CERIS : Civil Engineering Research and Innovation for Sustainability

Computational modelling and simulation of solar sail membranes: a multiscale approach

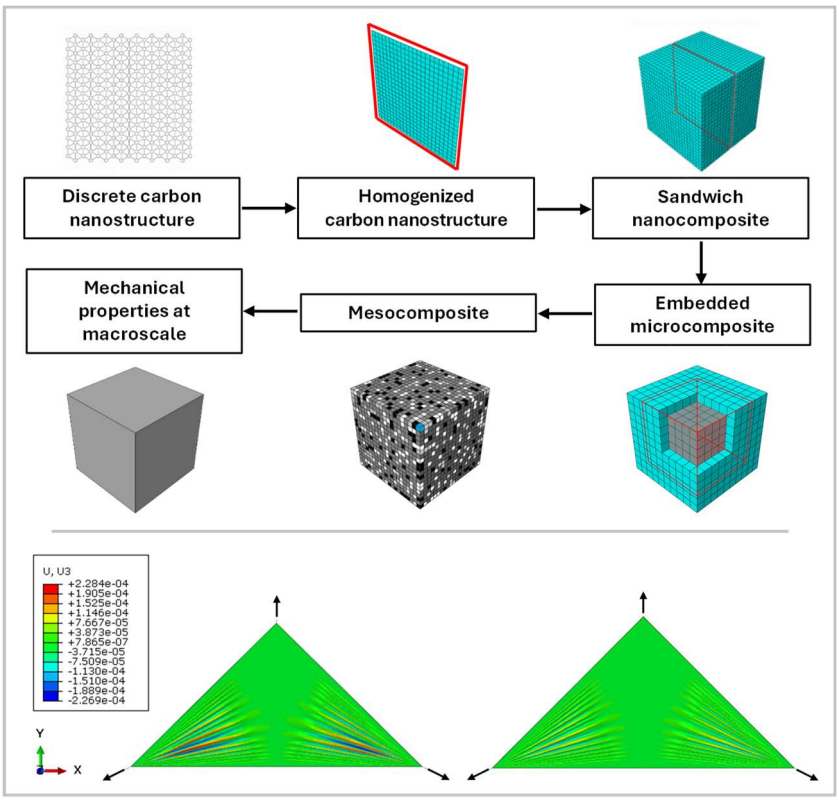
Summary

Solar sails are space vehicles that have been studied and used for several space missions. Their propulsive system is based on the incidence/reflection of photons, that transfers momentum to the sails. As this momentum is of a small magnitude, solar sails must possess a large and highly reflective surface area and, simultaneously, a low mass to generate the suitable acceleration. However, due to the very low thickness of the sail membranes, one problem that may occur is their wrinkling, which can degrade the efficiency of the space vehicle. Thus, the main objective of this work is to study the possibility of mitigating the wrinkling of solar sail membranes through the reinforcement with carbon nanostructures.

It is mainly concluded that the MPCS configuration presents lower deflections and is less prone to wrinkling than 5PCS, although it is more complex from a constructional point of view. The novel composite materials present superior mechanical properties (stiffness and strength) than Kapton and, simultaneously, similar densities. The inclusion of the novel composites on thin-membranes influences the static and wrinkling response of solar sails. In particular, both 5PCS and MPCS configurations present lower deflections due to solar pressure and lower wrinkle amplitude (in one case the wrinkling is eliminated) due to pre-tensioning. Therefore, the novel composite materials studied seem to be suitable options to include in solar sails membranes (in contrast, for instance, with the addition of strips in the wrinkling-prone regions that increase the weight of the membranes) in order to improve their structural behaviour and, in particular, to contribute to the mitigation of wrinkling.

Keywords

Solar sails thin-membranes, carbon allotropes, composites, multiscale analysis, finite element models.



Numerical multiscale analysis to obtain the mechanical properties of Kapton reinforced with carbon allotropes (top) and comparison of out-of-plane displacements between a wrinkled solar sail made of Kapton (bottom left) and a wrinkled solar sail made of Kapton reinforced with graphene (bottom right).

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