Aeroelastic-Tailoring of a Wind-Tunnel Model for Passive Alleviation of Static and Dynamic Loads

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Abstract:

The present work has been carried out within the ONERA-DLR's common research program (CRP) FIGURE, which aims to investigate the optimisation of the gust response of flexible wings. With this goal, ONERA and DLR designed two different wind-tunnel models, sharing the same cruise geometry – the common research model (CRM) [1] – and the fabrication process – a composite external skin, filled with a polymer foam. The two models have been manufactured by the DLR and they have been tested in Meudon (France) at the ONERA's transonic wind-tunnel S3Ch in 2021. This work presents the design process by ONERA.

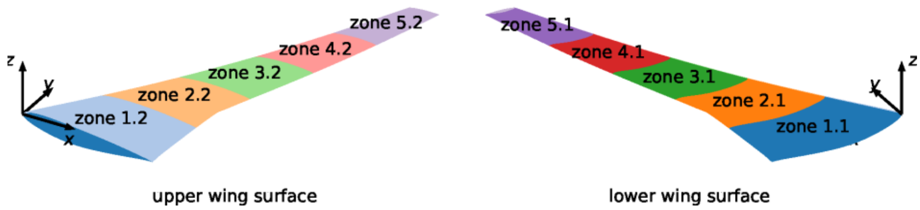

Figure 1. Wing-geometry and regions for the composite-optimisation.

Both the ONERA's and DLR's design strategies exploit composite materials to tailor the elastic properties of the structure: in aeroelasticity, this is widely known as *aeroelastic-tailoring* and it translates into the possibility of passively enhancing the aerostructural characteristics of the model. In particular, the present design process aims to alleviate both static and dynamic aeroelastic loads. The root bending moment for a high load-factor condition quantifies the former, while the deformation amplitude of the wing under sinusoidal gust the latter. Thus, the external composite skin is divided into ten design regions: laminates are considered uniform within each region in order to be optimised by the design procedure. Lamination parameters [2] are used to parametrise the elastic properties of the composite stacks, allowing a gradient-based optimisation. Unsteady and off-cruise performances are evaluated via a FEM/DLM model of the wing, while RANS simulations [3] are used for the cruise condition.

The twofold – static and dynamic – objective leads to the identification of a Pareto's front. Multiple design solutions are computed for different compromises of the two sub-objectives and, consequently, the final design is chosen among them via an additional criterion on the jig shape.

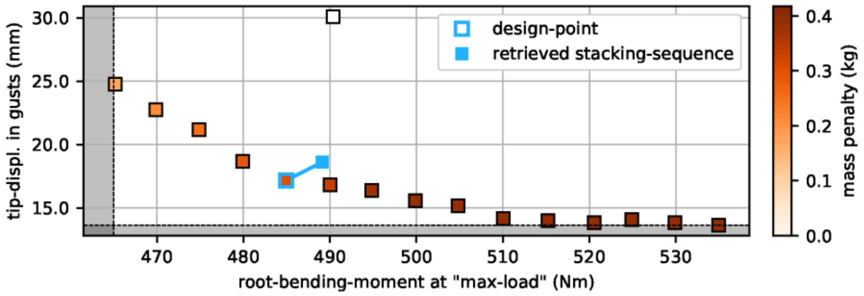

Figure 2. Pareto front. The color-scale report the mass penalty with respect to the optimal-mass solution, here in white. The light-blue contoured point is the selected design-point, while the light-blue square reports the performance of the retrieved stacking-sequence. The optimal limits for the two cost functions are reported by the shaded areas.

If, on the one hand, the lamination-parameters formalism allows a convex description of the optimisation problem, on the other hand it does not directly provide the *stacking-sequence* – i.e., the orientation and the order of each ply in the laminate – necessary to the fabrication of the wing. Hence, as final step of a bi-step design-strategy, the stacking-sequences are retrieved for each desing region via a specialised evolutionary algorithm [4] and the performance and constraints of the identified manufacturable solution are verified and compared against the design point.

References

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