GARTEUR
GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

AD/AG-54:
RANS-LES Coupling in Hybrid RANS-LES and Embedded LES

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

Background

Hybrid RANS-LES modelling aims at turbulence-resolving simulations, in particular, for unsteady flows with massive flow separation and extensive vortex motions, benefitting from the computational efficiency of RANS (Reynolds-Averaged Navier-Stokes) and the computational accuracy of LES (Large Eddy Simulation). Its development has been greatly facilitated by industrial needs in aeronautic applications.

Over nearly two decades since the earliest DES (detached Eddy Simulation) model by Spalart and co-workers, a number of alternative hybrid RANS-LES modelling approaches have been developed in previous work**,** being validated in and applied to a wide variety of turbulent flows. In the EU framework program, a series of noticeable collaborative work has been dedicated to improved hybrid RANS-LES methods, as well as to applications of hybrid RANS-LES models in numerical analysis of numerous flow problems in relation to, typically, unsteady aerodynamics, flow control and aero-acoustics. While hybrid RANS-LES modelling has been proved a powerful methodology in these and other previous work, its weakness and drawback has also been revealed.

AG54 has been established after EG69 and the work has been set up on the basis of AG49, which has explored the capabilities of a number of existing models in resolving some underlying physics of typical aerodynamic flows. AG54 focuses on effective RANS-LES coupling towards novel and improved hybrid modelling and embedded LES methods.

Partners: Airbus-F, CIRA, DLR, Airbus-Innovations (formerly EADS-IW), FOI (AG Chair), INTA, NLR,ONERA (AG vice-Chair), Saab, TUM, UniMan.

Programme/Objectives

Main objectives: By means of comprehensive and trans-national collaborative effort, to explore and further to develop and improve RANS-LES coupling in the context of embedded LES (ELES) and hybrid RANS-LES methods and, consequently, to address the “grey-area” problem in association with the RANS and LES modes and their interaction and leading to improved ELES and hybrid RANS-LES modelling.

Work plan: The work in AG54 is divided into three tasks. Task 1 and Task 2 deal with non-zonal and zonal hybrid RANS-LES methods, respectively, and an overall assessment of the developed methods is conducted in Task 3.

Task 1: Non-zonal modelling methods

(Task Leader: **NLR**)
For models with the location of RANS-LES interface regulated by modelling (not prescribed), typically, for DES-type and other seamless hybrid methods. Two TCs are defined.

TC M1 Spatially developing mixing layer
Initiated from two BLs of U_1 = 41.54 and U_2 = 22.40 m/s, respectively, with Re_θ = 2900 and 1200. Focus on modelling/resolving initial instabilities of the mixing layer.

TC O1 Backward-facing step flow
Incoming BL with U = 50m/s and Re_h = 40000. Focus on modelling/resolving the free shear layer detached from the step (h = step height).

Task 2: Zonal modelling methods

(Task Leader: **UniMan**)
For models with the location of RANS-LES interface prescribed, Including embedded LES. Two TCs are defined.

