The ERCOFTAC KNOWLEDGE BASE WIKI – AN AID FOR ESTABLISHING QUALITY AND TRUST IN CFD

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Abstract

A brief introduction is given to the ERCOFTAC Knowledge Base Wiki which provides structured knowledge and advice on a wide variety of flow situations and was designed to underpin quality and trust in the industrial application of CFD. The structure and content of the Knowledge Base Wiki are briefly described and a list of all the test cases is given, grouped into Application Challenges representing realistic flow situations appearing in practice and into Underlying Flow Regimes representing more generic, building block flows contained in the Application Challenges. A link to the Wiki is provided through which the reader can obtain detailed information on the Wiki and look at examples of test case documentations.

Introduction

CFD is used more and more in all industries involving fluid flow, and its potential in industrial applications is enormous. However, CFD is still an emerging technology and involves many uncertainties so that quality and trust in CFD applications is an important issue. Uncertainty can arise from numerical inaccuracies, but these can be kept more and more under control especially due to the ever increasing computer power. Of greater concern is the adequacy of the underlying mathematical models describing the physical processes, and here especially the effects of turbulence. Direct numerical simulations (DNS) are not possible in the foreseeable future for practical calculations. Large eddy simulation (LES) is seen as the technology of the future, and in some areas it is already used in practical applications. However, most practical flow calculations today are still carried out with statistical (or RANS) turbulence models, and it is now generally accepted that none of these models is or will be universal, i.e. there exists no model that produces reliable predictions for all flows. In view of this, reliable knowledge is required on which models work for which flows, and based on this knowledge guidelines need to be developed for solving individual flow problems. This is basically what was attempted in the EU-Network-Project QNET-CFD in which a Knowledge Base was generated containing various components. Knowledge was collected for two types of flows: One type are Application Challenges (AC’s) for individual industrial sectors representing flows close to those occurring in practice, and here the ability of CFD to predict reliably the main design and assessment parameters is of prime interest. These flows are generally complex systems containing certain Underlying Flow Regimes (UFR’s), the second type representing more generic flows (such as boundary layers, jets, step flows, etc.) for which much more detailed experimental data are available as well as better resolved numerical calculations so that a more thorough testing and validation of CFD methods and the turbulence models used can be carried out.

In the EU project a Knowledge Base was developed in which a larger number of AC's and UFR's were stored. The members of the project came mainly from industry but also from universities and national research organizations and from the major European CFD vendors, and each member had to provide one AC and one UFR and had to subject the submitted contributions to a strict quality control according to a review template. The resulting contributions forming the Knowledge Base were stored at the University of Surrey and the Knowledge Base was maintained there for a transition period in which ERCOFTAC (European Research Community on Flow, Turbulence and Combustion) took over the Knowledge Base and turned it into an interactive Wiki. In this process, further quality control was exercised and certain cases were taken out from the Knowledge-Base part to be made public and were stored away for eventual improvement. The remaining AC's and UFR's were grouped into Gold and Silver domains according to their quality as explained below. These were made available to the Fluid Mechanics community at: http://qnet-ercoftac.cfms.org.uk , and efforts are underway to enhance and expand the Knowledge Base Wiki by adding new test cases.

In this paper, a brief introduction to the Knowledge Base is presented: The concept, structure and operational features will be outlined and an overview over the content will be given. At the conference itself, an online demonstration of examples of one typical Application Challenge (AC) and one typical Underlying Flow Regime (UFR) will be given.

Structure of the Knowledge Base Wiki

The navigation tree of the Wiki is given in Fig. 1. Through this, the various parts of the Knowledge Base can be reached and it is provided here as reference will be made to it in the following descriptions.

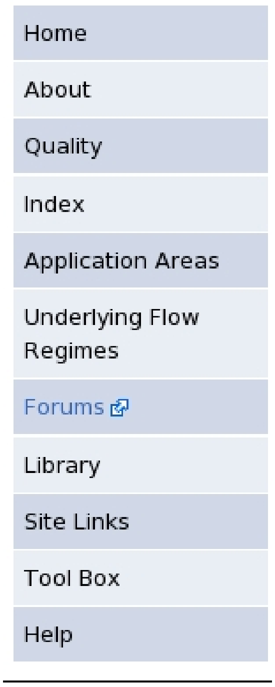

Fig. 1: Navigation tree of Wiki

As mentioned already, knowledge was collected and is provided for two types of flow test cases, namely:

