**_BALKANTRIB'O5_**
**_5th INTERNATIONAL CONFERENCE ON TRIBOLOGY_**
**_JUNE.15-18. 2005_**
**Kragujevac, Serbia and Montenegro**

# ANTIFRICTIONAL PROPERTIES OF SELF-LUBRICATING COMPOSITE MATERIALS UNDER FRICTION VACUUM CONDITIONS

*Anatolii G. Kostornov, Olga I. Fushchich, Tatiana M. Chevichelova*
*Institute for Problems of Materials Science at the National Ukrainian Academy of Sciences, Kyiv, Ukraine*
*E-mail: dir@ipms.kiev.ua*
*Yulika M. Simeonova, Georgy S. Sotirov*
*Space Research Institute at Bulgarian Academy of Sciences, Sofia, Bulgaria*
*E-mail: JSimeonova@space.bas.bg; office@s,ace.bas.bg*

***Abstract***

*Self-lubricating copper matrix composite materials, containing Pb globular formations, were studied. The materials possess high-heterogeneous structure, procuring good antifriction parameters and characteristics. The obtained experimental data about the friction coefficient of these materials were 0,12 – 0,22 under dry friction vacuum conditions at load from 2 to 20N and velocities 0,2 and 1 m/s. The values for wear intensity were $1.10^{-6}$ – $1.10^{-5}$ $mm^3/Nm$. The experience in studying and employing for space applications has shown that self-lubricating copper-matrix composite materials are suitable for use in space. They have high stability and reliability by continuous usage under dry friction vacuum conditions in space environment. One of these type materials, used in tribological junctions of space apparatus, was operating steadily under space vacuum on the MIR orbital station for 5 years (1996-2001).*

**Keywords:** *self-lubricant materials, dry friction, vacuum conditions.*

## 1. INTRODUCTION

Space research experience manifests the complex nature of a tribo-process, taking place in vacuum conditions, where the medium is highly rarefied with lack of oxygen and humidity. As a result the contact interactions take place at a higher temperature, greater plastic deformation and destruction of the oxide and the secondary surface structures, with strongly increased activity of the friction surfaces, resulting in the intensive wear and offer in blocking and clutching at the tribo-contact [1,2]. Friction in vacuum conditions usually takes place under dry conditions.

All these peculiarities necessitate the development of materials with improved antifriction properties.

## 2. EXPERIMENTAL STUDY

Self-lubricating copper matrix composite materials, alloyed with phosphorus (P), manganese (Mn), nickel (Ni) or tin (Sn), and containing lead (Pb) globular inclusions, were studied [3]. Particularity of these materials is the fact that functions of their structural components are strictly differentiated. The copper and his alloys play a part of matrix and the lead has antifriction functions as a solid lubricant.
The materials are as follows:

- System Cu-P-Mn-Pb, named IPM-301,
- System Cu-P-Sn-Pb, named IPM-304,
- System Cu-P-Ni-Pb, named IPM-305.

The composite materials have high-heterogeneous structure, procuring good antifriction properties and parameters. Alloying with Mn, Sn or Ni improves the mechanical properties of the material. They form a solid solution with copper (Cu), increasing composite's strength. Phosphorus and copper form a solid phase $Cu_3P$ improving the wear-resistance of the materials. Lead realizes practically no interaction with copper and it presents in the materials structure in the form of isolated inclusions.

The triboparameters were measured at rotation movement with counter-body (pin or disk) of steel AISI52100 (hardness of 700 HV) in vacuum ($1.10^{-5}$ mbar). A "pin-on-disk" type UHV-tribometer was used [5]. The tribological tests were done at ARC Seibersdorf Research GmbH - AMTT, (Austria).

## 3. RESULTS AND DISCUSSION

Irrespective of the distinct specifics of tribo-processes in vacuum conditions and especially due to the adhesion force increasing, the achieved experimental data concerning the friction coefficient in vacuum conditions of materials revealed that: friction coefficient is small (0,12-0,23) and that the measured values about wear intensity were also small ($1.10^{-6}$-$5.10^{-5}$ $mm^3$/Nm). Table 1 presents comparative data of material LB9 (Glacier) [5,7].

