

Research of lamellar lubricants mechanical-and-physical properties and structure

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Abstract. in the article ascertaining the applicability of lamellar solid lubricants is considered for the purpose of wear resistance increase of metal surface elements by their contact interaction in different operational conditions. Forms of binding in the structure of solid lubricants are described through the example of molybdenum disulfide MoS₂, as well as change properties at standard and high (350-480°C) exposure temperature. After solid lubricant application the additional treatment is made on the work surface of flanged wheels in the wheel set of a locomotive using plastic deformation for getting of multilevel micro relief resulting in working service increase of the wheel set in comparison with control set from 1.6 to 3 times.

1. Introduction

The large distribution, which was received last years by layered firm materials as lubrication substances, has involved in them attention of the researchers. However nowadays still there are no uniform reasonable representations about a nature of friction of layered lubrication

At the present it is impossible of the unequivocal and settling answer to a question that determines lubricant ability of layered film lubrication.

However already now it is possible to name some characteristics, common for materials with the brightly expressed lubrication ability.

To such characteristics it is possible to attribute the form of a crystal lattice; the form of surfaces of layers limiting a planes of sliding; a degree of heterogeneity of connections between atoms of a crystal lattice; size of work spent on splitting of a crystal of layered lubrication on a plane of sliding; high adhesion to metal surfaces.

The film layered materials having lubrication ability have in the majority a lattice hexagonal of a structural type.

2. Formulation of the problem

The layered structure is characteristic of all firm lubrication, with which the atoms which are taking place in one plane, are enough densely packed, and their crystal lattice consists of a number such mutually of parallel layers. In a lattice of graphite these unary layers consist of homogeneous atoms of carbon, in a lattice at of disulfides both diselenides of molybdenum and of tungsten there are threefold layers: the layers of atoms of molybdenum or of tungsten settle down between two layers of atoms of sulfur (disulfides) or between two layers of atoms selenium (selenides). In a lattice CdJ₂ the layer of



atoms cadmium settles down between two layers of atoms iodine.

The layered firm lubrication belong to a class so-called anisodesmal of connections, at which the relative durability of connections between atoms is sharply various in various directions [1]. This distinction is caused by that for anisodesmal of structures the sharp difference in internuclear distances is characteristic: shortest distance up to one — Three nearest atoms much more differs from the following on size of distance between similar atoms. For example, in a lattice of graphite distance between the nearest atoms of carbon in a layer is equal 1.42 \AA (shortest distance between atoms in parallel layers — 3.44 \AA).

In structure of firm lubrication two are usually combined such as connections: residual or Van—Der—Vaals connection with ion—covalent by a type of connection. So, in a crystal lattice MoS_2 the connection between atoms of sulfur located in parallel planes, is Van—Der—Vaals, and connection between atoms $\text{Mo} — \text{S} —$ covalent. The forces connecting atoms of carbon in one layer of a lattice of graphite, concern to covalent to connections, and interlayer of connection are connections of a metal type.

The durability of Van—Der—Vaals connection is extremely small; besides it back is proportional to the sixth degree of internuclear distance and in tens time more poorly purely ion of connection.

The presence of much weaker forces of connection between separate layers in comparison with similar forces inside layers is common for all materials with layered structure. In case of sharp anisodesmic of connections in a crystal, for example, such film layered lubrication, as sulphides both selenides of molybdenum and of tungsten, and also selenides niobium, under influence of external forces have sliding, i.e. Displacement of one blocks of a crystal concerning others in a plane, normal to a direction of action weakest of forces. At considered crystals this plane usually is a plane of cleavage.

So, in crystals of disulfides or diselenides the sliding occurs accordingly between parallel layers of atoms of sulfur or selenium, removed from each other on much large distances, than atoms of sulfur or selenium, located in one plane. The crystal structure of firm

layered lubrication though does not determine entirely their lubrication ability, however, essentially influences plasticity of a material and its behavior in conditions of friction. It proves to be true by existence of some correlation between factor of friction and parity of parameters of a crystal lattice. Last size (c/a) in any measure qualitatively reflects distinction of forces of connections between atoms located in a plane of shift and in a plane, perpendicular to it, and, hence, can characterize resistance to shift.