<u>Application Challenges (AC)</u>
These are complex flow situations close to industrial practice for which mainly global design and assessment parameters are of interest and measurements of the details of the flow are often not available. For this category, the Knowledge Base provides files with the actual data for the geometry, the measurements and the CFD results. The application challenges are grouped into test cases for different application areas:

- External Aerodynamics
- Combustion
- Chemical, Process, Thermal and Nuclear Safety
- Civil Construction and HVAC
- Environmental Flow
- Turbomachinery Internal flow

Underlying Flow regimes (UFR)
Application challenges contain Underlying Flow Regimes which are more generic, building-block flows for which much more detailed experimental results are available, which are better resolved in numerical calculations and for which also wider testing using different simulation and modelling approaches (RANS, LES, DES) was performed. For UFR's the experimental and computational results are mostly given only in graphical or tabular form, but in future, when new UFR's will be added, the actual data will also be stored in the Knowledge Base.

The UFR's are grouped into the following four flow types:

- Free Flows
- Flows Around Bodies
- Semi-confined Flows
- Confined Flows

Following a quality review based on the templates given in the *Quality* section of the Wiki, the Knowledge Base was partitioned for both AC's and UFR's into Gold and Silver Domains. The Gold Domain is the repository for content that has been carefully checked and therefore satisfies high quality standards. The Gold Domain is restricted to ERCOFTAC members (for information on ERCOFTAC see: www.ercoftac.org). However, the list of all AC's and UFR's, as given in the *Index* of the Wiki (reproduced below), and all the abstracts are in the public domain. The Silver Domain is the repository for less mature content which is still under discussion and open for improvement. Parts of the Silver Domain are marked as Silver Star. This indicates content which has matured to levels of quality and significance approaching Gold Standard and is made public to serve as examples of the quality found in the Gold Domain and in some cases will act to invite the addition of new CFD results obtained with alternative models. Both Silver Star and Silver test cases are fully in the public domain.

Content of the Knowledge Base

The content of each AC and UFR test case prepared according to the templates given in the *Library* section of the Wiki consists of an

- **Abstract -** Summary of content including a brief introduction to the flow considered.
- **Description -** Introduction to the test case and the physical phenomena involved – for AC's also practical importance and parameters of interest, and for UFR's review of previous studies and choice of test case.
- **Test case studies -** Description of the test case experiments with overview of experimental approach, a description of the experimental set-up and measurement techniques, an overview of the measured data and information on the measurement errors - description of CFD simulations, again with overview of the simulations and the solution strategy, computational domain, grid and numerical accuracy, boundary conditions, physical models, in particular turbulence models used. – For AC's provision of the actual experimental data and CFD results.
- **Evaluation -** Comparison of CFD calculations with test case experiments and discussion
- **Best Practice Advice -** Recapitulation of the key fluid physics, pointers to application uncertainties, provision of direct advice concerning computational domain, boundary

conditions, discretization and grid resolution and also which physical model to use for the case considered, and finally some recommendation for future work.

- **Quality review –** This is provided only for test cases in the Gold Domain.

A good impression of the content of the Knowledge Base can be obtained by looking at the publicly available examples of AC's and UFR's in the Wiki (http://qnet-ercoftac.cfms.org.uk). At the end of the paper lists of all Application Challenges and Underlying Flow Regimes presently available in the Knowledge Base are given, reproduced from the *Index* of the Wiki. The colour indicates the Gold and Silver Domains. At the conference, an online demonstration of 2 typical examples from these lists (one AC and one UFR) will be given.

Interaction with Users

Users are encouraged to make comments and suggestions on the individual AC's and UFR's, and exchange views and experiences with other users and with the Editorial Board through the *Forum* section. This also allows to comment on and suggest improvements for the Wiki itself and on its functioning and provides feedback questionnaires.

Users cannot directly edit or change the Knowledge Base documents, but they are encouraged to provide new content to the Knowledge Base, either by supplying modifications/extentions to existing content or by adding new contributions, that is AC's or UFR's for new test cases. How to do this is described in detail in the *Library* section which also provides the templates according to which the new content to be submitted has to be prepared. In the *Help* section further information is given on how to contribute material and the section also provides further useful information such as a glossary, links to other useful fluid mechanics sites and answers to questions that may arise.

