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A HIGHER-ORDER BEAM FINITE ELEMENT FOR THE FOLDING ANALYSIS OF COMPOSITE-MADE BOOMS WITH SILICONE MATRIX AND CARBON FIBERS

Abstract

Over the last few decades, elastic deployable space structures have been widely used to store the volume of a spacecraft during the launch phase and allow it to open once in orbit to achieve the designed operational shape. One of the most widely used examples of deployable systems is the tape spring in its metal, carbon fibre composite and memory matrix composite configurations. However, these configurations require a heating process to operate successfully. In fact, traditional tape-springs become softer above a transition temperature and then retain a rigid configuration after folding, but if re-heated they could eventually self-deploy. One of the solutions proposed is to use composites with very soft matrices, such as silicone matrices, which are orders of magnitude softer than standard epoxies. This approach has two advantages: 1) the same behaviour as traditional deployable mechanisms can be obtained without the need for heating procedures; 2) the fibres are allowed to micro-buckle without breaking within the soft matrix, and this phenomenon allows the material to reach very high curvatures. However, the simulation of these types of mechanisms is very often limited to simplified analytical models. These models are not able to capture the phenomena occurring at the micro level. To overcome these problems, this work proposes a unified beam element for the analysis of hyperelastic matrix composites. The beam finite element is built within the framework of the Carrera Unified Formulation (CUF), which allows the construction of refined one-dimensional models. Thanks to the so-called component-wise approach, the fibres and the matrix can be modelled as two separate entities, the former linear-elastic and the latter hyperelastic, and the micromechanics of the problem is addressed directly. A Gent hyperelastic model is used for the matrix. CUF is aldready beem demonstrated to be reliable when dealing with traditional deployable structures and for the analysis of hyperelastic components. Here, the formulation is further extended and applied to hyperelastic booms. The results are compared with those from the literature, including experiments and other numerical simulations.