Concluding remarks and future actions

This thesis has dealt with three of the most important topics within the field of Heat Transfer and Fluid Flow and that are currently motivating a large number of works and basic research projects all over the world: turbulence modeling, high performance computing (HPC) and verification and validation (V&V). Main objective was not only to contribute into these topics with new works and ideas overcoming the current state of the art, but also to consolidate the knowledge of the Group were the thesis has been developed. As a matter of fact, the work here presented was based in the know-how and tools (software, algorithms, papers) of the Group and has established the basis of future work that will be done or is already being done by other members of the Group and by the author himself within the frame of new PhD studies and research projects.

Work carried out about the topics of HPC and V&V has originated results of interest for the scientific community which have already been published in international journals. On the other hand, results on turbulence modeling are just in accordance to the current state of the art. They do not introduce new contents or ideas of interest for the overall scientific community but have really contributed to consolidate the know-how of the Group in this topic, and are already being used by other members of the Group. This fact, of course, also has to be considered as a successful outcome.

Conclusions of the work presented are properly discussed at the final pages of each chapter. However, and as final conclusion and a global guide for future actions, the accomplished work, the drawbacks to be solved and possible new research derived from the work done in the three lines (turbulence modeling, HPC, and V&V), are hereafter summarized.

Turbulence modeling

Main work carried out within this topic and that in fact has not directly been described in the different chapters of the thesis, is the consolidation of a software infrastructure that will permit in the near future to analyze the turbulence by means of the different levels of RANS models (Reynolds Stress Models, Algebraic Stress Models Eddy-Viscosity Models), but that at the current stage only permits the use of two-equations Eddy-Viscosity Models. This software has already been used so as to obtain several solutions of turbulent problems typically used for Benchmarking. Some of the solutions have been shown not to be credible (because they did not passed the verification test). Therefore, further work will have to be done so as to improve the quality of these solutions. Immediate work that also has to be done is the generalization of the software to the other levels of RANS.

Higher level turbulence models such as LES and DNS have not been considered within the scope of this work.

High performance computing (HPC)

A fully conservative multiblock algorithm with explicit information transfer between the blocks has been developed and has been proved not to introduce additional uncertainty in the numerical solution. Such multiblock algorithm can easily be parallelized. The work of each (or several) blocks is assigned to different CPUs and the information between the different blocks is transfered (communication) once all the CPUs have finished the work. The process has to be repeated till the convergence in all the blocks is reached. This parallel multiblock approach has already been used by the group in other works here not presented solving simple-connected parabolic (or semi-parabolic) flows. In these problems the parallel multiblock approach permits to dramatically reduce the execution time.

However, the method has some drawbacks that make it generally not suitable for non-parabolic flows or multiple-connected flows. An implicit information transfer between the different blocks may overcome the problem with the non-parabolic flows. Then, a special solver has to be developed and the parallelization approach has to be changed. On the other hand, the method could also be proper for multiple-connected flows provided that more information were transfered between the blocks (i.e. in the current algorithm the conservation of the momentum flux in the normal direction in the boundaries between the blocks is not always guaranteed). Further research is required in these two topics.

Verification and validation (V&V)

Contributions of the thesis in the field of V&V are a general tool and procedure to estimate the uncertainty of the steady state numerical solutions, and the studies carried out on the heat transfer on a ventilation channel.

The post processing tool has already been used in many different problems beyond those here presented, and nowadays is being used by most members of the Group working on steady state flows. However, it still needs to be completed and extended so as to be able to deal with numerical solutions of transient problems, to take into account the effects of the boundary nodes (which for some formulations can be the most sensitive) and to estimate the uncertainty of integral (functional) quantities of direct engineering interest, such as the net Nusselt number or the skin friction coefficient.

The goal of the work carried out with the ventilation channel was not only to develop a new credible heat transfer relation for a situation that has still not been studied by other researchers and that is of practical interest, but also to perform a complete engineering study according to the current state of the art so as to obtain credible numerical solutions. Such complete study involves the definition of a mathematical model (set of differential equations and boundary conditions), a numerical model from which an approach of the mathematical model is obtained (numerical solution), a test to assure that the numerical solution is a suitable approximation of the mathematical model (verification), and a final comparison of the numerical solution to the reality (validation). Therefore, two different outcomes have arisen from this study. The first is a credible heat transfer relation that will permit to perform low-level computations with less computational requirements (design and optimization codes). The second is an infrastructure and methodology that in the near future will serve as the basis of new works to obtain other credible heat transfer and fluid flow relations of interest.

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