SERBIATRIB '11

Serbian Tribology Society

12th International Conference on Tribology

Faculty of Mechanical Engineering in Kragujevac

Kragujevac, Serbia, 11 – 13 May 2011

EQUIPMENTS AND MATERIALS FOR TRIBOTESTING IN OPEN SPACE ON ISL

N.K. Myshkin[1],
A.Ya. Grigoriev[1], V.L. Basiniuk[2], A.I. Mardasevich[2], V.G. Kudritsky[1], I.N. Кavaliova[1]
[1]Metal-Polymer Research Institite NASB, Belarus, mpri@mail.ru
[2]Joint Institute of Meschanical Engineering NASB, Belarus, bats@ncpmm.bas-net.by

Abstract: *The problems of hardware and methodology of ground-based and on-board tribotesting are discussed as well as the main features of space test equipment. New materials for space tribosystems are presented. The method of estimation and selection of equivalent conditions of space- and ground-based tribotestings is considered. The method is based on comparing the results of experiments in multidimensional feature space. Input and output parameters of the experiments are interpreted as coordinates of a point, representing conditions of tribosystems in the multidimensional space. Analysis of the distance between corresponding points allows one to solve the problem of selection of equivalence conditions of ground-based test and estimate uncontrolled parameters of space-born experiment).*

Keywords: *space tribology, experiment "Tribospace", on-board tribometer, tribotesting.*

1. INTRODUCTION

The current trend in technology of space apparatus is increasing of their service life. Friction units are one of the important components of mechanical part of orbital technique. Tooth gears, rolling and sliding bearings, cam mechanisms, guides, seals, docking units, locks, and other units operates in open space. Only on International Space laboratory there are more than 300 such tribosystems.

In the open space the tribosystems were exposed in operation to the high vacuum (on the Moon $p < 10^{-5}$ Pa), a broad range of temperature variations (from 100 to 400 K), IR, UV and X-Ray radiation, high energy ions and elementary particles, microgravitation, full absence of oxidizing atmosphere and so on.

All the factors can change the processes in the surface layers of materials, such as diffusion, degasification, sublimation; they modify the chemical composition, structure and behaviour, physical-mechanical properties, including the parameters of the dimensional stability, the conventional limits of elasticity and relaxation [1]. As a result the friction and wear performance in space is very much different from the ground conditions. This problem is well recognized and already in 1974 in the frame of "Luna-2" program the first experiment on investigation of friction and wear in open space was realized [2]. The friction simulator (FS) operated in open space 150 h was installed on the "Luna-22" space vehicle (Fig.1).

Figure 1. Space friction simulator used in "Luna-2" program: 1 – hermetic drive; 2 – friction units

Tester was driven from the electric motor via 5-stage reducing gear with maximum torque 10 Nm. Temperature on the surface of drive housing was measured by transducer as well as internal pressure in the housing. Friction torque was measured by electric current of the motor

The tested samples were based on solid lubricant coating ВНИИ НП-212 with MoS_2 covered an aluminum alloys ДТ16Т and АМГ-6. Tests were done in a ground laboratory, at the launching position of a spacecraft, and at the Moon orbit.

The following parameters were measured in operation: friction forces in start and steady rotation; current in driving motor; pressure in the sealed drive housing; temperature on the surface of driving and measuring housings. Due to limitation of experimental equipment wear of materials was not measured and tests were carried out at very low sliding speed (0.008 - 0.01 m/s).

Tests in space were run during 15 months being controlled from the ground. First operation cycle started 32 days after launching. At first seconds of operation the friction was the same as at the launching position. After 1.5 - 2 min the friction coefficient was 0.22 - 0.24 for bush-on-shaft and 0.15 - 0.16 for pin-on-disc. At the end of first test cycle it was 0.10 - 0.14 for bush-on shaft and 0.09 - 0.10 for pin-on-disc. The following conclusions about influence of space factors were made:

- Local atmosphere around the ship was found more favorable than ground vacuum chamber;
- Microgravity was also found favorable due to wear debris locking at the friction surfaces.

