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Title

Robust CAD Methodology for CFD optimizations

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Abstract

The use of multidisciplinary design optimization (MDO) is becoming increasingly widespread in the aviation industry. The basis for RANS CFD simulations performed in this context is a parametric CAD model, which represents all geometry variations over the parameter space extended by MDO. In the context of describing the methodological structure of CAD models for CFD investigations, Ronzheimer [1] has given a general overview. Since the high aspect ratio commercial aircraft configuration investigated in the MDO project "Virenfrei" [2] is to be published as DLR-F25 [3], the structure of the CAD model is described in detail in this paper for reference.

The special thing of parametric CAD models is the feature-based structure, which leads hierarchically from simple basic geometries via more complex assemblies to the final model. Such a structure is not unique, each variant has advantages and disadvantages. Especially in the MDO context, the final CAD model is described by a large number of variable parameters, which makes a structured design of the model indispensable. The parametric follows a hierarchical structure: Primary parameters such as the wingspan develop in several steps into secondary parameters such as the curvature of the rounded wing tip. Consequently, it makes sense to separate these from each other. The primary parameters are combined in a 'skeleton model', in which also basic geometries such as leading and trailing edges are designed. At the lower hierarchy levels, all submodels reference these elements almost exclusively. In this way, the secondary parameters and modeling steps are encapsulated in the submodels. They follow an optimization iteration automatically but are also updated when copied into the context of other projects after adaptation of the skeleton model.

Another methodical benefit is the update robustness: while construction work for product design includes a large part of manual work, a basic requirement of parametric CAD models in the optimization context is the ability to update without any manual input. The chances of correcting update problems after a change of input parameters are strictly limited. Due to the hierarchical structure, an update error in one of the primary geometries thus leads to a failure of the full update cycle. Obvious causes of such errors are for example input parameters that lead to geometric incompatibilities, such as a changed profile top that penetrates the bottom. Another cause are changing normal alignments of curves and surfaces depending on the parameter combination, which have to be stabilized by suitable measures.

CAD models are of the first step in most CFD toolchains. The methodology described in the paper was implemented with the software CATIA from Dassault Systèmes. However, since this is transferable to any parametric CAD system, this paper contributes to improving the quality of CAD models and thus the CFD results.

References

[1] Ronzheimer, Arno. "CAD in Aerodynamic Aircraft Design." (2017).

[2] C. Ilic et al., “An Application of the Cybermatrix Approach for Many-Discipline High-Fidelity Multi-Disciplinary Optimization to Design of a Very High-Aspect Ratio Narrow-Body Airliner”, Abstract submitted to AIAA Aviation Forum 2023

[3] S. Wöhler et al., “Establishing the DLR-F25 as a research baseline aircraft for the short-medium range market in 2035”, Abstract submitted to EUCASS 2023.