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DEVELOPMENT OF A TECHNOLOGY FOR OBTAINING CYLINDRICAL FILTERS WITH AN ANISOTROPIC STRUCTURE AND HIGH OPERATIONAL PROPERTIES UNDER THE INFLUENCE OF CENTRIFUGAL FORCE

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Abstract: This article investigates the technology of producing cylindrical filters with an anisotropic structure and high operational properties under the influence of centrifugal force. According to the research results, it is established that the method of forming multi-layer filtering elements from metal powders of various sizes has a higher efficiency compared to other traditional methods. Experiments have confirmed that the permeability coefficient, mechanical strength, and efficiency parameter of the filters obtained by the new method increased 2-fold, and the cleaning indicator improved to 1–3 μm. In addition, it is reported that the ability to retain solid particles in the air has increased 3-fold, successfully extending the filter's service life to 8–10 years and reducing the technological process time by 3 hours.

Keywords: centrifugal force, powder metallurgy, anisotropic structure, cylindrical filter, high operational property, bronze powder, porosity, permeability coefficient, mechanical strength, cleaning indicator.

Introduction. Deep cleaning of liquids and gases from mechanical impurities is one of the most pressing technological problems in many sectors of modern industry. Porous materials and filters obtained by powder metallurgy are widely used in this process. The main indicators of filters are recognized as their pore size, permeability, and mechanical strength. In materials obtained by traditional methods, the permeability is often limited, and only the surface part of the material participates in the filtration process. This leads to rapid clogging of the filter and a reduction in its service life.

To solve these problems, extensive research is being conducted on technologies for creating filters with an anisotropic structure, consisting of layers with different pore sizes. This article is devoted to the development of a technology for obtaining cylindrical filters with an anisotropic structure and high operational properties from BrOF-10-1 bronze powders under the influence of centrifugal force, and the determination of its optimal regimes.

Main Part. Optimal regimes for the technology of obtaining cylindrical filters with an anisotropic structure and high operational properties under the influence of centrifugal force were determined:

1. The rotation speed of the container during the generation of centrifugal force is 200 rev/min.
2. The horizontal speed of the conical hopper for feeding metal particles into the mold is 20 mm/min.

The following research results were obtained from the nomogram (for the BrOF-10-1 material):

1. For the first layer: A cylindrical sample with a metal powder size of (+1000–1250) μm, an inner diameter of 45 mm, an outer diameter of 50 mm, and a length of 75 mm was selected.
2. The regularity of the d_n/D_0 ratio for the second, third, and fourth layers:

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A) Metal powder size for the second layer: $0.15 \leq d_1/D_0 \leq 0.25$ mm;

B) Metal powder size for the third layer: $0.063 \leq d_2/D_0 \leq 0.080$ mm;

C) Metal powder size for the fourth layer: $0.040 \leq d_3/D_0 \leq 0.050$ mm.

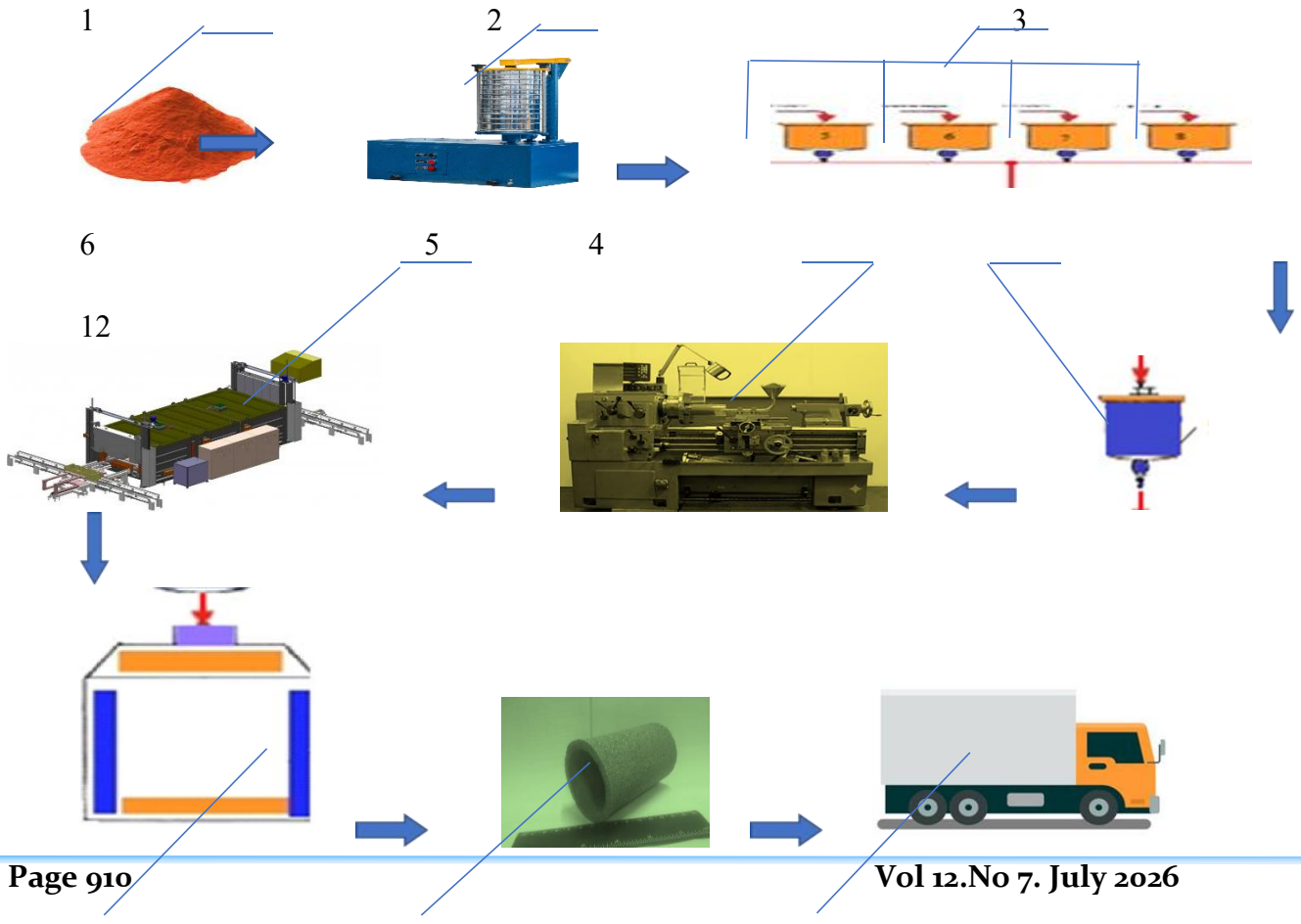
3. **Their height within the pores**: In the 1st, 2nd, and 3rd layers, it was found to be equal to 1.5, 0.5, and 0.25 times the average diameters of the powders of the respective layers.

