International Journal of Analytical, Experimental and Finite Element Analysis
Volume 10, Issue 1, March 2023, pp 21 - 28
https://doi.org/10.26706/ijaefea.1.10.20239556

Heat Treatment After Sintering Process and Development of Porous Metal Materials

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Abstract. In world science and practice, much attention is paid to new developments and improvements in hard alloy. At the same time, attempts are being made to improve all technological chains, on which the properties of the alloy and its operational properties depend. In this regard, it seems promising to develop new and existing methods for obtaining raw materials for the production of cemented carbide. The final stage of the technical method of powder metallurgy is the heat treatment of the formed blanks, which is carried out by the sintering method.

Keywords: sintering, alloy, powder material.

Technical Note – Peer Reviewed
Received: 1 March 2023
Accepted: 24 March 2023
Published: 31 March 2023

Cite this article:
Khaldoon Hussein Hamzah, "Heat treatment after sintering process and development of porous metal materials", *International Journal of Analytical, Experimental and Finite Element Analysis*, RAME Publishers, vol. 10, issue 1, pp. 21-28, 2023.
https://doi.org/10.26706/ijaefea.1.10.20239556

Introduction

Sintering is one of the most difficult technical steps in powder metallurgy, transforming low-strength billets into very strong sintered products. During sintering, the gas adsorbed on them is removed from the preform, undesirable impurities are sublimated, residual stresses in the particles and points of contact between the particles are removed, the oxide film is removed, and the surface layer is scattered. Metamorphosis occurs. The shape of the pores changes qualitatively. Sintering is carried out in two ways: solid phase (the workpiece is heated so that one liquid melt of the part does not form) and liquid phase. The result of sintering is a metal rod or plate from which the knife is made [1].

Vacuum technologies, methods of obtaining powders of starting materials in a nano dispersed state are promising. It is important in the technological chain to obtain mixtures of initial powders (obtaining an initial charge for pressing) and their granulation. High-energy mixing methods (mixing with simultaneous grinding in attritors, etc.), granulation of the resulting mixtures by spraying with simultaneous drying are promising. For sintering products made of tungsten-free hard alloys, along with sintering in hydrogen and vacuum, it is expedient to use compression sintering in autoclaves, which can significantly increase the mechanical characteristics of alloys by 1.5–2.0 times sintering in comparison with alloys sintered in vacuum. For the production of tungsten-free hard alloys such as TN20 and NTN30, the technological scheme shown in Figure 1 can be recommended. For alloys of grades KNT16 and TV4, it is almost identical. Only the first stage is the production of titanium carbonitride by carbothermal reduction-nitriding of titanium dioxide. With the use of modern technological equipment (attritors, installations for drying mixtures by spraying, corresponding sintering furnaces), this scheme can undergo significant changes, and the properties of all alloys - TN20, KNT16, TV4, NTN30 can be significantly higher [6].

The sintering operation consists in pressing the powder or heat treating a workpiece obtained in another way (below the melting point of the main component). The sintering operation is primarily aimed at improving the mechanical properties of the product. After sintering, additional processing can be carried out to obtain the desired properties.

For sintering, furnaces of various types are used, both in design and in the heating method. The choice of furnace type depends on many factors such as the sintering mode (protective environment, temperature, retention during sintering), cooling mode, product composition, quantity, size and shape. The choice of a suitable sintering mode largely depends on the furnace used [3].

