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ANTIFRICTION PROPERTIES OF SELF-LUBRICANT COMPOSITE MATERIALS UNDER FRICTION VACUUM CONDITIONS

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Abstract

Two self-lubricant copper-based composite materials, alloyed with Sn or Ni, P, and containing Pb, were studied. The obtained experimental data revealed a small friction coefficient in vacuum (for load of 2 and 10 N, and velocity of 0,2 and 1 m/s) with both materials. The "Cu-P-Sn-Pb" system's friction coefficient was 0,12 - 0,15. The "Cu-P-Ni-Pb" system's friction coefficient was 0,18 - 0,24. The measured wear values for friction in vacuum were also small. For system one wear reached 4.10^{-6} *mm*^{3}*/Nm, and for system two,* 4.10^{-5} *mm*^{3}*/Nm. An interesting fact is that, by increasing the load 5 times (from 2 to 10N) at 0,2 m/s in vacuum the wear of system one became* 6.10^{-6} *mm*^{3}*/Nm. For system two this value was* 5.10^{-5} *mm*^{3}*/Nm. The obtained results proved the good antifriction properties of these materials at dry friction in vacuum, resulting from the friction surface's enrichment with lead, Pb. During the friction process, Pb diffused from volume to surface and acted as a solid lubricant.*

Introduction

Space studies have shown the complex and non-traditional nature of tribological processes in vacuum, where the medium is greatly rarefied, lacking oxygen and humidity, convectional cooling, and traditional contact lubrication. As a result, contact interactions are realised at elevated temperature, increased plastic deformation, destruction of oxides, at strongly increasing adhesive activity of the frictional surfaces, leading to intensive wear [1]. Friction in vacuum usually takes place in dry conditions.

All these peculiarities necessitate the development of materials with improved antifriction properties, since in space practice, failures of tribological character are not quite rare.

Our experience in material research and use in space has shown that self-lubricant copper-based composite materials are suitable for space application. One material of this type was used in the bearings of the space apparatus which operated steadily in vacuum on the MIR Orbital Station for 5 years [1996 - 2001] [2,3].

Properties and parameters of new materials

The object of the study are the properties and triboparameters of two self-lubricant copper-based composite materials, alloyed with Sn or Ni, P, and containing Pb in the form of globular formations.

The materials are as follows:

1. System "(Cu - P) - (Pb -Sn)", to be called provisionally "material 1" and
2. System "(Cu - P - Ni) - Pb", to be called provisionally "material 2."

The main pecularity of this type of materials is the fact that the functions of their structural components are strictly differentiated. Some of the components play the role of the bearing part (the matrix). These are the copper alloys. The other components have antifrictional function as solid lubricant (Pb, Sn, their alloys). An important factor providing for the choice of these components was the interrelation between them in the material structure.

Alloying with Ni and Sn improves the mechanical properties of the alloys and forms a solid solution with Cu, increasing material strength.

Phosphorous increases the wear resistance of materials, forms a solid phase Cu_3P, which limits the formation of intensive plastic deformation at contact and restricts the creation of seizure centres at dry friction vacuum conditions. Pb actually does not interact with Cu, and plays the role of a solid lubricant, decreasing wear and increasing the reliability of the tribo-couple. Pb is present in the materials' structure in the form of isolated formations.

A general technological principle in the creation of this type of antifrictional materials is the formation of strongly heterogeneous structure, ensuring good antifrictional characteristics and parameters (small friction coefficient and high wear resistance).

"Material 1“ possesses complex heterogeneous structure built by α-solid solution of Sn in Cu with isolated formations of Pb. At the boundaries of α-solid solution grains, a web of Cu_3P is located with areas of complex eutectics "Cu_3P + Cu_3Sn + (Cu + Sn), and isolated crystals probably of the Pb_2SnO_4 type.

The structure of "material 2" is built of a hard solution of Ni and P in Cu with solid phase Cu_3P, located on the grains in the form of a broken web. Pb formations fill the gaps between the particles of the solid solution.

