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(Research Article)

Features of manufacturing case of hydraulic cylinders of structural powder steel

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Abstract

This work examines the dependence of the structure and properties of iron-based powder materials used for body parts of hydraulic cylinders on their composition and manufacturing technology. The role and importance of powder structural materials in industrial areas, the features of the production of parts for hydraulic devices and the characteristic features of methods for strengthening parts made from these materials are also explored here. During the research, powder materials containing Fe-Cu and Fe-Cu-graphite were used to prepare the hydraulic cylinder body part. The influence of the density and porosity of sintered materials on the physical properties of steam-processed powder material, the influence of the steam oxidation regime of parts made from powder material on the microstructure, mechanical and technological properties have been studied. The development of a technological process for producing iron-based powder materials and products made from them by cold pressing, sintering and steam-thermal oxidation makes it possible to improve the structure, physical, mechanical and technological properties of these materials. The results of this study highlight the importance of optimizing the composition of powder materials and processing conditions in order to develop more reliable and durable parts for hydraulic cylinders and other hydraulic devices, and also help to identify important parameters affecting properties.

Keywords: Hydraulic Cylinder; Iron-Based Powder Materials; Sintering Modes; Heat Treatment; Steam Treatment; Microstructure; Physical-Mechanical Properties.

1. Introduction

Many machines in the oil and gas industry, including those in mechanical engineering, are equipped with hydraulic cylinders. The fact that hydraulic cylinders have a simple and compact design makes them easy to install in various equipment and mechanisms. However, despite their simple design, hydraulic cylinders operate under heavy load, and for this reason their failure is not uncommon. Hydraulic cylinders consist of a body, piston, cylinder, etc. and often in these parts, due to the wrong choice of design and materials, various cracks, scratches, and bends can be observed.

Due to the use of low-quality materials and non-compliance with manufacturing technology, hydraulic cylinders last less than the standard period. Violation of tightness, oil getting between elements are also the main reasons for failure of hydraulic cylinders. In addition, violation of equipment operating conditions (exceeding the load capacity, using damaged equipment, etc.) accelerates wear of the hydraulic cylinder. Therefore, to maintain machines and equipment in working condition, it is of particular importance that the composition, structure and properties of the materials from which they are made meet the necessary requirements [1, 2].

Requirements for materials of hydraulic cylinder parts include high strength, hardness, high fatigue strength, good technological properties (pressure processing, welding, etc.), wear resistance and corrosion resistance in contact with the environment and working fluid, etc.

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Depending on the operating conditions, various materials and their combinations can be used for the manufacture of hydraulic cylinder parts. Currently, instead of classical materials for the manufacture of body parts of hydraulic cylinders, powder materials that meet the above requirements are widely used. The advantage of using powder materials is that it is possible to obtain parts close to their actual dimensions, as well as give them the necessary properties. Powder materials are widely used in various components of machines and devices. These materials can replace expensive alloys, reducing metal consumption and reducing energy costs by eliminating machining and using low-waste technology. In mechanical properties, porous powder materials, due to the presence of pores in their structure, are somewhat inferior to cast materials, but in their operational properties and, especially antifriction properties, they are significantly superior to them. Their service life, as a rule, is one and a half to three times longer. The antifriction properties of powder materials can easily be varied by selecting the optimal composition of the material, its porosity and solid lubricant content. promoting the formation of a separating film on the friction surface. An even higher level of properties of friction unit materials can be achieved by using composite powder materials made on the basis of high-alloy iron alloys, copper and also based on nickel, chromium and other known metals containing solid lubricants [3, 4].

Powder metallurgy occupies an important place in the creation of new materials and products from them, which have a number of advantages compared to traditional methods of producing these products (cutting, in some cases, pressure and casting). One of them is the possibility of obtaining materials with different properties by both thermal and chemical-thermal processing of scrap metal. Thus, to create corrosion-resistant structures on the surface of parts, various chemical thermal treatment methods can be used. When using new technological processes for processing powder materials, improving product quality can provide high economic efficiency when used in production by reducing the quantity and composition of alloying elements.

If we look at the production process in many industries, we see that hardening or surface hardening technologies for various purposes occupy a very important place. During operation these technologies are of great importance for increasing the durability of devices and installations, their individual parts and the parts from which they are composed. The chemical-thermal treatment method, which can be used to increase the durability of critical products or parts, is considered as a highly effective method that can have a wide range of applications in industries. The chemical-thermal treatment method is carried out by influencing the surface layers. After the chemical-thermal treatment process, in some cases, heat treatment of the product is necessary, and in some cases, the heat treatment process is carried out before the chemical-thermal treatment process.

