The Use of Topology Optimization in the Conceptual Design of a next generation Lattice Composite Fuselage Structure

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This presentation reports results of a conceptual design phase of a collaborative research programme aiming at the development of manufacture-optimized lattice fuselage structures satisfying fundamental requirements of airworthiness. Composite lattice filament-wound tubular structures have been successfully applied for several decades in Russian rocket technology due to their excellent strength and stiffness to weight ratio. This research was initiated by a geodesic design that is well-established and flight-proven in space technology and is now transferred to lattice designs for composite aircraft fuselage structures.

In the collaborative EU and RU project "ALaSCA", coordinated by the DLR on European side, a forward swept wing T-tail narrowbody aircraft concept has been chosen as composite "friendly" aircraft due to the long uninterrupted fuselage barrel section in front of the wing. Parallel to the iterative development of a preliminary airframe design, done by DLR, the topology optimization was used to analyse the different load cases and maximize the stiffness of the fuselage barrel, done by University of Leeds.

To identify an efficient pattern of ribs to carry given sets of loads, topology optimization has been initially performed for each individual load case by minimizing the compliance of the structure. This allowed to establish a rationale for the weightings in the weighted compliance objective function to be minimized in topology optimization under all relevant load cases subject to constraints on the amount of structural material in a predefined design space. This was followed by the investigation of the effect of the window pitch on the conceptual design. As a result, a pattern of the reinforcement ribs has been established, see Fig. 1, that provided a backing to the specific choice of the preliminary design concept shown in Fig. 2.

The analysis of the topology optimisation results shows clearly the need of high longitudinal stiffness at the top and bottom and a higher plus minus stiffening on the side of the barrel. Reason is the resulting main load case of bending around the y-axis, so that a classical beam structure would be the best solution. Considering the need of a constant structure due to manufacturing and assembly efforts, DLR has developed an airframe concept with load carrying skin, stiffeners in grid configuration and frames. A low rib angle is a compromise of high longitudinal stiffness at the top and bottom of the structure and a higher skin buckling stability capability of the resulting non-rectangular skin bays. Avoiding assembly and manufacturing intensive rib knots, the helical ribs are placed on the two sides of the skin. In consequence a second skin on the outside of the structure is necessary, whether additional advantages can be integrated in that second skin as lightning strike protection, thermal and noise insulation and impact protection. Result is an innovative airframe concept with high function integration, high damage resistance capability and consideration of actual airworthiness requirements and demands.

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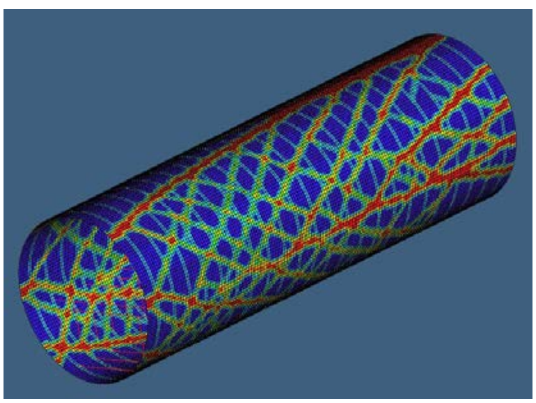

Figure 1. Rib pattern from topology optimization

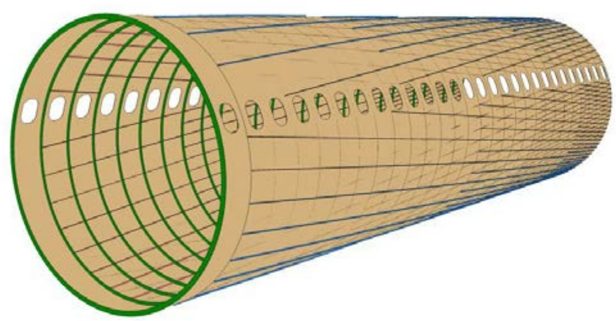

Figure 2. DLR lattice stiffened monocoque concept