The negatively buoyant wall-jet: LES results

Y. Addad[1], S. Benhamadouche[2], and D. Laurence[1,2]

Introduction

The results of a Large-Eddy Simulation (LES) of a downward hot wall-jet injected against a cold upward channel flow are presented. Based on an experiment of He et al. (2002), this flow was suggested as an ``application challenge" to the Qnet-CFD EU network by the industrial power generation sector. Indeed, numerical predictions vary significantly with the type of RANS model used, with only the most advanced models yielding reasonable agreement with the experiment: see the paper by Craft et al. [1]. The present LES was undertaken to confirm and complete the experimental data, which in some areas can be sparse. Computational resources limited the LES simulation to 1/2 million nodes, and an optimal LES mesh was defined from RANS-derived scales. Then, to reduce uncertainties, two independent codes were used to perform the simulations: commercial software in the form of *Star-CD* and the industrial code, *Code_Saturne*. Statistical quantities are compared with experimental data and show that both codes are able to return fairly satisfactory results for isothermal and moderately buoyant cases.

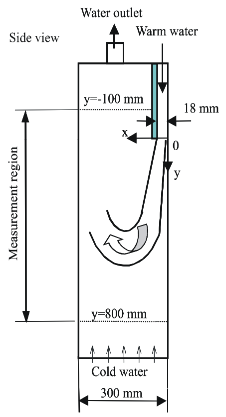

Figure 1 –A schematic sketch of the wall jet experimental rig.

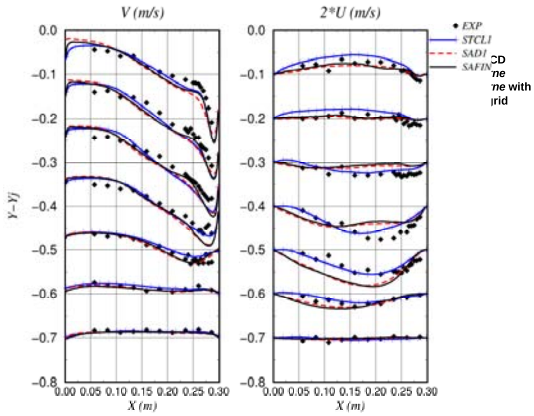

Figure 2 –Profiles of the averaged streamwise and spanwise velocity components. Good agreement is observed between the two codes predictions and the experiment.

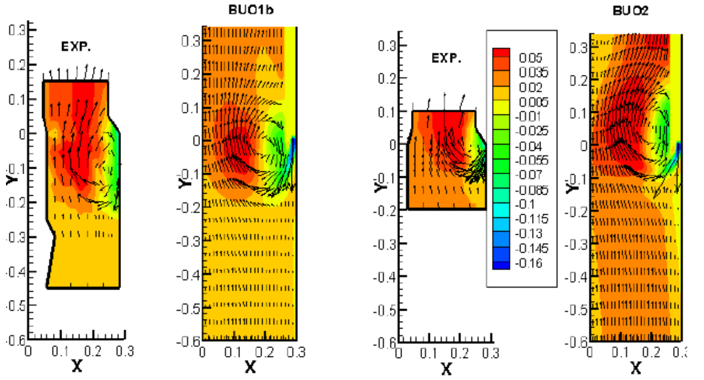

Figure 4 –Averaged vertical velocity field for the buoyant test cases. Left: buoyant case Vc/Vj=0.077, Right: buoyant case Vc/Vj=0.15. It worth noting that the experimental measurements were limited to a small region, not sufficient for RANS models validation.

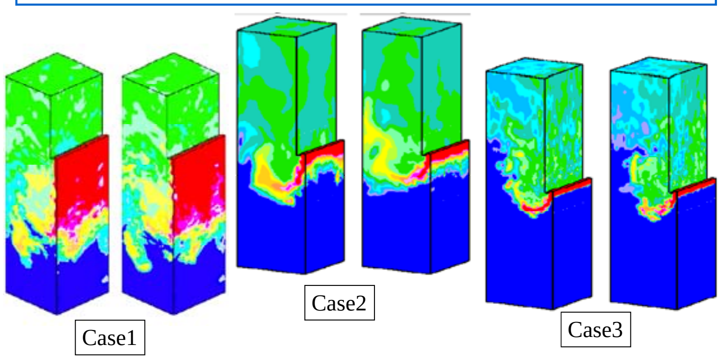

Figure 5 –Instantaneous temperature field at different times. Note the buoyancy effects on the wall temperature distribution.

Results

LES runs:

Case1-Non-buoyant negatively opposed wall jet, Vc/Vj=0.077

Case2-Negatively opposed wall jet with buoyancy effects, Vc/Vj=0.077

Case3-Negatively opposed wall jet with buoyancy effects, Vc/Vj=0.15

(Vj=0.14 m/s; Vc=0.011 m/s)

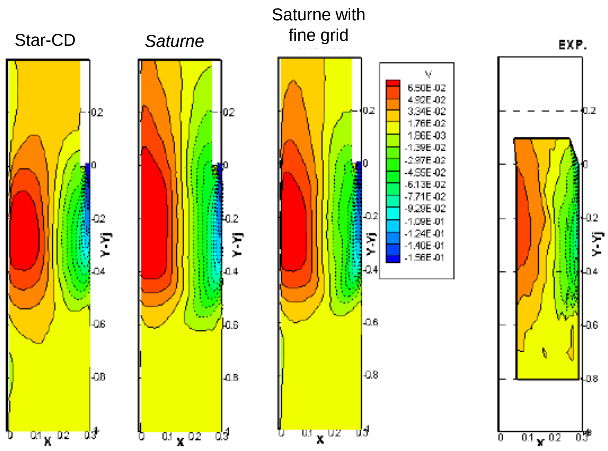

Figure 3 –Averaged vertical velocity field for the non-buoyant test case. Satisfactory agreement with the experimental dataset is observed.

Conclusions and future work

The present study of downward wall-jet flow with and without buoyancy effects gives a good example of fairly complex industrial related flows that may be tackled by the LES approach. Scaling obtained from rough RANS computations enabled a feasibility study and the development of meshing guidelines prior to undertaking the LES. The LES predictions of the mean quantities and low-order statistics, especially for the non-buoyant case, are in reasonable agreement with the experimental data even with fairly coarse grid. Again in this case, hanging nodes are found to be very useful. They allow for adapting the local refinement of the large eddy scales, but only in regions where it is needed most.

Runs with finer grids to carry out Quasi-DNS computations are needed (in the present computations a wall-function was used). In addition to the flows, mean and second moment statistics, wall temperature fluctuations will be provided for possible future thermal analysis studies.

References

[1] Craft T. J., Gerasimov A. V., Iacovides H., Kidger J. W. and Launder B.E, 2004, "The Negatively Buoyant Turbulent Wall Jet: Performance of Alternative Options in RANS Modelling", *Int. J. Heat and Fluid Flow*, Vol-25, pp 809-823.

[3] Addad Y., Benhamadouche S., Laurence D., 2004, "The Negatively Buoyant Turbulent Wall Jet: LES Results", *Int. J. Heat and Fluid Flow*, Vol. 25, 5, 595-806.

Acknowledgment

This work was sponsored by BritishEnergy and BNFL Magnox Generation. Helpful discussions with Dr. M. Rabbitt (British Energy) are acknowledged.

[1] School of Mechanical, Aerospace and Civil Engineering,The University of Manchester, Manchester, UK. Contact Email: yacine.addad@manchester.ac.uk

[2] Electricité de France R&D, MFTT, 6 Quai Wattier, Chatou F-78400, France