Although much of the metallurgy field's focus has been on iron-based structural materials, the use of pure iron powder as a starting material in the production of structural parts is limited due to the relatively low strength properties of sintered iron. To improve the known mechanical properties of structural parts, it is possible to use alloying elements and apply various types of chemical-thermal treatment. However, during this period, one of the important issues is ensuring tightness, as well as eliminating deficiencies after the chemical-thermal treatment process [5, 6].

A large number of studies show that iron-based powder structural materials have high strength, density, and in many cases correspond to the characteristics of corresponding parts produced by casting and pressure processing. In order for materials to have more specific properties, determining the iron powder and the additives used (such as graphite, copper, copper-coated graphite), that is, the composition of the charge, makes it possible the required properties of the material and parts. The process of steam-thermal oxidation of iron-based powder materials is one of the simplest and most economical methods for significantly increasing the wear resistance and corrosion resistance of powder materials. It consists in increasing their hardness, friction resistance, electrical resistance, compressive strength, tightness, as well as improving appearance [7].

In order to improve operational properties, manufacturing a hydraulic cylinder body part from iron-based powder structural materials and including graphite and copper in the charge makes it possible to improve the physical, mechanical and tribological properties of sintered products.

The properties of powder materials are determined by their composition and density. It is through the correct determination of the composition of the charge that the necessary operational properties are achieved. Improving alloying technology makes it possible to develop new powder materials. One of the ways to improve the properties of porous materials is their heat treatment, high-temperature annealing or steam treatment. Such processes give materials the necessary performance properties after sintering [8].

This work is devoted to determining the optimal composition of the charge and processing modes for the manufacture of hydraulic cylinder body parts from iron-based powder structural materials and studying their influence on the structure and properties of the material.

2. Material and methods

In the presented work, the dependence of changes in the structure and properties of alloyed powder structural materials based on iron on the composition of the charge and processing modes was investigated. Iron-based powder materials of various compositions were chosen as the starting material for the work (fig. 1).

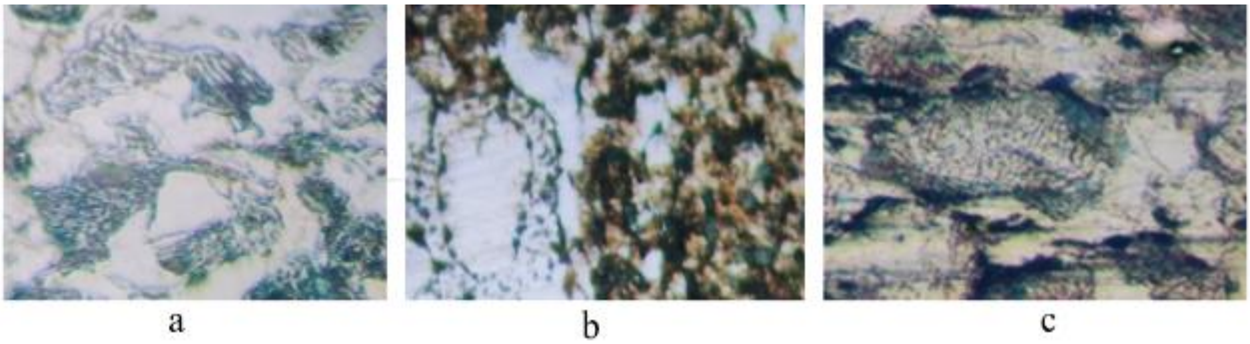

Figure 1 Microstructure of sintered powder materials based on iron, x400: a – ЖД1,5; b – ЖГр0,4 Д1,5; c – ЖГр0,1-3МГ

Table 1 presents the chemical composition and technological modes for manufacturing of the iron-based powder materials used in the study. Samples with standard sizes, with different porosities and prepared using all three selected mixture compositions, as well as parts of the hydraulic cylinder housing were studied.

Mixing the selected components, preparing the composition of the charge, pressing and sintering the pressed briquettes were carried out according to the procedure. From selected iron-based powder structural materials, samples were pressed under a pressure of 700 MPa, sintered in a protective gas environment at a temperature of 1100°C and treated with steam (fig. 2). Since steam treatment is considered the simplest and most effective method to achieve high hardness, strength, wear resistance, corrosion resistance, tightness and improved appearance [9, 10].

