6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11-15 June 2018, Glasgow, UK

High-performance adaptive CFD simulations for real-world applications

Massimiliano Leoni[*,1,2,3], **Johan Jansson**[2,1] **and Johan Hoffman**[1,2]

[1] KTH Royal Institute of Technology, Brinellvagen 8, 114 28 Stockholm, Sweden, {mleoni,jjan,jhoffman}@kth.se

[2] Basque Center for Applied Mathematics, Alameda de Mazarredo 14, 48009 Bilbao, Bizkaia, Spain

[3] Universidad del Pais Vasco/Euskal Herriko Unibertsitatea, Barrio Sarriena s/n, 48940, Leioa, Bizkaia, Spain

Keywords: *Adaptive FEM, Large scale, Time dependent, Dual-based solver*

A recent talk by Loehner at an AIAA meeting [1] finally addressed the elephant in the room pointing out that the dream of overnight industrial CFD simulations is still out of our reach, regardless of the available computing power or the numerical method employed. Our attempt to tackle this deficiency employs an iterative, adaptive, stabilized finite elements method, which we call Direct FEM Simulation (DFS), that generates a sequence of adapted meshes aimed at reducing the error on a cost functional of interest, usually a time average of some aerodynamic coefficient [2]. The underlying idea is to reduce the needed computation to the minimum amount that is sufficient to accurately approximate output quantities from a given setup. The key components are the aforementioned mesh adaptive procedure, which optimizes spatial discretisation costs, and the use of slip boundary conditions, that save on the cost of boundary-layer resolution. On the software side, we use FEniCS-HPC as a finite elements framework, which has proven records of parallel scalability on up to the order of ten thousand cores, and a high-level mathematical formulation in UFL language which is then source-to-source compiled to highly optimized C++ code [6]. The result of this combination is a high performance computing toolkit able to approximate aerodynamic forces on real-world cases in a matter of hours or days, as opposed to weeks. In this regard, we present a notable application from the industrial realm such as our recent contribution to NASA's 3rd AIAA CFD High Lift Prediction Workshop (HiLiftPW-3) [3] [5] involving adaptive, time-dependent simulations of a full aircraft (NASA's Common Research Model - CRM) approximating both aerodynamic forces and relevant flow features. We will also discuss our very recent contribution to the 5th International Workshop on High-Order CFD Methods [4] where our methodology proved to be able to yield high-order approximations of relevant target quantities.

REFERENCES

[1] Lhner, R., *Towards overcoming the LES crisis*. 6th Edition, AIAA SciTech Meeting and Exhibit. Kissimmee, Florida. `https://scientific-sims.com/cfdlab/WORKSHOP/assets/lohner.abstract.pdf`

[2] Hoffman, J., Jansson, J., Jansson, N., de Abreu, R. V., and Johnson, C. , *Computability and adaptivity in CFD*. In Encyclopedia of Computational Mechanics., John Wiley and Sons, Ltd. https://doi.org/10.1002/0470091355.ecm057.pub2

[3] https://hiliftpw.larc.nasa.gov/

[4] https://how5.cenaero.be/

[5] Jansson, J., Krishnasamy, E., Leoni, M., Jansson, N., Hoffman, J., *Time-resolved Adaptive Direct FEM Simulation of High-lift Aircraft Configurations*. in Numerical Simulation of the Aerodynamics of High-Lift Configurations, Springer.

[6] Hoffman, J., Jansson, J., and Jansson, N., *FEniCS-HPC: Automated Predictive High-Performance Finite Element Computing with Applications in Aerodynamics*. In Parallel Processing and Applied Mathematics, Springer International Publishing. https://doi.org/10.1007/978-3-319-32149-3_34