4. **Sintering process:** The temperature was 800–810°C in a hydrogen atmosphere for 1 hour. When the green compact (raw material) is sintered, the relative interparticle contact (sintering neck) at a temperature of 800–810°C constitutes F=0.15–0.20. This led to a 3-hour reduction in the time required for the technological process.

The technological process consists of the following operations (Figure 1):

Selection of metal powder (1); sieving the selected powders using a model 029 electric sieve set device (2); separating the sieved powders into large and small powders according to their fractions and placing them into hoppers (3); sequentially pouring the powders from large to small sizes through a conical hopper (4) into a container on a centrifugal force device (5) mounted on a lathe (where the rotation speed of the container is 200 rpm, and the horizontal reciprocating speed of the conical hopper is 20 mm/min).

An inner diameter mold (press-form) is placed onto the resulting green compact. Together with the mold, the green compact is sintered in an STN-1,6 model furnace (6) in a hydrogen atmosphere at a temperature of 800–810°C for 1 hour. The resulting filter is separated from the mold, its operational properties are determined in a complex of testing equipment (7), and its technical specifications are recorded; finally, the finished product (8) is delivered to the consumer (9).



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Figure 1 Legend & Caption

1 — metal powder; 2 — model 029 electric sieve set; 3 — hoppers for large and small-sized metal powders; 4 — conical powder feeder; 5 — device for obtaining cylindrical filters under the influence of centrifugal force, mounted on a lathe; 6 — model STN-1.6 sintering furnace; 7 — complex of equipment for determining the operational properties of filters; 8 — finished product; 9 — delivery to the customer (consumer).

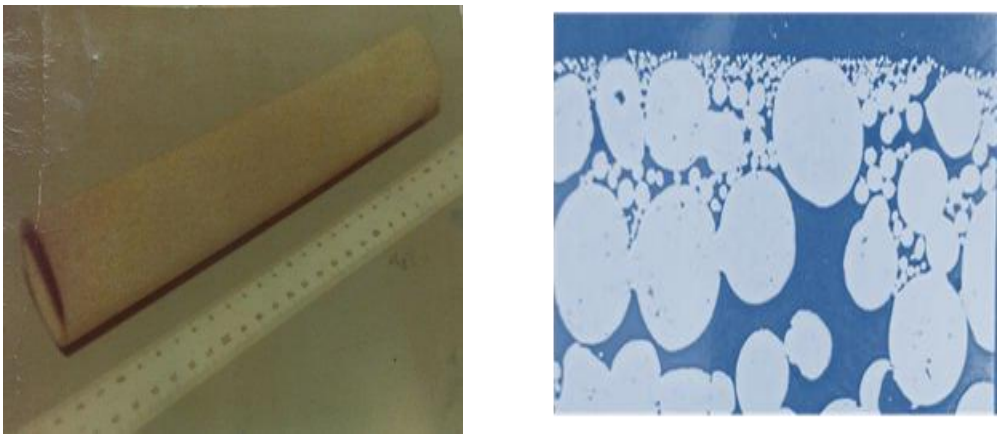
Figure 1. Technological block diagram for manufacturing cylindrical filters with an anisotropic structure and high operational properties under the influence of centrifugal force.