Table 1 Chemical composition and technological modes for manufacturing of iron-based powder materials

№	Materials	**Chemical composition (%)**				**Technological modes for manufacturing**	
		Graphite ГК-3	Copper ПМС-1	Copper-plated graphite	Iron ASC 100.29	Pressure, MPa	Sintering temperature, ^{0}C
1	Ж Д1,5	–	1.5	–	98.5	700	1100
2	Ж Гр0,4 Д1,5	0.4	1.5	–	98.1		
3	Ж Гр0,1-3 МГ	0.1	–	3.0	96.9		

The mechanical properties of the prepared samples and parts were determined. Hardness determination was carried out according to GOST 6508-86 using a TK-2M hardness tester using the Rockwell method. To determine the strength, a P-10 tearing machine was used according to GOST 1497-84.

The accompanying study of the open porosity and density of sintered and steam-treated powder materials of various compositions highlights the issue of studying the structure of these materials. Therefore, to study the microstructure of the polished sample, a Neofot-21 microscope was used.

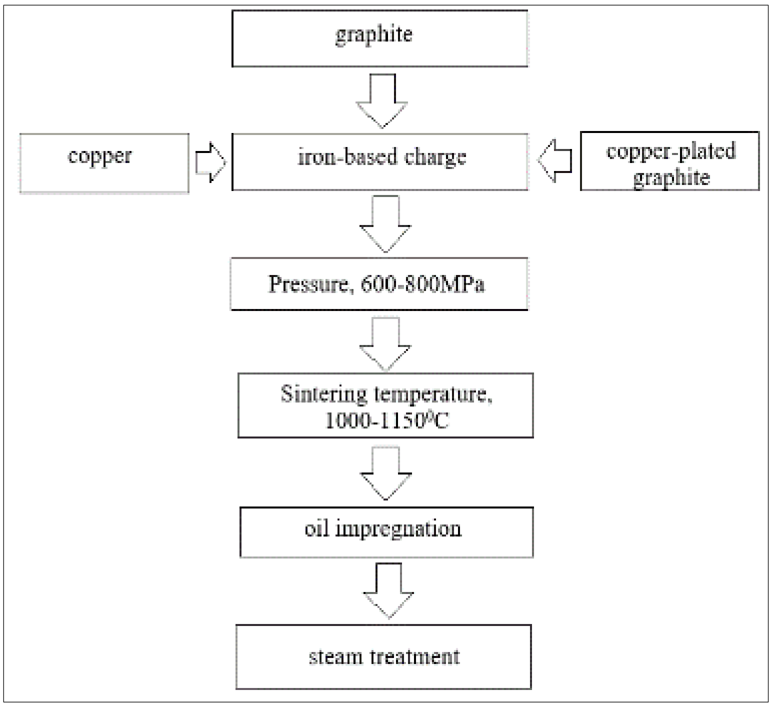

Figure 2. Technological flow diagram for the manufacture of parts from iron-based materials

3. Results and discussion

As a result of research, it has been established that an increase in open porosity in sintered and steam-treated sintered materials of various compositions increases the rate of oxidation. It is also observed that a thinner oxide layer is formed in the pores on the surface, while a relatively thick oxide layer is formed in the pores under the treatment layer. By closing the pores, steam treatment ensures the tightness of the material. In sintered materials ЖД1,5 and ЖГр0,4 Д1,5 with porosity up to 15%, thermal oxidation with steam forms a magnetite coating with a thickness of 5 and 7 microns (Fig. 3. a and b, respectively). In ЖГр0,1-3МГ materials containing 3% copper-plated graphite (МГ), thermal oxidation produces a magnetite coating 10-12 μm thick in the surface layer (Fig. 3.c).

Depending on the pressing and sintering modes, the density and strength of the studied sintered materials are given in Table 2. The reason for the effectiveness of tensile strength is the inclusion of up to 1.5% copper in the composition. The increase in hardness continues in all compositions. One of the reasons for the increase in hardness after steam oxidation was the increase in graphite content up to 2 times while maintaining the copper content at 1.5%. The inclusion of copper-coated graphite in the charge significantly increases strength. After steam oxidation, it was observed that the degree of oxidation increased with increasing open porosity and varied from 2% to 4% with an open porosity of 10-15% regardless of composition.

