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DEPLOYMENT OF THE LARGE SIZE SOLAR SAIL

Abstract

A solar sail presents a large sheet of low areal density membrane and is a propellant-less propulsion system for future exploration of the Solar System and beyond. One of the important objectives of the propulsion using a solar sail is the development of the mechanism for the deployment and stretching of large membranes in space.

In this work we present a comparison of two novel concepts for deploying and stretching of the large size solar sail:

i. the deployment and stretching of the thin circular membrane attached to the superconducting current loop [1,2],

ii. the deployment and stretching of the thin circular membrane attached to the inflatable toroidal shell [3].

In the framework of a strict mathematical approach based on the theory of elasticity elastic properties of a circular solar sail membrane, inflatable toroidal shell, and superconducting wire loop are analyzed. Within classical electrodynamics it is predicted the magnetic field induced by the Bi–2212 superconducting wire with today achievable engineering current densities can deploy and stretch the large membrane. The formulas for the superconducting wire and sail membrane stresses and strains caused by the current in the superconducting wire are derived.

It is predicted that by introducing the gas into the inflatable toroidal shell one can deploy and stretch a large size circular solar sail membrane. The formulas for the toroidal shell and sail membrane stresses and strains caused by the gas pressure in the toroidal shell are derived.

The analytical expressions obtained for both type of the deployment mechanism can be applied to a wide range of solar sail sizes. Numerical calculations for the sail of radii up to 100 m (10000 m^2) made of CP1 membrane are presented.

We demonstrate the feasibility of deployment and stretching of a solar sail with a large size circular membrane attached to superconducting wire loop or the inflatable toroidal shell.

References

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2. V. Ya. Kezerashvili and R. Ya. Kezerashvili, Solar sail with superconducting circular current-carrying wire, Advances in Space Research **69**, 664–676 (2022).

3. V. Ya. Kezerashvili, R. Ya. Kezerashvili, and O. L. Starinova, Solar sail with inflatable toroidal shell, Acta Astronautica **202**, 17–25 (2023).