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SPACE EXPERIMENT "OBSTANOVKA (1-STEP)", BLOCK DP - PM ON THE RUSSIAN SEGMENT OF THE INTERNATIONAL SPACE STATION

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Abstract

In the presented work is described the methodology for conducting the technological experiment DP-PM, which is part of the space experiment "Obstanovka 1-step". The DP-PM block was installed on the Russian Segment of the International Space Station in the period from 04/19/2013 to 08/10/2015. The purpose of the experiment is to study the effect of outer space on the properties of graphite samples with a glassy carbon coating and samples of B95 (7075) aluminium alloy with a quantitative addition of ultradisperse diamond powder and tungsten after a long stay in near Earth orbit.

Introduction

The study of outer space leads to the creation of new materials or the improvement of existing ones for the construction of space vehicles. These materials must not only work, but also not lose their physical and mechanical properties during long stays in non-standard conditions of outer space (microgravity, intense radiation, a wide range of operating temperatures, micrometeor bombardment, vacuum, mechanical effects: acceleration, vibration, etc.). They must also combine high modulus of elasticity, heat resistance, wear resistance, density, and other properties useful for space engineering.

To obtain complete and real data on the consequences of a long stay of new materials used for space technology, it is necessary to conduct special technological experiments on board interplanetary stations, which ensure the possibility of returning samples of the studied materials back to Earth. For this

purpose, the DP-PM experiment was planned and implemented, which is part of the “Obstanovka 1-step” space experiment [1], within the framework of the "Long-term program for scientific and applied research and experiments on the Russian segment of the International Space Station (ISS)". This is an international project in the interests of fundamental space research and is of an exploratory nature, carried out with the help of a plasma-wave complex of scientific equipment.

Purpose of the experiment

The purpose of the experiment, associated with a device called the DP-PM block (Potential Sensor - Material Surfaces), is to study the influence of outer space on the properties of new materials after a long stay in near-Earth orbit.

The DP-PM block is a container (Fig. 1) made of aluminium alloy. It has a nickel coating on the back and experimental samples inside. On one side 8 pcs. rectangular graphite samples with a glassy carbon coating [2, 3] (Fig. 1a), and on the other side of the block there are 10 pcs. cylindrical tubes made of aluminium alloy B95 (7075) with a quantitative addition of ultradisperse diamond powder and tungsten (Fig. 1b). The experimental samples are the goal of our experiment, and the block is the place where the samples are fixed. They are attached to the container using a spring-loaded cotter pin in the holes on both sides for better and more convenient work with them when they are removed and installed by a cosmonaut outside the ISS, in zero gravity conditions.

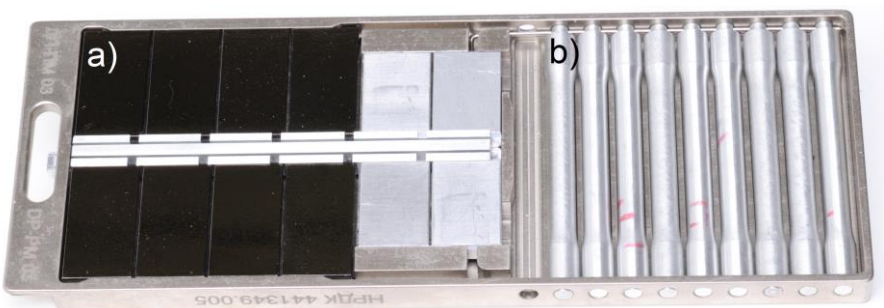

Fig. 1. Block DP-PM; a) graphite samples with a glassy carbon coating, b) samples of aluminium alloy 7075 (B95) with a quantitative addition of ultradisperse diamond powder and tungsten

The main stages in the development of the DP-FM block correspond to the specific stringent requirements for conducting experiments in space and include the preparation of a methodology for manufacturing and testing the device [4].

The first stage is associated with the construction (Fig. 2) and the manufacture of the DP-PM block, also called the Technological Sample (TS) for acceptance tests and design and finishing works.

