Can adaptive mesh refinement produce grid-independent solutions for complex flows?

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ABSTRACT

One of the trends in computational fluid dynamics today is the use of the ever-increasing computational resources for the high-fidelity simulation of more and more complex flows. For example, simulations are performed for realistic geometries such as ships with their propellers and appendices. Flow separation, vortex shedding and breakup are simulated in detail. Finally, multiphysics computations such as fluid-structure interaction or the modelling of cavitation become more and more common.

The results of such simulations depend heavily on the physical models being used, such as the turbulence model in the Reynolds-averaged Navier-Stokes (RANS) equations. In many cases, such models are being applied in situations which are far more complex than the ones for which they were developed and which may be outside their range of validity. Research of physical modelling for today's realistic simulations is therefore of prime importance.

A complication for this study is the inevitable appearance of numerical errors. To accurately assess the precision of a physical model, we need to know a numerical solution in which the numerical errors are small with respect to the physical ones: a solution that is close to grid convergence. In simple cases, it may be possible for an experienced user to generate reasonable meshes by hand which provide sufficiently small numerical errors. However, for complex flows it is impossible to know beforehand what mesh size is needed where, in order to obtain grid convergence. Adaptive grid refinement is therefore the ideal technique to master the numerical error.

In this paper, we pose the question whether grid refinement can be used in such a way as to guarantee that the solution of a complex flow problem is grid-independent. The work is based on the ISIS-CFD unstructured finite-volume incompressible RANS solver developed by ECN-CNRS [1], which contains an integrated anisotropic grid refinement technique [2].

As a reference, a two-dimensional airfoil flow is simulated on a series of ever finer adapted meshes; these results are compared with simulations on different fine meshes in order to understand if a converging series of adapted meshes truely leads to mesh-independence. The findings of this initial case will then be applied to the simulation of the three-dimensional vortical wakes behind ships in sideslip condition.

REFERENCES

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