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On the Challenges of Validation Exercises of Viscous Flow Simulations

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ABSTRACT

Computer based Modeling and Simulation has become common practice in Engineering and its results are often used to make decisions. Therefore, it is essential to quantify the modeling accuracy of the mathematical/computational models used in such simulations. That is exactly the goal of Validation, as defined in the ASME V&V 1 (2022) Standard.

The first step of a Validation exercise is the selection of the quantities of interest that need to be experimentally measured (the physical reality) and obtained from the simulations. As stated in the ASME V&V 20 (2009) Standard: "no experimental data, no Validation". Naturally, this choice depends on the selected mathematical/computational model. For example, solving the Reynolds-averaged Navier-Stokes (RANS) equations in statistically unsteady flows leads to ensemble-averaged simulation results that should not be compared to instantaneous measurements. On the other hand, obtaining statistically converged ensemble-averaged results from experiments is troublesome. Therefore, in this presentation, we will restrict ourselves to the time-averaged RANS equations and to quantities of interest that can be defined by a number.

One of the largest challenges of a Validation exercise is to guarantee that experiments and simulations are performed for the same conditions, i.e. same geometry, boundary conditions, fluid properties and heat transfer coefficients. Such equality of conditions is nearly utopic to achieve and so simulation results will be affected by input parameters errors/uncertainties. On the other hand, the need to use numerical solutions leads to numerical errors/uncertainties that are quantified by Solution Verification. Furthermore, the true value of the quantities of interest is not known because experiments are also affected by experimental uncertainties. Therefore, the traditional simple comparison between experimental and simulation results is insufficient and can be misleading, because experimental, input parameters and numerical uncertainties affect this comparison. In the ASME V&V 20 (2009) Validation metric, these uncertainties lead to the Validation uncertainty.

Last but not the least, many of the quantities of interest of viscous flow simulations require post-processing of the measured data, as for example the determination of the shear-stress at the wall from the mean velocity profile in the log-law region. In viscous flow simulations without wall-functions, the shear-stress at the wall is usually obtained from its definition. In this presentation, we illustrate the Validation process and that misleading conclusions can be obtained when the post-processing techniques used in the experiments and simulations are not identical.

References

ASME V&V 1. *Verification, Validation, and Uncertainty Quantification Terminology in Computational Modeling and Simulation.* American Society of Mechanical Engineers, 2022.

ASME V&V 20. *Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer.* American Society of Mechanical Engineers, 2009.