LES, TRANSITION MODELLING AND TURBULENT COMBUSTION

ERCOFTAC SIG10/SIG28 workshop, November 29-30, 2007, Ghent, Belgium

Erik Dick[1], Chris Lacor[2], Witold Elsner[3], Bart Merci[1], Andrzej Boguslawski[3]

1. Ghent University, Belgium
2. Vrije Universiteit Brussel, Belgium
3. Czestochowa University of Technology, Poland

Objectives

The workshop was a joint organization of SIG10 (Transition Modeling), SIG28 (Reactive Flows) and PC-Belgium. It served as the yearly meeting of the members of PC-Belgium. However, presentations from members of PC-Belgium had to fit into the themes of the workshop. The workshop also functioned as a meeting of two bilateral projects: one on transition modelling by Ghent University and Czestochowa University of Technolgy and one on LES for combustion by Vrije Universiteit Brussel and Czestochowa University of Technology. The objective was to discuss progress in development of methods for Large-Eddy simulation, development of models for transition, including experiments on better understanding of transition mechanisms and development of models for combustion simulation. There were three invited speakers, one for each of the topics of the workshop.

Invited speakers

Johan Kok from the Dutch National Aerospace Laboratory NLR, talked on 'a high-order finite volume scheme for extra Large-Eddy simulations'. He presented a numerical method with conservation of mass, momentum and total energy, conservation of kinetic energy by the convective operator, fourth-order accuracy, low numerical dispersion and zero numerical dissipation. The method is applied to LES in so-called XLES form, by which is meant that the grids may be quite coarse for normal LES standards. The XLES method is a particular form of DES (Detached Eddy Simulation) or hybrid RANS/LES. The simulation is RANS in the near-wall region with the $k-\omega$ turbulence model. The simulation is LES away from walls with the k-equation used to construct the subgrid scale eddy viscosity. He demonstrated the excellent qualities of the methodology.

Franco Magagnato from Karlsruhe University, talked on 'Prediction of the transitional flows of turbine blades with LES, DES and DDES'. He discussed LES with a high-pass filtered Smagorinsky model, DES with the Spalart et al. model and DDES (Delayed Detached Eddy Simulation) with the Spalart et al. model. He emphasized the need for high-quality numerical methods with as ingredients higher-order accurate discretisations and non-reflecting boundary conditions at inlet and outlet of the computational domain. He demonstrated with flows in a turbine cascade that non-reflecting boundary conditions are essential for accurate prediction of the boundary layer characteristics.

William Jones from Imperial College London talked on 'Large Eddy simulation of turbulent reacting flows'. He discussed the fundamentals and the numerical requirements for LES in flows with combustion. He demonstrated several examples. He emphasized that the simple

LES conserved scalar model is capable of reproducing the temperatures and major species in non-premixed flames, providing there are no local extinction effects. He showed that the Pdf equation method in conjunction with the stochastic field solution method shows much promise, but that more research is required, particularly for LES of premixed and partially premixed combustion.

Contributed presentations on LES

- L. Georges, K. Hillewaert, R. Capart, T. Louagie, J-F. Thomas, P. Geuzaine, Cenaero: 'DES and LES around complex geometries'. They demonstrated the Cenaero flow solver 'Argo', using unstructured tetrahedral meshes, edge-based hybrid finite volume/finite element formulation for the compressible flow equations, full implicit time integration using second-order 3-points backward differencing and a Newton-Krylov-Schwartz method to solve the systems. The solver can be used for URANS, wall-resolved LES, wall-modelled LES, DES and DDES. They demonstrated the simulation of the flow around a complete landing gear with DES.

- L. Georges, P. Geuzaine, M. Duponcheel, L. Bricteux, T. Longfils, G. Winckelmans, Cenaero and Université catholique de Louvain: 'Two-vortex system in ground effect with and without wind'. They demonstrated LES of a longitudinally uniform two-vortex system in ground effect with and without wind. As subgrid scale models the Smagorinsky model and the filtered-Smagorinsky model were used.

- J. Meyers, Katholieke Universiteit Leuven: 'Testing of high-pass-filtered Smagorinsky models and inertial-range consistent variants in LES of turbulent channel flow'. He showed channel-flow simulations using three variants of small-small VMS (Variational Multiscale) models, combined with a sharp cut off or a Gaussian filter. He demonstrated the influence of the filter shape to the results and concluded that final calibration of the subgrid model is not immediately evident.

- D. Fauconnier, C. De Langhe, E. Dick, Ghent University: 'High order dynamic finite difference scheme for large eddy simulation'. They demonstrated a methodology to optimise the dispersion error of non-dissipative discretisations based on a dynamic procedure similar to the existing procedure for optimisation of subgrid models. They demonstrated the high accuracy resulting from the adaptivity to the spectral properties of the flow fields.

