Session:

Application of Embedded Simulation Methods to Internal Pipe Flows

Joshua Holgate, Alex Skillen, Alistair Revell and Tim Craft

The School of Mechanical, Aerospace & Civil Engineering,
The University of Manchester, UK.

Introduction

Computational Fluid Dynamics has proven be a valuable tool for industry, and is increasingly used to understand instantaneous flow details of the complex turbulent flows that arise in industrial applications; over and above the mean flow information available from Reynolds Averaged Navier Stokes (RANS) models. The direct prediction of instantaneous turbulent flow at high Reynolds number is particularly challenging on account of the broad range of length and time scales it entails. Large Eddy Simulation (LES) is an attractive compromise but even this has limited practical usage within the present resources available to the majority of CFD practitioners. As such the development of Hybrid RANS-LES approaches remains an important area of research to deliver turbulent simulation capabilities to industry. In cases where the flow extends across a very large spatial domain the simulation of turbulence using high resolution approaches presents a problem. While a fully resolved turbulence simulation is possible in small regions it is unfeasible to extend this beyond domains which are even one order of magnitude larger than the primary integral length scale of the flow. As such 3D LES must sometimes be combined with 2D RANS, and possibly even 1D models in some cases; for instance gas and oil pipe networks which span hundreds of kilometers. The opportunity is thus presented for multi-level resolution approaches which combine different dimensional models and different levels of scale simulation. In the present work we investigate the use of a coupled RANS-LES solver for this practical purpose and give examples of its application, combining a recently developed evolution of the Synthetic Eddy Method [1] to provide inlet data. An interesting complication relevant to the problem of gas pipe networks is the need to simulate an unsteady mean inlet condition, i.e. a ramped up flow rate.

Proposed Results

We first present results from a recent update of the Synthetic Eddy Method (SEM) in the context of turbulent inlet boundary conditions for Embedded Large Eddy Simulation (ELES) implemented in OpenFOAM. Improvements are demonstrated in terms of both the statistical accuracy and the computational efficiency, first for an *a priori* test, before application to a pipe flow case to evaluate the downstream development length and the sensitivity to the input turbulent statistics (Figure 1).

Session:

We then report for both one-way and two-way coupled RANS-LES simulation of turbulent flow through a pipe section in the context of a 'zonal' IDDES approach inspired by [2] where SEM is used as a forcing method to trip IDDES into LES mode, with the RANS mode being recovered through an adaptation to the DDES length scale (Figure 2). The work is completed by investigating the application of these methods to the flow around a 90-degree pipe bend, recently studied by [3] which exhibits a pressure-induced separation at the apex that is shown to be sensitive to the location of the upstream inlet. Sensitivity to the underlying RANS model is tested and the location of the RANS-LES inlet is varied from 10 Diameters upstream to 3 diameters. Findings ultimately demonstrate that the new normalization procedure allows for a reduced development length i.e. realising similar results to a full LES computation in a short distance downstream from the switch from RANS to LES.
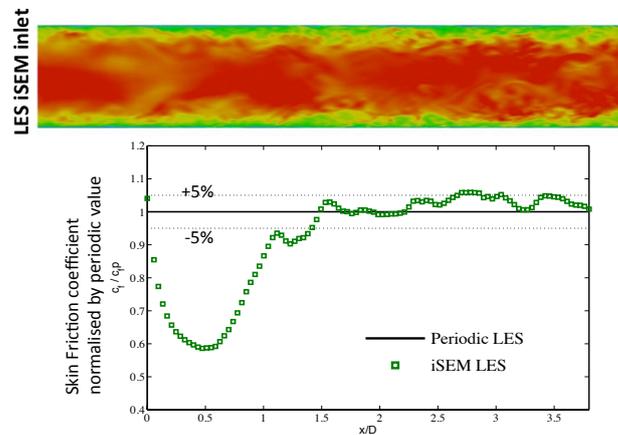

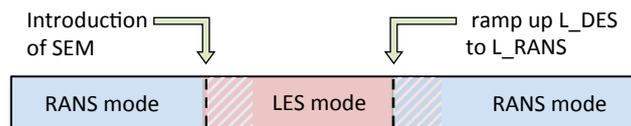**Figure 1** Development of skin friction downstream of the pipe inlet.

Figure 2 Schematic of embedded Eddy resolving scheme.

References

[1]   Jarrin, N., et al (2006). A synthetic-eddy-method for generating inflow conditions for large-eddy simulations. *Int J of Heat & Flu Flow*, *27*(4), 585-593.

[2]   Deck, S. (2005). Zonal-detached-eddy simulation of the flow around a high-lift configuration. AIAA journal, 43(11), 2372-2384.

[3]   Röhrig, R., Jakirlić, S., & Tropea, C. (2015). Comparative computational study of turbulent flow in a 90 pipe elbow. *Int J of Heat & Flu Flow,* 55, 120-131.