ISSN 0002-306X Изв. НАН РА и ГИУА. Сер. ТН. 2007. Т. LX, № 1.

UDC 621.762.4.016:539.389.2 MATERIOLOGRAPHY

S.G. AGHBALYAN, A.M. STEPANYAN, A.H. ZAKARYAN, A.A. PETROSYAN

TECHNOLOGICAL FUNDAMENTALS OF DEVELOPMENT OF COMPOSITE ANTIFRICTION MATERIALS WITH HIGH STRENGTH-TO-WEIGHT RATIO

Based on the carried out complex analysis the structural model of friction unit working under medium and high pressures and speeds and also the technological development fundamentals of antifriction aluminum material with high strength-to-weight ratio are worked out and according to it the model must have three-phase nonporous structure, and as a lubrication the molybdenum disulphide is recommended.

Keywords: friction, wearing and tearing, strength-to-weight ratio, heterogenic structure, hard phase, powder alloy, diffusion, film, antibody, lubrication, disulphide.

The present engineering development depends on working out such materials which can work at high working loads and speeds, at high and low temperatures, in chemical aggressive media, and also at limited and dry friction conditions.

As it is known [1 - 3], during the last years antifriction porous materials based on heavy and light metals of wide application, they could not work under high pressure (10 *MPa* and higher) and speeds (4...10 *m/s* and higher) conditions because of low strength and wear-resistance. It is conditioned by adhesion porous materials working under high loads, which appear during high speeds.

Adhesion is a result of antifriction coating wearing or forming oxide films, and in some cases imbibitions into the matrix. Often in the contact spot areas the temperature rises very high, which causes reduction of strength and wear resistance.

On the other hand, the friction and wearing are accompanied not only by elastic and plastic defonnation, but also with phase transformation in the blankets. It means efficacy of the work friction couples depends not only on the base structure, but also the secondary structure which appears in the friction area. As it can be seen, the positive solution of the question is possible in the case, when the stable interrelationship will be made between base and the secondary structures, which will bring to reasonable management of the friction and wearing processes.

At the same time it must be mentioned that in present days the components which are used in space industries, shipbuilding, as well as machinery industry must have high strength and at the same time light weight. The correct choice of metals allows reducing the weight of components to the minimum by keeping the high value of strength. At this point, the special attention must be paid not only to the body components, but also the construction machinery, like antifriction bearings, which work with sleeve mechanism.

In this case material of matrix is important, which density must be as low as possible. The materials like that are aluminum and titanium. But the mentioned metals have low strength (aluminum σ_b = 50 MN/m^2 = 50 MPa = 5 kg/mm^2, and titanium- σ_b = 260 MN/m^2 = 260 MPa =26 kg/mm^2) and antifriction properties. On the other hand, these metals have adhesive behavior; it means that they can't work as friction bearings without additional alloying and heat treatment.

Special attention must be paid to aluminum alloys, because of low density and high strength-to-weight ratio. They are widely used in space industries, shipbuilding (especially in the submarines); and machinery industry. The main alloying elements of aluminum are copper, manganese, magnesium and silicon, which make with aluminum eutectic type state diagram (Fig. 1).

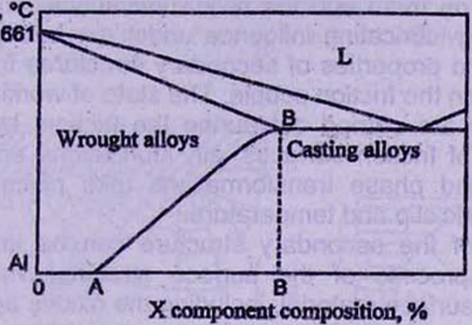

Fig 1. Aluminum double component alloys state diagram

As it is seen from the diagram, alloys lying between A and B points have a phase transformation in solid states so as the casting aluminum alloys (right from point B), can be strengthened by heat treatment, providing the necessary properties. But the mentioned properties, which can be obtained by hardening and tempering, can't provide the requirements of above-mentioned areas, it means they can't have high strength-to-weight ratio. This problem can be solved by complex alloying and strengthening with metal threads, which can be done by powder metallurgy technologies. Antifriction materials are based on aluminum, then the problem becomes more complicated.

It must be mentioned that powder metallurgy has important value and up to now it is one of perspective methods for getting the antifriction materials. Being developed in the Republic of Armenia, it raises new problems, especially in the direction of the engineering and under dry friction conditions the antifriction materials with high strength-to-weight ratio, are demanded very much for today's international market.

Dry lubrications are used in the case, when the usage of the liquid lubrications is not expedient or is not possible (refrigeration, space industries, shipbuilding, chemical and food industry, friction units of pumps, etc.). In this case liquid and plastic lubrications go out from friction surfaces and solidify, burn out.

