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A POD-DEIM Reduced Order Model with deforming mesh for aeroelastic applications

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Reduced-order models (ROMs) of nonlinear dynamical systems are essential for broadening the scope of high-fidelity non linear CFD design optimizations or aeroelastic investigations. In fluid mechanics, the wide variety of ROMs reported in literature shares the aim of reducing the dimensionality of dynamical systems by performing a projection of the governing equations. According to the state-of-the-art, the proper orthogonal decomposition (POD) is used to construct the projection basis. Unfortunately, the performance and the feasibility of POD based ROMs are still an open question for aeroelastic applications, that is when a moving grid is taken into account. Anttonen et al.[1] showed that an index-based POD-ROM reproduces accurately the response of a system for a potential flow with a moving grid. However, the performance of the aforementioned ROM is unsatisfactory when off-reference parameter configurations are investigated. Moreover, when addressing real-life applications, the non-linear compressible Navier-Stokes equations have to be considered resulting in an additional difficulty.

In the present work, we propose a ROM based on the classical Galerkin projection onto a basis constructed via the index-based POD. The discrete empirical interpolation method (DEIM) is adopted in order to efficiently deal with the compressible Navier-Stokes nonlinearities. In particular, we discuss the validity and applicability of the DEIM approximation when a deforming grid is taken into account. Numerical tests have been carried out to evaluate the performance of the model. First, we validate the classical POD-DEIM technique for a time dependent and slightly compressible flow around a NACA-0012 airfoil with high incidence [2]. Then, the POD-DEIM ROM is used to reproduce the solution of a high-fidelity model based on the Arbitrary Lagrangian-Eulerian (ALE) formulation combined with a deforming grid for a flow around an oscillating airfoil. Finally, on the basis of the achieved results, we highlight the limits and the strengths of the proposed technique when a parametric investigation is carried out [3].

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