The mechanism of the considered phenomenon is not still completely opened, two possible processes — Diffusion and formation of electrical charges — Influence increase of energy of inteijunction — type connection of graphite and mica in vacuum.

In the first case the water steam contained in air, diffuse in depth of a firm body (mica or graphite) also influence forces of connection of these layered substances, as the molecules of water weaken ion of connection between atoms. In vacuum diffusion, which is directly proportional to a gradient of concentration of gas, is considerably reduced, so the influence of molecules water pair on connection practically is excluded. Therefore energy of connection of a crystal, which is characterized by size of work spent on its splitting, grows in some times.

According to the second assumption with splitting a crystal on planes of cleavage there are forces of an attraction between planes. On air this effect will be quickly neutralized by atoms of gases, adsorbed on planes of sliding. In ultra high vacuum this opportunity is almost excluded, as results in increase of work spent on splitting of a crystal in these conditions.

The hypothesis which is put forward by Bryant with the co—authors, deserves attention and requires experimental check with reference to such known and perspective layered lubrication, as sulphides and selenides of molybdenum, of tungsten, niobium.

From positions of this hypothesis it is good explainable behavior of graphite with friction on air and in vacuum with moderate temperature. In the latter case factor of friction of graphite grows up to 0.5 and above depending on a material counterspecimen and considerably surpasses factor of friction

on air. In the literature, accessible to us, there are no data on factor of friction of mica in vacuum, and consequently it is inconvenient to establish precisely, whether there is for mica, as well as for graphite, a correlation between size of work spent on splitting of a crystal on planes of cleavage, and factor of friction. However, if to compare factor of friction on air for latest splitting of a surface of mica, when the various pollution from air had no time (was in time) yet adsorbed onto surface of friction, with factor of friction of mica after long sliding on air, it is possible to notice the certain connection between the data of Bryant and by frictional behavior of mica. So, in the first case factor of friction achieved size 0.35, and in second — 0.48.

The works of Bryant with the co—authors represent interest in the respect that they show an inconsistency of a hypothesis “easy shear” on planes of cleavage, explaining good lubrication property of graphite on air proceeding only from its layered structure and ability it is easy to be splitted on planes of cleavage. The theoretical size of work spent on splitting of a crystal of graphite on planes of cleavage, as well as certain experimentally in vacuum is rather high that, specifies presence significant cohesion between planes of sliding of graphite.

Concerning the mechanism of lubrication action MoS_2 there are various assumptions and hypotheses. So, Johnson and Van in 1956 have put forward a hypothesis, according to which high lubrication ability and low factor of friction MoS_2 in vacuum are caused by formation during sliding a thin layer amorphous of sulfur having extremely low resistance of shear. The authors believed, that during friction MoS_2 occurs original «tribo—cracking», which result is formation free sulfur.

Against this hypothesis speaks, first, that fact, that factor of friction of sulfur on sulfur is much higher, than MoS_2 on MoS_2 , and also research on friction MoS_2 in ultra high vacuum and nitrogen executed by Haltner.

The special point of view on a nature of friction MoS_2 has stated Braiwaite, which considers, that the good lubrication properties MoS_2 are caused by its layered structure and ability to be stratified with heating arising at the expense of friction.

Agrees Braiwaite with friction MoS_2 on air there is its oxidation, thus will be formed as nonvolatile oxides of molybdenum (MoO_2 , MoO_3), and volatile oxide of sulfur SO_2 . With heating MoS_2 during friction the formed oxides of sulfur are liberated earlier. Last, as believes Braiwaite, considerably weakens connection between planes of sliding MoS_2 and by that provides their easy shift and low factor of friction.

Braiwaite has shown, that the partial oxidation of a powder MoS_2 at the presence of oxygen can occur with temperature 423 — 443 K. It connects lubrication ability MoS_2 to process of its oxidation with friction. It is impossible to consider reasons of Braiwaite rather convincing, as they are in the contradiction with results of experiments on friction MoS_2 in vacuum of the theory, executed in laboratory, of friction IES (institute of Engineering Science) and in USA by Haltner. The numerous tests, earned out by us, have shown, that with friction in high vacuum, where the opportunity of oxidation MoS_2 is shown up to a minimum, factor of friction it falls in comparison with air in 2 times and more than [2].