New possibilities in the field of space tribology will be opened after coupling of Russian science module to the International Space Lab (ISL). It is planned that new space experiment “Tribocosmos” will be curried out in cooperation of Russia and Belarus while studying advanced materials for friction and wear in the open space.

The aim is the experiment is the following:

- Development and testing of efficient materials and coatings for space applications;
- Studies in the effects of space environment on friction and wear of prospective materials and coatings;
- Studies in the similarity of data on the tests in space and on the ground;
- Development of testing methods and techniques for lifetime forecast up to 15 years for materials in sliding bearings and gears based on short-time tests;
- Creation of database on prospective materials, coatings and lubricants for space applications.

2. TEST EQUIPMENT FOR “TRIBOCOSMOS” EXPERIMENT

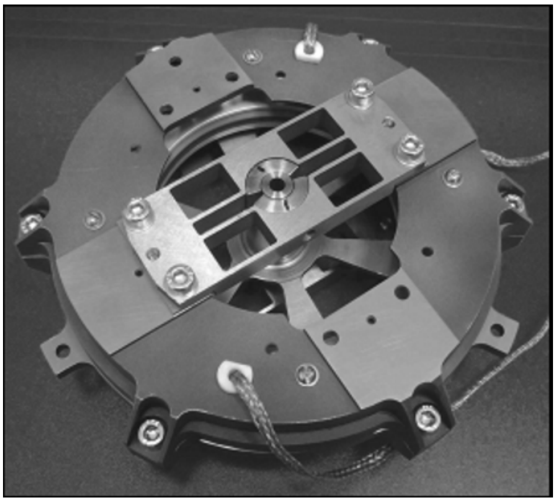
Test equipment [3] consists of two modules located in open space outside the ISL far from the engines. Orientation along the axes of ISL is not specified.

Tribotest module (TM) is designed as a pin-on-disc unit with 6 pins (3 on each side of disk) arranged at various radii of the sliding track. Normal load 0.1-30N, rotation velocity is up to 1000 rpm, on-line measurement of temperature, friction coefficient and wear.

Bearing module (BM) is designed as four bush-on-shaft units with an independent drive. Normal load is 10-100N, rotation velocity 6-1000 rpm. On-line measurement of friction coefficient and temperature should be provided.

The general view of developed equipment is presented in Fig. 2.

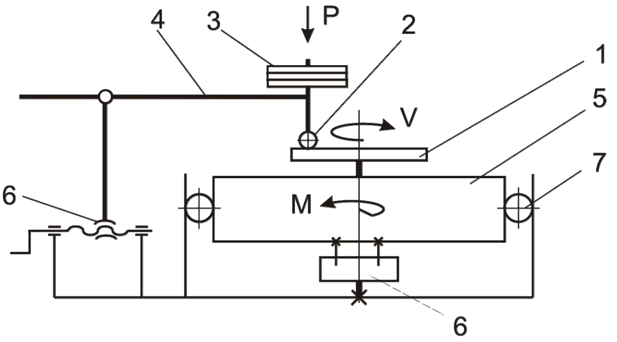
a



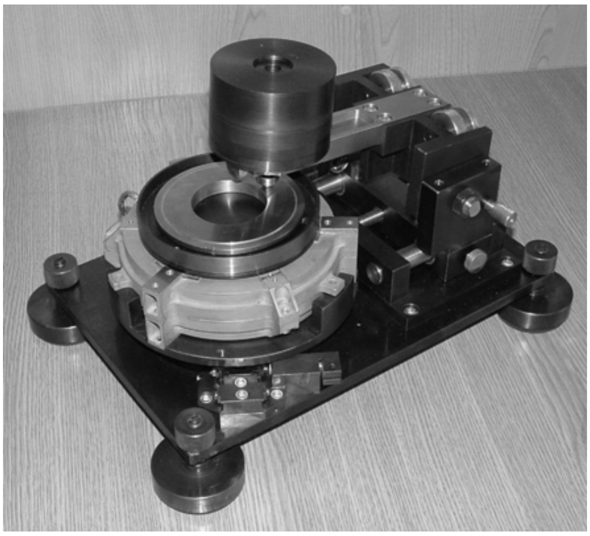
b

Figure 2. General view of tribotest (a) and bearing modules (b) for “Tribocosmos” experiment

