

INVESTIGATION OF NON-LINEAR STRUCTURAL DYNAMICS AND AEROELASTIC PROPERTIES OF STRUT-BRACED WINGS IN A CONCEPTUAL DESIGN STAGE

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ABSTRACT

Strut braced or truss braced wings are used on a number of aircraft configurations. A strut reduces the bending moment on the wings, generated by the lift, and therefore allows wings of higher aspect ratio, reducing induced drag and thus fuel consumption and related emissions. Until now, strut braced wings have mainly been used on small aircraft for the lower speed range, but current conceptual designs also propose the use of strut braced wings for transport aircraft in the A320 class. Well-known examples of this are the Subsonic Ultra-Green Aircraft Research (SUGAR) studies and the projected Transonic Truss-Braced Wing Demonstrator (TTBW), originally planned to be realised as the Boeing X-66A by converting an MD-90. In Europe, ONERA in France in particular has investigated aircraft designs with a strut-braced wing, such as the ALBATROS configuration, and the design of a LH₂-powered Strut-Braced Dry Wing configuration (SBDW) studied in several projects of the current EU-funded Clean Aviation funding framework. A variant of this latter configuration has been the basis of the investigations presented in this paper, Figure 1. The configuration is provided in the Clean Aviation project AWATAR (Advanced Wing mATuration And integRation).

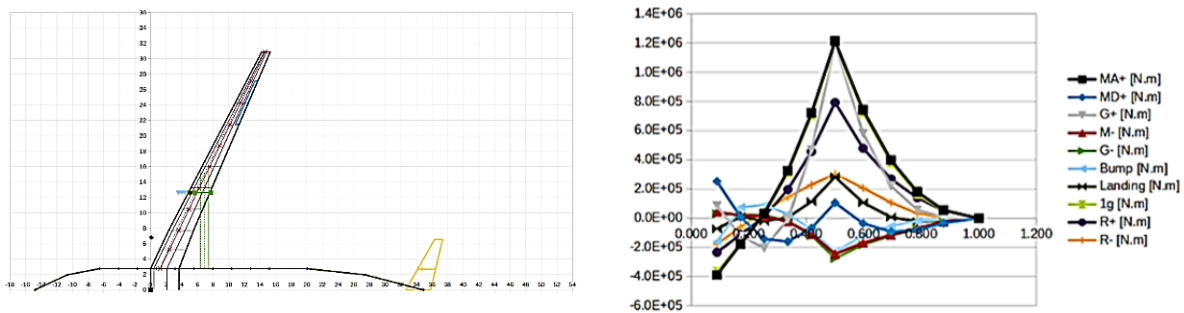


Figure 1: Left: Conceptual model of the strut-braced wing reference configuration (CLA tool); right: Contributions of different load cases on wing bending moment

A conceptual loads analysis (CLA) tool has been utilized to carry out parametric studies considering the strut attachment position on the wing span and chord, strut sweep angle, engine position in chord direction and lift factor. The CLA tool estimates the wing and strut mass based on an aeroelastic conceptual approach, considering empirical estimations as well as loads for 10 different load cases. An additional output are the stiffness distribution of the wing and strut along the span. For subsequent analyses outside the CLA tool, the beam model is exported as MSC NASTRAN input cards.

The optimum spanwise strut position depends on the chosen lift distribution. A good and robust compromise for a combined minimization of sizing loads and induced drag is reached

for a lift distribution shifted inboard with respect to an elliptic distribution, and the strut at the position of 47 % span, which corresponds to the value given for the reference configuration. The chord-wise position for the junction of wing and strut has also been investigated. Here, a position near the leading edge of the wing is most favourable. The optimum strut sweep for minimum total mass is rectangular to the fuselage.

Based on the CLA parametric studies for the AWATAR configuration an optimal baseline beam model with panel aerodynamic model and a respective mass distribution is derived. With this model the influence of an L-shape junction on the sizing of wing and strut, for varying lengths of the vertical element, is investigated. Such an “elbow” is required for a strut-braced wing flying at transonic speed to avoid strong interference effects and large local shocks in the region of the junction. Previous investigations had shown that local loads and stresses in the wing/strut junction increase considerably for an increasing length of the vertical element. Parametric studies performed in the course of the work presented here indicate that even vertical elements of moderate size have a visible positive influence on aerodynamic wing loads, Figure 3.