From various hypotheses and assumptions which have been put forward by the scientists for an explanation of the lubrication ability MoS_2 , most correct are the representations of Bryant with the co—authors in detail advanced by them with reference to graphite. Proceeding from these representations it is necessary to assume, that for splitting a crystal MoS_2 on planes of cleavage it is necessary to spend considerably smaller work, than in case of splitting a crystal of graphite.

As against graphite, which is a rather inert material. MoS_2 chemically is considerably more active. With friction MoS_2 on air its oxidation on separate sites of contact even is possible with temperature of the order 353 K. Such oxidation is considered as mechano—chemical reaction typical for juvenile of surfaces formed during oxidation. Oxidated the sites MoS_2 hydrophilic and easily are absorbed by water steam always contained in air.

The atoms of oxygen and water, adsorbed between layers MoS_2 , can become chemically connected, that will cause increase of resistance to shift along planes of sliding and as a consequence it growth of factor of friction. The study of kinetics of destruction films MoS_2 during friction on air [N =

5 kg (50 N), $v = 1.6$ m/s], executed with use electronic microscope and filming of a surface of friction, has allowed to establish, that the destruction of a film MoS_2 (earlier put on a metal surface by frictional a way) begins with formation on its surface of microswellings (size 400 \AA), which then are increased up to ~ 3 mm; the film under swellings becomes flat and flake. The authors consider, that such little bubbles will be formed on sites of concentration of pressure, as a result of which action arise fatigue of the phenomenon in superficial layers of a film MoS_2 and the chemical activity (interaction with a moisture and oxygen of air) amplifies. The combination of such processes results to fatigue to destruction of a film.

3. Theory

In work Savage is shown, that the efficiency of use of graphite as a lubricant material depends on presence water steam. Water and other exhalations, adsorbed on base planes, reduce factor of friction with 0.80 up to 0.18. The strong wear process named «pulverization», occurs in vacuum. Later was shown, that the graphite has rather strong interjunction — type connections. Pairs work as a lubricant material. These experiments were carried out with graphite cores sliding on copper, but film of graphite order how and with room temperature. The damp film provides factor of friction 0.12, which is reduced with its drying by heating. Such behavior confirms, that has a place infilm sliding model 4 tab. 1. The surfaces of graphite are greased with steam in the same way, as surfaces of diamond by a moisture, and metalin conditions of boundary friction — organic films.

These results have induced to research of influence of humidity on MoS_2 . It is revealed, that friction it is not enough in a dry atmosphere, however with growth of humidity is increased approximately by 85 %, and then is reduced. Growth of friction connect to presence of metal contacts through a film, while subsequent its reduction explain by chemical reactions between MoS_2 and surface of metal reducing metal contact. It was confirmed during the further researches. However friction grew even with low humidity and with absence of metal contacts.

Mataunaga [3] studied friction of spherical particles MoS_2 on steel and has received the following results. In a dry atmosphere the thin continuous film ensuring low meanings of factor of friction (0.15) and intensities of the wear process (2×10^{-6}) was formed. In a damp atmosphere factor of friction made 0.30, and intensity of wear process — 90×10^{-6} . These results similar received for graphite, confirm, that MoS_2 slides on MoS_2 , however adsorbed the moisture increases friction. Such increase of friction causes carry MoS_2 per itself in the form of separate fragments

