Consolidation of discrete metal fibers using fine powder

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Abstract: *Information is given on the study of the process of obtaining two-layer copper permeable powder-fiber materials, based on the activation of the fiber sintering by finely dispersed powder particles process, which are also used to form a thin filter layer. It has been confirmed that the activation of the fiber sintering process by finely dispersed powder particles ensures high-quality consolidation of metal fibers. The optimal ratios between copper fibers, polyvinyl alcohol used for applying fine particles to the fibers, and copper powder have been determined.*

KEYWORDS*: CONSOLIDATION, DISCRETE METAL FIBERS, FINE POWDERS, DOUBLE-LAYER COPPER PERMEABLE POWDER-FIBRE MATERIALS, PROPERTIES*

1. Introduction/Введение

One of the directions for creating effective filter systems is associated with the development of filter materials (FM). Based on copper cable waste (MCS) [1]. In [2], based on studies of the properties of MCOs, it was concluded that these materials are promising raw materials for the manufacture of permeable fiber materials. This direction was developed in works [3–6], in which the regularities and distinctive features of MCO compaction were studied, the relationship between the structural and hydrodynamic properties of MCO FM was established, the patterns of fiber laying in narrow annular gaps were studied, and an improved method of dry isostatic pressing was proposed, allowing to control the thickness of the layers of multilayer materials from CCM. It was noted in [1] that the solution to the issue of creating materials with high permeability, the required fineness of cleaning and a long service life is met by multilayer materials, and in many cases, when solving practical problems, it is advisable to limit ourselves to the creation of two-layer FM. However, the questions of the uniformity of the distribution of permeability over the area of products, properties on a batch of products, the value of the thickness of the filter layer that ensures the regularity of the structure remain open [7]. In this regard, the structure of a two-layer permeable powder-fiber material (PPFM) is more preferable, in which a thin layer of fine powder provided a given fineness of cleaning, and a fiber substrate provided strength characteristics and high permeability of the material. At the same time, it is necessary to solve the problem of high-quality consolidation of powder fiber particles both inside the layers and at the boundary, which is difficult due to the difference in sintering temperatures of fine copper powder and fibers.

The purpose of the work is to study the process of consolidation of discrete metal fibers using finely dispersed powders when creating two-layer powder-fiber materials.

2. Experiment results and their discussion

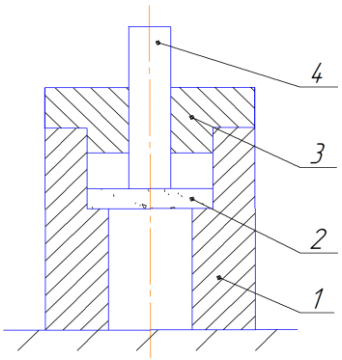
Information is given on the study of the process of obtaining two-layer copper permeable powder-fiber materials, based on the activation of the process of fiber sintering by finely dispersed powder particles, which are also used to form a thin filter layer. It has been confirmed that the activation of the fiber sintering process by finely dispersed powder particles ensures high-quality consolidation of metal fibers. The optimal ratios between copper fibers, polyvinyl alcohol used for applying fine particles to the fibers, and copper powder have been determined.

The following materials were used as starting materials: in the manufacture of the filter layer - electrolytic copper powder of grade PMS-1 in the state of delivery; in the manufacture of the substrate - fibers with a diameter of 0.1–0.4 and a length of 3–5 mm, obtained from waste electrical industries (appearance source fibers is shown in Figure 1).

Fig. 1 *Appearance of copper fibers*

Polyvinyl alcohol was used as a binder for applying fine particles to copper fibers. In the course of research, a mixture of different volume (V) and mass (m) ratios between fibers (ox), powder (p) and polyvinyl alcohol (p.sp) was used within: $V_{p.sp}$: V_{vol} = 0.002-0.015 and m_p:m_{vol} = 0.04-0.1. The samples were made in the form of disks 30 mm in diameter and 3 mm thick by the joint pressing of a substrate (fibers with applied fine particles) and a fine powder, and the fine powder was preliminarily deposited with a binder (paraffin) on one of the shaping elements [8]; pressed, based and the pore sizes and permeability coefficient of the samples were determined according to GOST 26849–8 and GOST 25283–93, respectively.

