Master thesis : Fluid-structure interaction simulations of separated flows through Detached Eddy Simulations

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FLUID-STRUCTURE INTERACTION SIMULATIONS OF SEPARATED FLOWS THROUGH DETACHED EDDY SIMULATIONS

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Abstract

The research in the field of Computational Fluid Dynamic in turbulent separated flows is a hot topic in the industrial and academic aerospace sector. Aeronautic industrial standards require each time better and more powerful CFD methods to inquire the behavior of turbulent flows as a consequence of their growing use in aeronautical design. They are extremely important in almost every engineering discipline, especially in those which are facing aerodynamic and structural design; as aerospace, vehicle or naval engineering.

This present master thesis centers its work exploring the turbulent separated flow physics and vortex detachment in a simple flat plate geometry. In the first place, the flat plate profile was considered static at an angle of attack of 30^{o} and $4{\cdot}10^{4}$ Re. In the second case, the flat plate was moved with a large oscillation angle of attack at a determined frequency of rotation in pitching motion. The simulation results were compared with experiments, trying to reproduce the reality of the flow behavior and detecting possible discrepancies.

For every case, a mesh refinement study was performed, reducing the numerical error to stabilize the solution. The aerodynamic coefficients, shedding frequency and vortex detachment results were presented for unsteady RANS and DDES approaches with two solvers: OpenFOAM and SU^2, both open-source software. Moreover, a certain sensitivity analysis was accomplished to discern how the span-length or the pivot point parameter might affect the results. The analysis was completed shifting the turbulence modeling; Spalart-Allmaras and k-ω SST model of Menter were both verified.

The results in the static plate show a better approach with DDES method than with RANS, finding those pretty acceptable for both solvers. The high angle induces separation, increasing the relative error in the aerodynamic coefficients. The DDES case was able to predict the reality with an error around 8%. The shedding frequency was exactly the same that the one detected in the experiment, both in 3D URANS and DDES. On the other hand, the performances with OF for the pitching plate have distortions when the plate is moved in rigid motion, although in SU^2 those results were quite accurate, with errors below 5%. The k-ω SST model has positive consequences in the static plate, reducing the relative errors for both codes. However, in the pitching mode, the S-A model presents a better approach for both solvers, even if the outcomes in OF are quite poor. Finally, and with the aim of further understanding the physics of the phenomena, the data resulting from the DDES cases were decomposed by using a Dynamic Mode Decomposition algorithm to extract the mode shapes.

Keywords: Computational Fluid Dynamics, Unsteady RANS, Detached-Eddy Simulation, Turbulent separated flows, Flat plate, SU^2, OpenFOAM, Dynamic Mode Decomposition.