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[Extended Abstract]

NURBS-based optimisation of TU Berlin Stator with moving endwall intersection

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Introduction

The application of adjoint CFD method has become a firmly-established technique in the turbomachinery industry and is more and more coupled with CAD tools in gradient-based shape optimisation. As a rule, these CAD-based methods rely on in-house parametrisations tailored for the specific application. Therefore, the result strongly depends on the knowledge and experience of the designer, who ensures the quality of the parametrisation is suitable to effectively tweak the corresponding flow physics.

In this paper we propose to use the generic BRep (Boundary Representation) and corresponding NURBS parametrisation, which could be further refined on-demand, composing the richest design space for the optimisation. We exploit recently differentiated version of OCCT (Open Cascade Technology CAD-kernel) that provides the necessary derivatives for CAD algorithms. The described techniques are used to optimise TU Berlin Stator testcase [1]. Configurations with fixed/moving blade and endwall are investigated.

1. CAD-based optimisation with differentiated OCCT

Successful automatic differentiation (AD) of the complete CAD-kernel OCCT was achieved by integrating the AD tool ADOL-C into its sources. [2]. The differentiated OCCT not only allows to get derivatives of NURBS surfaces with respect to their polygon control net, but also provides exact gradients for more elaborate algorithms such as surface-surface intersection.

Recently, several interesting approaches for CAD-based optimisation of the TU Berlin Stator [1] were proposed both using gradient-based and conventional optimisation methods. In [3] the authors rely on an in-house parametric engine to optimise the shape of the stator. In [4] the parametric CAD model of the blade is complemented by the endwall contouring controls based on smooth trigonometric functions. In both cases, the necessary CAD sensitivities are computed with finite differences and geometric constraints could be imposed directly on the explicit design parameters.

Another technique, used in the present work, consists of using NURBS surfaces which are put together at their borders, for which constraints are imposed to reach a certain degree of continuity [5]. This is obtained by distributing test points along the surfaces along which constraints are imposed, such as e.g. distance between pair of test points for constraining the minimum thickness of the blade, or curvature to constrain the radius of curvature near the leading or trailing edge.

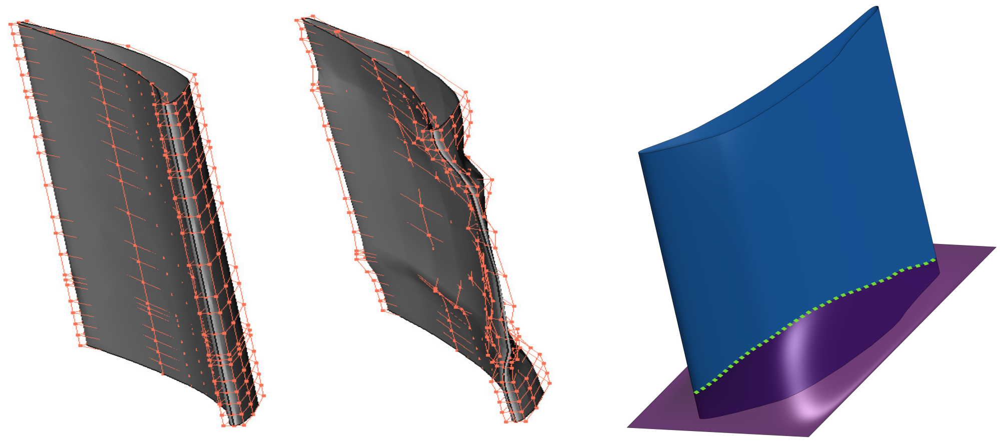

Figure 1. Left: Initial and Optimised NURBS of TU Stator; Right: Endwall perturbation and the moving intersection line

In Fig. 1 the preliminary NURBS-based optimisation results for the TU Berlin Stator are presented. Altering the NURBS control points resulted in a 13% reduction of total pressure loses and the shape is compliant with all geometrical constraints. In the final paper, more detailed description of the constraints and high-fidelity CFD results will be presented.

2. Moving Intersection

The following process is conducted to optimise the TUB endwall, also parametrised as a NURBS. The previously optimised blade remains fixed and any perturbation of the endwall will modify the intersection line with the blade as shown in the Fig. 1. By means of OCCT, the new intersection is recalculated and the mesh morphing tool is run again to take into account the updated CAD topology. All these operations are using the differentiated OCCT, therefore the actual endwall perturbation is naturally driven by the existing gradients of the above mentioned process. The recalculation of the intersection genuinely resembles the typical CAD workflow, when after series of manipulations different surfaces are intersected and then trimmed. This sequential optimisation (first blade, then endwall) will be compared to a more traditional approach, where continuity constraint is set on the intersection between the blade and the endwall and both entities are allowed to move simultaneously.

References

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