A high wear-resistance is inherent to these materials, because of the favourable relation between strength and plasticity resulting from the alloying of the bearing part (the matrix) with Ni or Sn, which increases the loading capacity of the materials.

Irrespective of the distinct specifics of triboprocesses in vacuum and especially due to adhesion increasing at dry friction vacuum conditions, the obtained experimental figures for the friction coefficient in vacuum for both materials were small. System's "Cu-P-Sn-Pb" friction coefficient was 0,12 - 0,15 and system's "Cu-P-Ni-Pb" friction coefficient was 0,18 - 0,24 (load 2 N and velocities 1 and 0,2 m/s). The measured wear values for friction in vacuum were also small - for material 1, the wear reached 4.10^{-6} $mm^3/N.m$, and for material 2, 4.10^{-5} $mm^3/N.m$. This result could be explained by the effect of self-lubrication. Our previous studies have shown that under dry friction in vacuum this type of materials certainly demonstrate a self-lubricant effect [3].

As a result of the increased temperature at contact, the plastic deformation and the differences in the diffusion and linear extension coefficients of the material's components, diffusion of Pb towards the friction surface is observed.

Such diffusion is also accomplished with friction in air, but in this case Pb on the surface is oxided, and with friction in vacuum Pb is metallic, acting as solid lubricant. Experience shows that metal Pb features more stable triboparameters than PbO. Metal Pb keeps its own plasticity and the formed thin layer is steady.

In Fig. 1, the dependence of the friction coefficient on distance at dry friction vacuum conditions is shown for material 1 (load 2 N and velocity 0,2 m/s).

With increase of load and velocity, friction power increases, contact temperature rises, the diffusion process is activated and the surface is enriched with Pb acting as lubricant, which decreases further the friction coefficient, as seen in Fig.2 with velocity 1m/s. The case with material 2 is similar, where the value of the friction coefficient decreases with increase of velocity from 0,25 to 0,18.

An interesting fact is that, by increasing the load 5 times (from 2 to 10 N) at velocity 0,2 m/s in vacuum the wear for material 1 was 6.10^{-6}

mm^3/N.m. For material 2 this value was 5.10^{-5} mm^3/N.m. This result proved the good antifriction properties of the materials under dry friction in vacuum. We assume that the load 10 N at 0,2 m/s is not limiting for both materials. The shown triboparameters are measured at rotation movement with counterbody of steel AISI52100 (100 Cr 6). The tribological study was carried out by the AMTT - Seibersdorf. UHV-tribometer [4].

The structural-morphological peculiarities of the friction surface at dry friction in vacuum are very specific. Wear by friction removes irreversibly oxide structures and cleans the surface. This can be seen in the micrograph of the surface at friction in vacuum for material 1 - Fig.3. This is the beginning of the formation of Pb layer on the surface, where well-outlined formation of Pb (1) is observed, assuming orientations along the direction of movement.

The Pb layer formed on the surface at friction under vacuum for material 2 is shown in Fig.4. The formation of a stable Pb layer depends on the structural-morphological configuration of the composite material, the distribution of lead in the surface layer and the friction regime, which makes the friction surface adaptable while in service. Therefore, the self-lubricant composite materials of this type are steady and reliable under dry friction vacuum conditions, including space environment. Our efforts show that they are suitable for space application as a material for bearings, working continuously in dry friction regime in vacuum.

Conclusions

1. Lubrication effect has been established for two antifriction copper-based composite materials under dry friction vacuum conditions for loads of 2 and 10N and velocities of 0,2 and 1 m/s.
2. The triboparameters friction coefficient and wear of these materials are comparable to those of the material LB9 (Glacier BS 1400 LB4-6).
3. Because of their good triboparameters and great operation stability in vacuum these materials are of interest for space material science and technologies. They are a promising material for space applications, involving continuous dry friction in vacuum.
4. It is purposeful the research to be continued on these materials in order to determine their ultimite potentials with regard to their loading with heavier operation regimes in vacuum.

Upon complete assessment of these materials, they could be proposed for use in space equipment and devices.

