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Abstract

This dissertation is concerned with the study of thin CFRP composite deployable structures, specifically tape-springs. Tape-springs have generated great interests within the aerospace industry because they can form lightweight, self-powered and self-locking hinges for space application. We are interested in plain weave CFRP composites, as a substitute for conventional materials, e.g. steel and copper-beryllium, for tape-springs because they not only provide weight-savings but also balanced and tailorable properties.

Simple analytical models have been developed to predict in-plane properties of plain weave CFRP composites, to estimate the maximum moment achieved by CFRP tape-springs (for both equal and opposite-sense bending) and to establish the relationship between the transverse radius and the fold radius of these tape-springs. The prediction of in-plane properties is verified experimentally using standard tensile, in-plane shear and compression tests. In addition, a newly devised bending test is used for investigating the tightest possible fold survived by a flat CFRP specimen. Failure strains derived from tensile, compression and bending tests show that one-, two- or three-ply specimens in bending survive much larger equivalent surface strain. Hence, the failure strain criterion is found to be unsuitable if such thin specimens are modelled as homogeneous plates. As a result, the failure of thin CFRP specimens is best described by a direct measurable parameter - their failure curvature. A biaxial bending rig has been developed in order to cater for the bi-directional folding of tape-springs. Limiting curvatures of flat and curved (i.e. tape-spring) specimens of equivalent dimensions are presented and their failure locus is plotted for different ply lay-up. This locus serves as a useful preliminary design guide for CFRP tape-springs.

FE models are created to simulate the folding of tape-springs and to study the effect of the angle subtended by a tape-spring. They are also used to design suitable tape-springs for testing and to confirm that neither uniaxial bending nor biaxial bending of the CFRP specimens has any edge effects during the test.

Finally, an application of CFRP tape-springs in a self-deployable boom is explored, both numerically and experimentally. FE models are developed to study the folding of this boom with hinges made of three tape-springs. Furthermore, deployment and repeatability tests have been carried out to study the stowage effects on the boom.

Keywords: CFRP, tape-springs, deployable structures, biaxial bending.

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