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Efficient Computer-Aided Design-Based Multilevel Optimization of the LS89

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Abstract : The paper deals with a single point optimization of the LS89 turbine using an adjoint optimization and defining the design variables within a CAD system. The advantage of including the CAD model in the design system is that higher level constraints can be imposed on the shape, allowing the optimized model or component to be manufactured. However, CAD-based approaches restrict the design space compared to node-based approaches where every node is free to move. In order to preserve a rich design space, we develop a methodology to refine the CAD model during the optimization and to create the best parameterization to use at each time. This study presents a methodology to progressively refine the design space, which combines parametric effectiveness with a differential evolutionary algorithm in order to create an optimal parameterization. In this manuscript, we show that by doing the parameterization at the CAD level, we can impose higher level constraints on the shape, such as the axial chord length, the trailing edge radius and G2 geometric continuity between the suction side and pressure side at the leading edge. Additionally, the adjoint sensitivities are filtered out and only smooth shapes are produced during the optimization process. The use of algorithmic differentiation for the CAD kernel and grid generator allows computing the grid sensitivities to machine accuracy and avoid the limited arithmetic precision and the truncation error of finite differences. Then, the parametric effectiveness is computed to rate the ability of a set of CAD design parameters to produce the design shape change dictated by the adjoint sensitivities. During the optimization process, the design space is progressively enlarged using the knot insertion algorithm which allows introducing new control points whilst preserving the initial shape. The position of the inserted knots is generally assumed. However, this assumption can hinder the creation of better parameterizations that would allow producing more localized shape changes where the adjoint sensitivities dictate. To address this, we propose using a differential evolutionary algorithm to maximize the parametric effectiveness by optimizing the location of the inserted knots. This allows the optimizer to gradually explore larger design spaces and to use an optimal CAD-based parameterization during the course of the optimization. The method is tested on the LS89 turbine cascade and large aerodynamic improvements in the entropy generation are achieved whilst keeping the exit flow angle fixed. The trailing edge and axial chord length, which are kept fixed as manufacturing constraints. The optimization results show that the multilevel optimizations were more efficient than the single level optimization, even though they used the same number of design variables at the end of the multilevel optimizations. Furthermore, the multilevel optimization where the parameterization is created using the optimal knot positions results in a more efficient strategy to reach a better optimum than the multilevel optimization where the position of the knots is arbitrarily assumed.

Keywords : adjoint, CAD, knots, multilevel, optimization, parametric effectiveness
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