# Aeroelastic tailoring of a blended wing body (BWB) aircraft structure using FSI simulation

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## Abstract

The Blended Wing Body (BWB) design promises excellent fuel efficiency for future civil transport aircraft, in particular for large, long-range airliners. Structural weight and aerodynamic drag are the key parameters to be minimized to achieve the best bang for the buck. However, a lightweight, flexible airframe sensitively responds, not only to atmospheric turbulence, but also to level-flight aerodynamic pressures. Therefore aerodynamic efficiency, as well as maneuver loads are strongly coupled to aeroelastic properties of the wing structure, which forms the main body of the integrated airframe. Atmospheric turbulence and gusts require special attention for the BWB configuration, too, as the comparably low wing loading makes the structural response prone to gusts, rather than maneuvers.

The herein presented research activities concentrate on a highly efficient BWB configuration, developed in the EC funded research project ACFA2020, see [1]. Aeroelastic tailoring for drag and loads minimization is considered crucial for this aircraft. Best weight efficiency is expected by a full composite airframe with an integrated load bearing concept for wing loads and cabin pressure. Dynamic aeroelastic properties have to be included in the design process, as the wing of this aircraft revealed severe flutter problems in the initial sizing task, see [2]. Further, transient gust loads need to be passively controlled by the structural properties, in order to remain in an acceptable range.

A structural design optimization process for the primary structure of the BWB aircraft is presented. The structural deflections and dynamics of the airframe are assessed by a finite element model, see figure 1. The level of detail allows for individual design of composite stringers, skins, ribs and spars. The structural parameterization of the composites is realized by the so-called lamination parameters, which allow for arbitrary laminate layup with only twelve parameters, or even six, if the laminate is balanced and symmetric.

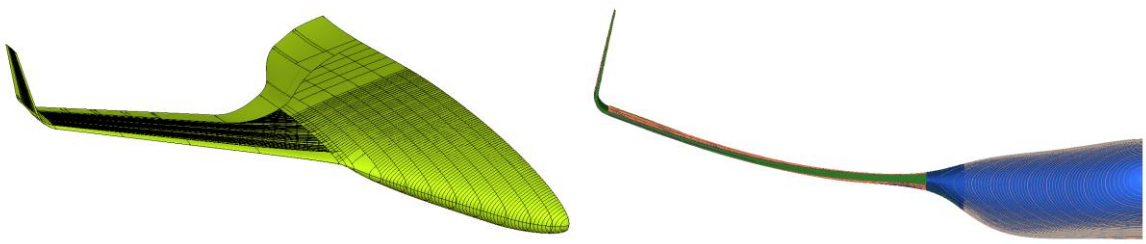

**figure 1: BWB aircraft configuration, FE model (left) and 1st structural mode (right)**

As one of the main goals of the design task is aerodynamic drag minimization, an accurate prediction of the flow field around the deformed aircraft (flight shape) in steady flight is required. Therefore a numerical simulation of the 3-d flow, described with the Reynolds-Avaraged-Navier-Stokes (RANS) Equation, is coupled to the design process. Steady fluid-structure-interactions (FSI), caused by the elastic deformation of the airframe, as well as control surface deflections, are directly accounted for in the iterative flow simulation. For this purpose, a strongly coupled, partitioned two way FSI Scheme is used, to solve the flow and structural field. Fast convergence of the simulation, which is crucial for acceptable computing time in optimization, is strongly influenced by mesh morphing. To avoid bad mesh quality near trailing edges, it is necessary to adapt the morphing algorithm in these regions. The mesh motion is calculated from a diffusion equation, so that morphing properties can be influenced by varying the mesh diffusion terms over the domain.

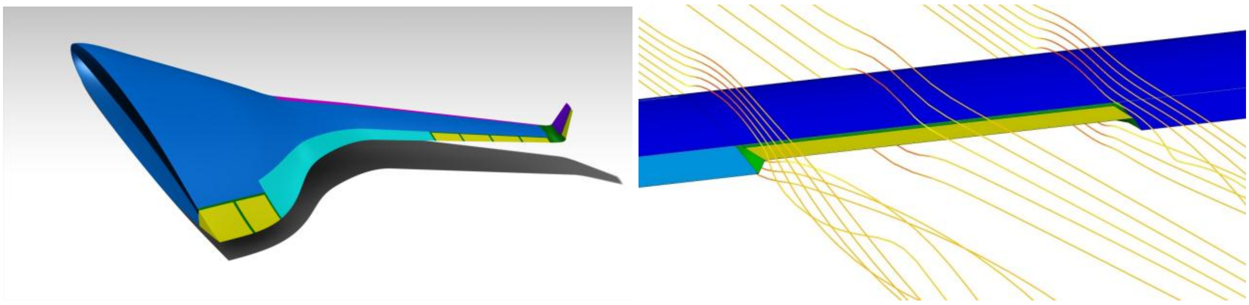

**figure 2: Aerodynamic shape with movables (left) and streamlines at a wing detail with deflected aileron**

Dynamic aeroelastic properties are predicted within the design process, making use of a low-order unsteady aerodynamic panel method (DLM). The airframe response to atmospheric gusts, flutter speed and other aeroelastic criteria, like required aileron efficiency, are then considered in the structural design task. The fuel efficiency of the optimized structural configuration is assessed by fuel burn in a simplified long-range mission. The potential of gust load alleviation (GLA) for this aircraft configuration has already been showed in the course of the ACFA2020 project, see [3]. For the aeroelastically tailored structural configuration, GLA is redesigned and tested in simulation.

## References

[1] *Paulus D. et al.:* "Configuration Selection for a 450 Passenger ultra efficient 2020 Aircraft" 3rd EUCASS, 2011

[2] *Stroscher F. et al:* "Reduced order model (ROM) of a blended wing body (BWB) aircraft configuration" 3rd EUCASS 2011

[2] *Wildschek A. et al:* "Hybrid Controller For Gust Load Alleviation And Ride Comfort Improvement Using Direct Lift Control Flaps" 3rd EUCASS 2011