U–Bend Optimization on the RBF4AERO Platform

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This work is based on both stochastic and gradient–based optimization methods used to solve industrial optimization problems. The optimization is carried out through the RBF4AERO platform, developed in the framework of the EU–funded project. The stochastic optimization tool of the platform uses Evolutionary Algorithms (EAs) assisted by off–line trained surrogate models, based on the appropriate sampling of the design space. The continuous adjoint developed on the OpenFOAM Toolbox that provides the sensitivity derivatives for gradient–based methods is the second optimization tool available on the same platform. In either method, the design variables stand for the coordinates of points controlling the deformation of the shape to be optimized along with the computational mesh. Shape and mesh morphing is based on Radial Basis Functions (RBFs). Herein, the aforementioned platform is used for the shape optimization of a U–bend for minimum total pressure losses.

I. Introduction

Nowadays, it is common for almost all industries to try to optimize their products, so as to achieve better performance/efficiency. Different optimization methods, stochastic and/or gradient–based ones, have been developed with their own features, advantages and disadvantages.

Evolutionary algorithms (EAs), the most popular stochastic optimization method, can handle any complex/constrained problem using any evaluation tool as a black–box, but at high cost, i.e. a lot of evaluations, for reaching the optimal solution. Among other, surrogate evaluation models are usually coupled with EAs, reducing the optimization turnaround time and making them attractive for industrial applications. On the other side, though computing the gradient using adjoint method requires high effort to develop and maintain the solvers, the optimal solution can be found in a few optimization cycles irrespective of the number of the design variables.

To profit from the advantages of both methods, the RBF4AERO platform[1] implements both EAs and continuous adjoint methods and can be used to cope with industrial scale optimization problems.

II. The optimization tools of RBF4AERO Platform

Apart from the optimization methods, the RBF4AERO platform comes with CFD and FEM solvers and is supported by a GUI which facilitates the set–up of the optimization problem.

In the case of EA–based optimization,[2] a sampling technique (Design of Experiments) is used to select the initial individuals, with which the surrogate model, herein Response Surface Method (RSM), is trained. Then, the EA evolves using the trained RSM as the low–fidelity evaluation tool. The "optimal" solutions found are re–evaluated on the high–fidelity evaluation tool. In the course of the optimization algorithm, the RSM is regularly updated.

On the other hand, the gradient–based method assisted by the continuous adjoint method starts from an initial point on the design space, practically the baseline geometry, and moves towards the "optimal" solutions using the gradient of the objective function. Using adjoint methods,[3] the cost for computing the gradient does not scale with the number of design variables.

In either tool, a morphing tool based on RBFs[4] undertakes the computational domain (including its boundary) deformation, according to the values of design variables. When coupled with the adjoint solver providing the sensitivity maps, the morpher tool additionally computes the grid deformation velocity, i.e. the gradient of mesh coordinates w.r.t. the design variables. The overview of this procedure is shown in figure 1.

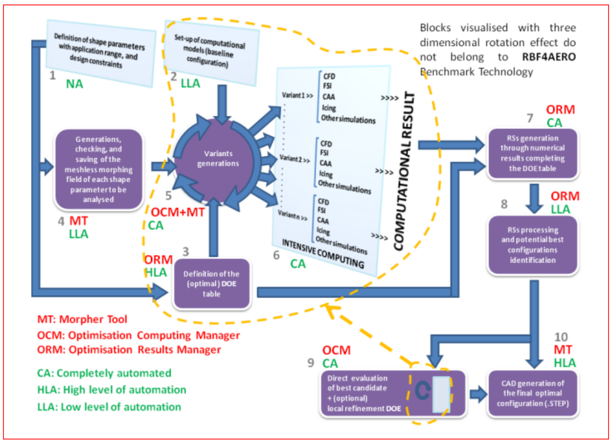

Figure 1. RBF4AERO optimization process

III. Results

The above algorithms included in the RBF4AERO platform are used for the shape optimization of a U–bend, aiming at minimum total pressure losses. The simpleFOAM solver is used along with the Spalart–Allmaras turbulence model. The continuous adjoint method includes differentiation of the turbulence model. Figure 2 presents the flow field at the midspan of the channel for the baseline U–bend geometry along with the control box used for the shape optimization.

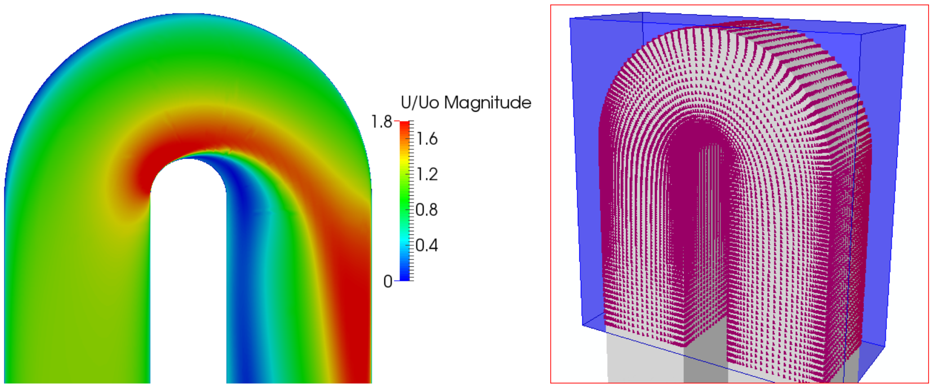

Figure 2. Design of a U–bend. Normalized velocity field in the midspan of the channel for the baseline U–bend geometry (left) and the control box used for the shape optimization (right).

Acknowledgment

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