Sixth HRLM Symposium, 26-28 September 2016, Strasbourg University, France

Session:

Predictions of turbulence and acoustics from an ultra-bypass serrated nozzle using hybrid RANS-LES

Zhong-Nan Wang, James Tyacke and Paul Tucker

Department of Engineering, University of Cambridge

Introduction

Large-eddy simulation is a vital method to capture the unsteady coherent flow structures in the jets and increasingly being used to predict the flow and acoustics of propulsive jets[1-3]. As the forward flight stream and wing installation effects are considered, the boundary layer development on the engine nacelle and the wing/flap becomes important to the turbulence and acoustics in the jets. Thus, RANS zones are needed near the nozzle and the wing to predict the turbulent boundary layer profiles and circumvent nonphysical separations with reasonable computational cost. This type of highly complex geometry jets simulation will replace parts of the test rigs in the near future and we are seeking to explore a reliable industrial production process chain.

In this paper, the jet flow from an industrial relevant ultra-bypass engine has been simulated in the forward flight stream. Serrations are attached on the nacelle to enhance the shear layer mixing and hence reduce the jet noise. The hybrid structured/unstructured mesh and RANS/LES modelling are demonstrated for the serrated bypass nozzle jet. The results are then analyzed in term of the near-field flows and the far-field acoustics.

Methodology and Results

The hybrid unstructured/structured mesh strategy is employed for the complex nozzle geometry to facilitate the mesh generation and improve the mesh qualities. The RANS are initially performed to inform the shear layer trajectory and then the prism layers have been generated to follow the shear layer development. Most part of the jet plume is meshed by hexahedral cells while the near field acoustic region is meshed with almost isotropic tetrahedral elements. The sketch of the mesh is shown in Fig. 1.

The RANS layers on the nozzle are generated to simulate the turbulent boundary layer based on the modified wall distance[4]. Since the non-dissipative KEP scheme is used[5], the nonlinear SGS model is implemented to model the unresolved scales in the LES region[6]. The

Session:

overview of the shear layer development is shown in Fig. 2. The far-field sound is to be predicted using the Ffowcs Williams-Hawkings integration.

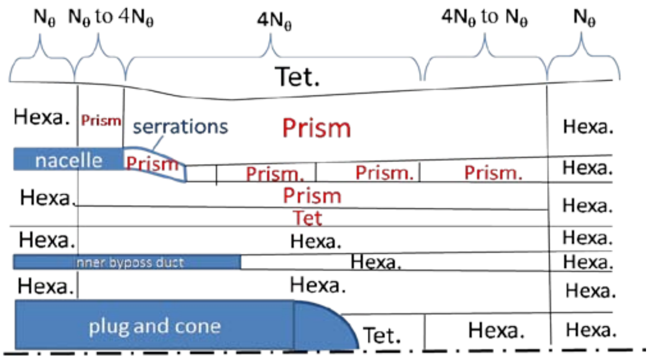

Fig.1 Sketch of hybrid mesh strategy

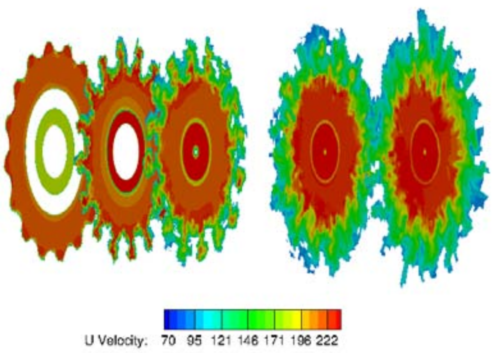

Fig.2 Shear layer development from the serrated nozzle

References

[1] Shur, M., Spalart, P., Strelets, M. K., and Travin, A., 2003, "Towards the prediction of noise from jet engines," International Journal of Heat and Fluid Flow, 24(4), pp. 551-561.
[2] Bodony, D. J., and Lele, S. K., 2008, "Current status of jet noise predictions using large-eddy simulation," AIAA journal, 46(2), pp. 364-380.
[3] Secundov, A. N., Birch, S. F., and Tucker, P. G., 2007, "Propulsive jets and their acoustics," Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 365(1859), pp. 2443-2467.
[4] Tucker, P., 2003, "Differential equation-based wall distance computation for DES and RANS," Journal of Computational Physics, 190(1), pp. 229-248.

[5] Wang, Z.-N., Naqavi, I. Z., Mahak, M., Tucker, P., Yuan, X., and Strange, P., 2014, "Far Field Noise Prediction for Subsonic Hot and Cold Jets Using Large-Eddy Simulation," ASME Turbo Expo 2014:Turbine Technical Conference and Exposition, pp. GT2014-27290.
[6] Liu, Y., Tucker, P., and Kerr, R. M., 2008, "Linear and nonlinear model large-eddy simulations of a plane jet," Computers & fluids, 37(4), pp. 439-449.