«Resource» Experiment

DEGRADATION OF MATERIALS AND CONSTRUCTIONS UNDER THE INFLUENCE OF OUTER SPACE FACTORS

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Non-metallic and polymeric composites (PC) are widely used for manufacturing space vehicles. In addition, space vehicles have been manufactured in the non-tight condition, which results in a long-term exposure of materials to all the space factors. Each of the space factors may disrupt the functions of a space vehicle. For example, the change of such mechanical characteristics as the coefficient of linear thermal expansion or the modulus of elasticity may change the geometrical parameters of orbital constructions made of PC, e. g., coal-filled plastic trusses and triplex panels for photo-converters, which are very important for the orientation accuracy and power supply of space vehicles. The usual thermal cyclic loads in a wide range of temperatures may destroy both the PC proper and structures including dissimilar materials.

The purpose of the proposed integrated experiment is to develop promising materials, coatings and structural elements intended for operation in outer space, as well as under the cryogenic temperatures, fine vacuum and radiation on Earth.

The objectives will be as follows:

1. To obtain test specimens of promising materials and coatings to study the influence of space factors on structural elements, friction units and power supply systems of space vehicle.
2. To develop techniques for adequate accelerated simulation of the influence of the space factors on materials on Earth and in space.
3. To test scientific equipment for conducting such studies in space.
4. To reveal the initial physical processes proceeding in materials and structural elements under the long-term influence of outer space factors.

It is intended to apply the following methods:

1. Long-term exposure of test specimens of the materials on the external side of the URM and control of the change of mass, charge accumulation, of the change in internal structure and surface temperature.
2. Experimental study of test specimens of the materials in the ground simulators using methods of adequate accelerated simulation of space factors.
3. Study of the influence of space factors on mechanical, tribotechnical, optical and physical properties of materials using the procedures developed in «Indentor», «Penta-Tribos», «Penta-Optics» and «Penta-Fatigue» experiments.
4. Monitoring the parameters of the vehicle's own environment and space factors, namely temperature, pressure, quantitative analysis of neutral and ionic components, density of atomic oxygen, density of power fluxes of positive protons, electrons and solar radiation.

The objects of study will be as follows:

- Non-metallic structural materials used for manufacturing space vehicles, e. g. carbon-filled plastics on the base of carbonic fillers LU-P*,

* Cyrillic abbreviator of name.

ELUR*, UKN-500* and epoxy resin such as EDT-10*; structural fiberglass plastics; cables coming in the set; lacquers, enamels, temperature-controlling and other coatings; adhesives such as VK-46*, VK-41*; plastic and rubber products.
(*authors:* Sitalo V. G., Tikhij V. G., Litvishko T. N., Primakov V. D. et al.);

- Mock-up of the solar battery frame with a photoelectric converter (FEC) consisting of the following layers: structural glass-reinforced or carbon-filled plastic — adhesive — honeycomb aluminium filler — adhesive — structural glass-reinforced or carbon-filled plastic — adhesive — FEC — optical adhesive — quartz glass and carbon-filled plastic truss

(*authors:* Sitalo V. G., Tikhij V. G., Primakov V. D. et al.);

- Metallic materials: cast and wrought aluminium alloys AL2*, AL4*, AL4C*, AMg6*, D16*; titanium alloy VT6*; high-alloyed steels 12Kh18N10T*, I654, EP56*, heat-resisting alloy E1868*

(*authors:* Kalinushkin E. P., Sinitcyna Yu. V.);

- Test specimens of reflecting coatings for a space-based helio-concentrator

(*authors:* Gudramovich V. S., Pasichny V. V., Stegnij A. I.);

- Metal and ceramic compounds with coatings based on transient metal borides, with high strength and resistance to radiation and temperature cycling

(*authors:* Podcherniajeva I. A., Panasiuk L. A.);

- New sealing, insulating and shielding materials on the base of thermally-expanded graphite reinforced by metal nets and strips for EVA operations.

(*authors:* Vishniakov L. R., Kosygin V. P., Moroz V. P., Kokhanyj V. A.);

- New polymeric composites for protection against the ionising radiation

(*authors:* Vishniakov L. R., Grudina T. V.);

- Radio-reflecting materials based on metal and metal-containing knitted reticulate structures for transformable structures and transformable aerials of space vehicles

(*authors:* Vishniakov L. R., Kokhanyj V. A., Kokhana I. N.);

- Self-lubricating anti-friction composite materials of a new generation on metal, polymeric, and glass-ceramic base

(*authors:* Kostornov A. G., Brodnikovskij N. P., Beloborodov I. I, Yuga A. I.);

- Test specimens of bearings, turbine rotors and other friction units from zirconia-based ceramics with magnesium stabilisation system (Mg-PSZ) and titanium intermetallic compounds for application in orbital devices

(*authors:* Firstov S. A., Vasil'ev A. V.);

- Compounds from titanium aluminides and high-temperature coatings based on Ti-Al system

(*author:* Oliker V. E.);

