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CAD-Based Adjoint Multidisciplinary Optimization of a Radial Turbine Under Structural and Vibrational Constraints

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Within the field of turbomachinery, the majority of adjoint-based optimization frameworks mainly consider aerodynamic objectives and constraints. The resulting design needs to pass through revisions to assure that structural requirements are met. Adjoint optimization frameworks have recently been extended to include structural constraints such as maximum stress tolerances. Additionally, these frameworks apply a CAD-based parametrization to maintain a connection to the master CAD geometry and to serve as an interface between the fluid and solid domains. However, vibrational constraints, which are essential in a turbomachinery design cycle, have so far still been neglected in adjoint mutlidisciplinary optimizations.

In this work, this shortcoming will be addressed by integrating a discrete adjoint vibration analysis into a CAD-based adjoint multidisciplinary optimization framework for turbomachinery components. The geometric shape is defined using a CAD-based design parametrization. This allows the possibility of defining geometric constraints in a natural manner, which, for example, can be used to constrain a shape's curvature for manufacturing purposes.

The aerodynamic efficiency is computed using a Reynolds-Averaged Navier-Stokes solver based on the finite volume method. The maximum von Mises stress and eigenfrequencies are computed using a linear stress and vibration solver based on the finite element method. The CFD, stress, and vibration solvers have adjoint capabilities, allowing an efficient evaluation of the gradients at a cost independent of the size of the design space. The fluid and structural domains are coupled with the CAD kernel to form a CAD-based adjoint multidisciplinary optimization framework.

A CAD-based adjoint optimization of a radial turbine is performed using a total of 24 CAD design parameters. A steepest descent algorithm is used with the objective of maximizing the total-to-static efficiency while maintaining a maximum von Mises stresses within a defined tolerance. Additionally, the vibrational constraint of avoiding resonance with dominant engine orders is defined.