Figure 2 shows the device for obtaining cylindrical filters under the influence of centrifugal force, mounted on a lathe.



Figure 2. Device for obtaining cylindrical filters under the influence of centrifugal force, mounted on a lathe.

Figure 3 depicts the general appearance (a) and the microsection structure (b) of a filter with an anisotropic structure and high operational properties prepared from BrOF-10-1 bronze powders under the influence of centrifugal force.



a) b) x100

Figure 3. General appearance (a) and microsection structure (b) of a filter with an anisotropic structure and high operational properties prepared from BrOF-10-1 bronze powders under the influence of centrifugal force.

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The following table provides a comparison of advanced technologies for obtaining anisotropic structure filters intended for deep purification of gases and liquids, alongside the operational properties of these filters.

Table.

Comparison of advanced technologies for obtaining anisotropic structure filters intended for deep purification of gases and liquids, and the operational properties of the filters.

No.	Filter Production Methods	Metal Powder Dimensions, mm	Porosity, P %	Average Pore Size, μm	Permea-bility Coefficient, $K=1*10^{-13}$, $м^2$	Mechanical Strength, MPa	Effici-ency Parameter, E_1	Local Permeability, $K_П$	Cleaning Indicator $A_Т$
	1	2	3	4	5	6	7	8	9
1	Loose packing of powders into the mold (Traditional methods) (Authors: P.A. Vityaz, V.M. Kaptsevich, L.P. Pilinevich)	**BpOf-10-1 *0,8-1,0 **0,2-0,25 **0,1-0,125** **0,05-0,063	40	20	172	95-110	0,140	0,65	11-15
2	Vibration method (M.Yu. Rakhimov)	**BpOf-10-1 *0,8-1,0 **0,2-0,25 **0,1-0,125 **0,05-0,063**	46	20	160	80-100	0,175	0,65	7-10
3	Method of introducing small particles into the pores of the green compact using gas-dust air flow (D. Abdisattarov)	**BpOf-10-1 *0,8-1,0 **0,2-0,25 **0,1-0,125 **0,05-0,063**	38	20	177	100-120	0,140	0,70	8-12
4	Method of introducing small particles into the pores of the green compact in a vacuum using a	**BpOf-10-1 *0,8-1,0 **0,2-0,25 **0,1-0,125 **0,05-0,063**	38	20	175	120-125	0,145	0,75	7-8

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	fluidized bed method (A. Sattarov)								
5	Based on improved introduction technologies (M. Karshiev)	**BpOf-10-1 *0,8-1,0 **0,2-0,25 **0,1-0,125 **0,05-0,063**	36	20	178	120-140	0,145	0,78	6-8
6	Development of technology for obtaining porous permeable materials by applying a layer-bylayer vibration method (K.I. Yunusalieva)	**BpOf-10-1 *0,8-1,0 **0,2-0,25 **0,1-0,125 **0,05-0,063**	38	20	176	120-135	0,150	0,80	4-6
7	Technology for obtaining cylindrical filters with an anisotropic structure and high operational properties under the influence of centrifugal force. New method (M.M. Fayziev)	**BpOf-10-1 *0,8-1,0 **0,2-0,25 **0,1-0,125 **0,05-0,063**	38	20	180	130-140	0,175	0,82	1-3

Note:

* — Sizes of large powders used in the preparation of the green compact (raw material billet).

** — Sizes of small powders introduced into the pores of the green compact.

When analyzing the advanced methods and techniques for obtaining filters mentioned above, it becomes apparent that the permeability performance of products obtained by other methods does not exceed 50% [1, 2, 3]. Furthermore, although these materials possess an anisotropic structure, only their surface layer functions during the filtration period; the structure across the entire volume does not actively participate in the process. As a result, such filters clog quickly, reducing both their permeability capacity and operational longevity.

An analysis of new methods for altering and controlling filter pores shows that one of the most effective approaches is the method of manufacturing filters with an anisotropic structure and high operational properties under the influence of centrifugal force (Method 7 in the table). In this method, the filtering elements are formed from layers of metal powders of various sizes, and their operational properties are significantly higher compared to single-layer elements.

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Conclusion. Based on the conducted research and investigations, the following conclusions were reached:

1. Technology Development: A technology for obtaining multi-layer cylindrical filters with an anisotropic structure from bronze powders of various sizes under the influence of centrifugal force was successfully developed, and its optimal operating regimes were determined.

2. Performance Improvement: When comparing the filters obtained by this new method with other traditional methods, a 2-fold increase was observed in the permeability coefficient, mechanical strength, and overall efficiency parameter.

3. Filtration Quality: The cleaning indicator (fineness) of the filtration process was significantly improved, decreasing from 11–15 μm down to 1–3 μm (yielding a 3-fold increase in purification quality).

4. Economic & Operational Value: The capacity to collect solid particles from air flows increased 3-fold, creating an opportunity to extend the filter's service life to 8–10 years. Additionally, the time required for the technological process was reduced by 3 hours, which significantly enhances the economic efficiency of production.

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