Solid lubrications are graphite, metal sulphides, tellurides, fluorides iodides, and also the metals, which melting temperature is low, oxides and different salts (phosphates, sulphates, carbonates, etc.).

In the case when the factor of the temperature is not so important, the ability of friction unit material lubrication is defined mainly by the structure characteristics of materials (the type and size of lattice). Passing from light regimes to the medium regimes changes the influence of lubrication mechanism, which is accompanied by the activation of lubrication particles, by means of destructing the bondings in the lattice particle material. In this case lubrication influence decisive mechanisms will be both structural and adhesive.

Passing to the friction heavy conditions (during the increase to high speeds and loads) is accompanied by intensive deformation of powdery lubrication beds and the friction metal stratum, and also increase of temperature, which promots the chemical reaction and diffusion processes between the bearing and roller and also increase of influence on them and the solid lubrications. The chemically modified thin surfaces providing lubricating influence under the heavy regimes are formed. The characteristics and properties of secondary structures formed during the work have a serious effect on the friction couple. The state of working stratum are defined with processes which are carried out during the friction: by diffusion, adsorption processes, influence of friction surfaces' air, lubrications and other surroundings, etc. The structural and phase transformations take place, the activity strongly depending on the plastic slip and temperature.

The formation of the secondary structure can be imaged as a chemical-mechanical alloying process of the surface stratum, which includes disperse crumble up of friction surface material, including the oxides appearing as inclusions, graphite, intermetallides, etc. Under the influence of high temperatures and pressure in some phases of friction on the surfaces of friction couple the caking takes place and the new material, which is defined by characters and properties of disperse-strengthen materials is formed.

Based on the present-day theory of friction and wearing, the requirements of antifriction powder materials, and also the practical studies, the principles of wear and tear resistant powder materials development have been worked out, according to which:

1. The structure of the material must be heterogeneous and will consist of plastic matrix and uniformly allocated hard particles. In this case the load is influenced mainly by inclusions of hard phase, and in the matrix the relaxation of tensions takes place.
2. During the friction the structure of the material must not be transformed, and in case of transformation it will become a suitable structure from the point of view of friction and wear.
3. The surface stratum of friction materials must have lower value of strength, than the substrata.
4. The surface stratum must not be cold-hardening.
5. Under the influence of surroundings the structural changings must not take place, which will bring to worsening strength and plasticity characteristics.
6. The components which can work as a lubrication must be added to the material.
7. The adhesion bonding must exist between the structural components of the material.
8. The antifriction inclusions must not reduce the strength too much.
9. The friction coefficient of hard inclusions between themselves and the matrix must be the minimum.

In the area of triboengineering materialography we have made theoretical analyses and defined the friction couples, the relation between the composition and structure of antifriction materials. From the point of view of classical materialography and physics of friction as well as the increasing of wearing and tearing resistance and self- lubricating effective realization the powder materials with micro-heterogeneous structure are shown.

According to the above-mentioned, the aim of this work is to work out high-strength (with high strength-to-weight ratio) wear and tear resistant antifriction powder alloys based on aluminum, which will be able to work under limited and dry friction conditions, especially under medium and high loads and speeds.

For achieving the mentioned aim the principles of structural formation of powder materials have been worked out; according to it if two bodies are in contact, at the beginning because of asperities they contact not with whole surfaces, but with some parts of surface (Fig. 2).

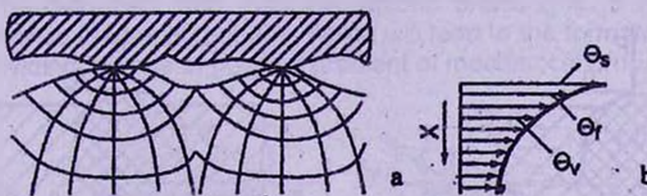

Fig. 2. The temperature field of surface stratum (a) and temperature distribution in depth of surface stratum (b) during friction

If these surfaces under outside loads are moving to each other, the main work is to carry out these asperities. In the contact zones great amount of energy is absorbed, by means of which the material can exist in any aggregative state (solid, liquid, gas). Therefore, in the contacts the mechanical, physical and chemical transformation increasing the intermolecular and interatomic forces can take place. After some time the perfect surfaces can be obtained and the process will be over. In this case the movement energy of solid bodies will be spent mainly for overcoming intermolecular forces. In some cases diffusion processes are non-excluded.

For planning or choosing the materials for friction units the friction coefficient and wearing as the main character is taken. As to outer load, slip speed, temperature, etc., they are taken as secondary factors. The friction unit will work normally, if the values of friction coefficient are not high, it means that the conditions for maximum reducing of influence on forces between friction surfaces are formed. In this case the wearing will be formed only by means of material fatigue because of the effective cyclic stresses; it means the potential abilities will be realized.