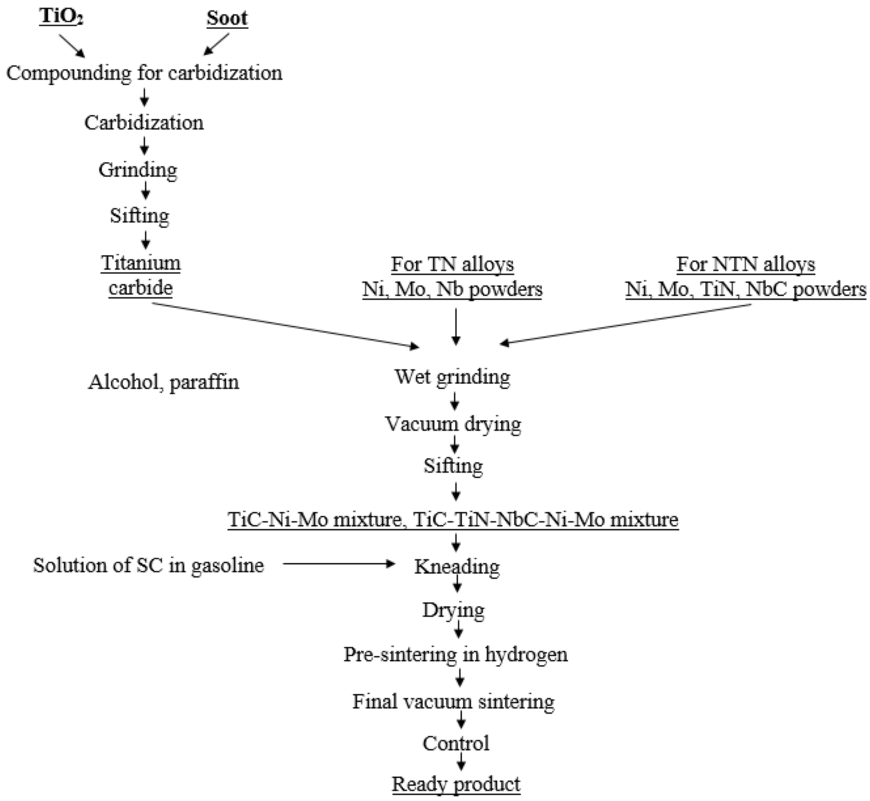

Figure 1. Technological scheme for the production of alloys of grades TN and NTN

One of the characteristics of powder materials is that powder metallurgy predetermines the presence of pores in the structure of the material. Pores are present in all powder metallurgy products. The size, shape and distribution of pores in a material determine its mechanical, physical and operational properties [4].

Modern technologies make it possible to change the content of pores in powder materials (from 0 to 70%), thus obtaining both non-porous or low-porous products and highly porous materials and products made from them.

The performance of porous powder materials and their fields of application are determined by the presence of an interconnected pore system. This pore structure provides the porous powder materials with permeability to gases or liquids, filtration ability, ability to capillary transport of liquid and its retention in pores, developed specific surface area and other properties.

Porous powder materials are successfully used in space technology, mechanical engineering and instrument making, industry (radio-electronic and chemical), nuclear energy, medicine, and agriculture. Compared to other permeable materials on organic (felt, paper, fabric, polymer) and inorganic (ceramics, asbestos, glass) substrates, porous powder materials are characterized by better permeability, greater strength, ductility and resistance to thermal shock. These materials are corrosion-resistant and heat-resistant, can operate at temperatures > 1000 ° C, are simple and economical to manufacture, and can be reused.

Porous powder materials are well known for gas distributors (eg for air transport in bulk media). In this case, the transported products (cement, fertilizers, fuel) fall on a porous plate, from which air is supplied from below. The resulting gas-dust mixture passes through the transport pipeline. This eliminates the possibility of dispersed particles being released into the atmosphere. In this case, porous powder materials can be used instead of belts and screw conveyors. The experience of using such materials in cement plants shows the huge advantages of pulp and paper mills, such as no moving and worn parts, low energy consumption, no noise and reliable operation [10-12].

According to the existing classification of porous powder materials [2]:

- Porous powder materials and its scope of application is divided into three groups:
- Filtration (filters, phase separators, gas and liquid flow distributors, mufflers of noise and mechanical vibration, flame arresters, etc.);
- Capillary-porous (evaporator, condenser, capillary structure of heat pipes, capillary pump, etc.);
- Materials with special properties (porous anodes, battery plates, bone substitutes, catalysts, catalyst diffusion membranes).
- Filtering porous powder materials. The most widespread are porous powder materials for filters, which are designed to separate gases and liquids from impurities.

Therefore, filters of porous powder materials are used to purify water, alkalis, acids, salts, fuels and lubricants, milk, resins, lacquer bases, molten salts and polymers. In addition, these filters are used for the production and sale of liquefied and compressed gases (nitrogen, oxygen, helium, air, etc.) and for filtering exhaust gases in technological production cycles (discs, plates, cylinders, glasses, cones, etc.) [7].

In some cases, these filters can trap expensive dusty catalysts used in chemical and petrochemical processes, significantly reducing costs. Depending on the field of application, operational and design requirements, filters are made in the form of discs, plates, cylinders, glasses, cones, etc.

Porous powder materials are resistant to extreme temperature fluctuations (thermal shock) and surpass other known permeable materials in machinability (machining, gluing, welding, brazing.