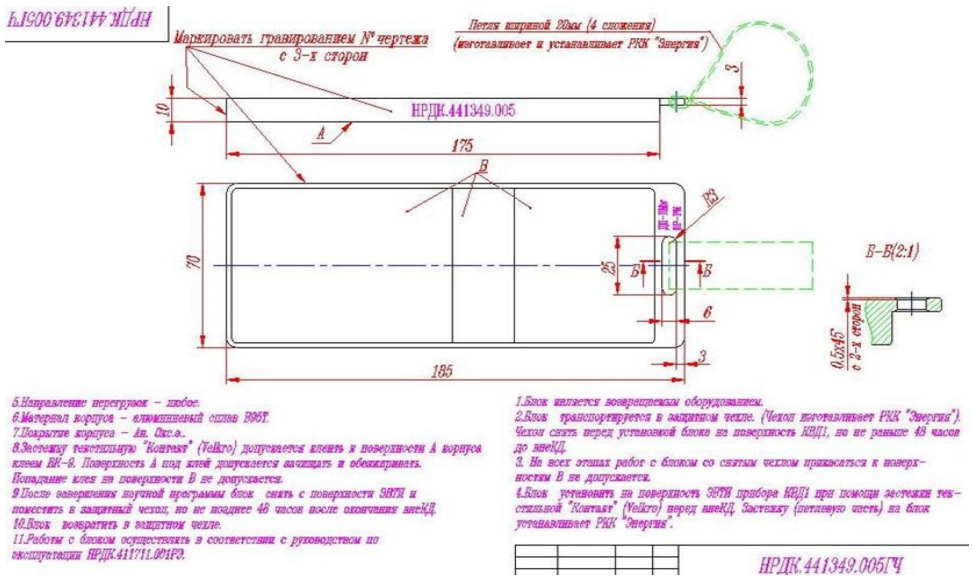

Fig. 2. Dimensional drawing of the DP-PM block

Certain requirements are imposed on the design of the DP-PM facility for solving experimental problems while simultaneously limiting the dimensions, connecting dimensions, weight, and appearance.

The developed DP-PM block meets the requirements of the program and methodology for conducting the DP-PM experiment, which is presented below:

1. Check the complete device package and documentation

The check is carried out in accordance with the current methodology, designations, markings, the presence of seals and factory numbering of the unit, as well as the availability of documentation required for testing.

2. Check the appearance, dimensions, connection dimensions and weight

2.1. *Appearance check*

The DP-PM block must be free of pores, dents, cracks, scratches on the protective coatings and other defects that affect the quality of the surface, compromising the subsequent studies of the quality of the samples. The marking must correspond to the dimensional drawings of the block. The device meets these requirements.

2.2. Check dimensions and connection dimensions

Checking the overall and connecting dimensions is carried out with measuring instruments having an accuracy of at least 0.1 mm.

Requirements for the dimensions of the DP-PM block are up to 200 ×100 × 20 mm.

The manufactured block DP-PM has dimensions of 185 × 70 × 10 mm.

2.3. Check the weight of the device

The mass of the product must not exceed 300 g, including the experimental samples contained in it, and must be checked on a balance with an accuracy of ± 50 g.

The mass of the Technological Model (TM) with experimental samples is 260 g, the mass of the Aircraft Model (AM, flying model) with experimental samples and loop grip is 268 g.

3. Vacuum tests

The DP-PM block is placed in a vacuum chamber. Its performance is checked in accordance with the procedure, then the pressure in the chamber is reduced to 10^{-4} and the unit is kept under these conditions in the chamber for 1 hour.

4. Test for high / low operating temperature

The tests are performed in a thermal chamber.

For the DP-PM installation the operating temperatures are from –50 ^{0}C to + 50 ^{0}C.

The operability is checked in accordance with this methodology.

4.1. Check heat resistance at transport temperature

The DP-PM block is installed in a non-working state in a thermal chamber.

The chamber is heated to a temperature of +50 ^{0}C, the device is kept for three hours. The heating of the chamber is turned off and the temperature is set (+20 ^{0}C). The device is kept under these conditions for 2 hours and they begin to check the operability of the device using this methodology.

4.2. Check for cold resistance at transport temperature

The DP-PM block is installed in a non-working condition in a thermal chamber.

The chamber is cooled down to –50 ^{0}C, the device stays for 3 hours. The chamber heater is turned off, the temperature is reached (+50 ^{0}C) and the device is kept under these conditions for 1 hour.