Take up possible working structures of materials, which will provide minimum values of friction coefficient and high wear and tear resistance during friction. Take material with double phase structure. In such models the first phase is matrix, which destination is to carry the outer loads after adaptation; the second is solid lubrication, which provides the formation of the secondary structure in the friction surface, reducing the friction coefficient. In Fig. 3 (a) the working schema of such material, and in Fig. 3 (b) its structure in stressed state are shown. Suppose that the deformations which are formed under outer forces must not exceed the limit of elasticity of the main phase. Besides, the material of antibody must be harder than the main phase, in order to pass wearing only due to antifriction material. According to the term, the second phase must consist of chemical compounds with anisotropic structure (Fig. 4).

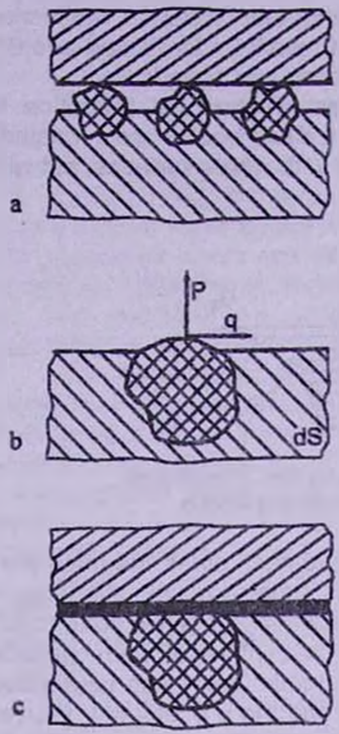

Fig. 3. The model of structure of three-phase material: (a) before work, (b) the schema of influence on outer loads, (c) during work

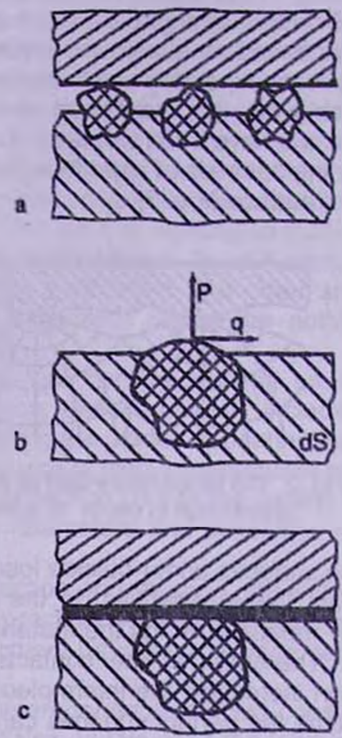

Fig. 4. Hexagonal structures during friction

During the friction in the working surfaces the films are formed because of the second phase (secondary structures), which provide the normal performance of friction unit under low value of friction coefficient, it means that it needs minimum energy consumption. Between friction materials residual deformations must not be formed, it means the untimely destruction of the surface film (secondary structure) must not take place. The wearing must be caused by fatigue of the matrix material.

As we can see, during the planning the antifriction materials with increased wear and tear resistant and minimum friction coefficient, it is necessary that the second phase is made from compounds with low resistance of slip (sulphides, selenides, phosphides, polymers, fusible metals, etc.). The first phase-matrix must have high strength, which can be reached by alloying.

The mentioned conditions include all main characteristics of wear and tear resistant antifriction powder materials, the principles of operation are that the second phase forms the film in the friction surface. It provides not only the low friction coefficient, but also forms in the working surface uniform allocation of load. In case of load exceeding the matrix limit of elasticity the plastic deformation takes place, as a result of which the film is terminated losing its antifriction properties. Therefore it is purposeful to use alloys with double phase structure for friction units which work under light and medium loads.

The aim of the next stage of studies is to work out the structural model for friction units which work under heavy conditions (heavy loads, speeds, dry and vacuum friction). In this case the outer load is taken by the third phase (Fig. 5(a)) which has maximum hardness, under which the influence of the base material particles will be deformed, and then the second phase (Fig. 5 (b)). The friction forces will influence the second phase, which will lead to the formation of secondary structures, providing the rule of positive gradient of mechanical properties.

