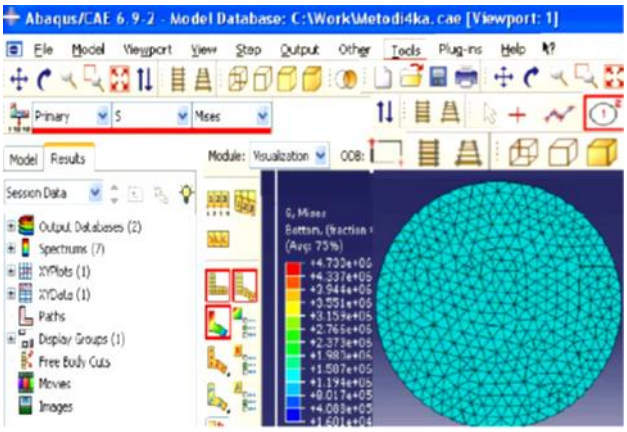


Figure 6 – The porosity model

4 Results and Discussion

The exact particle size distribution of the source powders makes it possible to adequately predict the future structure and properties of the finished PPM due to the logical relationship: the source material – structure – properties (Fig. 7).

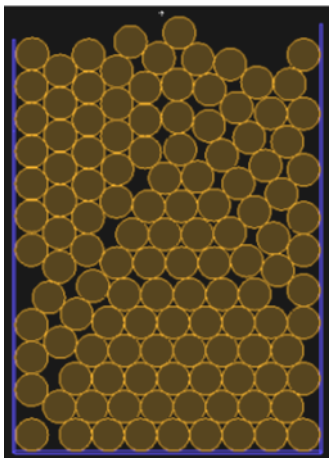


Figure 7 – Variant of filling a two-dimensional the hopper by balls of appropriate size

The modeling of the porous structure of a specific multilayered PPM from a steel powder BBS15 was carried out in the MatLab application package. According to the described methodology, software was developed in the programming language C++ ("FiltrN" program), which allowed modeling the process of radial isostatic pressing with given porosity of the PPM [3]. The initial parameters of the technological process of the mechatronic system for modeling the corresponding structure of the PPM are as follows: the inner diameter of the PPM – 40 mm, the outer diameter – 80 mm (Fig. 8).

Figure 8 – Multilayer PPM made of the steel powder BBS15 Ø40×220 mm using the radial isostatic pressing method

A multilayered PPM allows one to analyze the factors contributing to the density of distribution heterogeneity (Fig. 9).

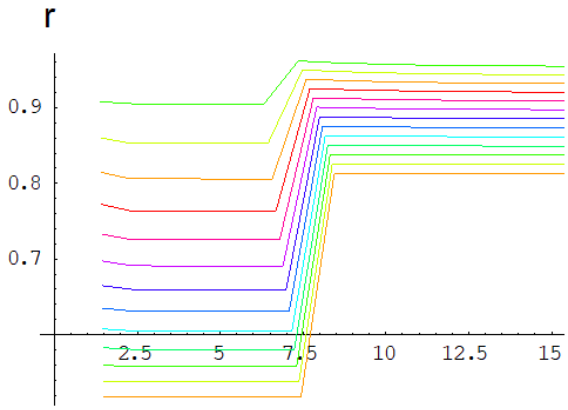


Figure 9 – A generalized distribution of density along the radius of each layer of PPM at different phases of deformation

Determination of the structural characteristics of the metal by the graphic method can be further analyzed using artificial neural networks [19] for ensuring the reliability of the proposed approach.

5 Conclusions

The analysis of existing traditional methods of pressing porous permeable materials showed no technological process, including the main positive features of traditional pressing, which would be non-defective. It is proved that the radial scheme of pressing can be the basis for creating rational equipment and technology for the production of filter materials, including metals, ceramics, graphite and waste industrial production, as it allows to realize the main positive features. In this context, an installation for pressing PPM of the new generation is proposed. The installation comprises technology to produce filter materials based on metals, ceramics, graphite, and industrial production wastes. PPM produced with the help of this installation contains a whole set of properties required for this type of product.

Essentially, the method of computer modeling of porous permeable materials was developed, allowing to consider the peculiarities of the distribution of porosity and radial velocity in radial isostatic compression. As a result, a new modern automation system for manufacturing the permeable materials from wastes of machine-building production was proposed. The method of computer modeling allowed not only to determine the distribution of porosity and other characteristics of the powdered porous units, but also to predict their impact on the operational properties of PPM.

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