For on-ground testing of materials in vacuum in a wide range of temperature special test equipment was developed. The general scheme of the test equipment and its photo are presented in Fig 3.



a



b

Figure 3. Scheme (a) and general view (b) of equipment for investigation of wear and friction of under conditions of space imitation

The device realizes sphere-plate geometry of testing with motion of test sample 1. Spherical indenter 2 is loaded by weight 3, located on lever 4. Sample 1 rotated by drive 5. The radius of wear track can be changed by drive-screw 6. Friction torque is maesured by torsion balance. For this aim drive 5 is installed on ball bearing 7. Friction torque is rotating the drive 5 being measured by detector 8.

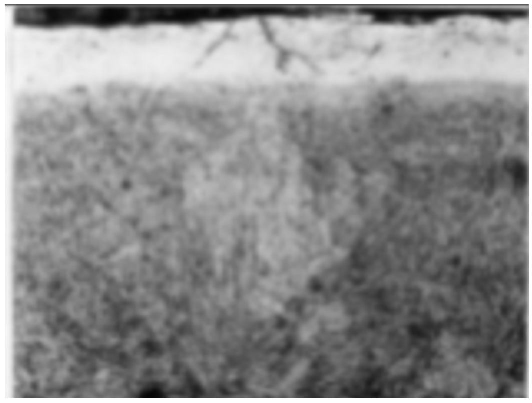
Design of the device allows one to use it in normal ambient conditions and in vacuum of 10^{-3} Pa and temperature range from от 120 up to 420 K. The test equipment can be used for investigation dynamical parameters of direct-drive systems developed for TM and BM.

3. MATERIALS FOR SPACE TRIBOTESTS

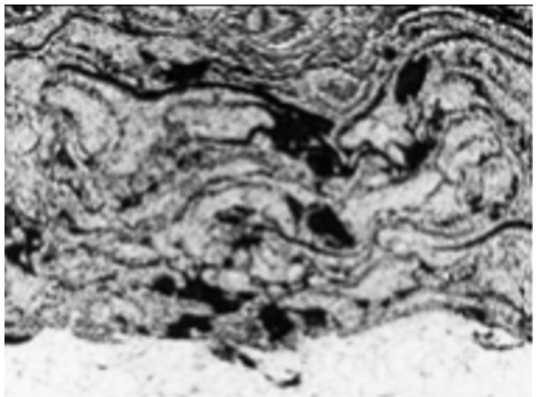
Depending on application the following materials were developed [4]:

- gears, drive screws, threads and rolling bearings – ion-implanted self-lubricated coatings based on dyhalcohenides of Mo, W–S, Se and Co
- bearings, guides, and joints – gas-flame facings with the oxides and self-lubricating fillers
- electrical contacts, sliding bearings, joints – galvanic and electroless metal-polymer coatings Ni-P, Ni-P+SiO2, Ni-B + PTFE.

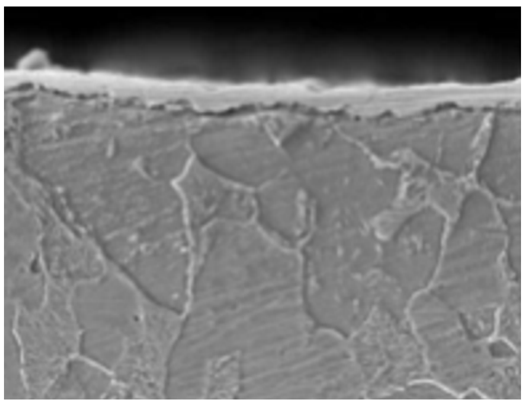
The structures of developed materials are presented in Fig. 4.