- Materials and designs for small-sized highly reliable on-board voltage converters on piezoelectric ceramics base for power supply to the space vehicle instrumentation

(*author:* Rud' B. M.);

- Thermal electric cells for conversion of solar energy into electric energy

(*author:* Goriachev Yu. M.);

- Module for solar energy accumulation on hydride base

(*authors:* Schur D. V. et al.);

- Materials on silicon carbide base for laser mirrors of information transmission in space

(*author:* Gnesin G. G.);

- Materials on rare-earth oxide base for coatings of laser mirrors of guidance systems and information transmission in space

(*authors:* Andrejeva A. F., Kasumov A. M.);

- New photoconductive materials with improved stability based on solid solutions of transient metal silicides for temperature-sensitive resistors exposed to outer space

(*author:* Dvorina L. A.);

- Hydrogen-containing compounds and ceramic materials activated with hydrogen, which are used as biological protectors against radiation and as the sources of hydrogen fuel

(*author:* Morosova R. A.).

The entire set of equipment of the experimental flight unit («Degradation») will be used to meet the objectives of such an integrated experiment by the mentioned methods. It is also planned to develop the following new scientific equipment.

- Space-based helio-concentrator

(*authors:* Skorokhod V. V., Gudramovich V. S., Pasichny V. V., Stegnij A. I., Frolov G. A.).

The mirror parabolic concentrator will be manufactured of eight all-metal nickel sectors by the method developed at the Institute of Technical Mechanics of the NASU-NSAU. Devices manufactured by this technology have already been used on «Ocean» (Yangel State Design Office «Pivdenne»), «Mars» (Lavochkin Scientific-Industrial Union), «Meridian» space vehicles, etc. The helio-concentrator will be equipped with precise tracking system for solar observations. This system will correct for the ISS's vibration and will be located on the outer platform of the URM. The characteristics of helio-concentrator are as follows:

— total power consumption is not more than 300 W;

— diameter of concentrator is up to 2 m;

— weight of mirror concentrator is up to 5 kg;

— focal distance is equal to 0.85 m;

— power concentration coefficient is about of 3000...5000;

— density of the heat flow in a focal spot of 0.01 m diameter is equal to 12000 kW/m^2.

- A complex of self-contained measuring instruments to control the loss of weight, charge accumulation, change of internal structure and surface temperature of test specimens of materials

(*author:* Surdu M. N.).

The measuring equipment developed by the State Scientific & Industrial Enterprise «Spetsavtomatica» is the hardware for system implementation, which may be integrated into a common information system by the onboard computer. The onboard computer should process the information in real time and compress it for telemetry. The measuring equipment is self-contained. Designed to vibration survival, the proposed measuring equipment will have the volume of about 150...200 cm^3 (excluding the volumes of the sensor and the studied test specimen), and the weight of not more than 100...200 grams. It will be able to operate within the temperature range of −40...+50°C and will bear g-loads during injection into orbit. The measuring equipment should be installed in a pressurised module.

- Fiber-optic sensor of atomic oxygen and radiation (designed by the Canadian Institute for Space Researches of the University of Toronto (UTIAS)). Upgrading of this sensor will be done by the Yangel State Design Office «Pivdenne».
- Space Ionic Micro-Analyser «SIMA»

(*author:* Cherepin V. T.)

On-board space ionic micro-analyser (SIMA) for local and layer-by-layer analysis of materials by the method of secondary ion mass spectrometry will have the following characteristics: total weight of up to 60 kg, power consumption of up to 60 W, localisation better than 10 microns, resolving power equal to 50 Ё and mass numbers in the range of 1...200. It will permit analysis of all the elements of the Mendeleev periodic system with up to 10 % response. SIMA will also permit remote-control analysis. This device is intended for conducting various materials science experiments, e. g., on study of corrosion under the actual space conditions, degradation of solar panels, nature and composition of various contamination on the ISS structural elements.

A ground-based facility will be used to improve the methods of study of the space factor influence on materials. It includes a 6-factor simulator of the KIPHK SDTO of the Institute for Low Temperatures Physics and Engineering (*author:* Abraimov V. V.), the helio-plant system of the I. N. Frantsevich Institute for Materials Science Problems in Kiev, and the Crimean Helio-Laboratory (authors: Trefilov V. I., Skorokhod V. V., Pasichny V. V., Frolov G. A., Stegnij A. I.).

«Astro» Sub-Experiment of the «Resource» Experiment

DEVELOPMENT OF BEARINGS AND TURBINE ROTORS AND OTHER FRICTIONAL PARTS MADE OF CERAMICS

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The purpose of the experiment is development of bearings and turbine rotors and other frictional parts for space industry, which are made of zirconia-based ceramics with magnesia and yttria stabilisation systems and of titanium intermetallic compounds.

Mechanical devices and moving parts are vital units for the actual and future space missions. Failures or degradation of such basic mechanical components as bearings and seals may impair a mechanism performance or interrupt a spacecraft operation. The designers consider zirconia-based ceramics as an ideal material for the space/vacuum