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PRODUCTION OF METAL-CERAMIC COMPOSITE MATERIALS

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Abstract:
The article is dedicated to the production of blanks or products from metal powders characterized by the method of compaction or sintering; devices specially designed for this / self-propagating high-temperature synthesis or reaction sintering.

Keywords: *powder, metal-ceramic matrix, composite, production, pressing.*

Introduction

Metal powders were also used in ancient times. Powders of copper, silver, and gold have been used in paints for decorative purposes in ceramics, painting at all known times. During excavations, tools made of iron by the ancient Egyptians were found (3000 BC), the famous iron monument in Delhi dates back to 300 AD. Until the 19th century, there were no known methods of obtaining high temperatures (about 1600-1800 ^{0}C). These iron objects were made by the crying method: first, in furnaces at a temperature of 1000 ^{0}C, by reducing iron ore with coal, a Krista (sponge) was obtained, which was then repeatedly forged in a heated state, and the process was completed by heating in a furnace to reduce porosity. Other materials were also actively developed - friction, sealing, wear-resistant, magnetic, filter, tool, fiber, and dispersion-hardened. A number of materials manufactured by rolling methods have been created - current-removing plates, electrode tapes, bimetallic wire, and other bimetallic and trimetallic materials. A typical technology for the production of blanks by powder metallurgy includes four main operations: obtaining the powder of the starting material; molding of blanks; sintering; final processing. Each of these operations has a significant impact on the formation of the properties of the finished product. Theoretical, methodological, and practical issues of obtaining cermets are the subject of research by both domestic and foreign scientists. The relevance and insufficient degree of elaboration of the problem determined the purpose and objectives of the research work. The purpose of the work is to study the process of obtaining cermets. Tasks of the work: - to determine the essence and content of cermets; - to investigate ways of obtaining cermets. The object of research is the process of obtaining cermets. The theoretical and methodological basis of the study was the fundamental concepts and hypotheses presented in classical and modern world and domestic science on the problem under study. The empirical basis of the study was legislative and regulatory acts, the results of empirical studies conducted by Russian scientists.

Methods of obtaining and technological properties of powders

Metal ceramics, or powder metallurgy, is a branch of technology engaged in the production of metal powders and parts them. The essence of powder metallurgy is that blanks are pressed from a metal powder or a mixture of powders, which are then subjected to heat treatment - sintering. Powder metallurgy can produce parts from particularly refractory metals, from metals insoluble in each other (tungsten and copper, iron and lead, etc.), porous materials and parts made of them, parts consisting of two (bimetals) or several layers of various metals and alloys. Metal powders consist of very small particles (0.5-500 microns) of various metals and their oxides. Powders are obtained mechanically and physicochemically. Ball mills, vibrating mills, and runners are used for the mechanical grinding of hard and brittle materials. Powders from ductile and low-melting metals and alloys are obtained by various methods based on blowing up a liquid material with a jet of water or gas. Powders are usually obtained mechanically from the waste of the main production [1]. The Physico-chemical methods of obtaining powders include the reduction of metal oxides, electrolysis, etc. Metal oxides can be reduced by gaseous or solid reducing agents. Gaseous carbonaceous and hydrocarbon compounds (natural gas, blast furnace gas, carbon dioxide) and hydrogen have found the greatest practical application. By electrolysis of aqueous solutions of salts, thin and pure powders of various metals and alloys are obtained. Powders from rare metals (tantalum, zirconium, titanium, etc.) are obtained by electrolysis of molten salts. The modes and technology of manufacturing powders by Physico-chemical means are given in the reference literature. The main technological properties of powders are fluidity, compressibility, and sinterability. Fluidity is the ability of a powder to fill a mold. Fluidity deteriorates with a decrease in the size of powder particles and an increase in humidity. A quantitative assessment of the fluidity is the rate of outflow of powder through a hole with a diameter of 1.5-4.0 mm per second. Compressibility is characterized by the ability of the powder to compact under the influence of an external load and the adhesion strength of the particles after pressing. The compressibility of the powder depends on the plasticity of the particle material, its size, and shape and increases with the introduction of surfactants into its composition. Sinterability is understood as the adhesion strength of particles as a result of the heat treatment of pressed blanks. Powder metallurgy finds the widest application for various working conditions of product parts. Powder metallurgy methods produce products with special properties: antifriction parts by the friction unit of devices and machines (bushings, inserts, support washers, etc.), structural parts (gears, cams, etc.), friction parts, tool materials (cutters, cutter plates, drills, etc.), electrical parts (contacts, magnets, ferrites, electric brushes, etc.) for electronic and radio engineering industry, composite (heat-resistant, etc.) materials [2]. The main advantage of using powder metallurgy: reduces the cost of further machining, which can be eliminated or significantly reduced. Gets the finished product accurate in shape and size. Ensures high quality of the product surface. uses energy and resource-saving technologies. Reduces the number of operations in the technological chain of product manufacturing. Uses more than 97% of the starting raw materials. Implements many subsequent assembly stages even at the sintering stage. allows obtaining products with unique properties using multicomponent mixtures, combining metal and non-metal components. Products of different porosity (filters) with adjustable permeability; Sliding bearings with self-lubricating effect. it obtains higher economic, technical, and operational characteristics of products in comparison with traditional technologies. it often simplifies the manufacture of products of complex shapes. provides precision manufacturing. Matching sizes in a series of products.

