Numerical Simulation of the Aerodynamics of High-Lift Configurations

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Preface

Wing loading has been increased as a result of a combination of higher cruise speeds and aerodynamic efficiency but with adverse effects on stall speeds. At the same time, the length of the airports' runaways cannot be increased due to economic reasons, in addition to the fact that the speeds of takeoff and landing are limited to satisfy safety standards. It is in this context in which the importance of high-lift devices for commercial aerodynamic applications comes into play.

The design of high-lift devices is focused on simpler systems to maximize the lift and reduce maintenance costs. The aerodynamic design of these devices is restricted by takeoff and landing distances, safe speeds during landing and takeoff and climb rates. All these operational parameters impose restrictions on aerodynamic properties such as the lift coefficient (C_L), lift-to-drag ratio (L/D) and stall angle of attack. In recent years, numerical simulations have played an important role in the prediction of these aerodynamics properties. As an example, NASA and the American Institute of Aeronautics and Astronautics (AIAA) have organized three events related to the application of numerical simulations in the prediction of the aerodynamic properties of high-lift configurations since 2010. I have personally participated in these events, called High-Lift Prediction Workshop (HiLiftPW), and in general the conclusion is that the problem of correctly estimating the turbulent and separated flow near C_{Lmax} is still an important challenge for modern computational codes and software. Also, there is still a need to develop reliable turbulence models for this application, and the computational cost of these simulations is considerable, given the fact that finer meshes (around 200-M cells) are needed to reduce the deviation of the numerical solution between the various different codes and softwares. Numerical results consistently show that C_L is typically under-predicted, as well as are the drag and the magnitude of the pitching moment. In this context, this book is devoted to gathering some of the results of the most recent version of the HiLiftPW that was held in June 2017.

This book has six chapters dedicated to the numerical simulations of high-lift configurations and specifically all of them that are related to full Navier–Stokes (NS) solvers. This means that the numerical and computational techniques used for these contributions are based on Computational Fluid Dynamics (CFD). All the chapters discuss numerical solutions of the high-lift system proposed for the third HiLiftPW held in Denver in June 2017. All the chapters show numerical solutions for the aerodynamic properties of the models studied and comparisons (validation) with experimental data when available.

The first chapter is a review of high-lift configurations in order to provide a context for the book. This chapter also shows some results of the simulation of the flow around the High-Lift Common Research Model (HLCRM), which was one of the models introduced in the last HiLiftPW. These results are briefly introduced only to give some insight to the reader about the physics of the turbulent flow around these devices. The second chapter is dedicated to the topic of grid generation of high-lift configurations for CFD simulations. Typically, this is not a topic deeply discussed in textbooks or technical articles, so I personally consider that this contribution helps to give a better idea of the challenges and main features that need to be considered when facing such a complex problem. One of the interesting topics in this chapter is the discussion of the guidelines given by the AIAA on grid generation for high-lift systems. The third, fourth and fifth chapters are all dedicated to numerical computations of the Japanese Aerospace Exploration Agency (JAXA) Standard Model (JSM), using three different CFD solvers and simplifications of the governing equations. For example, Chapter "Incompressible Solutions About High-Lift Wing Configurations" is devoted to the use of an incompressible flow solver. The conclusions reached and observations made in this chapter are quite interesting since one of the main requirements of the HiLiftPW is to use fully compressible NS solvers for the simulations. Chapter "Numerical Investigations of the Jaxa High-Lift Configuration Standard Model with MFlow Solver" deals with the numerical solution of the JSM using a fully compressible NS solver; a very interesting topic discussed in this chapter is the High-Performance Computing (HPC) resources needed and the estimation of efficiency for performance in parallel computation for this kind of simulation. In Chapters "Incompressible Solutions About High-Lift Wing Configurations" and "Numerical Investigations of the Jaxa High-Lift Configuration Standard Model with MFlow Solver", computations are performed using the Finite Volume (FV) method which is the standard way to discretize the governing equations. Nevertheless, in Chapter "Time-Resolved Adaptive Direct FEM Simulation of High-Lift Aircraft Configurations", the numerical method used for computing the solution of the flow is the Finite Element Method (FEM). Since I read the book "Computational Turbulent Incompressible Flow" by Professor Hoffman in 2007, I have been intrigued by the capabilities of the FEM proposed in that book. In Chapter "Time-Resolved Adaptive Direct FEM Simulation of High-Lift Aircraft Configurations", this question is solved by showing the efficiency of the solver based on this methodology and its advantages in comparison with other numerical techniques typically used in CFD. Finally, Chapter "RANS Simulations of the High Lift Common Research Model with Open-Source Code SU2" deals with the numerical solution of the flow around the HLCRM using an open-source code called SU2. This final chapter also uses an FV method for solving the fully compressible NS equations.

It is expected that this book can serve as a reference for graduate students, as well as researchers in the field of CFD applied to the aerodynamics of high-lift configurations. Designers and engineers from the aeronautical industry may also benefit from the content of the book as it provides the state-of-the-art in CFD computations applied to the prediction of aerodynamic properties of high-lift configurations, as well as flow characteristics. We hope that the way the book is organized helps the reader to find a specific topic of interest and to engage the reader as he/she goes from one section to the next one. Finally, I would like to acknowledge the help of Dr. Rumsey and Dr. Slotnick during the 3rd HiLiftPW for helping me in the realization of this project.

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