THE NEWLY DESIGNED GROUND SIMULATOR FOR SPACE INTEGRATED-IRRADIATION ENVIRONMENTAL SIMULATION AND SCIENTIFIC RESEARCH ON THE ORBITAL BEHAVIORS OF SPACE SYSTEMS

Chengyue Sun (1), Dandan Ju (1), Xinbin Zhang (1), Hao Wang (1), Chen Liu (1), Lifang Li (1), Xueyin Sun (1), Jihong Yan (2)*, Yiyong Wu (1,3)*

(1) Laboratory for Space Environment and Physical Sciences, Harbin Institute of Technology, Harbin, China, sunchengyue@163.com
(2) State Key Laboratory of Robotics and Systems, Harbin Institute of Technology, Harbin, China, jhyan@hit.edu.cn
(3) National Key Lab in Materials Behaviors and Evaluation Technology in Space Environments, Harbin Institute of Technology, Harbin, China, wuyiying@hit.edu.cn

ABSTRACT

Of the complex environments in space, the particle irradiations from Van Allen Belt, solar cosmic ray and also galaxy cosmic ray were improved the most important factors to affect the service reliability of spacecraft. Up to now, laboratory simulation of energetic particle is realized on the basis of accelerators of electrons and ions (proton or heavy ions). However, the orbital radiation environments include electrons, proton and heavy ions with a diapason from a few eV to some GeV, and also change from time to time or from orbit to orbit, together with other factors as solar electromagnetic radiation, vacuum, et al. In that case, it is necessary to simulate the integrated environments for the ground tests.

As one of the key parts of the solar-system environmental simulation and research platform, the integrated irradiation simulator is mainly aimed at the simulation of space comprehensive irradiation environment. It will enable integrated and equivalent tests of the major radiation environments in the solar system and to carry out comprehensive science research on irradiation environmental effects of materials, devices, especially spacecraft systems (modules). Thus it would help expose the essence of the space radiation-environmental effects, reveal the spatiotemporal behaviors, and also evaluate the orbital performance and the reliability of materials, devices and also spacecraft system.

According to the knowledge about the irradiation environments and characteristics in the solar system, the integrated irradiation simulator is designed not only to simulate the particle irradiations using some specific accelerators, but also to include other strongly-correlated environmental factors such as vacuum, thermal sink, high/low temperature or thermal cycling, and electromagnetic radiation (solar simulator and ultraviolet radiation). Among them, the basic parameters are determined for the systematic modular tests as followings: The vacuum chamber dimension is designed as Φ5000mm × 6350mm; The pressure of the vacuum simulator can be realized a vacuum better than 5 × 10⁻³Pa without load and the pressure better than 6.5 × 10⁻³Pa during the tests at temperature of 100K (controlled using thermal sink mode). Due to the diapason characteristics of the space charged particles, we set and design six accelerators as the particle sources of electron and proton/heavy ions to equivalently simulate the orbital particle irradiations and their effects. Hence, the energy levels of the accelerators were set as 200keV, 1MeV and 10MeV for electrons, while for protons as 200keV, 4MeV and 10MeV, respectively. In the meantime, the solar electromagnetic radiations were also designed with 2 Suns solar simulator (can be upgraded to 5 Suns in the future) and the vacuum ultraviolet irradiation at 3.5 UV Suns (can be extended to 5 Suns). Inside the simulator, a sample holder was designed with a five freedoms’ driver to load the tested sample with a dimension of 1000 mm × 1000 mm × 1000 mm and weight less than 200 kg. In order to carry out the in-situ scientific tests on the space environmental effects of the space materials, devices and system components, the newly designed simulator is also equipped with a variety of spectral analysis instrument, mass spectrometry, electrical meters, et al.

Thus, the main functions of the new-type integrated irradiation simulator include as followings:
(1) Synergistic effects of multi-particle irradiation on space materials, devices, and especially the system-level components;
(2) Combined effects of multi-environmental factors on space materials, devices, and especially the system-level components, such as thermal effects, irradiation effects (ionization effect, displacement damage and also charge-discharge effects, et al.), electromagnetic irradiation effects, et al;
(3) Reliability evaluation tests of system-level components, such as thermal vacuum tests, vacuum thermal balance tests, and some specific environmental tests;
(4) Researches on the damage effects and mechanisms of functional materials, devices and also complex systems under the combined environments.

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