

TOPOLOGY OPTIMIZED JUNCTIONS OF A STRUT-BRACED WING IN A CONCURRENT COMPOSITE OPTIMIZATION FOR A HYDROGEN AIRCRAFT

Lander Vertonghen⁽¹⁾, Charly Mollet⁽²⁾, Cédric Julien⁽¹⁾, François-Xavier Irisarri⁽¹⁾

⁽¹⁾DMAS, ONERA, Université Paris-Saclay, 92320, Chatillon, France

⁽²⁾DAAA, ONERA, Institut Polytechnique de Paris, 92320, Chatillon, France

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Abstract

In the context of reducing aviation's environmental footprint, conventional kerosene-powered, cantilever wing aircraft are approaching their performance ceiling. The drive for greater fuel efficiency and near-zero CO₂ emissions therefore prompts the search towards novel configurations that merge innovative layouts with alternative energy sources. Very high aspect-ratio (VHAR) wings, paired with liquid-hydrogen (LH₂) propulsion, emerge as a promising solution. Because LH₂ tanks can be housed inside the fuselage, the wing is freed from fuel-volume constraints, enabling a truly "dry" wing design. This liberty allows designers to develop wings with unconventional internal load-bearing structures. To reap the aerodynamic advantages of a very high aspect ratio and thin planform without incurring prohibitive structural weight, a supporting strut is introduced, yielding a favorable aero-structural compromise. Within the Clean Aviation UPWing project, ONERA, Delft University of Technology and University of Stuttgart are investigating such a LH₂-powered, strut-braced wing (SBW) concept (2500 Nm, 239 passengers, Mach 0.78) with the goal of minimizing the in-flight energy consumption through multidisciplinary optimization [1]. This communication presents a structural design methodology that combines topology and composite optimization to assess the structural opportunities and explore the extended design space of a SBW in order to estimate the primary mass of different configurations.

First, topology optimization is used to design the junction and load introduction of the strut into the wing, which is a key area for the SBW design. This topology optimization consists in a strength-constrained problem with isotropic stiffness properties and the worst load case, being a +2.5g elliptical lift distribution at maximum take-off weight (MTOW).

Thereafter, composite optimization is done in a bi-level framework. The composite optimization focuses on the wingbox and strutbox components (skin, spar, stiffener and rib), and aims at minimizing the total wing + strut mass under various load cases with strength and buckling constraints. Two designing load cases are

considered for this last analysis: the +2.5g elliptical lift distribution and a -1g lift distribution issued from an aero-elastic analysis, both at MTOW. The first level composite optimization is based on a homogenized stiffness approach of the laminates by means of the Lamination Parameters (LP) to obtain the overall stiffness distribution. Both wing and strut are divided into several zones chordwise and spanwise for the optimization. Each zone has its own thickness and LP properties. This first step serves to set the load distribution between the strut and the wing. Thereafter, a second step of fiber retrieval is performed from the homogenized properties using a Stacking Sequence Table (SST) optimization [2]. The SST ensures the continuity of the plies between zones of different thickness, and considers industrial guidelines on the layup sequence. The results of the methodology will be illustrated on different aircraft configurations issued from the SBW multidisciplinary optimization process.

References

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