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Using Adjoint CFD to Quantify the Impact of Manufacturing Variations on a Heavy Duty Turbine Vane

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Turbine efficiency is one of the main design criteria for heavy duty gas turbines. After the design, margin adaption factors are applied on the baseline to predict the impact of manufacturing variations (MV). These margins are normally based on testbed experience. A more detailed knowledge of the impact of MV, prior to testing, would therefore improve the margin prediction accuracy and could benefit in product cost and global efficiency.

For turbomachines the impact of MV can be quantified with a Monte Carlo (MC) simulation in combination with steady non-linear CFD calculations e.g. RANS. The drawback of this approach is the large number of RANS computations needed to quantify the impact of MV, which is prohibitive for a daily use in an industrial context. Assuming that the MV are small enough, the adjoint CFD method, which linearizes the governing equations, can be an alternative to the RANS evaluations. This kind of approach has been successfully used for compressors [1, 2] and turbines [3, 4].

The first part of this paper presents a systematic approach to evaluate a hand-derived [5] and an algorithmic-derived [6] version of the discrete adjoint CFD solver TRACE. To do so, the ERCOFTAC axial flow turbine known as Aachen Turbine has been selected [7]. For the adjoint version comparison a NACA-like parametrization is applied to compare and validate the adjoint-generated with finite difference gradients.

In the second part the adjoint-based method is applied to an industrial turbine vane to quantify the impact of MV. For this case real MV have been measured using 102 optical blade scans. The scans are used to generate the corresponding deformed geometries for which an adjoint and a RANS simulation are computed. The comparison between each computation demonstrates that the impact of realistic MV can be handled by the adjoint approach.

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