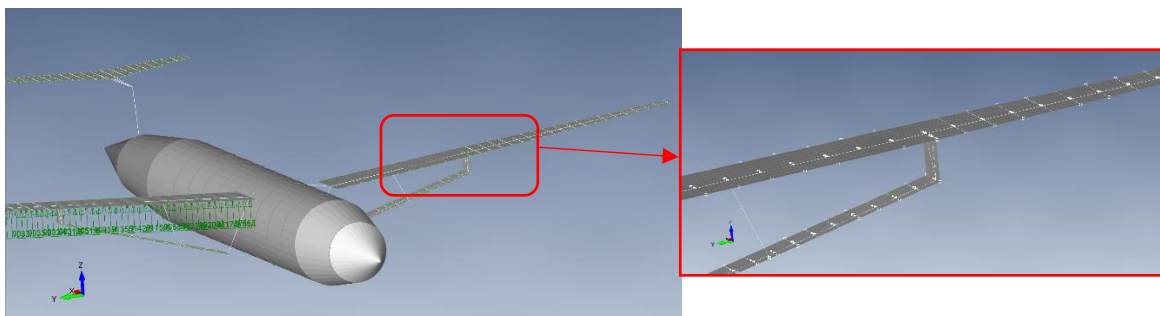


Figure 2: Beam finite-element model of the strut-braced wing reference configuration

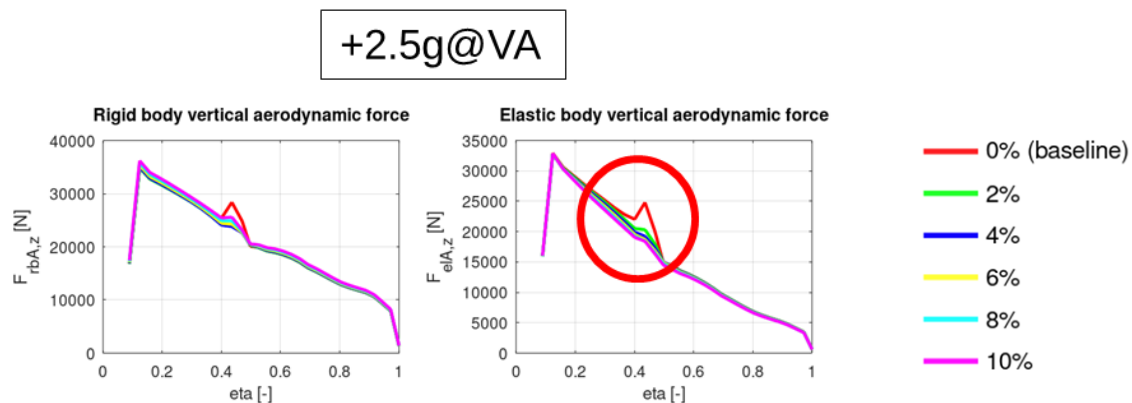


Figure 3: Loads for variations of “elbow” in beam model: 2.5 g manoeuvre

In classic aircraft configurations, the structural dynamics can be considered linear for small forces and deflections. Load analysis, flutter analysis and the design of the structures are usually carried out using linear methods. For strut braced wings, however, forces and moments as well as natural frequencies and natural shapes of the wings are dependent on the preload even for small deformations. Aeroelastic properties such as the flutter point are therefore also dependent on the flight condition, even when limited to linear aerodynamics. Thus, based on a baseline beam model with a reasonable L-shape, a comparison of linear and non-linear methods has been performed. In this study, a comparison has been made between loads, deformation and eigenmodes. Preliminary assessments indicate that the linear methods appear to be conservative in scenarios where the strut is subjected to a tension load. Further results regarding the linear and non-linear investigation will be shown in the full paper.