Concluding Remarks

The ERCOFTAC Knowledge Base Wiki launched in September 2009 has been briefly introduced, giving guidance to its structure and content. Developed from the Knowledge Base generated in the EU-Network-Project QNET-CFD, the Wiki is a unique repository of structured and quality-checked knowledge on a wide range of flow situations, both for complex flows close to industrial practice (Application Challenges) and for more generic, building block flows (Underlying Flow Regimes). This knowledge made available to the Fluid Mechanics community by the Wiki can be used in various ways. First, comprehensive knowledge from both experiments and numerical simulations on a wide variety of flows is provided which forms a useful source of information on these flows. Further, guidance is given on how best to calculate the individual flows, including details on the various aspects of a calculation such as the numerical method, the resolution requirements, the boundary conditions and the turbulence model, and this guidance is based on the evidence of the results provided and discussed. Also, the test cases provide target data for users to test their own calculation methods and hence help to improve the quality of and trust in their CFD procedures. The Knowledge Base Wiki is not static but will be enhanced and expanded by adding new test cases, and this is facilitated by the framework developed for storing results, in particular the templates for a common format of presentation of the information and the data. The Wiki provides an ideal tool for storing results generated in EU-funded and other projects that would otherwise be lost and for making these results available to a wide community.

AC Index

Application Area	AC number	Application Challenges	Contributor	Organisation
External Aerodynamics				
	1-01	Aero-acoustic cavity	Fred Mendonca	Computational Dynamics Ltd
	1-02	RAE M2155 Wing	Pietro Catalano, Anthony Hutton	CIRA, Qinetiq
	1-05	Ahmed body	Jean-Paul Bonnet, Remi Manceau	Université de Poitiers
	1-08	L1T2 3 element airfoil ★	Jan Vos, Anthony Hutton	CFS Engineering SA, Qinetiq
Combustion				
	2-01	Bluff body burner for CH4-HE turbulent combustion	Elisabetta Belardini	Universita di Firenze
	2-06	The confined TECFLAM swirling natural gas burner	Stefan Hohmann	MTU Aero Engines
	2-07	Confined double annular jet	Charles Hirsch	Vrije Universiteit Brussel
Chemical & Process, Thermal Hydraulics & Nuclear Safety				
	3-01	Buoyancy-opposed wall jet	Jeremy Noyce	Magnox Electric
	3-02	Induced flow in a T-junction	Frederic Archambeau	EDF - R&D Division
	3-03	Cyclone separator	Chris Carey	Fluent Europe Ltd
	3-08	Spray evaporation in turbulent flow ★	Martin Sommerfeld	Martin-Luther-Universitat Halle-Wittenberg
	3-10	Combining/dividing flow in Y junction	Lewis Davenport	Rolls-Royce Marine Power, Engineering & Technology Division
	3-11	Downward flow in a heated annulus	Mike Rabbitt	British Energy
Civil Construction & HVAC				
	4-01	Wind environment around an airport terminal building ★	Steve Gilham, Athena Scaperdas	Atkins
	4-02	Flow and Sediment Transport in a Laboratory Model of a stretch of the Elbe River	Wolfgang Rodi	Universität Karlsruhe
	4-03	Air flows in an open plan air conditioned office ★	Isabelle Lavedrine, Darren Woolf	Arup
	4-04	Tunnel fire	Nicholas Waterson	Mott MacDonald Ltd
Environmental Flows				
	5-05	Boundary layer flow and dispersion over isolated hills and valleys ★	Ian Castro	University of Southampton
Turbo-machinary Internal Flows				
	6-02	Low-speed centrifugal compressor	Nouredine Hakimi	NUMECA International
	6-05	Annular compressor cascade with tip clearance	K. Papailiou	NTUA
	6-06	Gas Turbine nozzle cascade	Elisabetta Belardini	Universita di Firenze
	6-07	Draft tube	Jan Eriksson, Rolf Karlsson	Vattenfall Utveckling AB
	6-08	High speed centrifugal compressor	Beat Ribi, Michael Casey	MAN Turbomaschinen AG Schweiz , Sulzer Innotec AG
	6-10	Axial compressor cascade	Fred Mendonca	Computational Dynamics Ltd
	6-12	Steam turbine rotor cascade	Jaromir Prihoda	Czech Academy of Sciences