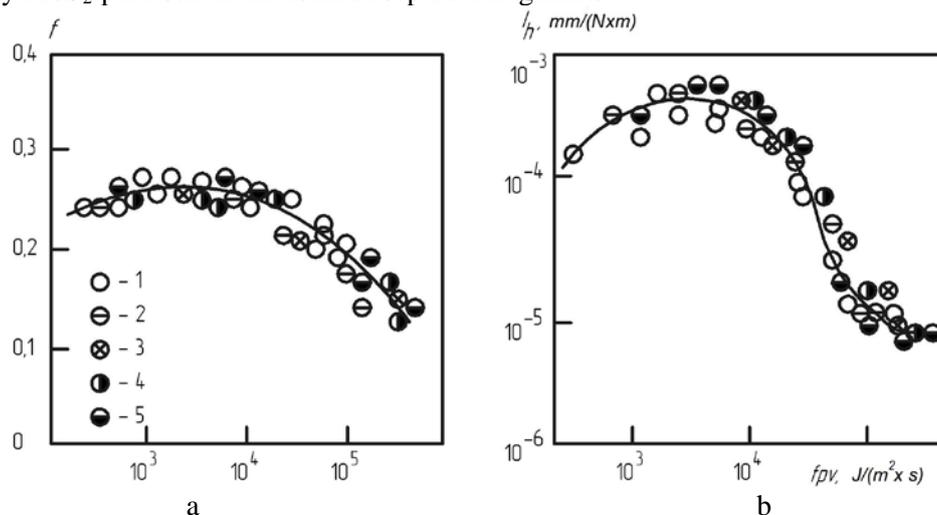


Figure 1. Influence of humidity of a film on factor of friction f (a) and intensity of wear process I_H (b) with contact pressure, MPa: 1 – 0.082; 2 – 0.165; 3 – 0.247; 4 – 0.330; 5 – 0.

4. Experimental results

The subsequent researches have shown, that features of sliding with higher loadings, speeds and temperatures same, as well as in a dry atmosphere. The increase of temperature of a film results in downturn of its humidity and reduces friction and deterioration. For example, in a Figure 1 the data, illustrating influence «predrying» of a film MoS₂ on friction and intensity of wear process are submitted. Haltner studied influence different steams on lubricant ability MoS₂ in vacuum. It has come to a conclusion, that the presence steams is not an obligatory condition of lubrication; with vacuum 1.3×10^{-7} Pa factor of friction was equalled 0.08. The increase of factor of friction fixed, with lower vacuum (1.3×10^{-4} Pa), coincides with the beginning of adsorbitive pollution of surfaces MoS₂. Thus, adsorbed of pair increase adhesion. Similarly layers of talc, connected by forces of Van—der—Vaals, at the presence of a moisture appear connected strongly, as their weak connections are replaced hydrogen.

Haltner investigated also behavior WS₂. With high vacuum 8.5×10^{-8} Pa factor of friction essentially did not depend on structure of environments and was equated approximately 0.17, however with low vacuum 1.3×10^{-3} Pa exhalation hydrocarbons (isoamyl alcohol) provided small friction ~ 0.09. Thus, exhalation of some organic substances grease layered structures, however pressure should be rather low, that could be formed of a strong film. The similar results are received for MoS₂ with research films, received by dispersion, and individual crystals [3]. Such behavior, first of all, testifies to an opportunity superficial of sliding, but thus it is necessary also to take into account chemical and physical effects. For example, anybody from the listed researchers did not consider, how exhalation can influence hardness of a film. The softer, the there should be a factor of friction more. Fleischauer has found out, that the chemical activity of a film is influenced also by its orientation. As have shown Johnston and Moore, it is quite possible, that the orientations of a film are promoted by humidity.

The stratification was studied some by the researchers. Bryant has measured interlayer cohesion of graphite in high vacuum and has found, that it makes 1.75×10^{-4} J/cm². It is higher the order, than appropriate size on air. The authors came to a conclusion, that MoS₂, talc and pirophyllite lubricant ability internally is inherent. These materials are easily stratified without influence of gas environments. For others of materials the presence steams is necessary, that they have displayed lubricant ability. A question in this connection is of interest, why talc it is much worse as lubrication, than MoS₂. The obvious answer consists that, first, it chemically is not linked to a surface. Mechanically it should be linked so well, as well as MoS₂, but the chemical reactions are not found out. Secondly, cohesion the durability of its film is lower. The experiment is of interest which would allow to find conditions or materials, for which talc would be an effective lubricant material. It would ensure essential progress in understanding of criterion of lubrication.