The sintering quality was assessed according to the method described in [9]. It allows you to evaluate the quality of sintering on the same sample on which the pore sizes and the permeability coefficient are determined. Compared to shear tests, the results of which, when testing fiber materials, correlate to a greater extent with the characteristics of the fiber material, when implementing the proposed method, the fracture areas are concentrated in the places of interparticle contacts (during the studies, the goal was not to analyze the stress-strain state of the material). Figure 2 shows a diagram of the equipment for assessing the quality of FPVM sintering.



1 - matrix; 2 - test sample; 3– insert; 4 - punch

Fig. 2 *Scheme of equipment for assessing the quality of FPVM sintering*

The operability of the tooling is illustrated in Figure 3, which shows photographs of the appearance of samples made from powder of tin-phosphor bronze and PPVM and having a sufficiently high strength ($\sigma_и$ = 50 MPa). The photographs show the identical nature of the destruction.

a) b)

a) porous tin-phosphor bronze *б) permeable fiber-powder material*

Fig. 3 *Samples appearance after mechanical testing*

As a result of the research, it was found that the proposed technology makes it possible to produce two-layer permeable powder-fiber porous materials with a high set of properties by joint single pressing and sintering. Finely dispersed particles deposited on the fibers activate the sintering process, making it possible to obtain PPVM with satisfactory strength. At the same time, it was found that when carrying out the process of applying fine copper particles to a fiber, it is necessary to observe certain ratios between the volumes of polyvinyl alcohol ($V_{p.sp}$) and fiber particles (V_{vol}) and the masses of copper powder (mp) and fiber (m_{vol}): $V_{p.sp}$: V_{vol} \u003d 0.009-0.014; mp: m_{vol} = 0.06-0.1. Figure 4 shows the structure of the material obtained by the described technology.

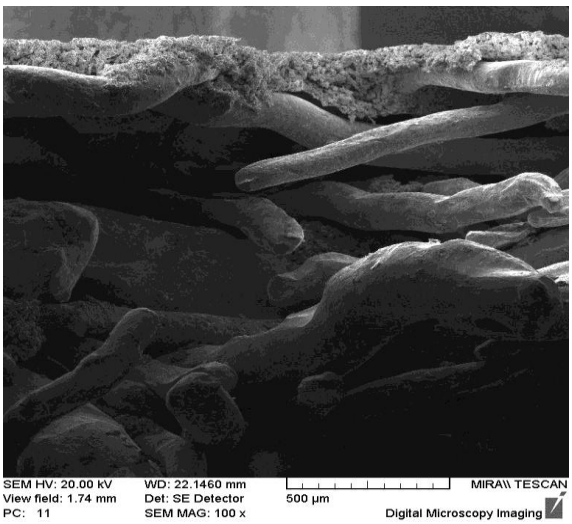


Fig. 4 *The FPVM structure, manufactured at the ratio $V_{p.sp}$: V_{vol} =0.01; m_p : m_{vol} = 0.1*

Figure 5 shows the surface structure of the material from the side of the powder layer, which indicates the absence of deformation traces characteristic of pressing in a rigid matrix, which is explained by the use of paraffin as a binder for applying copper powder to the surface of the punch.

Characteristics comparison of the developed and known two-layer powder materials, the comparison showed a significant (more than 1.6 times) increase in the permeability of PPVM at the same values of the average pores.

Conclusion. The process of obtaining two-layer permeable copper-based powder-fiber materials has been studied. and allows to produce two-layer permeable powder-fiber materials with a high complex of properties by joint single pressing and sintering. The optimal ratios between the fibers, polyvinyl alcohol used for applying fine particles to the fibers, and powder were determined. It is shown that the developed materials have a higher set of properties compared to traditional two-layer powder materials.

