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Session:

Scale-Resolving Simulations Based on a Lattice-Boltzmann Method

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Abstract

Steady state simulations based on RANS equations in combination with statistical turbulence models have enabled accurate flow predictions for a wide variety of applications. Since turbulence models cannot universally account for all flow phenomena, improvement for simulations where RANS fails can be expected by resolving turbulence (at least partially) instead of modelling it. The full resolution of turbulence by DNS or at least of the energy-bearing structures by LES have produced accurate results. However, these types of simulation are usually restricted to simplified test cases at lower Reynolds numbers because of the associated computational costs. The path currently favoured by industrial users is a simulation method that resolves turbulence where necessary (such as flow separations and shear layers) and models the effect of turbulence where possible (such as attached boundary layers). This approach is usually termed hybrid RANS/LES. This paper focusses on simulations based on a Lattice-Boltzmann method[1] (LBM), which is conceptually similar to hybrid RANS/LES and is called LBM-Very Large Eddy Simulation[2] (VLES). This approach is incorporated in the solver PowerFLOW used throughout the paper. Lattice-Boltzmann methods are uniquely suitable for performing this type of simulation because they are inherently unsteady and have very low artificial dissipation.

In order to show the applicability of this approach, different flow problems with increasing complexity are presented here. This abstract focusses on qualitatively showing the capability of switching from modelled to resolved turbulence. A more qualitative assessment of the results as well as insight into the transition mechanism will be given in the final paper by comparison with experimental data. The left part of Fig. 1 shows an incompressible mixing layer developing downstream of a splitter plate. The boundary layer along the plate is modelled with a statistical turbulence model whereas turbulent fluctuations are resolved in the shear layer. The transition shows no delay and thus no dominant grey area problem as observed in standard DES. The right part of Fig. 1 shows the

separating flow downstream of the NASA Hump. Similar to the previous example the oncoming boundary layer is modelled whereas turbulent fluctuations in the recirculation zone are resolved. This improves the prediction of the reattachment point on the symmetry plane when compared to RANS simulations. The observed behaviour of LBM-VLES thus encourages its application to more complex flows, such as the one shown in Fig. 2. This image shows the flow over a three-dimensional ice shape on a NACA 23012 airfoil. Turbulent structures over a wide range of sizes are again quickly resolved and agreement with experimental data is good (to be shown in the final paper).

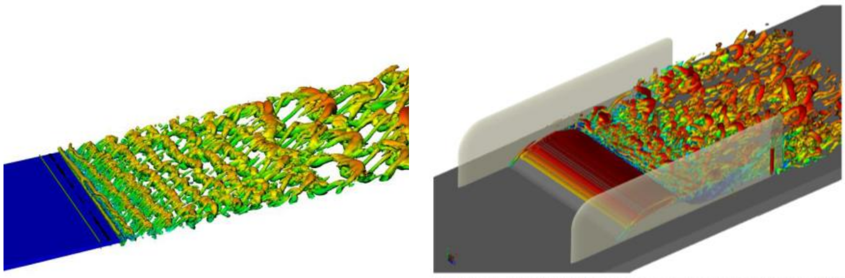

Fig. 1 Visualization of resolved turbulent structures for a mixing layer (left) and for the separated flow behind the NASA Hump (right)

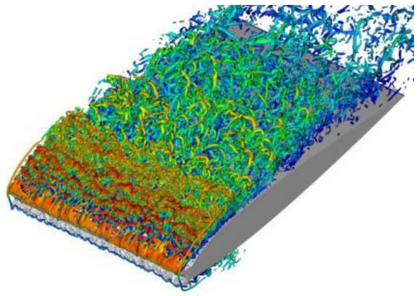

Fig. 2 Visualization of resolved turbulent structures for an iced airfoil

References

[1] Chen, H., Chen, S., and Matthaeus, W., “Recovery of the Navier-Stokes Equations Using a Lattice-Gas Boltzmann Method,” Physical Review A, Vol. 45, No. 8, 1992, pp. 5339–5342.

[2] Chen, H., Kandasamy, S., Orszag, S. A., Succi, S., and Yakhot, V., “Extended Boltzmann Kinetic Equation for Turbulent Flows,” Science, Vol. 301, No. 5633, 2003, pp. 633–636.