Contributed presentations on Transition Modelling

- P. Jonas, O. Mazur, V. Uruba, Czech Academy of Sciences and W. Elsner, M. Wysocki, Czestochowa University of Technology: 'On turbulent spots during boundary-layer by-pass transition'. They discussed results of experiments on the influence of the free stream turbulence length scale on the evolution of turbulent spots in an attached boundary layer. They showed that the evolution of the intermittency can be described with Narasimha or Fashifar laws and that the spot production rate obeys well-known correlations. The influence of the free stream turbulence length scale is on the starting position of the transition.

- J. Zabski, Z. Wiercinski, Polish Academy of Sciences: 'Phase averaged characteristics of the boundary layer in transition induced by wakes'. The reported research is on the effect of negative jet impact (compressors) and positive jet impact (turbines) of wakes. They demonstrated with wavelet analysis that there is no becalming region after a negative jet.

- S. Tirtey, O. Chazot, Von Karman Institute: 'In-flight hypersonic roughness induced transition experiment on EXPERT program'. They discussed experimental tools based on infra-red thermography for characterizing a transitional hypersonic boundary layer in both wind tunnel and real hypersonic flight conditions.

- T. Arts, R. Heutermans, D. Paolucci, Von Karman Institute: 'High speed low Reynolds number flows in the turbine cascade T106C'. They showed results of experiments in a cascade tunnel for high speed low Reynolds number flows with impinging wakes. Smooth and rough suction side surfaces have been employed. A large data base has been constructed for verification of transition models.

- W. Piotrowski, W. Elsner, Czestochowa University of Technology: 'Modelling of laminar-turbulent transition with the use of an intermittency transport equation'. An intermittency transport model is developed based on the same equations as proposed by Menter. The correlations, necessary as input and kept secret by Menter, are reconstructed by numerical experiments on the T3-test cases. The excellent quality of the model is then demonstrated for wake-induced transition on the N3-60 turbine blade.

- A. Beevers, Cranfield University: 'Simulation of wake-induced transition on an axial compressor stator blade'. The Langtry-Menter model, as implemented in Ansys-CFX, is tested for a 2D slice at mid-span of a 1.5 stage low speed axial compressor. Although not perfect, simulation results are quite good.

- K. Lodefier, W. Piotrowski, S. Kubacki, W. Elsner, E. Dick, Ghent University and Czestochowa University of Technology: 'Validation of a dynamic intermittency model for the prediction of wake-induced bypass transition on turbine blades'. The dynamic intermittency model of UGent is tested for wake-induced transition on the N3-60 blade for various flow conditions. The results are quite good but a systematic delay at the start of transition is observed.

Contributed presentations on Combustion Modelling

- X. Kuborn, M.V. Papalexandris, H. Jeanmart, Université Catholique de Louvain: 'Modelling and simulation of the flow and transfer phenomena through a shrinking porous medium'. A modelling strategy is presented for simulation of gasification of wood.

- M. Vanierschot. K. Vanoverberghe, E. Vanden Bulck, K.U. Leuven, Belgium: 'The physics behind zero swirl coanda flames'. Experimental research is presented on the possible flow patterns in a combustion chamber equipped with a nozzle which allows coanda flow. The conditions to reach the coanda flow are discussed.

- A. Tyliszczak, A. Boguslawski, Czestochowa University of Technology: 'Preliminary results of CMC/unsteady flamelet modelling of Sandia flame'. A conditional moment closure (CMC) modelling approach is presented. First results of LES with this model on the

Sandia D flame are presented. Comparison is made with results from a flamelet model. Both models give quite good agreement with experimental data.

- P. Rauwoens, J. Vierendeels, B. Merci, Ghent University, Belgium: 'Numerical issues for time-accurate non-premixed flame simulations'. It is demonstrated that the standard pressure correction method typically leads to unstable results. A remedy is proposed based on a strict satisfaction of the equation of state. It is proved that then stable results are obtained.

- J.E. Anker, K. Claramant, B. Wegner, M. Nullmeier, Ch. Hirsch, Numeca International, TU Delft, TU Darmstadt, U Heidelberg: 'Non-premixed combustion models in a compressible Navier-Stokes solver on unstructured hexahedral grids'. The mixture fraction approach for non-premixed combustion is implemented in the unstructured hexahedral grid software package of Numeca. RANS and LES results are shown for a generic combustion chamber.

- B. Merci, B. Naud, D. Roekaerts, U. Maas, Ghent University, Ciemat, TU Delft, Karlsruhe University: 'Joint scalar and joint velocity-scalar PDF modelling of turbulent non-premixed combustion with REDIM'. Two variants of PDF approaches are discussed: joint scalar PDF and joint velocity-scalar PDF. The approaches are tested on the Sydney bluff body stabilised frame for two different flow conditions. No significant differences between the approaches are observed.

- M. Zakyani, T. Broeckhoven, C. Lacor, Vrije Universiteit Brussel: 'Study of LES modelling for non-premixed combustion'. The mixture fraction approach is combined with LES. The methodology is tested for two flames. The importance of sufficient numerical quality is demonstrated.