GARTEUR — GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

AD/AG-49:
Hybrid RANS-LES Methods for Aerodynamic Applications

Action Group Chairman: Dr Shia-Hui Peng (FOI)

Background

Hybrid RANS-LES modelling (including DES – Detached Eddy Simulation) combines RANS (Reynolds-Averaged Navier-Stokes) and LES (Large Eddy Simulation) modelling approaches. Its development has been greatly facilitated by industrial needs in aeronautic applications, particularly in CFD analysis of unsteady aerodynamic flows characterized by massive separation and vortex motions. Computations using a hybrid RANS-LES model are able to provide turbulence-resolving simulations.

A number of hybrid RANS-LES modelling approaches have been developed in **Previous work,** being validated in and applied to a wide variety of turbulent flows.

The work in AG49 has focused on an exploration of modelling capabilities in resolving some underlying flow physics in typical aerodynamic applications, e.g., free shear layer, confluence of BLs and wakes, flow separation, recirculation and reattachment. Several selected hybrid RANS-LES methods are scrutinized and evaluated. Some further modelling improvements are also reported.

Fundamental aspects: Examination of hybrid RANS.LES models, modelling evaluation and improvement, modelling-related numerical issues.

Aerodynamic applications: high-lift flows with boundary-layer separation, vortex bursting and shedding, and unsteady flow phenomena associated potentially to flow control and aero-acoustic noise generation.

Partners: Research and academic organizations : CIRA, DLR, FOI, INTA, NLR,ONERA and TUM.

Programme/Objectives

Main objectives: To evaluate and to assess selected hybrid RANS-LES methods with a focus on the simulation and modelling capabilities of handling B.L. separation, shear-layer instabilities and vortex motions and, further, to bridge the gap between "academic" modelling and industrial application.

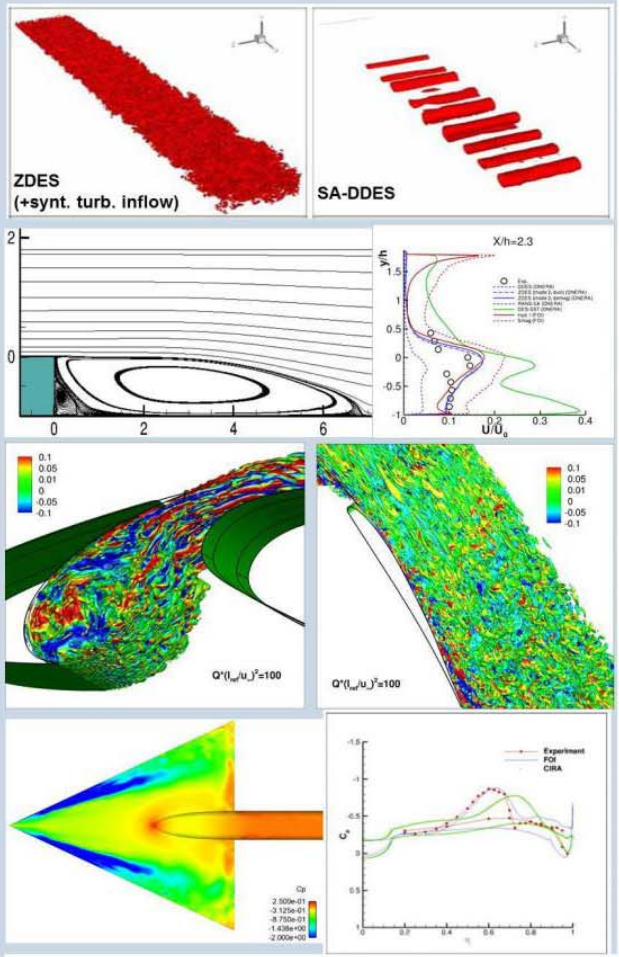
Work plan: The work in AG49 is divided into three tasks. Task 1 and Task 2 are test-case based and each contains two different test cases. "Best-practice guidelines" are addressed in Task 3. AG49 was completed in April 2013.

TC 1.1 Spatially developing mixing layer
Participants: NLR, FOI, INTA, ONERA & TUM
Flow conditions: U_1 = 41.54 m/s, U_2 = 22.40 m/s, with BL. θ =1.00/0.73 mm, Re_θ = 2900/1200
Focus: shear-layer instabilities (in association to grey-area problem), effect of upstream inflow condition, LES mode accounting for downstream vortex motions.

TC 1.2 ONERA backward-facing step flow
Participants: ONERA, FOI, NLR, CIRA & TUM
Flow Conditions: U = 50m/s, Re_h = 40000
Focus: shear-layer instabilities (in association to "grey-area" problem), effect of inflow condition, flow recirculation and reattachment, downstream flow recovery.

TC 2.1 F5 high-lift configuration
Participants: DLR, FOI, ONERA & TUM
Flow conditions: M = 0.15, Re = 2.094 M
AoA = 7.05 deg. (WT), 6.0 deg. (CFD-corrected)
Local transition specified
Focus: BL and wakes confluence, shear-layer interaction, BL separation and subsequent vortex motions, effect of local transition.

TC 2.2 VFE-2 delta wing
Participants: TUM, CIRA, FOI & NLR
Flow Conditions: M = 0.07/0.14
Re =1.0 M, AoA = 23 deg, round leading edge
Focus: formation of primary and secondary vortices, vortex breakdown and shedding.



Results

- **E**xploration and further improvment of modelling and turbulence-resolving capabilities based on a number of test-case computations using different hybrid RANS-LES models
- **A**ssessment of hybrid RANS-LES methods in terms of their respective advantages and disadvantages, by means of cross comparisons of partners' computations.

Summary:

- **A**sessment made for a number of hybrid RANS-LES models through test-case computations, and further improvement on XLES with stochastic forcing and/or based on EARSM; HYB0 with energy backscatter in the LES mode, improved ZDES with vorticity-based length scale in the LES mode.
- **A**ll AG members have computed the test cases planned and contributed to the cross plotting of the results for computed TCs.
- **P**artners have used the following hybrid models: *SA-DES / DDES and IDDES, SST-DES / DDES, zonal SA-DDES, zonal RANS-LES/DNS, HYB1, HYB0, X-LES, ZDES and their variants.*
- **C**ross plots have been conducted for all TCs in comparison with available experimental data, and reported in the final summary report.
- **C**omparative studies have been conducted for modelling evaluation.
- **T**he impacts of other significant factors have been explored, typically, incoming BL, numericla dissipation, grid resolution and domain size etc..
- **E**xperience gained and lessons learned from the work conducted are summarized
- **A** new EG (EG69) has been set up in 2013 by the AG49 members, plus several new EG members. A new AG is planned to launch in 2014 to address RANS-LES coupln g for zonal and embedd LES methods.

CIRA DLR FOI INTA NLR ONERA THE FRENCH AEROSPACE LAB TECHNISCHE UNIVERSITÄT MÜNCHEN