Metal-ceramic materials

Powder metallurgy produces various structural materials for the manufacture of blanks and finished parts. Materials with special properties are widely used. Sliding bearings for various industries are manufactured from antifriction metal-ceramic materials. In antifriction materials with a porosity of 10-35%, the metal base is a solid component, and the pores filled with oil, graphite, or plastic act as a soft component. Oil-soaked porous bearings are able to work without additional lubrication for several months, and bearings with special "pockets" for oil reserves - for 2-3 years. During the operation of the bearing, the oil heats up and is displaced from the pores, forming a lubricating film on the rubbing surfaces. Such bearings are widely used in machines for the food industry, where the ingress of grease into products is unacceptable. For porous antifriction materials, iron-graphite, iron-copper-graphite, bronze-graphite, aluminum-copper-graphite, and other compositions are used. The percentage composition of these compositions depends on the operational requirements imposed on the designs of parts. Friction materials are complex compositions based on copper or iron. The coefficient of friction can be increased by the addition of asbestos, carbides of refractory metals, and various oxides. Graphite or lead is introduced into the composition to reduce wear. Friction materials are usually used in the form of bimetallic elements consisting of a friction layer sintered under pressure with a base (tape or disk). The coefficient of friction on cast iron without lubrication for friction materials on an iron basis is 0.4-0.6. They are able to withstand temperatures in the friction zone up to 500-600 °C. Friction materials are used in brake assemblies and clutch assemblies (in aircraft, automotive, etc.). Filters and other parts are made from highly porous materials. Depending on the purpose, the filters are made of powders of corrosion-resistant steel, aluminum, titanium, bronze, and other materials with a porosity of up to 50%. Highly porous metal materials are obtained by sintering powders without pre-pressing or rolling them between rotating rolls in the production of porous tapes. Add substances that emit gases during sintering to the powders. Metal-ceramic hard alloys are characterized by high hardness, heat resistance, and wear resistance. Therefore, cutting and drilling tools are made of them, as well as applied to the surface of worn parts, etc. The basis for the manufacture of hard alloys are powders of carbides of refractory metals (WC, TiC, TaC). Cobalt is used as a binder. The percentage of these materials is chosen depending on their purpose, diamond-metal materials characterized by high cutting properties are manufactured by powder metallurgy. Metal powders (copper, nickel, etc.) or alloys are used as a binder for diamond powders. The highest hardness is characterized by materials made of boron carbides (elbor). Parts operating at high temperatures are made of heat-resistant and heat-resistant materials. These materials must have high heat resistance, resistance to creep, and oxidation. Metal alloys based on nickel, titanium, tantalum, tungsten, and other elements meet these requirements when working up to temperatures of 850-900 °C. At higher temperatures (up to 3000 °C), refractory and solid compounds such as oxides, carbides, borides, etc. can be used. However, these materials are highly brittle and therefore in their pure form cannot be used as structural materials for the manufacture of various parts [3, p.52]. The use of powder metallurgy makes it possible to increase the plasticity of these brittle refractory compounds. Metals and alloys, the heat resistance of which is close to the heat resistance of refractory compounds, are chosen as a metal bundle.

