Industrial LES applications with Unstructured Finite Volume

D. Laurence
EDF R&D, MFTT, 78400 Chatou, FR.
The Uni. of Manchester/MACE/Fluids, M60 1QD, UK.

1. Introduction

Although successfully conducted by Schumann as soon as 1975, LES of pipe might have been considered “a complex geometry” just ten years ago, while in the wake of Moin & Kim (1982) most of the LES community was later focusing on channel flows with modestly higher Re numbers and refined subgrid-scale models. Spectral or high order numerical methods where believed to be mandatory for LES, while distinct numerical methods (with upwinding) were being developed for complex geometries only with RANS models. Still, at end of the century LES was producing very fruitful insight into complex flow physics, including 2 phase flows and combustion, but in simple geometries. It was also realized that LES on coarse grids could be quite successful for bluff body flows because the large scale eddies where then compatible with the grids affordable at that time. Detached Eddy Simulation (Spalart 1997) opened the way to blending RANS and LES models, which is today a buoyant research field. The MILES approach (Boris et al. 92, Grinstein 2002) on the other hand is an interesting approach to blending numerical dissipation and subgrid-scale modeling. High Reynolds numbers and resolving boundary layers present still today major challenges, but the arrival of very economic PC clusters accessible to almost any CFD group has led to an explosion of “industrial applications” of LES and related methods in the last few years, such that the present lecture can be no means be considered “a review”. We will merely illustrate some applications conducted at EDF R&D and The University of Manchester, with a special focus on the numerical methods and properties of an industrial code and a similar commercial code, at the same time highlighting the importance of energy conservation and grid quality.

EDF R&D LES investigations started 20 years ago, motivated by the flow complexities in power plants (heat transfer, buoyancy, rotation, large and non-streamlined complex geometry), availability of experimental data, and because traditional turbulence models could not provide detailed knowledge of, e.g. extreme or cyclic thermal loading. These early simulations used the staggered pressure-velocity arrangement, which has the well known property of conserving both momentum and kinetic energy *in a discrete sense* on regular Cartesian grids.
After these early Cartesian codes, production runs with RANS for complex geometries had naturally shifted to finite elements, for their unstructured griding flexibility, and LES attempts followed. However, as reported in Rollet-Miet *et al.* (1999), it was soon realised that the traditional P1-P0 tetrahedral element of EDF’s N3S FE code (linear velocity and constant pressure per element) was unsuitable for LES, because pressure actually requires more accuracy at high wave-numbers than velocity. A simple illustration of this is the classical Taylor vortex array test-case where the pressure wavenumber is double that of the velocity, and indeed Rollet-Miet *et al.* only successfully reproduced this vortex array on coarse grids using a collocated element (P1-P1) thus departing from FE practice. Finally the collocated finite volume approach is now used quite successfully. The presentation will tend to show that for industrial LES applications, the issue of numerical methods is perhaps more important