Hybrid LES Simulation of Turbulent Flows using Adaptive Grid Refinement Based on Averaged Quantities

Sajad Mozaffari*, **Michel Visonneau and Jeroen Wackers**

* LHEEA, Centrale Nantes/CNRS, Nantes, France
e-mail: sajad.mozaffari@ec-nantes.fr

ABSTRACT

Mesh generation with a proper resolution is a challenging step of any simulation, which is not possible without a clear view of the physics of the problem. In unsteady hydrodynamics simulations where flow structures vary and move within the domain (for example studies on ship maneuverability) achieving a compromise between the mesh resolution and computational cost without years of experience may be difficult. Adaptive grid refinement (AGR), by adapting the grid to the flow as it develops during the simulation, can help and make it possible to optimize the mesh during the computation. It is effective for flows that have localised structures; fine cells can be used to keep the error near these structures low and to get good resolution, while coarse cells are used in the rest of the domain to reduce the total costs for the simulation.

However, trying to follow all the structures of a turbulent flow requires frequent changes in the mesh and introduces extra truncation error into the system since the grid refinement interfaces require interpolation to transfer the solution between grids. This is certainly the case when hybrid LES methods are coupled with AGR since the resulting flows are highly unsteady. Therefore the question is if it makes sense to use the adaptation frequently and follow all the turbulent structures, or to go to a static mesh and to base the AGR on averaged quantities, especially in configurations for which the spatial resolution requirements do not vary significantly over time (statistically steady or periodic turbulent flows).

In this work, the idea of applying the adaptation based on time-averaged quantities is investigated. A Hessian criterion (second derivative of the flow components) is selected as the refinement criterion, which specifies where the mesh should be refined. Two different approaches are taken into consideration: in the first approach, the averaging is applied over the instantaneous solutions for a specific interval. When the mesh is to be refined, the refinement criterion is computed from this mean solution and the adaptation takes place based on that. In the second approach, the refinement criterion is computed from instantaneous solutions for each time step; the refinement is based on the time average of the computed criterions. In addition, the effect of the averaging interval is studied since it can affect the speed of the mesh evolution. As a test case, the turbulent separated flow behind a backward facing step which is studied experimentally by Vogel and Eaton [1], is chosen.

Applying AGR based on averaged quantities reduced significantly the computational cost compared to the case when the instantaneous solutions were used, especially for the case in which the time-averaged criterion is used for the refinement. Comparing the two averaging approaches shows that the time-averaged criterion does not create any noise and the distribution of the grid size is regular unlike the other case where the mesh is based on the mean flow. Changing the averaging interval changes the mesh evolution. For instance by averaging over a short interval, more unsteady structures are seen in the averaged quantities, so the mesh will change more frequently than when a larger interval is used. And by using a large interval the mesh converges faster to a more or less static mesh.

REFERENCES

[1] Vogel, J.C. and Eaton, J.K. Combined heat transfer and fluid dynamic measurements downstream of a backward-facing step. *J. of heat transfer*, Vol. **107**, pp. 922–929, (1985).