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VIRTUAL TESTING OF FOLDING AND DEPLOYMENT OF COMPOSITE ULTRATHIN TAPE SPRING HINGES VIA UNIFIED 2D SHELL MODELS

Abstract

Over the years, deployable structures have become increasingly popular in space engineering, since they make it possible to obtain a consistent reduction of mass, volume and consequently of the cost of a satellite. The most common type of deployable booms is tape springs, which can be described as thin-walled elastic strips. A combination of those can be used to generate other types of booms, such as tape spring hinges, which are self-locking hinges that are able to deploy autonomously. The utility of these structures has already been highlighted in a variety of explorations missions for deploying solar panels in a space environment (see, for instance, the MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding) antenna deployment system). It has been demonstrated that the geometric characteristics strongly in influence the mechanical behaviour of these structures. Moreover, their applied momentum vs rotation angle curve shows a peak, which value is a key parameter for a proper design. Finally, once the peak momentum is reached, the equilibrium curve is strongly nonlinear. Those effects are mainly evaluated through experiment tests, since standard analyses demand for a high cost in terms of computational effort and requested calculation time. However, a numerical tool able to reproduce the real structural properties of tape spring hinges could represent an advance on this topic. In this context, this work proposes a unified model for the virtual testing of composite tape-spring hinges. By employing the Carrera Unified Formulation, the ultra-thin boom can be modelled using refined two-dimensional shell elements. The complex three-dimensional displacement field is accurately evaluated across the nonlinear equilibrium curve using higher-order through-the-thickness expansion functions, for a layer-wise description of the composite material. This capability allows for an accurate description of the failure prediction within the structure during folding and deployment movements. The nonlinear governing equations are solved in a total Lagrangian scenario using a Newton-Raphson linearization scheme along with a path-following method of arc-length type. The results highlight the accuracy of the proposed approach, comparing the numerical results with those obtained with experiments, and the capability of dealing with di different geometric properties and evaluating failure indexes during the folding and deployment simulation.