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Session: Comparative studies of hybrid RANS-LES and/or other turbulence-resolving simulations

Comparison of Hybrid RANS/LES Methods for Supersonic Combustion in a Model Scramjet Combustor

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Abstract

Since detached-eddy simulation (DES) was proposed, various models of DES approach have been developed such as improved delayed detached-eddy simulation (IDDES) most currently. However a few studies have been performed on supersonic flows using hybrid RANS/LES (HRL) methods in addition to supersonic combustion. In this study, comparisons were made to analyse characteristics of several HRL methods in the supersonic combustion problem. Model scramjet combustor experimented by German aerospace center (DLR) were selected to this study [1]. The model scramjet combustor consists of fifteen holes for hydrogen injection located on the base of a wedge shaped fuel injector providing hydrogen at sonic speed. The computational domain concerns only one injection hole out of fifteen holes, and periodic boundary condition is applied in the spanwise direction for the convenience. The grid points of 1.8 million in total were used to this calculation.

The three dimensional Favre-averaged Navier-Stokes equations were solved numerically on a structural grid topology using finite volume method, also it was developed into the in-house code. Inviscid fluxes are evaluated by using advection upstream splitting method by pressure weight function (AUSMPW+) with fifth order weighted essentially non-oscillatory (WENO) method. Dual-time stepping with preconditioning method and lower-upper symmetric successive over-relaxation (LU-SSOR) were applied for second-order time integration to optimize the convergence of inner iterations. To simulate hydrogen oxidation in the combustor, steady laminar flamelet method was applied. Flame solutions can be obtained from mixture fraction of SLF model which is reading from the flamelet library, such as temperature and species concentrations by using FlameMaster code.

For the comparative study, k-ω SST, IDDES [2], l^2ω-DDES [3] and dynamic l^2ω-DDES [4] models were selected to this study. Calculated

temperature contours are shown in Fig. 1. l^2ω-DDES model could represent dynamic flame structures comparing to IDDES model. Comprehensive studies will be more specifically discussed and compared on the full paper.

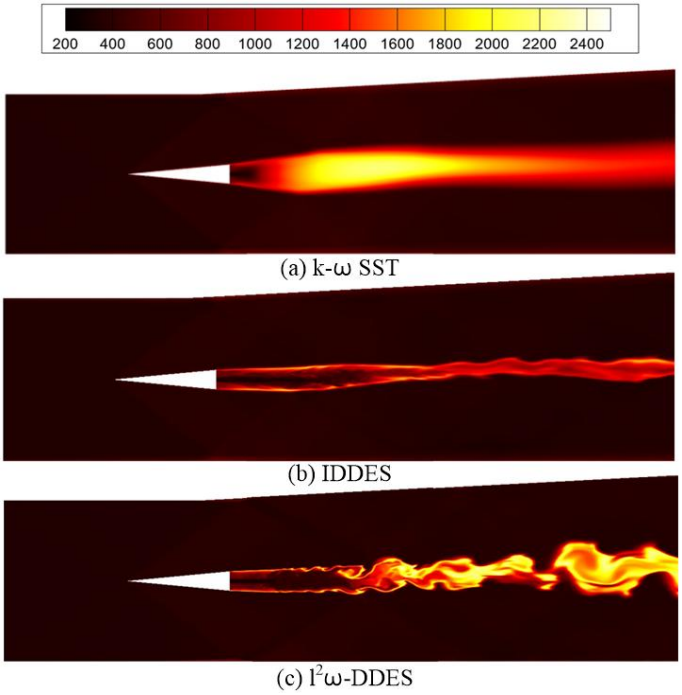

Fig. 1 Static temperature contours for each turbulence models

References

[1] Waidmann et al., "Supersonic combustion of hydrogen/air in a scramjet combustion chamber", *Space technology*, Vol.15, No.6, pp-427-430 (1995)

[2] Gritskevich et al., "Development of DDES and IDDES Formulations for the k-ω Shear Stress Transport Model", *Flow, Turbulence and Combustion*, Vol. 88, Issue 3, pp. 431-449 (2012)

[3] Reddy et al., "A DDES model with a Smagorinsky-type eddy viscosity formulation and log-layer mismatch correction", *International Journal of Heat and Fluid Flow*, Vol. 50, pp. 103-113 (2014)

[4] Yin, Zifei. (2015) "Development of the ℓ^2 ω Delayed Detached Eddy Simulation model with dynamically computed constant" (Unpublished master's thesis), Iowa State University, Ames, United States.