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Title
Next steps in aerostructural design of ultra-high aspect ratio wings

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Abstract

The ultra-high aspect ratio wing (UHARW) concept is one of the promising configurations to satisfy strict sustainable aviation goals by improving aircraft aerodynamic efficiency. Unconventional aircraft configurations are required since the wing bending moment, and shear force in UHARW structures are significant if the conventional cantilever wing is utilized. UHARW is characterized by tight aerodynamic and structural coupling, thus requiring a multidisciplinary design optimization approach for the integrated design of UHARW aircraft. This paper summarizes our research activities in the conceptual design and aerostructural optimization of the UHARW aircraft.

Strut-braced-wing (SBW) and twin-fuselage (TF) are promising configurations for UHARW implementation since they can significantly reduce the wing bending moment by the additional support of struts or off-centerline-located fuselages [1]. Conceptual design methodology and framework of SBW and TF aircraft have been developed by the authors, including the weight estimation method for TF aircraft [2], TF aircraft conceptual design and optimization [3], and SBW and TF aircraft conceptual design and comparative study [1].

Fig. 1 SBW and TF aircraft with UHARW design.

Next, the conceptual design studies have been extended to the preliminary design level by executing higher fidelity aerostructural optimization method. FEMWET, a coupled-adjoint aerostructural optimization tool, developed by Elham and van Tooren [4] has been improved by integrating a geometrically nonlinear composite structural solver for UHARW [5]. The modified FEMWET was used for the resized mid-range SBW and TF aircraft aerostructural optimization according to the uncertainty analysis results [6]. During the optimization, both wing box structures, wing planform, wing airfoil shape, and strut thickness (for SBW) have been optimized and both the mission fuel weight, gross weight, and wing structural weight have been reduced significantly [7, 8]. Aileron design would influence the UHARW performance remarkably. Therefore, aileron design parameters, including spanwise aileron placement and aileron geometry, were included in design variables for the aerostructural optimization of the SBW aircraft [9]. Considering UHARW is prone to dynamic aeroelasticity, flutter constraints have been added to the coupled-adjoint aerostructural optimization method for high aspect-ratio wing aerostructural optimization with flutter constraints [10].

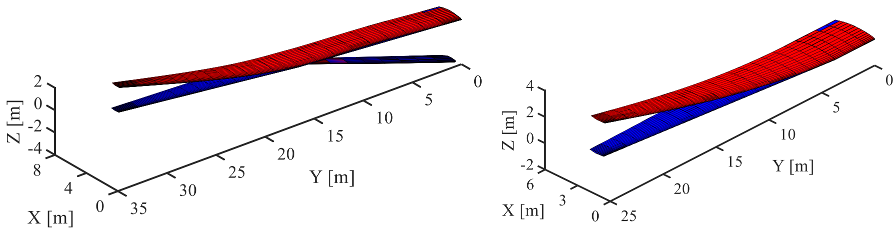

Fig. 2 Optimized wing deformed shape and jig shape of the SBW (left) and TF (right, fuselage is 4.5m in the Y direction) aircraft under +1.5g load case.

The research on UHARW has been extended to a high-fidelity level. Reynolds-average Navier-Stokes (RANS) method was used for the aerodynamic analysis of a high-aspect SBW. The structured mesh was generated and RANS solver ADflow was employed for computation. The results of RANS computational fluid dynamics are used for the flow characteristics investigation and utilized for the correction of the aerodynamic results in the above-mentioned mid-fidelity aerostructural optimization.

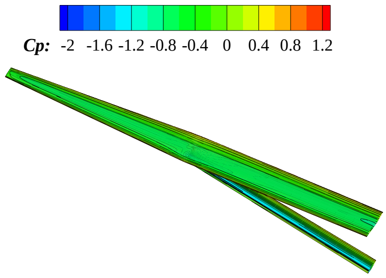

Fig.3 Surface pressure contours of the SBW.

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