 Paper ID: 3018

SPACE PROPULSION SYMPOSIUM (C4)
Advanced Propulsion : Non Chemical, Non Electric (6)

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THICKNESS OF SOLAR SAIL FILMS FOR INTERSTELLAR TRAVEL

Abstract

We discuss mission opportunities to the outer solar system using solar sail propulsion with high cruise speed that allows exploring an extra solar space during a span of human lifetime. Estimation of the maximum possible approach to the Sun region by a solar sail propelling spacecraft for the interplanetary space mission is provided when the thickness of the sail film and temperature restrictions are taken into account. Applying the system of Maxwell's equations for linear conducting media we find the minimum film thickness that provides the maximum reflectivity and investigate dependence of this minimum thickness on temperature and electromagnetic spectrum frequency of solar radiation as well as estimate the mechanical strength of given material for the above found thicknesses of film. 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. The minimal thickness has explicit dependence on the frequency through the factor $1/\sqrt{\omega}$, where ω is the frequency of solar radiation, as well as it has implicit dependence on the frequency, because the conductivity and dielectric function are functions of the frequency. Results of thickness calculations for different candidates of metallic foils for solar sail are presented.

Increase of the temperature of the solar sail film in the near-Sun space environment changes electrical conductivity of the film material, thus effecting the reflection ability of the sail and imposing requirements on the film thickness. It is shown that temperature dependence of the conductivity of film at a constant temperature coefficient of conductivity requires an increase of thickness of the solar sail by a factor 2 to 3, depending on the solar sail material. On the other hand, an additional consideration of the temperature coefficient of conductivity dependence on temperature also requires an increase of film thickness by more than of about 35% at temperature above 600 K. Therefore, we suggest that these factors should be taken into consideration for the solar sail design.

This approach allows finding isothermal spheres for which solar sail spacecraft trajectories should be tangent. It can be applied to a wide variety of materials, and sail configurations utilizing metallic thin films in the near-Sun space environment.