Porous powder filters can be made in almost any shape and size. By choosing the right material, you can ensure high corrosion resistance, heat resistance and durability of the filter [8].

Gas distributors based on the pulp and paper mill are irreplaceable and reliable, they are effectively used in unloading equipment when unloading raw wagons and containers. A diagram of such a device is shown in Figure 1.

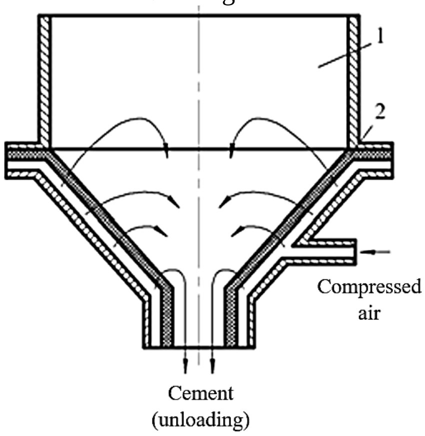

Figure 2. Diagram of the unloading device: 1 - container; 2 - gas distribution baffle made of porous powder materials

These materials are widely used for aerating liquid media for mixing and gas saturation. In this case, the gas is supplied through the porous wall, which is in direct contact with the liquid. The bubbles emerging from the wall come into contact with the liquid, developing the surface of gas-liquid phase interactions and enhancing the gas saturation process. The use of porous powder materials for these purposes not only significantly reduces the amount of air consumed to saturate water with oxygen, but also saves energy and time required for biochemical processes [2].

Aeration is used to saturate a liquid medium with atmospheric oxygen. This is necessary to ensure the viability of aerobic microorganisms, which microbiologically synthesize bioactive substances necessary for biological treatment and the production of domestic and industrial wastewater. From enzymes used in the biochemical process of breaking down starch molecules to form alcohol. The most common is pneumatic aeration. It uses a porous aerator placed in the liquid to be treated to split the gas stream into smaller bubbles. Porous aerators of various designs are made from permeable materials in the form of perforated or porous sheets and pipes, as well as fabrics, polymers and ceramic materials. However, porous powder materials are superior to other materials in terms of corrosion resistance, long-term strength, reproducibility and coating performance. Aerators for porous powder materials are available in two main types: tubular and disc. They are made from titanium powder, corrosion-resistant steel and bronze [7].

The disc aerator scheme is shown in Figure 3.

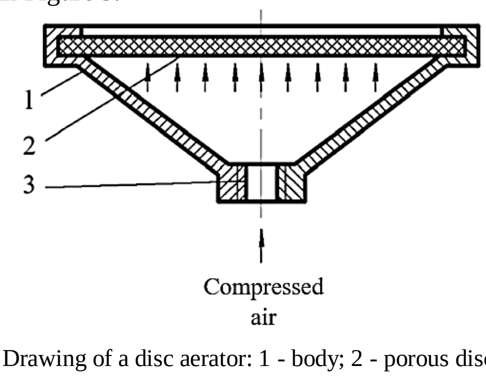

Figure 3. Drawing of a disc aerator: 1 - body; 2 - porous disc; 3 – fitting

A porous powder filter is used to protect objects from heat. As a result, the heat carrier (gas or liquid) passes through the porous powder materials and reaches the protected surface. Cold zones are created on the protected surface. Such cooling is used in aviation, space and nuclear technology (for example, to protect combustion chambers and walls of jet engines, spacecraft returning to Earth, walls of MHD generators, electric arc gas heaters, etc.). For this reason, pseudo alloys are promising. Refractory frameworks can retain the required strength properties at high temperatures. Copper improves the ductility and workability of the material, and also improves its thermal conductivity [10]. Cooling of freshly formed synthetic threads in the chemical industry is carried out in a similar way (Fig. 3).

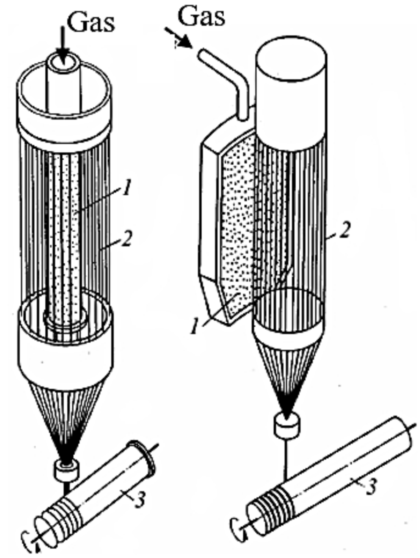

Figure 4. Constructive options for cooling using porous powder materials in the technology of producing synthetic fibers with tubular (a) and plate elements (b): 1 - porous element; 2 - threads; 3 - coil

In practice, heating of porous powder materials is also used (for example, to remove ice from aircraft). In this case, heated air is supplied through a porous plate on the leading edge of the wing or tail of the aircraft.