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Captions:

Fig.1. Friction coefficient dependence of distance under dry vacuum friction (load 2N, velocity 0,2 m/s) material 1.

Fig.2. Friction coefficient dependence of distance under dry vacuum friction (load 2N, velocity 1 m/s) material 1.

Fig.3. Micrograph of friction surface of material 1 at dry friction in vacuum (load 2N, velocity 0,2 m/s), (x 1000).

Fig.4. Micrograph of friction surface of material 2 at dry friction in vacuum (load 2N, velocity 1m/s), (x 1000).

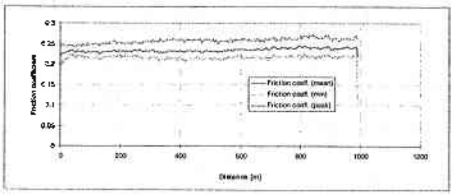

Fig.1

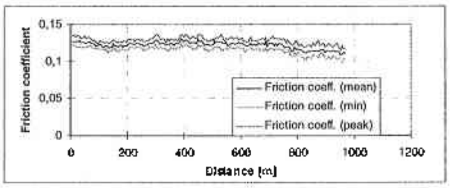

Fig.2

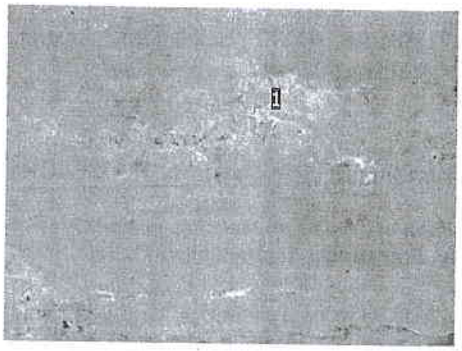

Fig.3

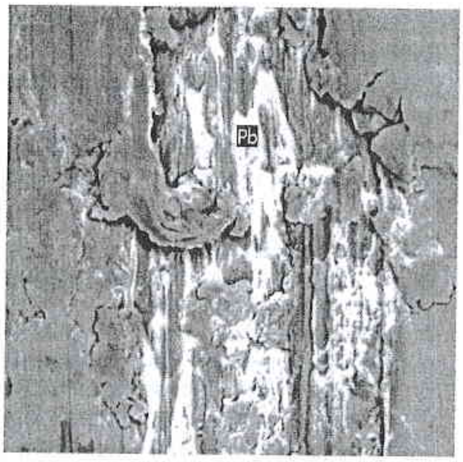

Fig.4

АНТИФРИКЦИОННИ СВОЙСТВА НА САМОСМАЗВАЩИ СЕ КОМПОЗИТНИ МАТЕРИАЛИ ПРИ ТРИЕНЕ ВЪВ ВАКУУМ

Юлика Симеонова, Георги Сотиров

Резюме

Изследвани са два самосмазващи се материала на медна основа, съдържащи олово, сплавени с калай или никел и фосфор. Получените експериментални данни показаха нисък коефициент на триене във вакуум (за товар 2 и 10 N, и скорост 0,2 и 1 m/s) и при двата материала. Коефициентът на триене на системата "Cu-P-Sn-Pb" е 0,12 - 0,15. Коефициентът на триене на системата "Cu-P-Ni-Pb" е 0,18 - 0,24. Измерените стойности на износване при триене във вакуум също са малки. Износването в първата система е 4.10^{-6} mm^3/Nm, а във втората система - 4.10^{-5} mm^3/Nm. Интерес представлява фактът, че увеличавайки товара 5 пъти (от 2 на 10N) при 0,2 m/s във вакуум, износването на първата система става 6.10^{-6} mm^3/Nm. За втората система тази стойност е 5.10^{-5} mm^3/Nm. Получените резултатаи потвърждават добрите антифрикционни свойства на тези материали при сухо триене във вакуум, получени в резултат от обогатяването на фрикционната повърхност с олово Pb. В процеса на триене Pb дифундира от обема към повърхността и действа като твърд лубрикант.