Mataunaga stratified individual crystals MoS₂ and has found out surplus of sulfur on planes of cleavage. Frictional of test the similar results have given. With sliding diamond on an individual crystal MoS₂ in a mode of faltering friction it is revealed, that the contents of sulfur is increased with coupling, and subsequent sliding of surfaces has a place, when superficial density of sulfur grows up to some appreciable size. Johnson and Vaughn the hypothesis about a layer MoS₂ with adsorbed by sulfur is offered, but Haltner refute it, as this effect could not observe with higher vacuum. It has come to a conclusion, that the faltering friction is caused by any pollution of vacuum system. However it is necessary to note, that in the experiences on shift with high pressure Bridgeman very much frequently observed free metal, in particular for CuCl₂, CuBr₂, PbO, Pbl₂, Bi₂S₃ and Al₂SO₄. All this – effective lubricant materials. If under action of high pressure the substance is decomposed, should be observed certain friction effect. This idea requires the further research.

MoS₂ (a — MoS₂) crystallizes in hexagonal to system. The atoms of molybdenum are located between two layers of atoms of sulfur. Distance between the nearest atoms of molybdenum and sulfur makes 2.41 °A, and nearest distance between atoms of sulfur in parallel layers — 3 °A.

Natural MoS₂ — MoS₂ receive with production of copper ores from collateral products, which contain so—called molybdenum shine. The first mentions of application MoS₂ as a lubricant means concern to XVI centuries.

Synthetic MoS₂ also has structure of a layered type, but or rhombohedral (β – MoS₂) with

parameters $a = 3.15 \text{ \AA}$, $c = 18.38 \text{ \AA}$, or intermediate between $\alpha - \text{MoS}_2$ and $\beta - \text{MoS}_2$.

Table 1. The basic properties MoS_2

| Property | Meaning |
|--|--|
| Densities | 4,8 g/cm ³ |
| Hardness on Moos | 1,0—1,5 |
| Temperature of a beginning sublimation | 723 K |
| Temperature of melting | 1458 K |
| Coefficient of linear expansion in the field of temperatures 323 — 973 K | $7 \times 10^{-6} \text{ 1/K}$ |
| Electroconductivity | Dielectric or semiconductor |
| Thermal conductivity | $4,9 \times 10^{-3} \text{ kcal/cm s K}$ |
| Magnetic properties | Diamagnetic |
| The chemical resistance | Is dissolved in imperial vodka, oxidize in concentrated H_2SO_4 and HNO_3 |
| Shine | Metal |
| Color | Bluish—gray up to black |
| Transparency | Weak in seen area, high in infrared area of spectrum. |

The electrical resistance MoS_2 large with a low pressure, but falls with increase of a pressure. Partially occurrence conductivity in MoS_2 is caused by heating at the expense of passage of an electrical current and partially at the expense of action of an electrical field. With temperature about 1123 — 1173 K it becomes a rather good conductor.

Light falling on the surface MoS_2 , reduces its electrical resistance. In this respect MoS_2 reminds selenium, but to change of light exposure reacts more quickly. The greatest influence is rendered by beams concerning red area of a spectrum (with length a waves up to 10000 \AA).

On air MoS_2 oxidize up to MoO_3 and sulfur or SO_2 . Such oxidic of a film begin to be formed with 623 K, and with temperature the fast oxidation MoS_2 is higher 753 K occurs. In vacuum MoS_2 , up to temperature 1373 K is stable.

Fluorine vigorously reacts with MoS_2 , the chlorine with heating transforms MoS_2 in MoCl_5 , and bromine practically does not react with MoS_2 .

The hydrogen restores firm MoS_2 directly up to metal without formation intermediate connections:



MoS_2 has high radiating resistance: any damages are absent with a doze 5×10^9 rad.

The moderate heating MoS_2 in the electrical furnace without access of air results in formation Mo_2S_3 on reaction:



Crystals Mo_2S_3 is grey—steel colors have a needle structure of density 5.9 g/cm³ ($5,9 \times 10^4 \text{ kg/m}^3$).

With friction on air MoS_2 in some modes (temperature on a surface of friction is higher 343 — 373 K) there is a partial oxidation MoS_2 up to MoO_3 .

