CAD-free vs CAD-based parametrisation method in adjoint based aerodynamic shape optimization

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ABSTRACT

Key words: Parametrisation, CAD-based, Node-based, Adjoint, Shape optimisation.

Adjoint based aerodynamic shape optimisation methods have recently become very popular in the aerospace, automotive and marine industries. The adjoint method is essential for gradient based optimisation with many design variables since the gradient of the objective function is computed at a cost that is independent of the number of design variables. This method reduces the computational complexity in sensitivity evaluation for each design variable. Various methods for parametrisation of the geometry have been proposed [1]. Two well-known 3D geometry parametrisation methodologies are focused upon here as they offer rich design spaces: a) the CAD-free node based approach and b) the CAD-based NURBS.

The CAD/NURBS approach [2] works with the generic boundary representation using NURBS patches as typically given in the STEP file format. The control points and weights of the NURBS patches are used as design variables, offering the richest design space the geometric representation can express. Additional constraints have to be introduced to maintain continuity between the patches, thickness, radius or box constraints during the optimisation.

In the node-based parametrisation the positions of the grid nodes on the shape are taken as the design variables. This is the richest design space the grid can express, and is typically too rich as it allows high-frequency oscillations that the flow solver does not adequately resolve, regularisation of the gradients or smoothing of the shape is required.

In this paper, the two approaches are discussed and compared using an in-house flow and adjoint solver. The test case is the minimisation of pressure loss of a 3-D S-Bend duct and the drag minimisation of an Onera M6 wing in transonic flight. Particular attention will be paid to comparisons of computational time, quality of the optima and their sensitivity to the choice of regularisation method and value, or constraint accuracy parameters.

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