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ON THE DEVELOPMENT OF A HARMONIC BALANCE METHOD FOR AEROELASTIC ANALYSIS

Graham Ashcroft, Christian Frey, Hans-Peter Kersken*

German Aerospace Center (DLR), Institute of Propulsion Technology
Linder Höhe, 51147 Cologne, Germany
graham.ashcroft@dlr.de, christian.frey@dlr.de, hans-peter.kersken@dlr.de

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To efficiently simulate time-periodic, non-linear flows in turbomachinery a Harmonic Balance (HB) method has recently been developed within the framework of DLR's compressible, Unsteady Reynolds Averaged Navier-Stokes (URANS) solver TRACE [2]. As a hybrid time- and frequency-domain method, that solves directly for the complex valued solution harmonics $\hat{q}_k$ of the URANS equations (Eqn. 1), the approach allows both the integration of highly accurate non-reflecting boundary conditions and the efficient resolution of non-linear flow phenomena.

$$\mathbf{i}k\omega\hat{q}_k + \mathscr{F}(R(\mathscr{F}^{-1}\hat{q}))|_k = 0 \tag{1}$$

In the current work the HB-solver is extended to investigate flutter and forced-response problems in turbomachinery. Within this context the HB-method is developed, under consideration of the Geometric Conservation Law (GCL), to support deforming meshes. To validate the approach the well documented aeroelastic test case Standard Configuration 10 [1], a two-dimensional compressor cascade that operates at subsonic inlet and outlet conditions, is simulated and results are compared to those obtained with both inhouse time-linearized and non-linear flow solvers [3], and reference data from the literature [1]. In Figure 1 a preliminary comparison of the computed solution fields obtained using the time-linearized, frequency-domain solver linearTRACE and the new HB-solver is shown. The results have been obtained by solving the Euler equations on a coarse 2D grid with 5600 cells. The results plotted are for an inter-blade phase angle of -130 degrees at which acoustic resonance is known to occur [3]. The results show an excellent degree of agreement.

Following the basic validation of the HB-solver the ability of the method to accurately capture non-linear flow effects in the context of flutter problems is to be investigated in the final paper by varying the amplitude of the blade oscillations of the flutter test case Standard Configuration 10 and comparing the results with those from non-linear, time-domain simulations.

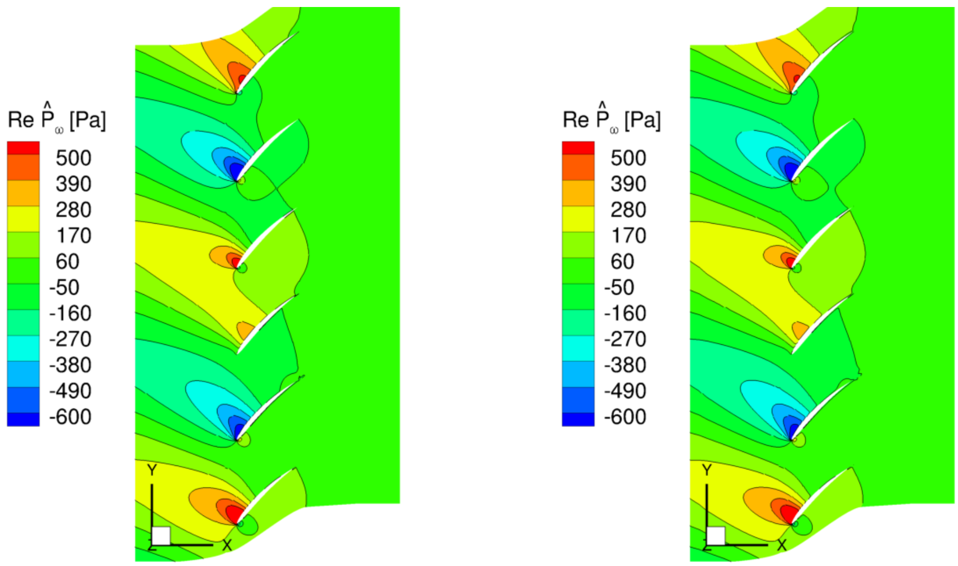

Figure 1: Comparison of the real parts of the computed pressure perturbation fields for Standard Configuration 10 with an inter-blade phase angle of -130 deg.: time-linearized method (left) and harmonic balance method (right).

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