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THE EFFECTS OF SPACE ENVIRONMENT ON THERMO-OPTICAL DEGRADATION OF SOLAR SAIL MATERIAL

Abstract

Currently the most research related to the solar sail mission performance, analysis and design is accomplished assuming constant thermo-optical and mechanical properties of the solar sail materials. However, during the mission space environment significantly affects on the thermo-optical and mechanical properties of a solar material and they undergo the changes. Therefore, to address theoretical aspects of degradation of the thermo-optical and mechanical properties of a solar sail material when the solar electromagnetic and corpuscular radiation are considered as sources of degradation is a significant task.

Today very little is known how material degradation may affect the stability and functionality of solar sails during long term space missions. We present the analysis of the interaction of two components of solar radiation, the electromagnetic radiation and radiation of low- and high-energy elementary particles like electrons, protons, and helium nuclei emitted by the Sun with the solar-sail materials [1]. Physical processes of the interactions of photons, electrons, protons and α-particles with sail material atoms and nuclei, leading to the degradation of solar sail materials are analyzed. This analysis evaluates worst-case solar radiation effects during solar radiation pressure acceleration. Calculations utilized conservative assumptions with the highest values for the available cross sections for interactions of solar photons, electrons and protons with solar sails material. We suggest the model that considers the time evolution of decrease of the reflectivity and the increase the absorptivity of a solar sail material. Within this model a variation of the forces induced by reflection, absorption, and reradiation by the sail due to degradation of the thermo-optical characteristics of the solar sail material by the corpuscular part of solar radiation and its influence on a solar sail mission analysis is discussed. It is shown that the minimal thickness has strong implicit dependence on the temperature through the temperature dependence of the electrical conductivity of the solar sail material [2]. The temperature dependence of the solar sail material on the perihelion distance of the solar sail when the optical and physical properties of the sail material depend on the temperature is obtained.

1. R. Ya. Kezerashvili, "Solar Sail: Materials and Space Environmental Effects," in the book: Advances in Solar Sailing, pp 573-592, 2014. Editor: M. Macdonald, Springer Praxis Books, Berlin Heidelberg 2014.

2. R. Ya. Kezerashvili, Acta Astronautica 65, 507-518, 2009; JBIS 61, 430-439, 2008.