In industry (chemical, oil refining, gas), the process of contacting gas with solid dispersed material in a fluidized bed or fluidized bed is widely used.

A fluidized bed (CS) is formed when a gas stream passes between the catalyst particles at a speed sufficient to suspend the catalyst particles, causing a violent turbulent motion similar to the boiling of a liquid. The uniformity of degassing over the entire surface of porous powder materials makes it possible to simulate this process. Processes in combustors are also used in many areas of organic synthesis (production of alcohol, rubber, vinyl chloride), where gasification and combustion of fine fuels and catalytic cracking of oil take place.

The principle of creating lift by a flow of liquid or gas from porous powder materials is used in aero- or hydrostatic bearings, where there is no contact between surfaces.

Figure 5 shows a diagram of the operation of an air cushion bearing. The purity of the air that creates the air cushion is ensured by four filters made of stainless steel PPX18H10. Such bearings are used in computing devices and instruments.

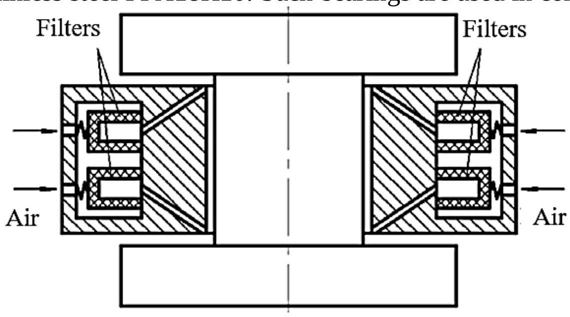

Figure 4. Scheme of operation of a bearing on an air cushion

Porous powder materials are successfully used in mixers to obtain gas-liquid mixtures (Fig. 5). Such mixers are used in liquid propellant rocket engines to carbonate fuel before it is injected into the combustion chamber.

Filtration of porous powder materials, which operates in critical transient filtration modes, is used in flame arresters and active mufflers.

Flame arresters are used to detect flame propagation (acetylene-oxygen and hydrogen-oxygen) in the production of our own equipment, gas analyzers, explosive equipment for protective coatings and explosion-proof electrical equipment. The flame arrester is made of titanium powder. Bronze in the form of stainless steel, nickel, tubes, glass and discs. As a rule, they are installed at the outlets of cylinders and ramp reducers, as well as at the inlets of gas burners. The most popular are mufflers made of various bronze powders [5].

Capillary-porous porous powder materials. The scope of application of capillary-porous porous powder materials in modern technology is expanding in connection with the improvement of the processes of heat and mass transfer of machines and equipment.

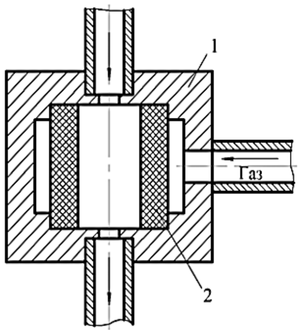

Figure 6. Mixer diagram: 1 - body; 2 - porous element

One of the most effective ways of cooling (heating) various devices is to implement an evaporation-condensation cycle in a closed space installed in a heat pipe as shown in Figure 7 [5].

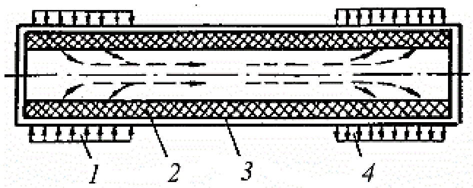

Figure 7. Heat pipe diagram: 1 - evaporator; 2 - capillary structure; 3 - body; 4 – capacitor

Such pipes are sealed casings from which non-condensable gases are removed. The inner surface of the housing has a porous capillary structure saturated with a liquid heat carrier. During the operation of the heat pipe, the supplied heat is transferred to the capillary porous structure due to the thermal conductivity of the wall, and the heat is supplied to the gas-liquid interface due to thermal conductivity or convection. Evaporation will occur. Steam enters the cooled part of the pipe, where it condenses at the interface for subcooling. The condensate formed under the action of the capillary force returns to the evaporation zone through the capillary porous structure. In such a system, the latent heat of vaporization is transferred, so that the heat pipe can transfer a large heat flux, and the small vapor pressure gradient reduces the temperature difference between the evaporator and the condenser. The effective thermal conductivity of heat pipes is several orders of magnitude higher than that of silver, one of the best heat conductors.