5. Check for moisture resistance

The DP-PM block is placed in the humidity check chamber. After reaching the required test mode - temperature +25 ^{0}C ±10^{0}C and humidity 95 ± 3 %, the block stays in the chamber for 48 hours. The chamber turns off. Remove and temper under normal weather conditions for at least 3 hours.

6. Vibration resistance tests for sinusoidal accelerations at a frequency of 25 Hz

The DP-PM block is mounted on the plate of the vibrating stand by means of Velcro in the operating position. The vibrating stand is set at a frequency of 25 Hz, acceleration 2 g, and the block is vibrated for 30 minutes. At the end of the test, the block is removed from the hob, visually inspected for mechanical damage or background noise. After the test, no mechanical damage was observed, the integrity of the experimental samples, the surface contacts and the operability of the DP-PM block were established.

7. Impact test or linear load test

The DP-PM block must operate under conditions of external influencing factors that supplement and clarify the requirements for equipment according to OST 92-5100-2002.

The DP-PM block is fastened with Velcro to the platform of the impact stand. The test is carried out in accordance with the operating instructions on the bench, with a load of 40 g, pulse duration of 1–3 s, three impacts on each of the three mutually perpendicular axes of the block (18 strokes in total). The stand is turned off, the block is removed, an external inspection is carried out to identify mechanical damage and performance.

The DP-PM block does not need power supply and has no electronic elements. It is a mechanical structure, therefore all the requirements are mechanical and therefore, the block was subjected only to the necessary series of thermal and mechanical tests and subsequent incoming inspection in accordance with the technical requirements for the space experiment "Obstanovka 1-step" on the Russian segment of the International Space Station.

After the successful conducting of the tests of the Technological Model (TM) according to the approved methodology, two DP-PM blocks were manufactured. A Flight Model (LM), designed for full-time tests and one block DP-PM (GL - main model), intended for training a cosmonaut-operator in a hydro-laboratory pool. All samples are structurally identical.

The second stage of the project is connected with the development of a methodology, according to which the operator-cosmonaut trains in the hydro-laboratory pool. The goal is to make every action work and that each action is performed from the extraction of the block from the transport bag to its installation on the surface of the PWC1 (plasma wave complex), through the simulation of the

real environment in outer space. Both cosmonauts take part in each training session, each time wearing gloves that simulate the real conditions of mounting the block on the outside of the ISS in orbit.

The third stage is associated with the development of a methodology for delivering the DP-PM unit to the ISS, as well as installation on its outer side [5].

On April 12, 2013, the DP-PM unit was delivered by the Progress M418 transport spacecraft to the ISS. On April 19, 2013, it was taken out and installed by cosmonauts Pavel Vinogradov and Roman Romanenko on the outer side of the ISS, on the plasma-wave complex (PWC) through “Velcro” (Fig. 3).

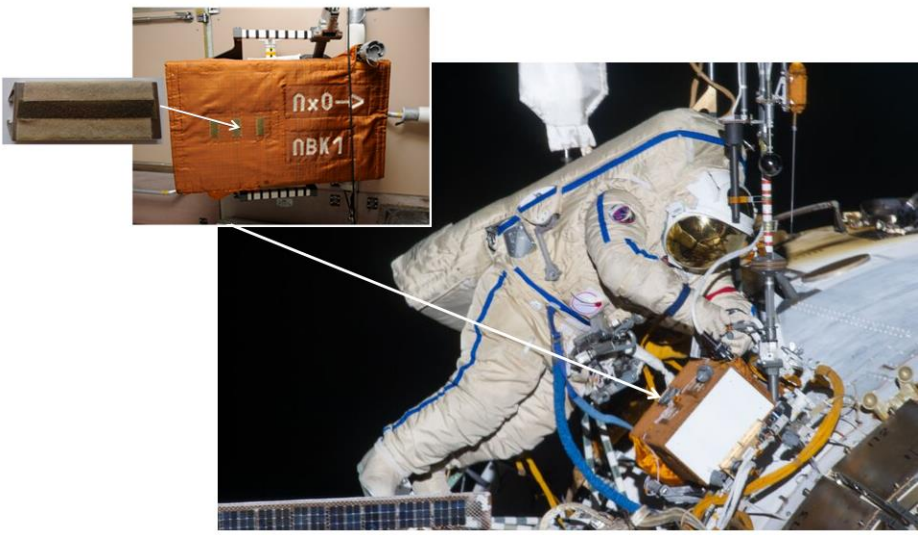

Fig. 3. Cosmonaut Pavel Vinogradov, Plasma Wave Complex (PWC) and DP-PM block installation

The fourth stage of the experiment "Obstanovka 1-step" includes the dismantling of the DP-PM unit in strict accordance with the special dismantling methodology [6–8] developed by SRTI-BAS, IKI-RAN and approved by RSC Energia.

