Assembly constraint fit during gradient-based shape optimization of the TU Berlin Stator

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Shape optimization in industrial workflows is usually performed on individual components of a product rather than considering complex CAD (*Computer Aided Design*) models that define the complete product's assembly. However, the optimal shape of a component may cause a collision with adjacent components when re-inserting it in the assembly CAD model. This would imply further changes on the component's geometry which would impair the optimality of the shape. Therefore, it is of crucial importance to respect assembly constraints during the optimization. One type of assembly constraint is related to fasteners such as bolts and screws, that serve to connect various components in the product's assembly. Such a constraint is defined for the TU Berlin (TUB) *TurboLab* Stator test-case, which is a component used in modern jet-engine compressors. In particular, the optimal blade has to accommodate four mounting bolts (cylinders) that serve to mount the blade to its casing. To tackle this requirement, a gradient-based workflow has been developed in this study in order to integrate a CAD kernel into an optimization loop. However, computing CAD gradients is a challenging task and typically this information is not provided within CAD systems.

For this reason, algorithmic differentiation (AD) is applied to the open-source CAD kernel Open CASCADE Technology (OCCT) to obtain the so-called *geometric sensitivities*, e.g. derivatives of a surface point with respect to design parameters of the CAD model to be optimized. Next, the differentiated OCCT is coupled with a discrete adjoint CFD (*Computational Fluid Dynamics*) solver developed at Queen Mary University of London, also produced by AD. This completely differentiated design chain is employed to perform the aerodynamic shape optimization of the TUB stator blade, with the aim to minimize the total pressure loss. Moreover, an automatic positioning of the cylinders during the optimization is accomplished using the derivative information from the differentiated OCCT.

The gradient-based optimization with a high-fidelity CFD simulation converged after 42 iterations and yields 14% reduction of the objective function. Moreover, the developed approach ensures there is no collision between the optimal blade and the cylinders.

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