Production of metal-ceramic parts

The process of preparing the mixture consists of the classification of powders by particle size, mixing, and pretreatment.

Powders with particle sizes of 50 microns or more are divided into groups by sieving on sieves, and smaller powders are separated by air separation. Technological additives for various purposes are introduced into metal powders: plasticizers (paraffin, stearin, oleic acid, etc.), which facilitate the process of pressing and obtaining a high-quality workpiece; fusible additives that improve the sintering process, and various volatile substances to obtain parts with a given porosity. To increase the fluidity, the powder is sometimes pre-granulated. The prepared powders are mixed in ball mills, drum mills, and other mixing devices.

Preliminary mechanical or thermal treatment (for example, annealing) is used to improve the technological properties of powders.

Methods of forming blanks and parts

Blanks and parts made of metal powders are formed by pressing (cold, hot, hydrostatic) and rolling.

Cold pressing. A certain amount of prepared powder 3 is poured into mold 2 and pressed with punch 1 (Fig. 1, a). During the pressing process, the contact between the particles increases, porosity decreases, and individual particles are deformed or destroyed.

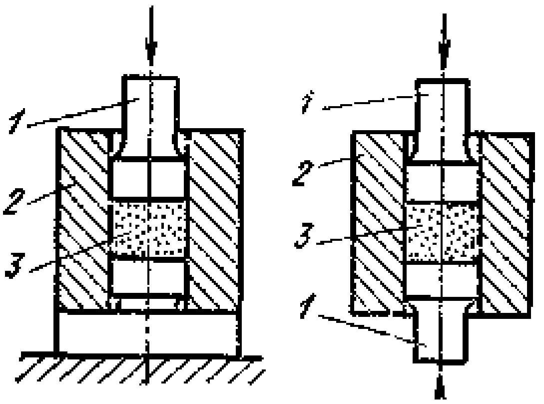

Fig.1. Cold pressing schemes: a – one-sided; b - two-sided

The strength of the resulting workpiece is provided by the forces of mechanical adhesion of powder particles, electrostatic forces of attraction, and friction. With increasing pressing pressure, the strength increases. The pressure is distributed unevenly along with the height of the pressed workpiece due to the influence of the friction forces of the powder on the walls of the mold. This is the reason for obtaining blanks with different strengths and porosity in height. Depending on the overall dimensions and complexity of the pressed blanks, single- and double-sided pressing is used.

By one-sided pressing (Fig. 1, a), blanks of a simple shape with a height-to-diameter ratio of less than one and blanks of the sleeve type with a diameter-to-wall thickness ratio of less than three are made, as a result of which a uniform density of the resulting blanks is ensured. Double-sided pressing (Fig.1, b) produces blanks of complex shape, while the required pressure to obtain a uniform density is reduced by 30-40%.

When the part is removed from the mold, its dimensions increase. The value of the elastic aftereffect in the direction of pressing is 0.3–0.5% and 0.1–0.2 – in the direction perpendicular to pressing. This must be taken into account when calculating the executive dimensions of the molds.