**Table 1-Main triboparameters of materials in vacuum conditions**

| Composite materials | Friction regime | Friction Coeffi-cient | Wear Intensity, mm³/Nm |
|---|---|---|---|
| IPM-301 | Load 2N | | |
| | Velocity 0.2 m/s | 0.23 | $5.10^{-5}$ |
| | Velocity 1.0 m/s | 0.21 | $2.10^{-5}$ |
| IPM-304 | Load 2N | | |
| | Velocity 0.2 m/s | 0.22 | $2.10^{-5}$ |
| | Velocity 1.0 m/s | 0.12 | $8.10^{-6}$ |
| | Velocity 0.2 m/s | | |
| | Load 10 N | 0.15 | $6.10^{-6}$ |
| | Load 20 N | 0.19 | $1.10^{-5}$ |
| IPM-305" | Load 2N | | |
| | Velocity 0.2 m/s | 0.23 | $5.10^{-5}$ |
| | Velocity 1.0 m/s | 0.19 | $4.10^{-5}$ |
| | Load 10 N | | |
| | Velocity 0.2 m/s | 0.21 | $5.10^{-5}$ |
| LB9 (Glacier) | Load 2N | | |
| | Velocity 0.2 m/s | 0.18 | $1.10^{-5}$ |

With velocity increase, the friction coefficient decreases as seen in Table 1 and Fig.1. Another interesting fact is that by increasing 10 times the load (from 2 to 20N) at velocity 0,2 m/s the wear intensity in vacuum conditions does not increase. The wear of material IPM-304 is even lower that of the material LB9.

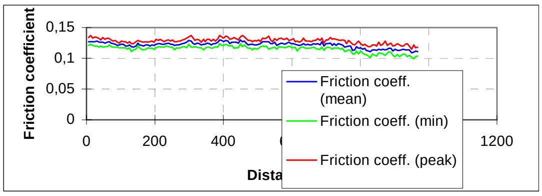


**Fig.1:** *Friction coefficient dependence of sliding distance under dry friction vacuum conditions (load 2N, velocity 1 m/s) (IPM-304) [5]*

When there is dry friction in vacuum at a higher load (20N) this material (IPM-304) shows the same value as LB9 at only 2N. Our experience shows that these composite materials possess an improved loading level at prolonged exploitation under dry friction vacuum conditions, as seen on Fig.2.

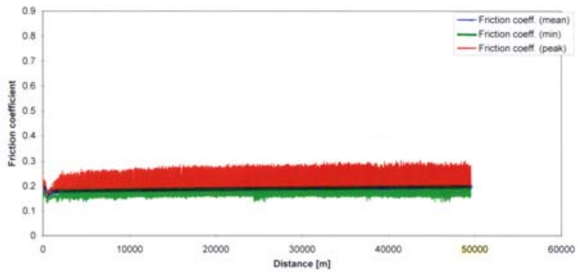


**Fig.2:** *Friction coefficient dependence of sliding distance under dry friction vacuum conditions (load 20N, velocity 0,2 m/s and a distance 50 000 m) (IPM-304) [7]*

The achieved good frictional properties of these materials under dry friction vacuum conditions are result of the friction surface enrichment with the metallic Pb. As our previous studies have shown, certain well-activated self-lubricating effect appears [4, 5, 6] under dry friction in vacuum for this type of composite materials. Due to the increased temperature in the tribo-contact, to plastic deformation and to differences in the coefficients of thermal extension and diffusion of the material's components, enrichment with lead of the friction surfaces is observed. During the friction process the Pb press out from material's volume to the friction surface and forms a thin layer acting as solid lubricant–Fig.3.

With the load and velocity increase the friction process power increases also, the temperature in the contact grows, the Pb enrichment is activated and a thin Pb layer, which acting as a solid lubricant, forms on the friction surface. It keeps its own plasticity and has stable active triboparameters.

