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MODELING AND ANALYSIS OF REINFORCED MEMBRANES FOR SPACE APPLICATIONS

Abstract

In the past decades, R&D of ultra-light ultra-flexible membrane structures has drawn continuous interests in both industry and academia. These structures have been extensively used for space deployable optics, reflectors and solar sails to succeed diverse space missions such as remote sensing, weather forecasting, satellite communication and space observation. Since membrane devices suffer from structural durability and damage tolerance limits, the recent studies have initiated a novel approach to reinforce the tear resistance of thin-film membranes, which prints a hierarchical structure on the film using fused deposition modeling technology. While the improvement on tear resistance has been experimentally demonstrated, the objective of this research is to develop a numerical approach to analyze the structural behaviors of such reinforced membrane. First, a finite element model is built to accurately describe the elastic-plastic performance of the membrane. The printed structure is considered as a beam with predefined curvatures, and appropriate boundary conditions are suggested to model the connections between the film and the printed structure. In the following part of the work, the numerical investigations are carried out in Abaqus on a reinforced square membrane which is clamped and loaded in one dimension. The stress distribution and the load-displacement curves are obtained from the finite element analysis, showing the modified Young's modulus and the improved tear resistance comparing to the thin-film itself. To validate the proposed approach, the numerical results are also compared with the experimental ones in the literature. Finally, numerical cases are investigated for different printed structures with various thicknesses, material properties, shapes and orientations. The discussions on these cases are addressed, providing the design guidance of the printed structure to achieve the desirable damage tolerance in future space applications.