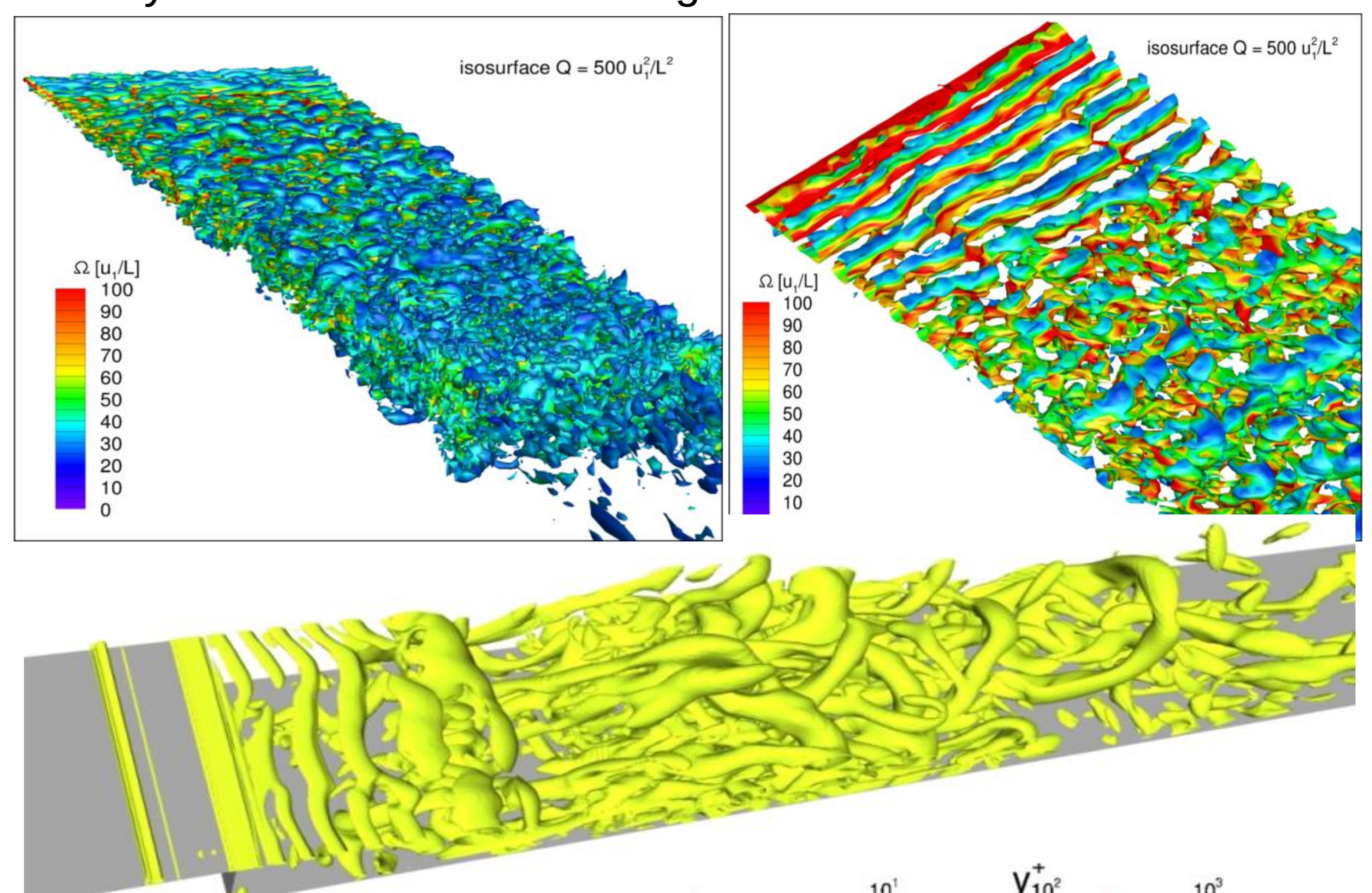
TC M2 Spatially developing boundary layer
Inflow defined with U = 70m/s and Re_θ = 3040. Focus on turbulence-resolving capabilities on the attached BL after the RANS-LES interface.