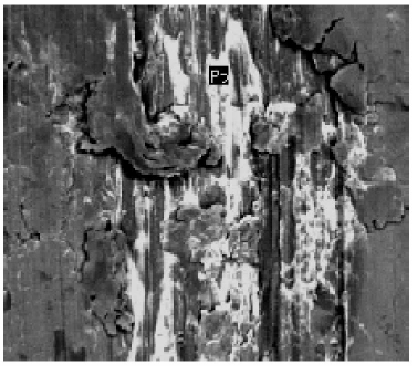


**Fig.3:** *Micrograph of friction surface after dry friction in vacuum conditions (load 2N,velocity 1,0 m/s and a distance 1000 m) (IPM-305) [5]*

The formation of a stable Pb layer depends on structural particularities of the composite materials, on Pb distribution in the structure and on friction regime [5]. This makes the friction surface adaptable in the friction process. In all probability therefore the self-lubricating composite materials of this type are steady and reliable under dry friction vacuum conditions, including space environment [7].

Our efforts show that they are suitable for space application as material for bearings, operating continuously in dry friction regime under vacuum conditions. A self-lubricating composite material IPM-301 was used at tribojunctions of the Bulgarian space radiometric system "R-400". It was steadily operating on the MIR Orbital Station for 5 years (1996–2001) [4, 8]. The radio-thermal emission of the Earth's surface, registered from Space by this system operating in International PRIRODA Project, is shown in [8].

## 4. CONCLUSION

The self-lubricating effect of three new antifriction composite materials under dry friction vacuum conditions at velocities 0,2 and 1,0 m/s and loads from 2 to 20N can be established. With their triboparameters the materials are comparable to the analogous material LB9 (Glacier BS 1400LB4-6).

Stability of the triboparameters and the characteristics of these materials are established at continuous dry friction in vacuum conditions. Because of the good triboparameters and high stability at prolonged exploitation in vacuum these composite materials are of interest for the space technologies and space applications.

## 5. REFERENCES


[1] Drozdov Y.N., V.G. Pavlov, et al., Friction and Wear under Extreme Environment, M. Machine Construction, 1986 (in Russian).

[2] Silin A. A., Friction in Space Vacuum, Friction and Wear, Issue No 1, 1989 (in Russian).

[3] Kostornov A. G., O. I. Fushchich, Y. M. Simeonova, T. M. Chevichelova, A. D. Kostenko, The influence of metal-lubricant on the structural and the tribological characteristics of copper based composite materials in vacuum conditions, Proc. Conf "Science for Materials in the Frontier of Centuries", Kyiv, 2002, Ukraine.

[4] Yuga A. I, T. M Chevichelova, Y. M. Simeonova, T. G. Nazarsky, Application of New Antifriction Material at Tribological Junctions of Space Research Equipment, 2-nd World Tribology Congress, Vienna, 2001, Session "Tribology in Extreme Environment", 63-4, 734.

[5] Simeonova Y., G. Sotirov, Study of the parameters of new antifriction materials under dry friction vacuum conditions, Report, BAS, ARC-Seibersdorf, Austria, ARC-W-0136, pp. 1-30, July 2002.

[6] Simeonova Y., G. Sotirov, Peculiarity of the Friction Surface of Antifrictional Composite Materials under Dry Friction Vacuum Conditions, Tribology Science and Application, Fr. Franek and Cz. Kajdas, Scientific Centre of the PAS, Vienna, Austria, 2004, pp 277-283.

[7] Simeonova Y., G. Sotirov, Triboparameters of New Antifrictional materials under Dry Friction Vacuum Conditions for Space Applications, Proc. Int. Conference on Recent Advances in Space Technologies, Istanbul, 2003, Turkey, 566-568.

[8] Bankov N., L. Todorieva, Data Processing of the microwave system "R-400" on Board of the MIR Station, Aerospace Research in Bulgaria, BAS, book 16, 2001, p. 82.