In addition to high efficiency of heat transfer, heat pipes have other advantages (no mechanical elements or additional energy, relatively ease of manufacture and operation, high reliability and efficiency), due to the successful combination of heat characteristics, heat pipes occupy a leading position in heating technology.

Heatpipe heatsinks are used to cool tablet power semiconductors, uninterruptible power supplies for continuous production, power plants for controlling nuclear power plants, mining and processing plants, and power supplies for electrical circuits. This reduces the overall dimensions of the cooling device (by 15%) and its weight (by 30%). Having the same thermal load as the cooling power semiconductor devices simplifies the design of the converter and reduces the manufacturing cost of these devices.

Heat pipes are used as an element of air heat exchangers for cooling high voltage power cabinets. Mounted on the rear of the power cabinet, the heat exchanger (Figure 8) is a tube plate with heat pipes located in 13 rows of hot (B) and cold (A) circuits. It is closed by a housing cover [8].

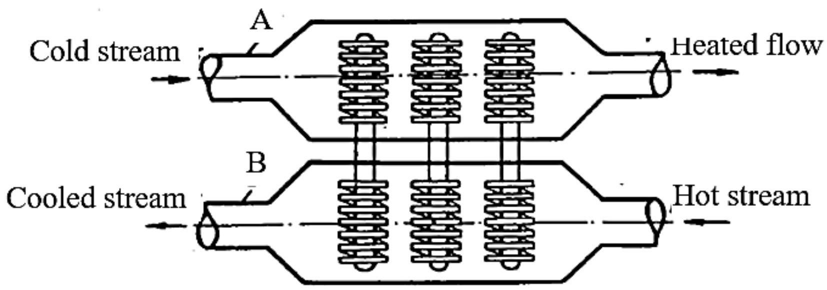

Figure 7. Diagram of an air-to-air heat exchanger

When the heat exchanger is in operation, hot air with a temperature thout is supplied from the cabinet to circuit B. Passing through it, the air cools down to a temperature t^g_{out} of thout and enters the cabinet again. Cold air from the environment with a temperature t^g_{in} thir is supplied to circuit A, passing through which it takes heat from the heat pipes and is released into the environment. In this case, the average volume overheating in the cabinet, depending on the power to be removed, is reduced by 15 ... 28% in comparison with the used plate heat exchangers.

Flat heat pipes are promising designs used for cooling and thermal stabilization of electronic equipment modules.

Saving energy through a more complete use of the consumed heat in recent years has become more important. Heat pipes are used to recover the heat of flue gases from grain dryers and heat generators. So, a heat exchanger with dimensions 400 × 1500 × 2000 mm, containing 200 heat pipes 2000 mm long, allows you to utilize the heat of the drying agent of recirculating grain dryers with a capacity of 50 kW, designed for drying grain, seeds and other bulk materials in agriculture and the food industry. The heat exchanger makes it possible to utilize the spent coolant emitted into the atmosphere through the exhaust windows of sediment chambers and cyclones, which has a sufficiently high heat content (50 ... 70 ° C) due to its high humidity. This achieves a decrease in fuel consumption (by 25.6%) and moisture content of the spent drying agent (2 ... 3 times).

When utilizing the heat of flue gases from domestic heating boilers using a heat exchanger of 18 heat pipes 360 mm long, significant fuel savings (more than 10%) are achieved.

Heat pipes are also used in electric machines for cooling rotors and stators of motors, generators, in welding equipment for cooling electrodes, transformer windings, high-voltage switches of high power, as well as for cooling molds for plastic molding, for stamping glass and plastic dishes, casting aluminum parts.

Evaporative cooling is one of the most effective ways to cool high-temperature components and mechanisms. It involves the supply of liquid to the cooling zone under the action of capillary forces. It should be noted that evaporative cooling is more efficient than convective or film cooling in equivalent systems. Evaporative cooling in porous heat exchangers is a reliable means of thermal regulation of the elements of the fuel systems of engines, preventing overheating of the fuel tanks. In this case, both a special liquid and cryogenic fuel can be used as an evaporating liquid.

