Report on the 10th joint ERCOFTAC (SIG-15)/IAHR/QNET-CFD Workshop on Refined Turbulence Modelling, Poitiers, october 10-11, 2002

Remi Manceau

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Rémi Manceau
Laboratoire d'études aérodynamiques
CNRS UMR 6609, Université de Poitiers
86 962 Futuroscope Chasseneuil cedex
France

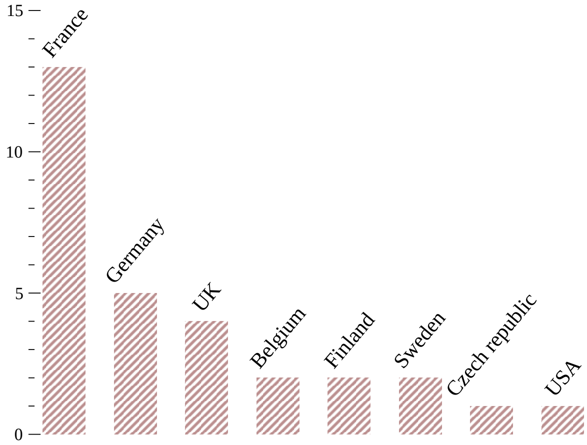

Figure 1: Repartition of the participants

1 Introduction

Computational Fluid Dynamics (CFD) has developed to a key technology which plays an important role in analysis, design, development and optimization in engineering practice. Although increasing computer capacities enable a broader use of highly resolved computational schemes such as Direct Numerical Simulation (DNS) and Large Eddy Simulation (LES), the statistical turbulence modelling used in the framework of the Reynolds Averaged Navier-Stokes (RANS) approach represents the current industrial standard. The ERCOFTAC-IAHR Workshops on Refined Turbulence Modelling (SIG-15) aim to bring together scientists, researchers, users and developers from industry and from the academic field.

The QNET-CFD network was associated to this ERCOFTAC/IAHR workshop because the case 9.4 (Flow around a simplified car body) is one of the 53 test cases under consideration in this network, in its Thematic Area 1 (External Aerodynamics), Application Challenge 5 (Ahmed body). This network is aimed at providing European industries with a knowledge base of high quality application challenges and best practice guidelines. Therefore, the second day of the workshop was completely dedicated to the Ahmed body test case, in order to analyse in detail the features of the flow and the performances of the models.

2 Participants

The workshop attracted 32 participants from 9 countries, distributed as shown in figure 1.

Most of them came from European universities or research institutes (24), 7 from European industries and 1 from NASA.

They represented 24 different institutions. 15 of them submitted results.

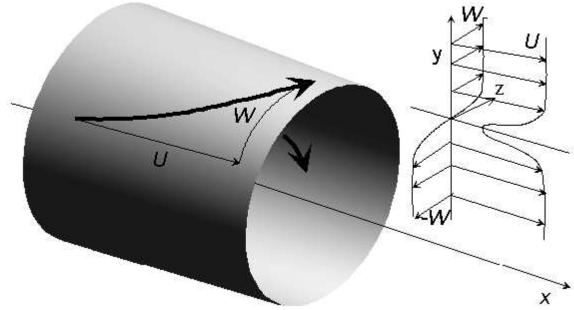

Figure 2: Sketch of the wake/mixing layer interaction test case

3 Test cases

This series of workshops of the Special Interest Group on Refined Turbulence Modelling (SIG-15) aim at evaluating the comparative performances of turbulence models in the prediction of very challenging test cases, involving complex underlying mechanisms of primary significance for industrial applications.

Two of the test cases, i.e., the flow over a periodic 2D hill and the flow around the Ahmed body (simplified car body), were already selected for the preceding workshop held in Darmstadt, Germany [2]: the complexity of the underlying mechanisms and the challenge they represent for turbulence models have led to the renewal of these test cases.

3.1 Case 10.1: Wake/mixing layer interaction (contra-rotating jets)

The flow is generated by two coaxial jets with opposite rotation. An azimuthal mixing layer develops, and an interaction between the wake of the inner nozzle and the azimuthal mixing layer takes place, as shown in figure 2.

A transition from a wake to a mixing layer behaviour occurs as the flow develops is x-direction. In particular, the Reynolds stress tensor experiences a drastic change in its structure.

Detailed experiments performed at the LEA [1] at $Re = 212,000$ were made available for this workshop. The database contains profiles of the mean velocities, Reynolds stresses (6 components) and budgets at 15 location downstream of the nozzle.

3.2 Case 9.2: Periodic flow over a 2-D hill

This case is a statistically 2D turbulent flow in a channel with a wall consisting of a periodic series of hills, as shown in figure 3. Separation occurs on the leeward face of the hill due to adverse pressure gradient and reattaches on the flat part, before the next hill.

The main difficulty of the case is to predict the location where separation and reattachment occur, as well as the high level of turbulent stresses in the shear region.

Detailed statistics of the flow were available from a highly resolved LES [4].

