1 Introduction

The aim of this secondment was to numerically test in the framework of POD (Proper Orthogonal Descomposition)-ROMs (Reduced Order Models) an efficient time-splitting approximation of the Navier-Stokes equations with open boundary conditions already performed for Finite Volume FOMs (Full Order Models) in [2].

The motivation to develop this ROM comes from the high computational cost of solving the Navier-Stokes equations with open boundary condition, especially in a many-query context, where a numerical simulation has to be performed for different values of parameters. The time-splitting scheme proposed in [2] allows to solve the Navier-Stokes equations with open boundary conditions reducing the size of the computational domain and, as consequence, the offline computational cost. Therefore, the ROM offers a greater computational advantage over this scheme.

This work has been done in collaboration with Mejdi Azaïez (University of Bordeaux), Tomás Chacón Rebollo (University of Seville), and Carlos Núñez Fernández (VirtualMechanics SL).

2 Reduced order modelling for Navier-Stokes time-splitting methods with open boundary conditions

A pressure-correction scheme is considered, with a non-standard way to enforce open boundary conditions that provides higher pressure and velocity convergence rates in space and time than found in the present state of art. The main difficulty of this method is the non-standard treatment of the open boundary conditions, for which we consider a 1D problem at the boundary for the FOM. In order to avoid this non-standard treatment of the open boundary conditions into the ROM, we have used a non-intrusive ROM based on RBF (Radial Basis Functions) [1].

By using the proposed ROM, we present some numerical results performed on the benchmark problem of the 2D unsteady flow around a cylinder with circular cross section at Reynolds number $Re = 100$ [3].

These numerical results are performed over three different computational domains where the distance between the outflow boundary condition and the cylinder is, respectively, 0.4 m, 0.9 m, and 2 m. In Figure (1), we show the vorticity magnitude and contours (left) and the pressure field (right) of FOM (top) and POD-ROM (bottom) after the extrapolation of six periods over the minimal computational domain.

The results for both FOM and POD-ROM (almost identical) shows that using the reduced computational domain does not induce distortion of the vortices nor disturb flow around the cylinder. Thus, they suggest that the porposed POD-ROM could be successfully applied to more complex 3D flows (e.g., flow around wind turbines) to obtain faster simulations.

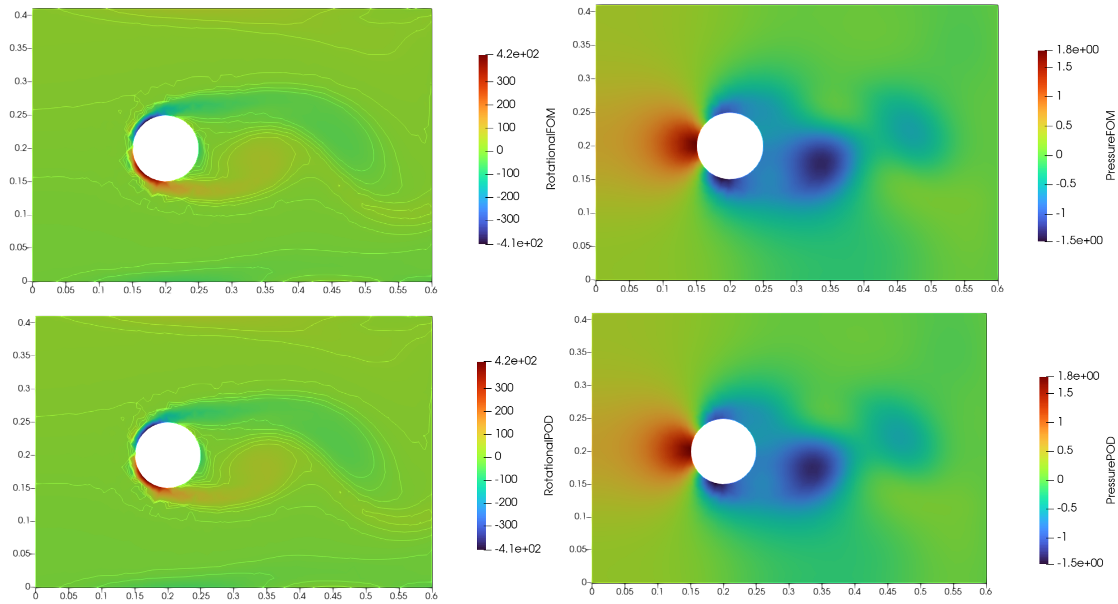

Figure 1: Vorticity magnitude and contours (left) and pressure field (right) of FOM (top) and POD-ROM (bottom) at final simulation time.

References

[1] M.D. Buhmann. Radial basis functions. *Acta numerica*, 9:1–38, 2000.

[2] A. Poux, S. Glockner, and M. Azaiez. Improvements on open and traction boundary conditions for Navier-Stokes time-splitting methods. *J. Comput. Phys.*, 230:4011–4027, 2011.

[3] M. Schäfer and S. Turek. Benchmark computations of laminar flow around a cylinder. In Ersnt Heinrich Hirschel, editor, *Flow Simulation with High-Performance Computers II*, volume 48 of *Notes on Numerical Fluid Mechanics*, pages 547–566. Vieweg, 1996.