Experimentalist's requirements for a safe methodology in CFD code validation

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Summary

The past 40 years have known a spectacular development of CFD capabilities. It is now possible to compute complex three-dimensional unsteady flows even at the design stage by solving the Unsteady Averaged Navier-Stokes Equations (URANS approach) and progress are made every day in still more advanced approaches such as LES and DNS. However, the confidence in CFD methods is still limited because of uncertainties in the numerical accuracy of the codes and of the inadequacy of the turbulence models they use. Thus, there is still a need for well made and well documented experiments to validate the codes and to help in their improvement

A comparison restricted to the wall properties is in general insufficient to validate the most advanced predictive methods. In particular, information on the Mach number, temperature, density fields is essential to elucidate the cause of discrepancies affecting, for example, the wall quantities distribution. Such a requirement is still more demanding in high Mach number flows where one has to represent strongly interacting and shock-separated turbulent flows. In this case, information on turbulence quantities is also needed, which is a formidable challenge in high Mach number flows! The problem of code validation is crucial in three-dimensional applications where the Navier-Stokes approach becomes mandatory. Due to the complexity of such flows, it is clear that the consideration of the surface pressure alone is inadequate.

Such experiments must also fulfil quality criteria to be considered as safe enough and really useful for code validations. The article presents a discussion of the strategy to be followed to ensure the reliability and accuracy of a code by placing emphasis on the experimental aspects of code validation.

The paper is divided into four main sections :

- The four steps of the validation methodology are first presented, extending from numerical verification to validation on a complete vehicle including all the physical phenomena.

- The second section is devoted to the requirements for good test cases constitution, by considering in succession : the definition of the model or ttest set-up geometry, the problem of the boundary conditions to be provided, the risks of parasitic effects, the question of measurements reliability and accuracy, the physical interpretation of the results.

- The third part is an overview of the modern measurement techniques which can be used to qualify complex separated flows, with emphasis on field measurements using non intrusive methods (LDV, DGV, PIV, CARS, DLCARS, etc).

- The important question of data banks constitutions is discussed in the fourth section.