Adjoint Harmonic Balance Method for Forced Response Analysis in Turbomachinery

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ABSTRACT

For the design of turbomachinery components, aeroelastic analysis is an important issue, in particular the prediction of blade flutter and vibrations due to blade row interactions (forced response). Within the flow solver TRACE developed at DLR, several methods are available which can be applied for aeroelastic computations. Besides the solution of the nonlinear flow equations in the time domain and a time-linearised approach [6, 7], a Harmonic Balance method based on the work of Hall et al. [4] has also recently been implemented [2,1]. Since the considered phenomena are time-periodic, frequency domain methods are particularly suitable for their simulation. In particular, they are computationally more efficient than unsteady computations in time domain.

When aeroelastic analysis is part of an optimisation process, it can be very helpful to have sensitivity information of the aeroelastic performance of a configuration with respect to the design parameters. Since in typical real world applications the number of design parameters is much larger than the number of objectives, it is more efficient to compute sensitivities using the adjoint approach rather than the forward approach. An adjoint method based on a frequency domain approach has been presented by He and Wang [5].

In this paper, we derive the adjoint version of the discrete Harmonic Balance equations as they are implemented in TRACE. For their solution we use an extension of an existing steady adjoint solver [3]. If it is assumed that the residual can be linearized about a steady flow solution, one obtains an adjoint version of the time-linearised solver. To demonstrate the capabilities of the method, we apply it to model problems consisting of a single blade row.

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