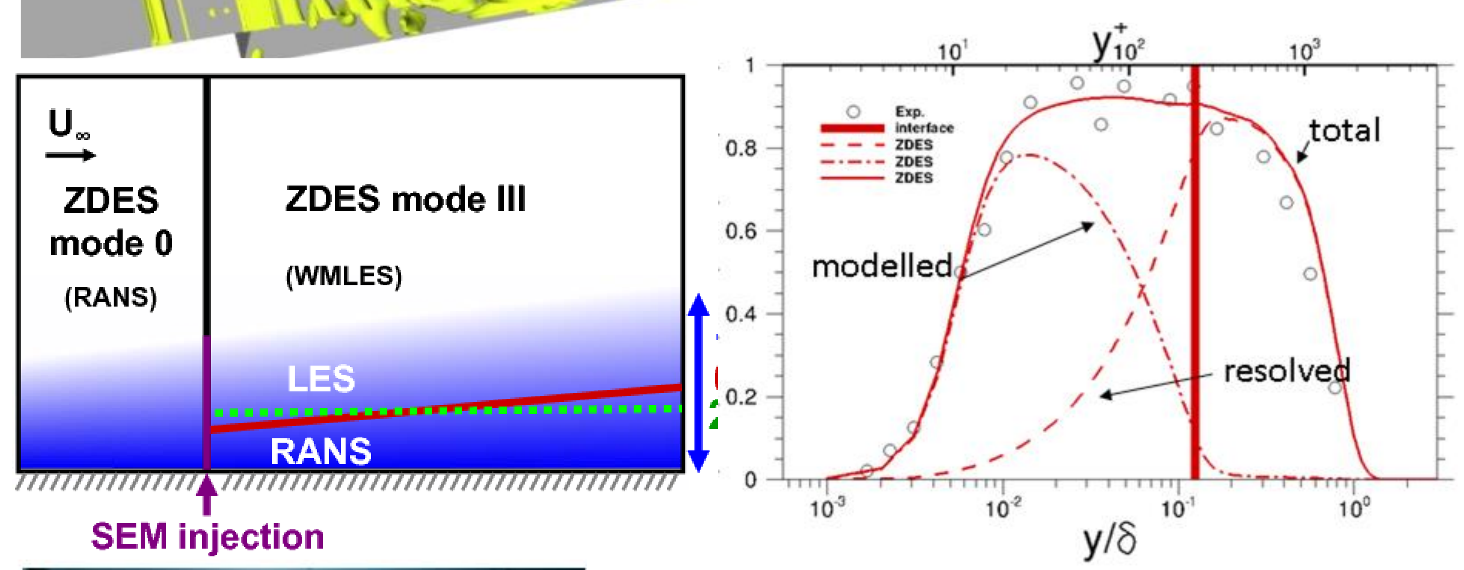
TC O2 NASA hump flow
Incoming BL has U = 34.6m/s, Re_c = 936000 (c = hump length). Focus on the turbulence-resolving capabilities on the flow separation over the hump

