Virtual Testing of a Composite Cylindrical Lattice Structure

Composite grid structures are a promising solution for replacing some of the current aluminium and traditional composite parts in aerospace applications because they achieve a significant weight reduction. Traditional composites are characterized by their strength and stiffness along fiber direction, while mechanical properties in other directions are not favorable. In contrast, the principal load-bearing elements of grid composite structures are unidirectional composite ribs, maximizing their specific structural contribution. The optimum weight-saving solution is a lattice structure, which is a grid structure formed by a lattice pattern without skin.

Researchers Jordi Torres and Norbert Blanco at Universitat de Girona and Encarna del Olmo and Eugenio Grande at EADS CASA Espacio developed a virtual testing tool implemented within Abaqus/Standard to assist during the design of a cylindrical lattice composite structure for aerospace applications. This design will be manufactured by EADS CASA Espacio following the Advanced Fiber Placement (AFP) composite layering method within the frame of the CENIT-ICARO Spanish research project. The AFP manufacturing method is a well-consolidated technology at EADS CASA Espacio, which has been selected to build a new generation of ultralight structures based on grid and lattice designs.



Figure 1. First buckling mode calculated with a beam-based model used to assess the structural response.

The virtual testing tool was implemented in two steps. First, a parametric analysis with a preliminary model was considered to determine the best design solution for the cylindrical lattice structure in terms of natural frequency, buckling load and weight. Due to the nature of lattice structures, the geometry of all the lattice configurations was completely parameterized and analyzed with beam-type element simulations.

The second part of the virtual testing procedure consisted of the lattice structure testing simulation to predict the mechanical behavior of the real structure. Due to the size differences between the large-scale structure and the local interactions, the virtual testing was divided into two analyses. A Finite Element (FE) model composed with beam elements (Figure 1) assessed the global structural response—natural frequency and buckling load, while the local failure was obtained with a FE model including solid elements only. In this case, a global model provided the displacements to a local submodel that assessed the failure criteria (Figure 2). The intralaminar failure was calculated with LaRC-04 failure criteria, which account for different composite failure mechanisms and consider nonlinear shear behavior and in-situ effects. The possible adhesive peel-off between the lattice part of the structure and the extreme load interfaces was also analyzed through the following procedure: 1) Determine critical zones using a stress-based criterion, 2) Apply the Virtual Crack Closure Technique (VCCT) with a pre-crack with the measure of the minimum detectable defect and 3) Run a nonlinear analysis involving cohesive elements.

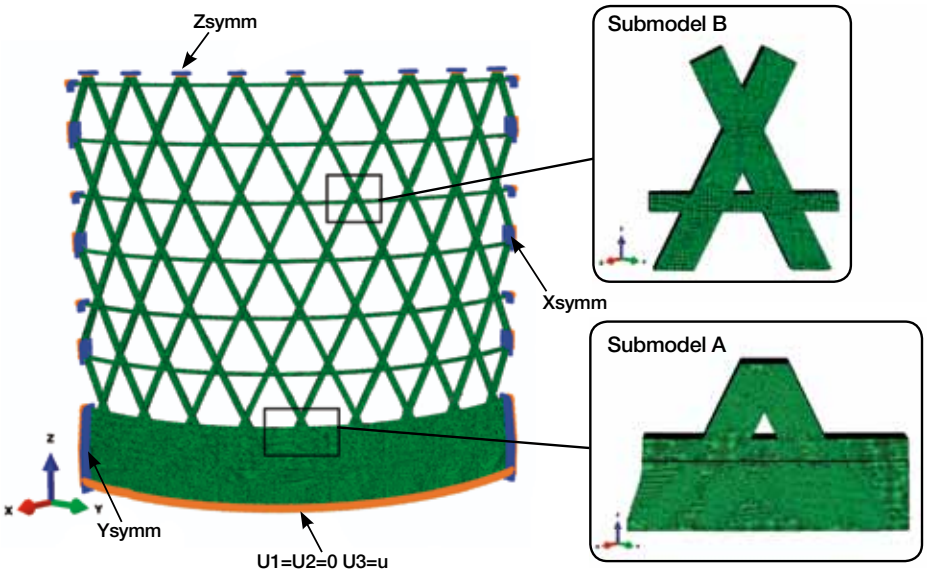


Figure 2. Solid model and submodels to analyze the failure mechanisms of the cylindrical lattice.

The results of the composite cylindrical lattice virtual testing procedure showed an optimum ratio between weight and load capacity of the structure. As desired, fiber compressive failure in the ribs of the lattice part far from the load interfaces was predicted before the general collapse of the structure under buckling conditions. Moreover, the stability and stiffness requirements could be achieved with a significant weight reduction in comparison with current designs.

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