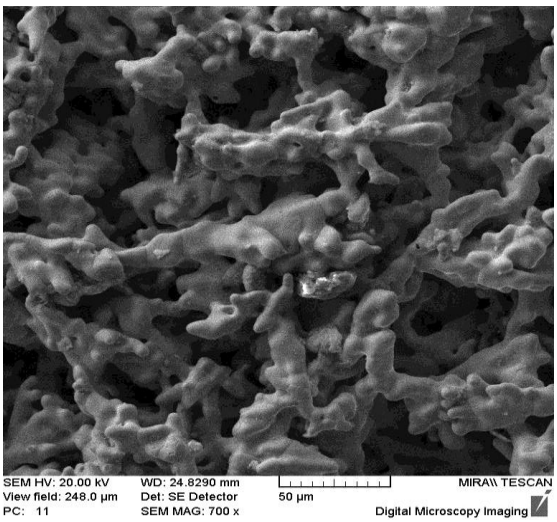


Fig. 5 *Appearance of the FPGA surface from the side of the filter layer*

3. References

1. Kaptsevich V.M., Korneeva V.K. Permeable materials from copper cable waste. Message 6. Properties prediction of the multilayer tubular elements based on copper cable waste obtained by dry isostatic pressing / Powder metallurgy, Minsk, Belaruskaya Nauka, 2017. Is. 40. pp. 125-129. (V. Kaptsevich, V. Korneeva) (in Russian).

2. Ilyushchanka A.Ph., Kaptsevich V.M., Korneeva V.K. Permeable materials from copper cable waste. Message 1. Properties of copper fiber waste / Powder metallurgy, Minsk, Belaruskaya Nauka, Is. 36, 2013, pp. 243-249. (A. Ilyushchanka, V. Kaptsevich, V. Korneeva) (in Russian).

3. Ilyushchanka A.Ph., Kaptsevich, V.M., Korneeva V.K. Permeable materials from copper cable waste. Message 2. Patterns of compaction of copper waste / Powder metallurgy, Minsk, Belaruskaya Nauka, Vol. 36, 2013, pp. 250-256. (A. Ilyushchanka, V. Kaptsevich, V. Korneeva) (in Russian).

4. Ilyushchanka A.Ph., Kaptsevich, V.M., Korneeva V.K. Permeable materials from copper cable waste. Message 3. Correlation of structural and hydrodialytic properties of permeable materials from copper fiber waste obtained by dry isostatic pressin / Powder metallurgy, Minsk, Belaruskaya Nauka, Vol. 37, 2014, pp. 121-126. (A. Ilyushchanka, V. Kaptsevich, V. Korneeva) (in Russian).

5. Kaptsevich V.M., Korneeva V.M. Features of laying copper fiber waste when filling into annular gaps when obtaining long-length filter elements by the SNP method / New materials and technologies: powder metallurgy, composite materials, protective coatings, welding: mater. 12th Intern. Scientific-technical conf. (Minsk, May 25-27, 2016). Minsk: Belaruskaya Nauka, 2016. pp. 81-84. (V. Kaptsevich, V. Korneeva) (in Russian).

6. Ilyushchanka A.Ph. Kaptsevich, V.M., Korneeva V.K. Permeable materials from copper cable waste. Message 4. Method of dry isostatic pressing improvement for the manufacture of composite multilayer tubular filter elements based on copper fiber waste / Powder metallurgy, Minsk, Belaruskaya Nauka, 2015. Is. 38. pp. 162-165. (A. Ilyushchanka, V. Kaptsevich, V. Korneeva).

7. Vityaz, P.A., Kaptsevich V.M., Kusin R.A.: Filter materials: properties, areas, applications, manufacturing technology. Minsk: Research Institute of PM with PP, 1999. 304 p. Vityaz, P.A., Minsk: NII PM, (1998). P. 158 (P. Vityaz, V. Kaptsevich, R. Kusin) (in Russian).