Talk: Challenges of Residual Minimization-based Model Order Reduction in Car Aerodynamics

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Abstract: The central enabling methodology for interactive aerodynamic car design with real-time aerodynamic evaluations is Reduced Order Modeling (ROM). In industrial applications, such ROMs mostly rely on the "POD + Interpolation" (POD-I) paradigm (e.g. [1]). While very robust, the accuracy of this approach depends on the formal order of the interpolation scheme and the sampling density. With the aim of more accurate predictions, also in areas of the design space with poor sampling or even outside of it, we started to implement a Residual Minimization-based ROM [2] adapted to the requirements of interactive aerodynamic car design.

While the full-order solution for vehicle aerodynamics is based on time-averaged incompressible Detached-Eddy Simulations (DES), we restricted ourselves for the time being to steady-state incompressible Reynolds-Averaged Navier Stokes (RANS) computations, more precisely with the SIMPLE solver in OpenFOAM®. As our ROM strategy, we chose the steady-state version of the well-known Least Squares Petrov Galerkin approach (LSPG, [3,4]).

The starting point of this work is the empirical evidence that for industrial settings, i.e. for problems with finite but acceptable projection errors, the solution in the reduced space with minimal residual is often far from the projected solution. We refer to this as the "shift problem": the minima of the objective function for the ROM – calculated as some norm of the residual fields – and of the state vector error w.r.t. the full order model solution do not coincide. This shift compromises the superiority of Residual Minimization-based ROMs with respect to pure data-driven approaches like POD-I for coarsely sampled solutions.

In this talk, the various implementation aspects and their respective effects on mitigating this shift will be presented along two test cases: a 2D laminar backward facing step and a coarse 3D Ahmed body.

REFERENCES

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