a



b



c

Figure 4. Materials for space tribotests: *a* – ion-implanted self-lubricated coating W-S on steel; *b* – gas-flame facings with the oxides and self-lubricating fillers; *c* – Ni-B coatings

4. METHODS OF TRIBOTESTING

The scheme of experiment is presented in Fig 5. It is planned to test all materials in the open space at the International Space Laboratory. In the same time all samples will be tested on the ground while imitating the space factors in similar test equipment. Ground-based tests will be carried out on extended program with realization all possible loads and velocities and registration of the additional parameters (measurement of wear, vibration and triboacoustic parametrs, analysis of wear debris and surface morphology). The purpose of ground-based tests is the extending parametrical space of experiment and obtaining data on influence space factors on friction and wear modes.

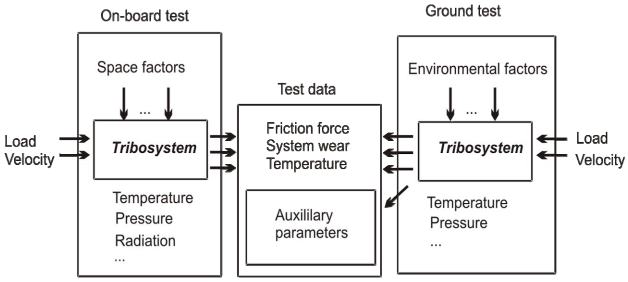


Figure 5. Scheme of friction test materials on space and ground-based conditions

Because some unknown acting space parameters the complexity of on-ground and on-board experiments arises. For solving the problem special method is developed [5].

The method is based on comparing the results of on-board and ground based experiments in multidimensional feature space. Input and output parameters of the experiments are interpreted as coordinates of a point, representing conditions of tribosystems in the multidimensional features space. Analysis of the distance between corresponding points allows us to solve the problem of selection of equivalence conditions of ground-based test and estimate uncontrolled parameters of space-born experiment.

5. CONCLUSIONS

International Space Lab "Tribocosmos" project is a real opportunity of accelerating the progress in space tribology. Combination of new generation of tribotesters on the orbit and ground with the possibility of on-line monitoring provides a unique chance of future fruitful applications. The major task in "Tribocosmos" project is bridging the gap between macroscopic data available and scientific advances in micro/nano.

International cooperation based on standard and reproducible measuring techniques is a milestone in "Tribocosmos" project. Final result of the project is foreseen mostly in prospective self-lubricating films and coatings as well as in development of novel in-situ monitoring techniques.

REFERENCES

[1] Yu.N. Drozdov, Seok-Sam Kim. Tribological behaviour of mechanical systems in the outer space, Journal of Friction and Wear, Vol 20, No 1, pp 8-14, 1999.

[2] V.M. Yarosh, A.A. Moisheev, M.A. Bronovets. Study of friction and wear of materials in open space at curcumlunar orbit, Journal of friction and wear, Vol. 24, No 6, pp. 41-49, 2003

[3] N.K. Myshkin, A.Ya. Grigoriev, V.L. Basiniuk et al. Equipment and methods for test materials on friction and wear in open space, in: *Proceedings of the IV Belorussian Space Congress,* 27-29.10.2009, Minsk, Vol. 1, pp. 58-62 (in Russian).

[4] V.L. Basiniuk, A.I. Mardosevich, N.K. Myshkin et al. Problems in development of composite materials for drives operated in extreme temperature conditions, in: *Proceedings of the IV Belorussian Space Congress,* 27-29.10.2009, Minsk, Vol. 1., pp. 69-73 (in Russian).

[5] N.K. Myshkin, A.Ya. Grigoriev, V.G. Kudritsky, A.P. Zozulya. Ground-based and on-board tribometers for test materials in space, Informatics, No 3, pp. 41-50, 2007 (in Russian)