EasyChair Preprint

№ 4711

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December 7, 2020

(Preprint) AAS 17-183

SYNTHESIS OF LOW-TEMPERATURE POWDER MATERIALS FOR SPACE INDUSTRY

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Statistics show that more than 80% of machines and mechanisms fail as a result of wear of friction parts. Parts of rubbing pairs made of known materials do not meet the requirements of reliability and durability, which hinders the improvement of technology. There are the following ways to solve this problem: creation of new promising materials by powder metallurgy; creation of new anti-friction wear-resistant materials and polymer-based coatings; creation of new lubricants. The work shows the relevance of the development of antifriction materials by powder metallurgy. The obtained antifriction material is described for operation under ordinary conditions, in river or sea water, inert gas and / or high vacuum, in aggressive environments, for the production of plain bearings, gears, which includes a plasticizer consisting of a low-viscosity polar -active mineral oil, calcium soaps, and filler in the form of fine powders, as well as its properties and the method of its production.

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INTRODUCTION

Statistics show that more than 80% of machines and mechanisms fail as a result of wear of friction parts. Wear is in direct proportion to the speeds, loads, capacities and operating conditions of the machines. Parts of rubbing pairs made of known materials do not meet the requirements of reliability and durability, which prevents the improvement of technology[1,2].

There are the following ways to solve this problem[3]:

1. Creation of new promising materials by powder metallurgy;

2. Creation of new anti-friction wear-resistant materials and coatings on a polymer basis;

3. Creation of new lubricants;

The range of materials obtained by powder metallurgy is extremely diverse. To obtain powder materials, powders of almost all known metals and non-metals are used.

Composite materials of practically any composition are obtained by mixing powders.

For example, by this method, a non-scarce, heat-resistant material based on aluminum was obtained, strengthening it with oxide, pipes, strips, sheets, rods, forgings are made from this material.

The introduction of powders of refractory compounds into metals and alloys makes it possible to increase the physicochemical properties of the metal base at high temperatures.

The advantage of powder materials over the well-known technology of obtaining materials by melting and casting is the possibility of obtaining materials with a given porosity and permeability [4].

Powder filters are widely used in industry because they have significant advantages over filters made of cloth, paper and other organic materials and over ceramic filters. They are more durable, able to work at high and low temperatures, have uniform controlled porosity and good permeability. Filters made of powders are widely used to filter fuels and lubricants, various oils and resins, molten low-melting metals (sodium), acids, alkalis and other corrosive media, to clean the air in aircraft from dust.

The porous cooling principle is used in nozzle and turbine blades.

Porous materials have found applications as ionizers in ion-powered rockets. In these engines, a nuclear reactor generates electricity to ionize and accelerate propellant particles. Ion engines make it possible to obtain high flow rates of the working fluid with low fuel consumption and long-term operation. The thrust of such engines is small, and they can be used for propulsion in outer space. The purpose of this work was to analyze the research of antifriction materials and create products from antifriction material using powder metallurgy methods at low temperatures.

STATEMENT OF THE PROBLEM AND ANALYSIS OF STUDIES OF ANTIFRICTION MATERIALS

It is known that approximately one third to one half of the world's energy resources are lost during their use due to friction. Losses of various materials for the replacement of worn-out machine parts and structural elements are just as large.

This problem is also typical of power engineering, where friction is the cause of bearing wear, which reduces the resource of thermal power plants, and also contributes to the rapid destruction and failure of sliding and breaking contacts. Sliding contacts provide continuous current switching between moving and stationary parts of electrical machines, apparatus and devices. Sliding contacts include, for example, the collector, rings and brushes in electrical machines, windings and sliders in rheostats and potentiometers. The operation of a large number of electrical devices (relays, contactors, switches) is based on the use of break contacts [5].

Therefore, knowledge and understanding of the laws of friction at the macro-, meso-, micro- and especially the nanoscale will allow predicting measures to reduce the wear of machine parts and increase their service life.

In modern tribology, it is customary to distinguish three areas, each of which has its own laws:

• macrotribology;

• microtribology;

• nanotribology.

Macrotribology deals with large objects and does not consider the structural features of matter. The task of nanotribology is to explain friction at the level of interaction of individual atoms. Microtribology studies friction at the micro level.