The pressing pressure is 200-1000 MPa, depending on the required density, size, shape of the pressed part, type of pressed powder, and other factors. The use of vibration pressing allows you to dramatically (50-100 times) reduce the required pressure. The working parts of the molds were made of high-alloy, tool steels, and hard alloys.

Hot pressing. With such pressing, the processes of forming and sintering the workpiece are technologically combined in order to obtain a finished part. Hot pressing produces parts made of hard alloys and special heat-resistant materials. The manufactured parts are characterized by high strength, density, and uniformity of the material. Graphite molds are used for hot pressing. The high temperature of the powder allows you to significantly reduce the required pressure. Hot pressing also has significant disadvantages: low productivity, low resistance of molds (4-7 compressions), and the need for processes in the environment of protective gases, which limit the use of this method.

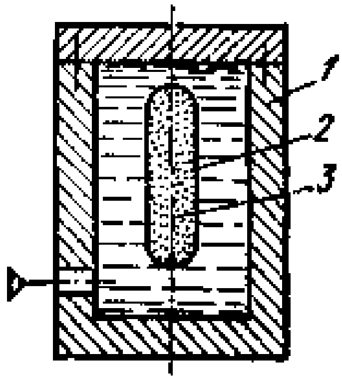

Fig.2. Scheme of hydrostatic pressing

Hydrostatic pressing. This pressing is used to produce metal-ceramic blanks, which do not have high accuracy requirements. The essence of the process is that powder 3, enclosed in an elastic rubber or metal shell 2, is subjected to uniform and comprehensive compression in special sealed chambers 1 (Fig.2). The liquid pressure reaches 3000 MPa, which ensures the production of blanks of high strength and density. With hydrostatic pressing, there is no need to use expensive molds. The overall dimensions of the manufactured workpieces depend on the design of the sealed chamber.

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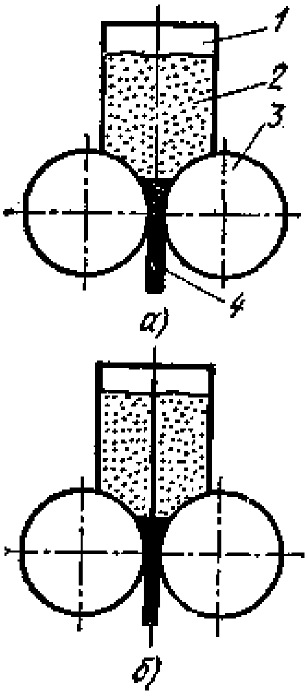

Fig.3. Powder rolling scheme

Extrusion. Rods, pipes, and profiles of various cross-sections are manufactured in this way. The process of obtaining blanks It consists in squeezing the powder through the combined opening of the mold. A plasticizer is added to the powder up to 10-12% of the powder weight, which improves the process of joining the particles and reduces the friction of the powder against the walls of the mold. The profile of the manufactured part depends on the shape of the calibrated opening of the mold. Hollow profiles are performed using a divider. Metal-ceramic profiles are obtained by extrusion on hydraulic and mechanical presses.

Rolling. This method is one of the most productive and promising ways of processing metal-ceramic materials. The powder continuously flows from hopper 1 into the gap between the rolls (Fig.3, a). When the rolls 3 rotate, the powder 2 is compressed and extracted into a tape or strip 4 of a certain thickness. The rolling process can be combined with sintering and final processing of the resulting blanks. In this case, the tape passes through a pass-through sintering furnace, and then enters the rolling machine, which provides its specified thickness.

By rolling, tapes are made of various metal-ceramic materials (porous, carbide, friction, etc.). Due to the use of bunkers with a partition (Fig.3, b), tapes are made of various materials (two-layer).

Metal powders are rolled into strips with a thickness of 0.02–3.0 mm and a width of up to 300 mm. The use of rolls of a certain shape makes it possible to obtain bars of various profiles, including wire with a diameter from 0.25 mm to several millimeters.

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