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 tapersprings 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.