In macrotribology, it is believed that the geometric contact area of two bodies is equal to the real contact area at the atomic level. Of course, this is some approximation, since in fact, even the smoothest surfaces on a smaller scale are uneven, and the actual contact between the two bodies occurs over a much smaller area - only the protruding parts are in contact.

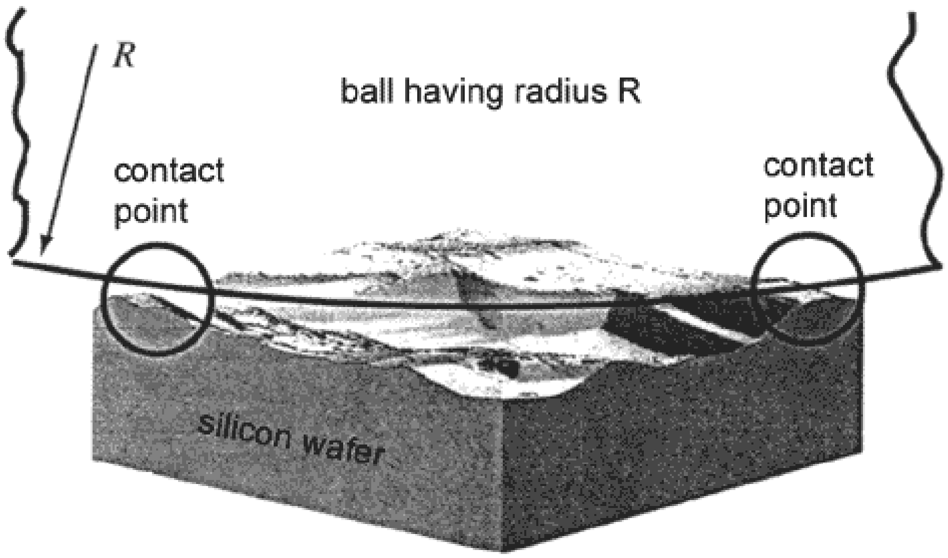

Figure 1. Contact at the macroscale of a ball and a silicon wafer [5].

A macro-scale contact is a set of micro-contacts (Fig. 1). Macroscopic friction force is the average microscopic friction force of individual microcontacts, which can vary greatly.

Friction is a dissipative force. When surfaces slide against each other, mechanical energy dissipates.

The most important problem of the aviation, automotive and power engineering industries is the creation of antifriction materials capable of operating without lubrication, since the rejection of it greatly simplifies the design of machines, facilitates their maintenance and increases the reliability of operation.

The first powder antifriction materials were: porous iron, porous iron-graphite, porous bronze and bronze-graphite, and now they successfully compete with cast antifriction materials such as bronzes and babbits [6,7,8,9,10]. For example, the coefficient of friction of powder bearings is lower than that of some babbitt alloys, and they hardly wear out the shaft journals.

Manufacturing technology of porous bearings differs from cast technology in that it is extremely simple. It consists of mixing powders, forming bushings or liners, sintering, oil impregnation and machining by sizing or cutting. Raw materials for making powder bearings are cheaper and less scarce than for making bearings by casting. The mechanical properties of such bearings vary within wide limits, changing the porosity, the amount of graphite, the structure of the initial powders, and the sintering conditions.

Turbine and instrumentation, aircraft and rocketry require bearing materials that operate at high temperatures and without lubrication. The main requirement for them is their resistance to oxidation at high temperatures, high antifriction properties and stability of the physicochemical properties of the material. Materials with such properties are obtained on the basis of iron with a high content of graphite and sulfides.

The difficulty in creating metal-graphite materials with a high graphite content is to provide a strong bond between the metal and the graphite particles. When creating an iron-graphite material, additives of metals such as chromium, calcium, magnesium, barium have a positive effect on the bond between the metal and graphite, which, during sintering, reduce the surface energy at the graphite-liquid metal interface. By introducing such additives, it is possible to produce materials containing up to 90% by volume graphite.

Materials of the metal fluoroplast type are of particular interest. Fluoroplastic has a low coefficient of friction when operating without lubrication (0.05-0.10), high chemical resistance and good running-in properties, and it can operate at temperatures of +250 and –250 C.

In addition to porous materials, compact powder antifriction layers applied on strong cast bases, which include bimetallic and trimetallic liners, have also found wide application.