After a stay of 2 years and 4 months, on August 10, 2015, the DP-PM block was dismantled from the surface of PWC1 without disrupting the operability of the plasma-wave complex (PWC1), which includes measuring equipment. The unit was dismantled and brought on board the ISS by cosmonauts Gennady Padalka and Mikhail Kornienko. All requirements are met to prevent mechanical damage to the surface of the samples and the integrity of the installation, as well as contamination when it is stored in the operator's bag.

Fig. 4. Hermetic container for storage of the DP-PM block

When storing the DP-PM unit on board the ISS, there are no special requirements for the composition of the atmosphere, humidity, and hermetic degree. The airtight container (Fig. 4) guarantees that the samples will not be damaged or contaminated during the storage of the facility on board the ISS, as well as during its delivery to Earth.

The methods for assembling and disassembling the DP-PM block are extremely accurate. Each action of the cosmonaut is described in detail, starting with opening the hatch and ending with its closing after the cosmonauts have completed their work in outer space. This includes an accurate timeline of the cosmonauts' activities. The entire process is monitored and controlled by the Mission Control Center in the Moscow Region.

The requirements for the delivery of the DP-PM block to Earth are identical to the requirements for the delivery of the DP-PM block on board the ISS. They are performed in accordance with the instructions of PKK "Energy" [8].

On September 12, 2015, the Soyuz TMA-16M transport spacecraft with a crew consisting of cosmonauts Gennady Padalka (Russia), Aiden Aimbetov (Republic of Kazakhstan) and astronaut Andreas Mogensen (Denmark) was launched from the International Space Station to Earth. On the same day, the lander vehicle landed in Kazakhstan (146 km southeast of the city of Zhezkazgan).

After the delivery of the DP-PM block from the ISS to Earth, in accordance with the requirements for ensuring the further safe operation of the samples, the block was first subjected to microbiological examination and autoclaving in accordance with the instructions (recommendations) of PKK Energia.

Results

The technological experiment DP-PM, which is part of the space experiment "Obstanovka 1-step", was successfully completed in the period 19.04.2013 - 10.08.2015 on the Russian Segment of the International Space

Station. The DP-PM block was launched (taken out) into outer orbit, was in space and returned to Earth intact, unharmed, and undamaged, both on itself and on the experimental samples.

Two separate methodologies have been developed based on modern methods for analysis and determining the influence of outer space on both materials: graphite samples with a glassy carbon coating and a newly created composite of B95 (7075) aluminium alloy with a quantitative addition of ultradisperse diamond powder and tungsten.

The methodology includes a precisely selected and complex set of spectroscopic, mechanical, and physical methods for characterizing the physicochemical, structural, and morphological changes that have occurred under the influence of space conditions.

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КОСМИЧЕСКИ ЕКСПЕРИМЕНТ „ОБСТАНОВКА (1 - ЕТАП)", БЛОК ДП – ПМ НА РУСКИЯ СЕГМЕНТ НА МЕЖДУНАРОДНАТА КОСМИЧЕСКА СТАНЦИЯ

А. Бузекова–Пенкова, С. Климов, В. Грушин, О. Лапшинова, Д. Новиков, Д. Теодосиев

Резюме

В настоящата работа е описана методиката на осъществяване на технологичен експеримент ДП-ПМ, който е част от космическия експеримент „Обстановка 1-етап". Блок ДП-ПМ е бил монтиран на Руския сегмент на международната космическа станция в периода 19.04.2013–10.08.2015. Целта на експеримента е изследване на влиянието на открития космос върху качествата на графитни образци със стъкловъглеродно покритие и образци, изработени от алуминиева сплав В95 (7075) с количествена добавка на ултрадисперсен диамантен прах и Волфрам, след продължителен престой в околоземна орбита.