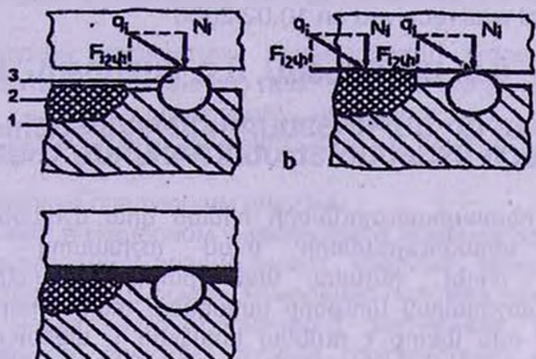

Fig. 5. The model of structure of three-phase material: (a) before, (b) after (c) during friction 1-first phase, 2-second phase, 3-third phase

In the friction units the tolerance values of outer loads depend on elastic deformations, and also on properties of matrix material, and on sizes and allocation of hard inclusions.

Deterioration of friction surfaces which are in contact with antibodies are conditioned by weariness of matrix caused by repeated cycles of elastic deformation.

The analysis shows that powder alloys will have high tribotechnical properties (f, J) if their structure provides the optimal correlation between properties of the first and the second phases, and also between capacities and sizes of the third phase. We showed that in case of low contents of solid lubrication (<15% volume) the film is formed not in all working surface. The excess content of lubrication (> 25% volume) has negative influence, reducing the physical-mechanical properties. It is defined by the experiences that the film thickness must be 0.1...0.2 *mkm*.

Based on carried out complex analysis the technological development fundamentals of antifriction aluminum material with high strength-to-weight ratio are worked out. The model must have three-phase nonporous structure, and as a lubrication the molybdenum disulphide is recommended.

The alloy can be developed both by traditional and powder metallurgy. During the last method nonporous structure can be provided by extrusion. It is expedient to use copper, nickel and silicon as an alloying element, and the formation of hard phase to provide with heat treatment (hardening and aging) is possible.

REFERENCES

1. **Fedorchenko I.M.** The problems of antifriction materials in the present engineering // Grinding and wear and tear resistance of metalloceramic materials.-Kiev: IPM AN USSR, 1966.-P.5-17.
2. **Fedorchenko I.M., Pugina L.I.** Composition composite extruded antifriction material.- Kiev: Nauka dumka, 1980.- 404 p.
3. **Zabolotniy L.V.** Allocation of tensions in composite antifriction materials // Powder metallurgy.-1979.- N11.-P.51-58.

SEUA. The material was received on 10.02.2006

Ս.Գ. ԱՂԲԱԼՅԱՆ, Ա.Մ. ՍՏԵՓԱՆՅԱՆ, Ա.Հ. ԶԱՔԱՐՅԱՆ, Ա.Ա. ՊԵՏՐՈՍՅԱՆ

ԲԱՐՁՐ ՏԵՍԱԿԱՐԱՐ ԱՄՐՈՒԹՅԱՄԲ ԿՈՄՊՈԶԻՏԱՅԻՆ ՀԱԿԱՇՓԱԿԱՆ ՆՅՈՒԹԵՐԻ ՍՏԱՑՄԱՆ ՏԵԽՆՈԼՈԳԻԱԿԱՆ ՀԻՄՈՒՆՔՆԵՐԸ

Համալիր հետազոտությունների հիման վրա մշակվել է միջին և բարձր ճնշումների ու արագությունների տակ աշխատող շփման հանգույցի կառուցվածքային մոդել, ինչպես նաև բարձր տեսակարար ամրությամբ ալյումինային հակաշփական նյութերի ստացման տեխնոլոգիական հիմունքները, որոնց համաձայն այն պետք է ունենա եռաֆազ և անծակոտկեն կառուցվածք: Որպես պինդ քսանյութ առաջարկվում է օգտագործել մոլիբդենի դիսուլֆիդ:

Առանցքային բառեր. շփում, մաշում, տեսակարար ամրություն, հետերոգեն կառուցվածք, կարծր ֆազ, փոշեհամաձուլվածք, դիֆուզիա, թաղանթ, հակամարմին, քսանյութ, դիսուլֆիդ:

С.Г. АГБАЛЯН, А.М. СТЕПАНЯН, А.А. ЗАКАРЯН, А.А. ПЕТРОСЯН

ТЕХНОЛОГИЧЕСКИЕ ОСНОВЫ ПОЛУЧЕНИЯ КОМПОЗИЦИОННЫХ АНТИФРИКЦИОННЫХ МАТЕРИАЛОВ С ВЫСОКИМИ УДЕЛЬНЫМИ ПРОЧНОСТЯМИ

Разработаны структурная модель антифрикционного узла, работающего при среднем и высоком давлениях и скоростях, а также технологические основы получения антифрикционных алюминиевых материалов с высокими удельными прочностями, на основании которых материал должен иметь трехфазную и беспористую структуры. В качестве твердых смазок предлагается использовать дисульфид молибдена.

Ключевые слова: трение, срабатывание, удельная прочность, гетерогенная структура, твердая фаза, порошковый сплав, диффузия, пленка, антитело, смазка, дисульфид.