For example, recently, valve guides for internal combustion engines have been manufactured from brass with a large amount of graphite. These bushings work over 500 hours without lubrication at 430 C, while cast bushings work under these conditions no more than 50-75 hours.

For the first time, powder materials obtained by a metallurgical method were used to solve problems in electrical engineering. Currently, powder metallurgy methods are used to produce semi-finished products and products for oscillator and electronic lamps, a very wide range of contact materials, resistances, conductive and semiconductor materials with various characteristics.

Generally, powder materials are used in break and sliding contact assemblies designed for periodic closing and opening of an electrical circuit under various conditions. The contacts are manufactured for low, medium and high currents. Powerful circuit breakers must be capable of breaking tens of thousands of amperes at a voltage of several kilovolts. The material of the contacts should be characterized by low specific and contact electrical resistance, insignificant erosion of contacts, lack of weldability during closing and opening, thermal, chemical resistance and high strength, thermal conductivity.

Contact materials include tungsten, silver, molybdenum, copper, nickel and other metals, but none of them combine the properties required for a good contact material.

Powder metallurgy makes it possible to create compositions in which all the properties required for a contact material can be summarized.

In some cases, powder contact products have no competitors at all. For example, only with the use of powder materials in arc suppression devices and other structural elements of powerful oil, air and vacuum switches did it become possible to switch currents with a capacity of millions of volt-amperes on transmission lines.

Materials for sliding contacts can be divided into three groups: for electric motor collectors, for electric brushes, and for motors of rheostats, rectifiers, potentiometers, current collectors, etc. The wear of powdered copper collectors is lower than that of traditional copper; in addition, with a powder collector, brush wear is reduced.

Metal-graphite electrical materials are manufactured exclusively by powder metallurgy. The graphite included in the material protects the parts in sliding contact from adhesion of the rotor metal and welding under the influence of adhesion forces, especially at elevated temperatures and sparks, reduces the oxidizability of the base metal, reduces the coefficient of friction and material wear of both the part itself and the part with it in contact with.

Sliding contacts are widely used to supply current to electric train and trolleybus motors. They have completely replaced the contact rollers previously used in trolleybuses.

The contacts based on tungsten carbide are especially resistant to erosion during the formation of a volt arc. In addition to tungsten carbide, they contain cobalt, octium or noble metals as a binder. The use of tungsten carbide contacts in telegraph relays has increased the transmission rate from 140 to 700 characters per minute.

From the above, it follows that all powder materials are obtained mainly by a high-temperature and energy-intensive metallurgical method, which leads to a change in the structure of the powders and, ultimately, the powder material itself. Therefore, it is time to pay close attention to the creation of powder materials at low temperatures.

Low-temperature methods for the synthesis of powder materials include the creation of materials based on organic and inorganic polymers with a molecular weight of 10,000 to several million and the use of various binders.

A large number of thermoplastic and thermosetting polymers have been synthesized, studied and described. Many of them are of particular interest from the point of view of their use as a binder for the production of antifriction materials or coatings.

For example, a new method of producing antifrictional filled polymer materials with low-temperature polyesterification in the presence of a heterogeneous matrix – antifrictional filler is considered. Comparative analysis of frictional properties of coatings prepared from a polymer filled in with graphite is given[11]. Or using Sol-gel technology[12].

EQUIPMENT, RESULTS AND DISCUSSION

For our work we used equipment for hot pressing.

