NUMERICAL ALGORITHMS FOR COUPLED MULTI-PHYSICS SIMULATIONS WITH APPLICATION TO AEROELASTICITY

Thomas Wuilbaut, Belgium
Supervisor: Prof. H. Deconinck
Promoter: Prof. H. Deconinck (Université Libre de Bruxelles, Belgium)

The numerical simulation of steady aerodynamics have reached an industrial maturity such that they are now fully integrated in the industrial processes, even for viscous flows with turbulence modeling. The problem of simulating the interaction between fluid and structures (or aeroelasticity) is in a development phase and the industry demand for such simulations is growing. The main difficulties encountered when dealing with fluid-structure interaction are: (1) an unsteady viscous (turbulent) flow (2) the ability for the schemes solving the fluid flow to deal with the deformation of the geometry in function of time (accuracy, mesh deformation, boundary conditions) (3) the coupling between the fluid and the structural solver and (4) the interfacing between the fluid and the structure mesh when these meshes are non-matching.

The purpose of this thesis is to apply the Residual Distribution Schemes (RDS) and Finite Volume schemes for the computation of unsteady flows coupled with deforming bodies (using moving and deforming meshes) on large scale industrial problems. Algorithms for the simulation of complex multi-physics phenomena are also studied.

The study is integrated in the COOLFluiD (Computational Object-Oriented Library for Fluid Dynamics) framework. In this work, the ALE formulation of the SpaceTime RDS (Dobes) has been implemented and extended to obtain unconditionally monotone schemes on moving meshes. A Finite Element solver for structural mechanics has also been implemented to compute the deformations of the solid bodies. Robust mesh movement techniques (using a solid body analogy for the mesh) and coupling algorithms for non-matching meshes have been developed. The focus has also been put on the implementation of Finite Volume ALE schemes together with the implementation of several turbulence models (Spalart-Allmaras, k-Omega, BSL).

These tools have been developed with the goal of obtaining an efficient, robust and versatile parallel Fluid-Structure Interaction and more generally, multi-physics coupling solver.

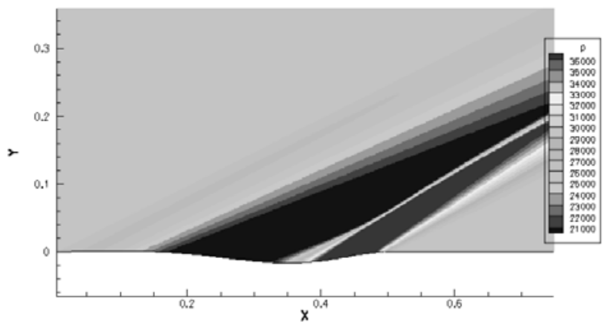

Figure 1: Supersonic Panel Flutter (Fluid-Structure Interaction)

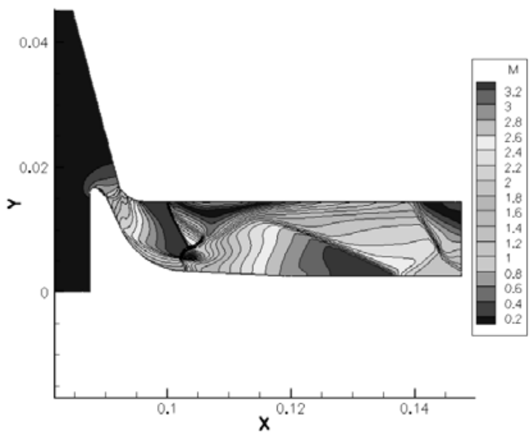

Figure 2: Unsteady Simulation of the flow in an exhaust valve