MoO_3 represents a white powder, frequently with a greenish or dark blue shade. Sublimation MoO_3 begins with 973 K, melt it with 1068 K. Firm MoO_3 — dielectric, but in melted a condition becomes a good conductor.

MoO₃ is restored up to MoO₂ with heating in hydrogen (573 — 743 K) and up to metal of molybdenum with temperature above 773 K. The acetylene (C₂H₂) will form with MoO₃ carbide of molybdenum — Mo₂C; methane (CH₄) restores trioxide of molybdenum up to dioxide and, probably, up to metal; oxide of carbon restores MoO₃ up to oxides of violet colouring.

Such metals as Na, To, Hg, Al u Si are capable to restore MoO₃ up to metal. MoO₃ is well dissolved in alkali, forming hydrate oxide of molybdenum MoO₃—H₂O and MoO₃—2H₂O.

WS₂ crystallizes in hexagonal to system [5]. The crystal lattice WS₂ is similar to a lattice MoS₂, in which the atoms of molybdenum are replaced by atoms of tungsten. In comparison with MoS₂ WS₂ has greater heat resistance (is stable on air up to temperature 783 K) and resistance to oxidation. Its bearing ability in 3 times is higher, than at MoS₂.

WS₂ chemically is inert, is insoluble in all environments, including water, oil, alkali and almost all acids. Is sensitive only to influence free gaseous fluorine, hot chamois and hydrofluoric of acids. WS₂ is non—toxic a material and does not cause corrosion on metals.

5. Conclusion

Use WS₂ as the additive to lubricant oils for formation colloidal suspensions is complicated because of its high densities ($\rho = 7.4 \text{ g/cm}^3$), exceeding almost in 8 time densities of mineral oil a little.

So, in suspension on the basis of mineral oil and 50 % (on weight) graphite, MoS₂ or WS₂ will accordingly be on volume 36 % of graphite or 15.5 % MoS₂, or 11 % WS₂.

For work in a usual atmosphere with temperature use WS₂ is higher 673 K is recommended, whereas with lower temperatures it is better to use cheaper MoS₂. With use in vacuum WS₂ and MoS₂ display almost identical properties and have lubrication ability down to 1593 K.

In vacuum of $1.3 \times 10^{-13} \text{ Pa}$ WS₂ is stable up to 1373 K, and the decomposition it occurs with temperature, exceeding 1673 K.

In more late research executed by the soviet scientists, was established, that in vacuum dissociation WS₂ occurs completely only with 2273 K. With heating WS₂ vacuum up to 673 K from it the part of sulfur is allocated.

In England to units of dry friction working with temperature up to 1853 K in vacuum or in an inert atmosphere, apply paste containing 50 % (on weight) WS₂. Such paste keeps the lubrication properties and with low temperatures (up to — 328 K) [6], it is insoluble in water and has high resistance to the concentrated acids, alkali and gases.

Selenides of molybdenum, of tungsten, niobium successfully are applied last time in quality ingredients self—lubricating of materials intended for work on friction in ultra high vacuum. Despite of it, about properties of these connections there are only very poor isolated items of information.

Diselenide of molybdenum — MoSe₄ for the first time was received by heating of molybdenum acid with selenium in a current of hydrogen. Crystallochemical and the electrical properties MoSe₂ remained unexplored till 1961, when diselenide of molybdenum was received by sintering a powder of molybdenum with 973 K during 100 hour (cleanliness — 99 %) with stoichiometric by quantity selenium in the quartz ampoules, sealed — in under vacuum.

The received preparation MoSe₂ represented a grey powder with metal shine, quite steady on air. X—ray research of a powder MoSe₂ has allowed to establish, that diselenide of molybdenum has hexagonal an elementary cell with parameters: $a = 3.28 \text{ \AA}$ and $c = 12.84 \text{ \AA}$, density 6.9 g/cm^3 ($6.9 \times 10^4 \text{ kg/m}^3$).

The crystal lattice MoSe₂ is similar to a lattice MoS₂, in which the atoms of sulfur are replaced by atoms selenium.