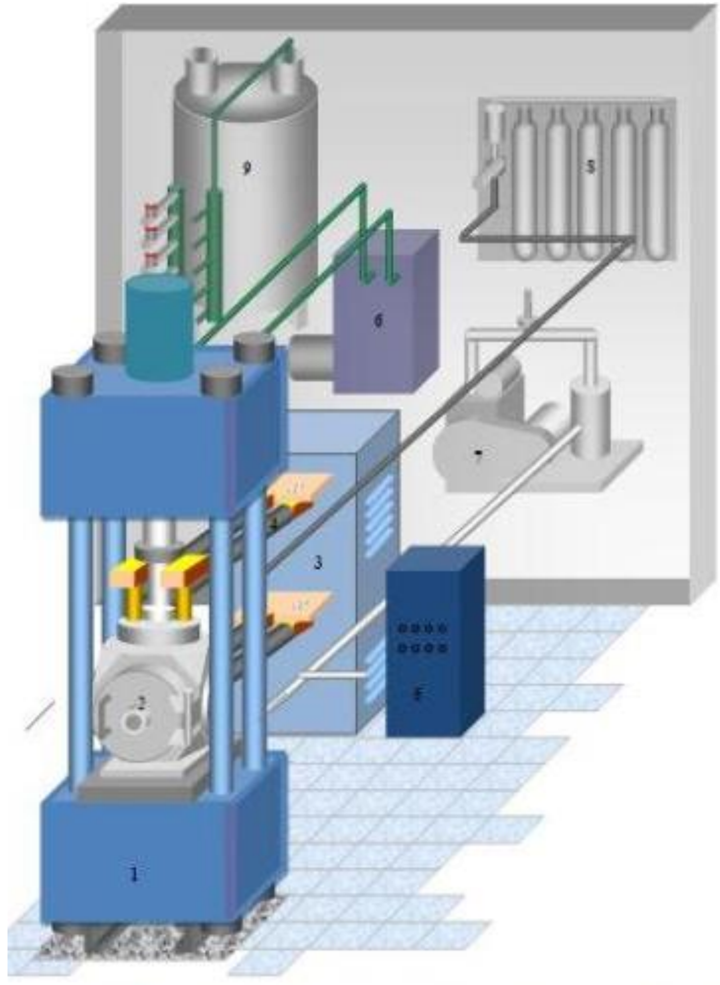

Figure 2. Diagram of a hydraulic press for hot pressing.

Hot pressing is performed on special hydraulic presses with devices for temperature control during pressing (Fig. 2).

The main units of the installation are: a hydraulic press (1), providing a pressing force of 120 tf, a vacuum chamber (2) made of stainless steel with built-in copper shoes, a power source (3) designed to heat the mold.

The chamber (2) is connected to the power source (3) by flexible copper water-cooled current leads (4). The power supply power regulation, as well as the control of all plant systems, is carried out using the electrical cabinet (5). The operation of the press is provided by a hydraulic unit (6), which is equipped with three pumps: idle, working stroke and control pressure.

The chamber is evacuated by a vacuum system (7), the working vacuum is ~ 1 Pa (in the cold state). The filling of the working gas into the chamber and the control of the working medium inside the chamber is provided by the gas supply system (8). The water-cooling system (9) is designed to cool the power supply rectifier, the walls of the vacuum chamber, flexible current leads and copper shoes.

Figure 3. Press PG-20.

Figure 3. A set of molds.

For work, we used a PG-20 press, which is shown in Fig. 3. and a set of molds shown in fig. 4.

Using equipment for hot pressing, we have created an antifriction material that includes a plasticizer consisting of a low-viscosity polar-active mineral oil, calcium soaps, and a filler in the form of fine powders.

This material is produced by hot pressing in molds but at a significantly lower temperature than in the conditions of powder metallurgy. The lubricant is in the material in a bound state, and certain conditions are required for its release, however, even in this case, the lubricant is not squeezed out, but sweats out on the surface in very small quantities, which are enough to create boundary lubrication. This material has a very low coefficient of friction. high viscosity fluid is the best lubricant. That can be explained by the fact that the higher the viscosity, the slower the process of extrusion or sweating. More strictly, in the case of boundary friction, it is not so much the viscosity of the lubricant that is important as the length of the lubricant molecules: the longer the molecule, the more atoms it holds on to the substrate and the more difficult it is to remove it from the contact zone[13]. In some systems, however, the dependence of viscosity on the length of the lubricant molecules may be non-monotonic. The idea of using the advantages of rolling friction when using spherical C60 molecules (fullerenes) as a lubricant is also interesting [14,15] – as is well known, in a macroscopic system, the rolling friction coefficient is 102–103 times lower than sliding friction, which will be studied in subsequent works.

CONCLUSION

A material has been developed from powders based on a polymer binder for operation under normal conditions, in river or sea water, in inert gases and high vacuum, in aggressive environments. Various friction parts are made from it, including plain bearing shells, gear wheels, etc.

Antifriction materials based on polyimides for work in high vacuum have been created. Its compressive strength is higher than 200 mPa, the operating temperature reaches 500 C, the coefficient of friction on steel in high vacuum is 0.015-0.020. In such conditions, the material has practically no wear.

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