3.3 Case 9.4: Flow around a simplified car body (Ahmed body)

The Ahmed body is a simplified car, shown in figure 4, defined by the car industry in order to focus on a particular aspect of the flow: the complex wake structure at the origin of the drag crisis experienced by ground vehicles when the angle of the hatchback approaches 25 degrees.

Detailed experiments were provided by Lienhart, Stoots and Becker, 2000.

4 Programme

4.1 October 10

Morning: case 10.1 (chairman: Dr. Bonnet)

The first talk was given by Dr. Delville (LEA, university of Poitiers/CNRS) who presented the test case, its underlying physics and the experiments performed at the LEA.

The 4 teams that performed computations of the case presented their numerical methods and turbulence models. 12 different computations had been submitted, using 7 different RANS models and 1 LES model.

Dr. Manceau (LEA, university of Poitiers/CNRS) then presented cross-plots of the results submitted by the participants and tried to analyse the relative merits and weaknesses of the different turbulence models.

Finally, an open discussion allowed commenting and completing this analysis.

Afternoon: case 9.2 (chairman: Pr. Launder)

First, Pr. Leschziner (Imperial College) presented the test case and the highly resolved LES performed by Imperial College.

8 teams then presented the computations they had submitted for this case, i.e., 38 different computations using 23 different turbulence models.

Pr. Leschziner gave a synthesis of the comparative performances of the numerous turbulence models.

An open discussion closed the first workshop day.

4.2 October 11

Case 9.4 (chairman: Pr. Hanjalić)

The first talk was given by Dr. Spohn (LEA, university of Poitiers/CNRS), who presented visualisation performed at the LEA at a low Reynolds number in order to better understand the flow structures.

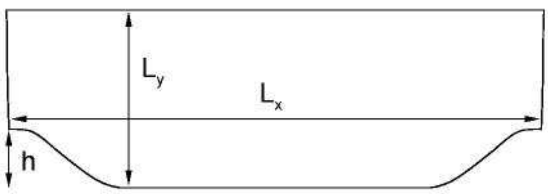

Figure 3: Geometry of the case 9.2

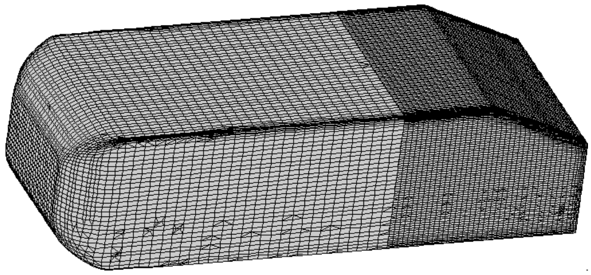

Figure 4: Geometry of the case 9.4

The second talk was given by Dr Lienhart (Erlangen University), who presented the flow conditions and the experiments performed at Erlangen.

The 5 teams that had submitted results for this case then gave an overview of their numerical methods. 10 computations were presented for the 25 degree case and 11 for the 35 degree case, using 11 different RANS models and 1 LES model.

Dr. Menter (CFX) then synthesized the computational results for both the 25 and 35 degree test cases.

5 Conclusions

So many comments were made about the relative performances of the models in the reproduction of the different physical mechanisms involved in the 3 test cases that it is not possible to go into details in the frame of this report. However, some aspects were particularly interesting and deserve some comments.

Wake/Mixing layer interaction. It was clear that linear eddy-viscosity models are not suited to this case in which the turbulence production mechanisms of the different components are absolutely not the same. However, even for nonlinear and Reynolds stress models, which are able to reproduce these subtle production mechanisms, the transition from a wake to a mixing layer behaviour, which is clearly seen in the experimental budgets, is not obtained correctly.

Periodic flow over a 2-D hill. Pr. Leschziner particularly emphasized the large scale unsteadiness of the flow at the origin of large variations of the instantaneous locations of the separation and reattachment points: this feature, observed in the highly resolved LES computation, makes the case very challenging for statistical models. Reynolds-averaged computations do not resolve this low frequency unsteadiness and the turbulence models do not predict its mean effect, which is probably far from standard turbulence agitation.

Flow around a simplified car body (Ahmed body). While the low-drag configuration (35 degrees) is correctly predicted by different turbulence models, the complex 3D structure of the wake of the body for the high-drag case is only reproduced by LES. Conclusions must be drawn with caution for this very complex flow, but it seems like either some fundamental physical mechanism is missed by RANS models or large scale unsteadiness plays again a crucial role in the sustainment of the complex 3D wake.

6 Proceedings

Detailed descriptions of the test cases, the numerical methods used by the participants and the results can be found in the proceedings of the workshop:

R. Manceau, J.-P. Bonnet, M. A. Leschziner, F. Menter, editors. *Proc. 10th ERCOFTAC (SIG-15)/IAHR/QNET-CFD Workshop on Refined Turbulence Modelling.* Laboratoire d'études aérodynamiques, UMR CNRS 6609, Université de Poitiers, France, October 10–11, 2002.

Links to the databases used for the workshop can be found on the workshop web site:

http://labo.univ-poitiers.fr/informations-lea/Workshop-Ercoftac-2002/Index.html

7 Acknowledgement

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