Diselenide of molybdenum is the semiconductor, its specific electroconductivity makes: with 295 K — $1.23 \times 10^{-4} / (\text{Ohm} \times \text{cm})$, and with 333 K — $2.3 \times 10^{-4} / (\text{Ohm} \times \text{cm})$.

Diselenide of tungsten — WSe₂ has hexagonal a lattice of a type MoS₂. The ways of reception WSe₂ are similar to ways of reception MoSe₂. Diselenide of tungsten has semi—conductor properties [4].

Diselenide niobium. In the literature there are only data on crystal structure NbSe₂ [4] With temperature 1073 K on air diselenide niobium begins sublimate. The possible updatings of an elementary crystal cell are considered in work.

The graphite, as well as other layered firm lubrication, has a lattice hexagonal of a structural type. Distance between atoms of carbon in parallel layers (3.44 °A) exceeds similar distance between atoms in a lattice borazon. In this connection the connection between planes of cleavage at graphite should be more poorly, than at borazon. The indirect proof it is served by lower size of factor of friction of graphite in comparison with borazon, observable in identical conditions of test.

Such carbonaceous of substance, as stone coal, coke, soot have crystal structure of graphite and usually are used for reception from them by thermal processing (temperature 3173 K) of polycrystalline graphite with a high degree of perfection separate crystallites.

Some physico—mechanical properties of graphite used in reactor building (table 2) are resulted below

Table 2. The basic properties of graphite

| Property | Meaning |
|--|--|
| Density | 2.21 – 2.25 g/cm ³ |
| Porosity | 20 – 32% |
| Temperature of melting | 4073 – 4173 K |
| Thermal conductivity | 30 – 32 kcal/m hour K |
| Factor of linear expansion in an interval 273 — 1273 K | 3.5–8×10 ⁻⁶ 1/K |
| Strength on a stretching | 50 – 95 kg/cm ² (5×10 ⁶ – 9.5×10 ⁶ N/m ²) |
| Strength on compression | 160 – 300 kg/cm ² (16×10 ⁶ – 30×10 ⁶ N/m ²) |
| The module of elasticity | 5,6×10 ⁴ kg/cm ² (56 × 10 ⁸ N/m ²) |

Borazon crystallizes in hexagonal to system. The crystal lattice borazon is similar to a lattice of graphite, in which one atom is replaced on boron, and other with nitrogen. The atoms of boron and nitrogen are located in horizontal layers alternately. Distance between the next layers at borazon (3.34 °A) is less a little, than at graphite (3.44 °A), therefore connection between layers at BN is stronger, than at graphite.

As against graphite at borazon there is no metal connection between layers. The connection between atoms of boron and nitrogen has ionic character. BN has low electroconductivity, and also is steady in neutral and reducing atmospheres.

Oxidation BN largely depends on temperature of its reception or preliminary of calcination. So, with increase of temperature preliminary of calcination with 1273 up to 1373 K speed of its oxidation decreases in 4 times. In the form of dense products borazon begins oxidize with temperature 973 K, the amplified oxidation occurs with 1273 — 1373 K. With heating in vacuum up to temperature 1273 K is not decomposed. With carbon borazon reacts with 2273 K, forming carbide of boron and nitrogen. With metals in an atmosphere of nitrogen borazon will form borides. In boiling water and diluted acids is decomposed with formation of ammonia NH₃ and boric acid. The amplified decomposition begins with temperature 403 K. The Concentrated acids on work poorly. For example, H₂SO₄ decomposes borazon only after 6 — 10 hours influence.

Besides considered above, lubrication ability other materials (CdJ₂, PbJ₂, BiJ₃, Sb₂S₃, AgJ) find out also. In firm lubricant coverings are used also PbO, CaF₂ and organic materials phthalocyanine and PTFE.

6. Acknowledgments

Experimental studies carried out on the surfaces of flanges tires wheelsets and necks motor — axial bearings with the application of solid laminated lubricants followed, proved the possibility of increasing the wear resistance of flanges surfaces by 40 percent in the initial period of operation, and the surfaces of the necks of motor — axial bearing not less than 6 times in comparison with surfaces treated according to current technology.

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