RANS Panel

Here are the initial questions to be considered:

- Do you believe we have stagnation in RANS Turbulence Modeling?
- Does it matter anymore?
- What activities, including Machine Learning, can cause a breakthrough?
    - What is the role for data-driven modeling: Machine, Statistical learning..?
    - What activities can cause a breakthrough?

- **PANELISTS: P. Batten, P. Durbin, C. Hirsch, B. Smith**
- Answers from M. Strelets and F. Menter (who could not be here) are given first…

Although our group has carried out huge amount of work related to RANS Turbulence Modeling with Philippe and, to a less extent, with Florian, our primary input consists in implementation and validation of their ideas and in calculating a large number of flows with various RANS models.

Hence, the answers below actually present user's rather than modeler's viewpoint.

- **Do you believe we have stagnation in RANS Turbulence Modeling?**
  - I believe we do. Since the beginning of the 90s of the last century, progress has been slow and consists, mainly, in adjusting existing models to specific classes of flows. In terms of universality, which means the capability of ONE turbulence model to predict a flow of arbitrary complexity with acceptable accuracy, no significant progress has been made. Moreover, for a number of flows, such e.g., as massively separated flows, none of the existing RANS models provides accurate predictions
- **Does it matter anymore?**
  - I think it does matter. Scale-Resolution Approaches, which play an increasingly important role in applied CFD research and potentially may replace RANS modeling, are still very (in many cases prohibitively) computationally expensive and are much more demanding than RANS in terms of user expertize. In addition, the most technologically mature SRA, such as RANS-LES hybrids and WMLES, include RANS modeling as an essential component. Finally, SRA usually rely upon precursor RANS computations which are needed for imposing inflow boundary conditions (STGs) and getting information on the parameters essential for grid-generation
- **What activities, including Machine Learning, can cause a breakthrough?**
  - This depends on what "breakthrough" means. If this means building a universal RANS model, it seems that there is no way to reach this staying within the conventional ("classical") RANS modeling framework, unless some fundamentally new idea springs up "of all a sudden". If, however, this means radical enhancements of the existing models for some specific flow classes, this seems to be reachable by means of coordinated mutual efforts of modelers, experimentalists, CFDers, and Machine/Statistical learning experts

Response to Turbulence Questionnaire

Florian Menter
Chief Scientist

Ansys

First Things First:

Congratulations to Philippe for an outstanding career

Your role as a partner in the competition for the best industrial turbulence models is highly appreciated

I am certain you will be around and help us all in pushing turbulence technology to the next level

Questions and Answers

- Do you believe we have stagnation in RANS Turbulence Modeling?
  - RANS turbulence modeling is like a turtle – it does not move when you watch it, but over time it can cover significant distances
  - There is still significant progress in RANS transition modeling
  - For us 'rubber-band' models like GEKO are a significant step forward, as they allow users to tune models for their applications without destroying the basic model calibration
- Does it matter anymore?
  - Yes – RANS models will be central to CFD for many years and will always serve as a low-cost element in any foreseeable future (unless there is a break-through in quantum computing)
  - Obviously, RANS boundary layer models are essential in hybrid RANS-LES models. Again, models like GEKO are helpful as they allow tuning of the RANS part (separation)
- What activities, including Machine Learning, can cause a breakthrough?
  - I don't see a breakthrough not even with ML but there will be areas where it can lead to improvements
    - Transition modeling is strongly data driven – much wider calibration and tuning can be achieved by ML
    - EARSM tuning has a potential for systematic improvement for more complex flows
  - The 'blanket' of RANS models can be stretched by ML but in the end will always be too short to be reliable (error bars)
  - The scale-equation is too uncertain (even in its definition) to be eliminated as a source of error
  - Entirely new model formulations – I am doubtful
  - Many technical flows feature some sort of unsteadiness (most often vortex shedding) which is out of reach of RANS

Model Tuning and Machine Learning

- Ansys has implemented full field inversion for GEKO (adjoint)
  - It is used by clients to optimize model settings for specific applications
  - It allows users to ‘pull’ the calibration space of the model closer to their application
  - Example – variations of automotive shape for drag reduction
    - ➢ Optimize the GEKO model for a specific type of car (different tuning for ‘sedan’ vs ‘station wagon’ etc.)
    - ➢ Start with the baseline configuration using the tuned model which gives close representation with data
    - ➢ Run variations using the identical settings to assess differences
    - ➢ Ideally, the initial tuning of the model should be based on field data
    - ➢ Typically, high-quality hybrid RANS-LES should be used – can later be replaced by WRLES
    - ➢ Tuning against exp. sparse data (Cd, Cl) poses risk of cancelation of errors.
  - No generic improvement of models observed so far
  - It is a ‘horses for courses’ strategy but still very helpful
- GPU computing will be a substantial step forward as it ‘democratizes’ data generation (DNS, WRLES) for model tuning