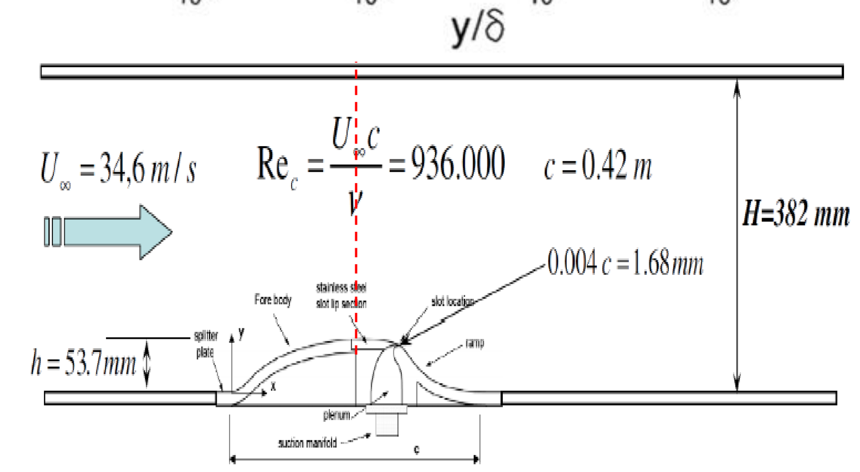
Task 3: Modelling assessment

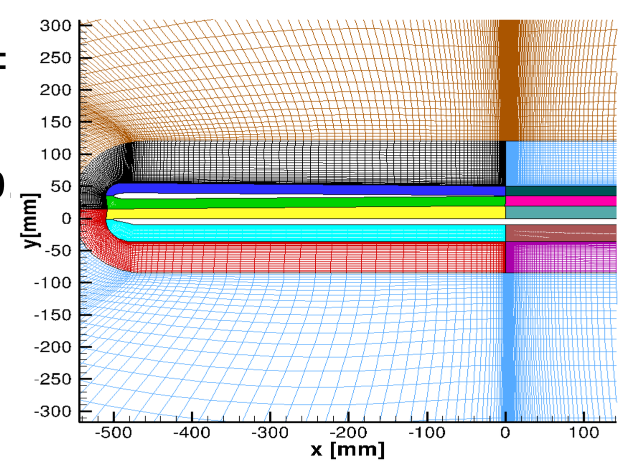
(Task Leader: **Airbus-Innovations** (EADS-IW))
Evaluation and assessment of the methods developed in Tasks 1 and 2 with one TC.

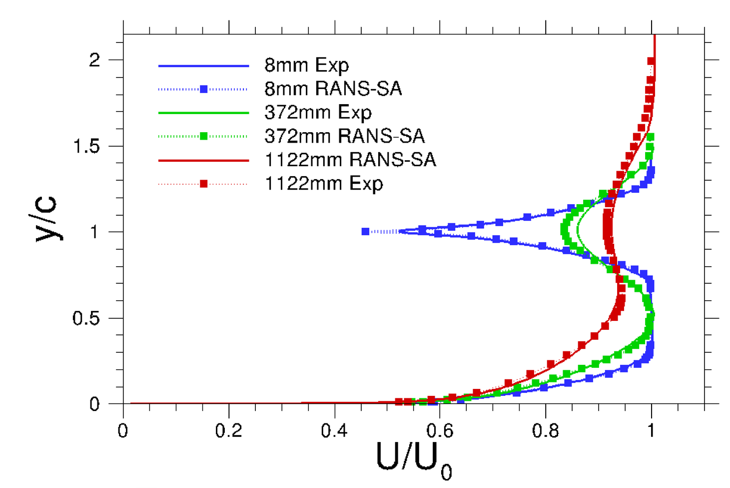
TC M3 Co-flow of BL and wake
Re = 2.4×10^6/meter and M = 0.2. Examination of modelling capabilities for a complex flow case.











Results

- **E**valuation of existing hybrid RANS-LES methods of zonal and non-zonal modelling in computations of test cases.
- **I**mproved modelling formulation to enhance turbulence-resolving capabilities with special focus on the so-called “grey-area” problem.
- **D**efinition of all the test cases, and a number of preliminary computations conducted for different test cases.

Summary:
The project kick-off took place in April 2014. Since then, AG54 has made the following progress.

- In the evaluation, the following baseline hybrid RANS-LES models have been planned/used in test-case computations, *SST-IDDES, HYB0, HYB1, X-LES, ZDES, 2-eq. based DES, 2-velocity method, WMLES, RSM-based hybrid model, SAS and other variants*.
- For non-zonal hybrid RANS-LES modelling, improvement has been progressing on, among others, X-LES with stochastic backscatter model; HYB0 and HYB1 with energy backscatter, improved ZDES with vorticity-based length scale; SST-IDDES model with well-defined hybrid length scale.
- For zonal hybrid RANS-LES modelling, including ELES, synthetic turbulence has been further examined with ZDES formulation. Noticeably, the synthetic eddy method, DFSEM, has been further improved for ELES.
- All the test cases have been defined with formulated test-case description, including the mandatory test cases M1, M2 and M3, as well as the optional test cases O1 and O2.
- Most of AG members have actively started computations of test cases according to the plan, and some preliminary results have been presented
- AG54 had its 1st progress meeting in October 2014, hosted by UniMan.

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