Proper Orthogonal Decomposition and Recursive Dynamic Mode Decomposition: accuracy and dimensionality reduction in reconstructing the flow of impulsively started lifting surfaces

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ABSTRACT

Investigating the dynamics of unsteady flows is an important aspect in the design of modern aircrafts and it can be a really time-consuming task, often intractable even with modern supercomputer, since the unsteadiness needs to be combined with parametric and/or sensitivity studies. In the attempt to circumvent this problem, a common practice in literature is the recourse to Reduced Basis Methods (RBM), whose main aim is to reduce the number of degrees of freedom in order to describe the physics of the fluid system in a fast yet accurate manner.

The classical Proper Orthogonal Decomposition (POD) [1] has been widely used in literature for both parametric and unsteady problems. Nevertheless, POD has a well-recognized limit, that is the lack of any dynamic information while performing the basis extraction, which is crucial when dealing with unsteady problems. Each snapshot of the initial system, used to build the POD basis, is in fact treated as a statistical determination of the system, stochastically independent from any other snapshot. Alternatives have been proposed in literature to overcome this recognized limit at a basis extraction level. In particular, Dynamic Mode Decomposition (DMD) [2] has soon become very popular in the fluid dynamics community, since its introduction in 2010 by Schmid. It allows to extract dynamic information from data, in terms of frequencies and grow/decay rates. Important drawbacks are present for this technique as well and they are mainly related to the analysis of transient flows and non-orthogonality of the extracted basis, which makes the method unsuitable for projection techniques. The more recent Recursive Dynamic Mode Decomposition (RDMD), recently introduced by Noack et al. [3], tries to solve this limitations combining DMD with classical POD. The former preserves dynamical information, the latter the orthogonality among modes and it promotes dimensionality reduction.

The present work investigates how the classical POD and the recent RDMD perform in reconstructing vortex-dominated unsteady flows, when only strong transients are present and there are no frequency patterns in the flow. The two methods will be paired with an equation-based approach, instead of physically-blind interpolation methods, where a residual minimization for the unsteady problem, constrained in the space spanned by the reduced basis, will be performed. Problems of high relevance to the aerodynamics field will be considered, such as the impulsive start of 2D and 3D complex geometries in high-lift configurations.

REFERENCES

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