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CFD-Based Aeroelastic Reduced-Order Modeling Robust to Structural Parameter Variations

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Abstract

This article deals with the development of two efficient computational-fluid-dynamics (CFD) based models for the computation of unsteady aerodynamic motion-induced forces. In contrast to established reduced-order modeling (ROM) approaches, which are generally fixed to a given set of structural eigenmodes, the proposed methods can be applied for variable mode shapes. Hence, the generated aerodynamic models remain valid to some extent even if mass and stiffness variations within the underlying finite-element (FE) model are considered. In this way, additional computationally demanding CFD computations are avoided once the model has been obtained. Under this premise, two modeling frameworks robust to structural parameter variations are developed, while so-called basis modes are employed to approximate arbitrary mode shapes. Firstly, a time-domain ROM originating from linear system identification principles (SI-ROM) is presented and, secondly, a frequency-domain approach based on a small disturbance CFD solver (SD-ROM) is proposed. Moreover, two different strategies for the basis mode generation are evaluated. The first method is based on a local approximation using radial basis functions, whereas the second method uses two-dimensional Chebyshev polynomials in order to yield a global approximation of the structural grid deformations. Both novel ROM approaches combined with the two basis mode construction techniques are demonstrated and assessed regarding their efficiency and accuracy. The results in terms of the well-known AGARD 445.6 wing configuration demonstrate that the proposed methods can reproduce the unsteady aerodynamic forces accurately, while the computational effort is significantly reduced. Moreover, generic modifications with respect to the FE model are considered to indicate the potential of the new methods regarding aircraft aeroelastic design and optimization.

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