UFR Index

Flow Type	UFR number	Underlying Flow Regime	Contributor	Organisation
Free Flows				
	1-01	Underexpanded jet	Christopher Lea	Health and Safety Laboratory
	1-02	Blade tip and tip clearance vortex flow ★	Michael Casey	Sulzer Innotec AG
	1-05	Jet in a Cross Flow	Peter Storey	ABB Alstom Power UK
Flows around Bodies				
	2-01	Flow behind a blunt trailing edge	Charles Hirsch	Vrije Universiteit Brussel
	2-02	Flow past cylinder	Wolfgang Rodi	Universität Karlsruhe
	2-03	Flow around oscillating airfoil ★	Joanna Szmelter	Cranfield University
	2-04	Flow around (airfoils and) blades (subsonic) ★	K. Papailiou	NTUA
	2-05	Flow around airfoils (and blades) A-airfoil (Ma=0.15, Re/m=2x10^6)	Peter Voke	University of Surrey
	2-06	Flow around (airfoils and) blades (transonic)	Jaromir Prihoda	Czech Academy of Sciences
	2-07	3D flow around blades	Dirk Wilhelm	ALSTOM Power (Switzerland) Ltd
Semi-confined Flows				
	3-01	Boundary layer interacting with wakes under adverse pressure gradient - NLR 7301 high lift configuration	Jan Vos	CFS Engineering SA
	3-03	2D Boundary layers with pressure gradients (A)	Florian Menter	AEA Technology
	3-04	Laminar-turbulent boundary layer transition	Andrzej Boguslawski	Technical University of Czestochowa
	3-05	Shock/boundary-layer interaction (on airplanes)	Anthony Hutton	Qinetiq
	3-06	Natural and mixed convection boundary layers on vertical heated walls (A)	André Latrobe	CEA / DRN / Department de Thermohydraulique
	3-07	Natural and mixed convection boundary layers on vertical heated walls (B)	Mike Rabbitt	British Energy
	3-08	3D boundary layers under various pressure gradients, including severe adverse pressure gradient causing separation	Pietro Catalano	CIRA
	3-09	Impinging jet	Jean-Paul Bonnet, Remi Manceau	Université de Poitiers
	3-10	The plane wall jet ★	Jan Eriksson, Rolf Karlsson	Vattenfall Utveckling AB
	3-11	Pipe expansion (with heat transfer)	Jeremy Noyce	Magnox Electric
	3-12	Stagnation point flow	Beat Ribi	MAN Turbomaschinen AG Schweiz
	3-13	Flow over an isolated hill (without dispersion)	Frederic Archambeau	EDF - R&D Division
	3-14	Flow over surface-mounted cube/rectangular obstacles ★	Ian Castro	University of Southampton
	3-15	2D flow over backward facing step	Arnau Duran	CIMNE
	3-18	2D Boundary layers with pressure gradients (B)	Fred Mendonca	Computational Dynamics Ltd
	3-30	2D Periodic Hill Flow ★	Christoph Rapp, Michael Breuer, Michael Manhart, Nikolaus Peller	Technische Universität München, Helmut-Schmidt Universität Hamburg
Confined Flows				
	4-02	Confined coaxial swirling jets	Stefan Hohmann	MTU Aero Engines
	4-03	Pipe flow - rotating	Paolo Orlandi, Stefano Leonardi	Universita di Roma 'La Sapienza'
	4-04	Flow in a curved rectangular duct - non rotating	Lewis Davenport	Rolls-Royce Marine Power, Engineering & Technology Division
	4-05	Curved passage flow ★	Nouredine Hakimi	NUMECA International
	4-06	Swirling diffuser flow	Chris Carey	Fluent Europe Ltd
	4-08	Orifice/deflector flow ★	Martin Sommerfeld	Martin-Luther-Universitat Halle-Wittenberg
	4-09	Confined buoyant plume	Isabelle Lavedrine, Darren Woolf	Arup
	4-10	Natural convection in simple closed cavity	Nicholas Waterson	Mott MacDonald Ltd
	4-11	Simple room flow	Steve Gilham, Athena Scaperdas	Atkins
	4-13	Compression of vortex in cavity	Afif Ahmed, Emma Briec	RENAULT
	4-14	Flow in pipes with sudden contraction ★	Francesca Iudicello	ESDU