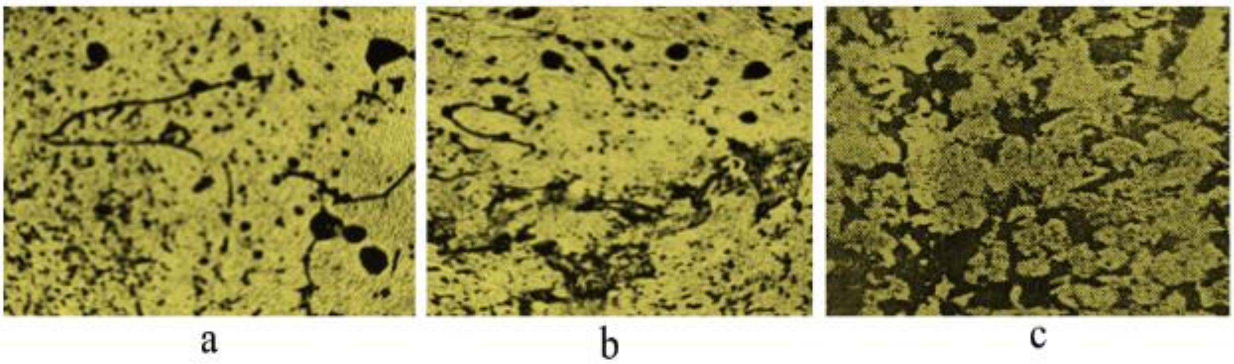

Figure 3 Structure of the surface layer of steam treatment of sintered parts based on iron of various compositions, x500: a – ЖД1,5; b – ЖГр0,4 Д1,5; c – ЖГр0,1-3МГ

Table 2 Properties of iron-based sintered materials

№	Materials	Density of sintered materials, g/cm³	Strength of sintered materials, MPa
1	Ж Д1,5	6.32	230
2	Ж Гр0,4 Д1,5	6.48	270
3	Ж Гр0,1-3 МГ	6.65	340

An increase in the mass amount of graphite and copper in the charge (%) more than the specified limit leads to changes in the strength properties and dimensions of parts after sintering. Structural and physical-mechanical properties were determined depending on cold pressing pressure and porosity as the main parameters for optimizing the composition when studying materials made from all three layers. Figure 4 shows a graph of the dependence of total and open porosity on compaction pressure.

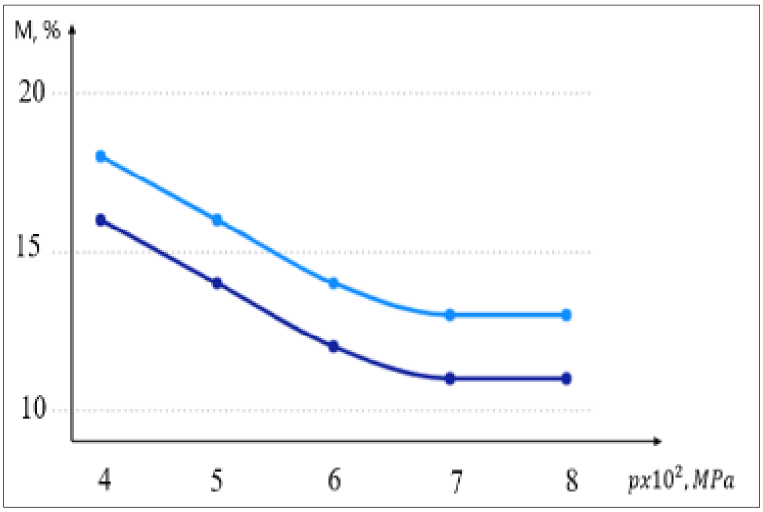

Figure 4 Dependence of porosity on compaction pressure in prepared samples from Ж Гр0,1-3 МГ:1 – total porosity; 2-open porosity.

As can be seen from the graph, as a result of increasing the compaction pressure to 700 MPa, the total and open porosity decreased, and the closed porosity increased. As a result of increasing compaction pressure, a decrease in porosity is also reflected in hardness. Thus, the hardness index stabilizes at a pressing pressure above 700 MPa.

Also interesting are the graphs of the dependence of the strength properties of samples prepared from selected compositions, sintered and subjected to a steam oxidation process, on the sintering temperature (Fig. 5). The optimal sintering temperature for pressed samples with a porosity of 10-15% is considered to be 1100°C.

