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Aircraft composite fuselage structural modelling, analysis and optimisation

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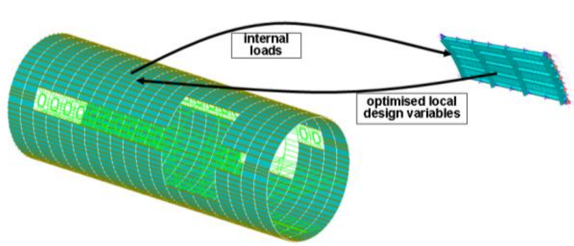
Abstract

In the past decades the use of carbon fibre reinforced composite materials on commercial aircraft has been gradually growing, reaching levels of up to about 50% of the structural weight of current state of the art aircraft like the Boeing B787 and the Airbus A350. The advantages offered by these materials are multiple, such as allowing for the design of more integrated structures, yielding lighter and stiffer structures and requiring less maintenance than the traditional metallic structures [1]. In the design analysis and optimisation of primary aircraft structures the focus is usually on the sizing of structural design variables that represent the local thin-wall properties of the structure, like skin thicknesses and stringer dimensions [2]. The increasing use of composite materials in these primary aircraft structures requires that the design analysis and optimisation methods that are used for these structures take into account the specific properties of these materials. For example for structural design and weight optimisation, both the structural geometrical configuration parameters and the composite properties have to be taken into account. These composite properties typically include ply level material properties and laminate stacking sequences, leading to a design problem with both continuous design parameters e.g. for geometric variables like stiffener dimensions, and discrete design parameters e.g. for ply orientations and laminate thicknesses. Dedicated optimisation methods have been developed for that, which are however often applied to smaller scale structures such as fuselage panels [3] and not the complete fuselage structure.

The present paper deals with methods for design analysis and optimisation of larger scale structures, in particular of a composite fuselage barrel. Efficient simplified

representations of the composite parameters are considered to avoid discrete design parameters. An optimisation methodology was developed where global barrel level structural optimisations are combined with buckling failure constraints coming from more detailed panel level structural optimisations [4]. Design analyses are based on finite element method (FEM) models of different fidelity for the different levels and computational efficiency is achieved by exploitation of various surrogate modelling methods [5]. Instead of the relatively coarse FEM model that was previously used for the barrel level analyses [4], the present study makes use of a much more detailed FEM model of the barrel in order to examine the validity of the representation of the local loading condition in the barrel by the panel level FEM model and its surrogate models. This is achieved by sub-model extraction of a panel level model from the detailed barrel FEM model and evaluation of the sub-model buckling response in comparison to the panel level FEM and surrogate models.



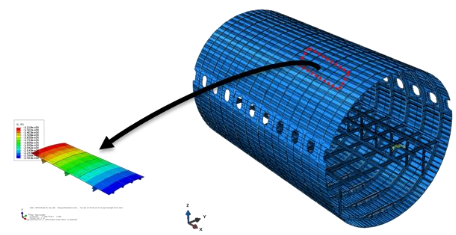


Figure 1: Coarse FEM barrel model and panel model used in optimisation (left) and detailed FEM barrel model and panel sub-model used in validation (right).

References

[1] C. Kasapoglou, Design and analysis of composite structures: with applications to aerospace structures, Wiley, 2010.

[2] S. Grihon, L. Krog and D. Bassir, Numerical Optimization applied to structure sizing at AIRBUS: A multi-step process, Int. J. Simul. Mult. Des. Optim. 3, 432-442, 2009.

[3] P. Kaletta, K. Wolf, D. Hachenberg, Optimisation of composite aircraft panels using efficiency enhancing evolutionary algorithms, ICAS2006, Hamburg, Germany, 2006.

[4] W.J. Vankan, R. Maas, S. Grihon, Efficient optimisation of large aircraft fuselage structures, RAeS 3rd Aircraft Structural Design Conference, Delft, the Netherlands, 2012. (NLR-TP-2012-377).

[5] W.J. Vankan, W.F. Lammen and R. Maas, Meta-modeling and multi-objective optimization in aircraft design, in: Advances in Collaborative Civil Aeronautical Multidisciplinary Design Optimization, chapter 6, E. Kesseler, M. Guenov, eds., AIAA, 2010. (NLR-TP-2009-718).

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