The use of porous powder materials as evaporators in carburetors of internal combustion engines enhances the evaporation of fuel, better homogenization of its mixture with air. As a result, fuel economy is achieved (8 ... 14%), the dynamic qualities of cars are preserved, the content of carbon monoxide in exhaust gases is reduced (by 30 ... 50%).

Porous evaporators compare favorably with other designs of heat exchangers in that they have no moving parts, have high performance, durability, have a small mass, and are easily restored after long-term operation. A diagram of the operation of evaporators used, for example, to cool the flow of hot gas is shown in Figure 9.

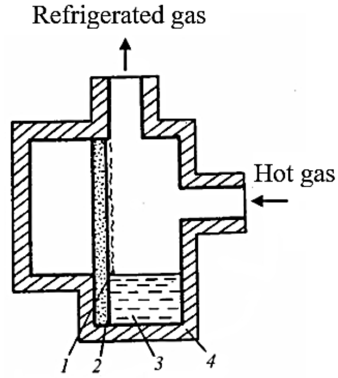

Figure 8. Evaporator for cooling the hot gas flow: 1 - steam; 2 - porous plate; 3- liquid; 4 - case

Here, the lower part of a vertically located porous plate is lowered into a container with an evaporating liquid, and the upper part is washed by a stream of hot gas. The liquid level in the reservoir is maintained automatically. The principle of evaporative cooling is used in devices designed to convert a liquid into a vapor state.

The function of porous powder materials, which absorbs fluid into pore channels by capillary force and retains it for a long period of time, is used in the manufacture of porous self-lubricating bearings. Period of normal operation. According to the same principle, jewelry is made from a porous material with a rich aroma, which retains a pleasant aroma for a long time. Soldering irons for soldering and disassembling wireless electronics are also made of porous capillary material.

Porous powder materials with special characteristics. Such materials are used in applied chemistry such as porous electrodes, chemical current sources (eg, porous electrodes for nickel-cadmium batteries, porous nickel plates for making alkaline batteries).

Porous electrodes are used in electrochemical generators (fuel cells) to directly convert the chemical energy of a fuel into electrical energy [10].

Porous materials are also used in medicine. They are used as surgical materials for bone replacement. These elements usually have a pore size of 10-500 microns and are made from titanium powder or corrosion-resistant steel. The presence of bifurcated networks of pore channels in such materials promotes the penetration of their bone tissue into the pores and transplantation into the human body.

The anode of bulk porous electric capacitors uses a porous powder material made of aluminum, niobium and tantalum powder.

There are many devices that regularly operate under water or under the influence of water jets. Gas evolution and gas accumulation during operation of these devices create unacceptably high pressure inside the structure, which can lead to deformation or destruction of the structure. A porous, semi-permeable membrane that prevents water from passing up to a certain pressure, while at the same time preventing water from entering the work equipment and providing sufficient gas permeability to remove accumulated gas. Also, from these materials, you can make street lamps with increased protection against water and dust, as well as lamps

Many methods called refining (IC production, physicochemical surface treatment of metals, chemicals, etc.) use hydrogen with a strictly limited oxygen content (less than 10-4% of the total). Required as a secure environment. Such ultra-high purity gases can be obtained using a two-layer membrane consisting of a permeable copper base and a layer of high density palladium deposited on top of it. However, in some technologies (for example, in the production of integrated circuits, crystal growth). Even the presence of copper particles and their ions is undesirable. In this case, porous powder materials made of corrosion-resistant steel powder are used as a substrate, on which a layer of a mixture of palladium and cobalt powders (15% by weight) is applied and sintered. Such two-layer membranes are successfully used for diffusion-catalytic purification of hydrogen from oxygen, and the residual oxygen content meets the requirements of ultra-high purity technology [9].

Porous powder materials are increasingly used in catalytic processes (for example, to obtain nitrogen-hydrogen mixtures by catalytic decomposition of ammonia) due to the surface development and increased capacity of materials with many deviations in the crystal structure.

The production of porous powder materials is constantly increasing due to the improvement of the technology for obtaining these materials and the expansion of their areas of application.

Conclusion

Therefore, a promising direction for improving heat treatment technology is the installation of heat treatment units in mechanical shops, the creation of automated lines that include heat treatment processes, and the development of methods that ensure growth. Possesses excellent strength characteristics, reliability and durability of parts.

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