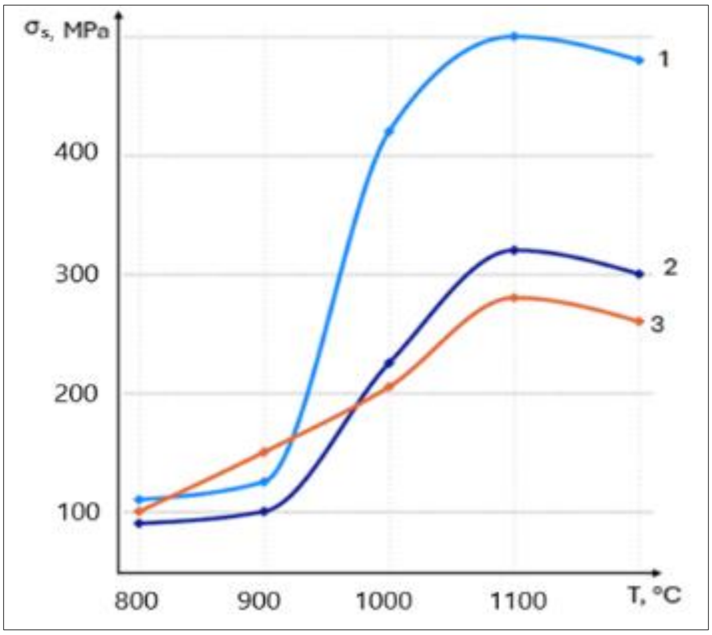

Figure 5 Graph of the dependence of the tensile strength of sintered samples of various compositions on the sintering temperature: 1-ЖГр0,1-3МГ; 2-ЖГр0,4 Д1,5; 3-ЖД1,5

Obtaining the optimal structure and properties in iron-based powder materials of the selected composition is possible by selecting a pressing pressure of 700 MPa, a sintering temperature of 1100°C and subsequent steam treatment. The magnetite film formed in the pores as a result of steam oxidation ensures tightness of the material and stabilizes the properties.

4. Conclusion

A study of samples prepared in this mode shows that the structure contains ferrite and pearlite phases, as well as pores of various sizes. To obtain sealed, corrosion-resistant materials from all three compositions, it is considered important to carry out a steam oxidation process. As a result, the properties are significantly stabilized and usable materials are obtained. It has been established that the inclusion of copper and graphite together, as well as graphite in copper-coated form, in the composition of the charge and their amount in the composition within the specified limits leads to the production of materials with a homogeneous structure. A study of materials ЖД1,5, ЖГр0,4 Д1,5 and ЖГр0,1-3МГ for the manufacture of hydraulic cylinder housing parts shows that these parts can be made with complete confidence from these materials.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Liu, Y., et al. Recent Advances in the Structural and Mechanical Properties of Hydraulic Cylinder Materials. Materials Performance and Characterization, 13(1), 2024, pp. 12-28;

[2] Kumar, V., et al. Optimizing the Tribological Properties of Iron-Based Powder Metallurgy Materials for Hydraulic Cylinder Components. Journal of Materials Science & Technology, 89(2), 2023, pp. 245-259;

[3] Chen, L., & Huang, G. Improved Performance of Hydraulic Cylinder Materials: A Study on the Effect of Powder Composition and Processing Techniques. Powder Metallurgy, 67(4), 2024, pp. 421-436;

[4] Justyna Skowronska, Andrzej Kosucki and Lukasz Stawins. Overview of Materials Used for the Basic Elements of Hydraulic Actuators and Sealing Systems and Their Surfaces Modification Methods. Materials 2021, 14(6), 14-22;

[5] Xrenov O.V., Afanacev L.N., Leşok A.V., Materialı i texnolonii poroşkovoy metallurqii, Uçebno-metodiçeskoe posobie, Minsk, 2010, 37 c.;

[6] Namazov S.N., Djafarova A.A., Abdulazimova E.A. Leqirovanie poroşkovıx materialov na osnove jeleza, poverqaemnıx oksidirovaniyu. Metallurqiçeskaya i qornorudnaya promışlennost. Dnepropetrovsk, 2017, №2, s. 38-40;

[7] Wang, H., et al. "Impact of Powder Metallurgy and Heat Treatment on the Durability of Hydraulic Cylinder Components." Journal of Materials Engineering and Performance, 32(3), 2023, pp. 890-903;

[8] İlyuşenko A.F., Sevastyanov E.S., Kireev P.N. Visokoplotnıe poroşkovıe stali i texnoloqii izqotovleniya iz nix konstruksionnıx detaley slojnoy formı. 50 let poroşkovoy metallurqii Belarusi. İstoriya, dostijeniya, perspektivı – Minsk, QNPOPM, 2010. Qlava 11. c. 218-229;

[9] Namazov S.N., Djafarova A.A., Taqiev T. A. Poluçenie poroşkovoqo jelezoqrafita s posleduyuşim oksidirovaniem. Uçenie zapiski AzTU, 2016, №3, TOM 1, c.122-129;

[10] Stoyanov A.A., Burko V.V., Oyadiçev V.V i dr. Texnoloqiya i proizvodstvo poroşkovıx izdeliy. Uçebnoe posobie. 2021, 236 c.