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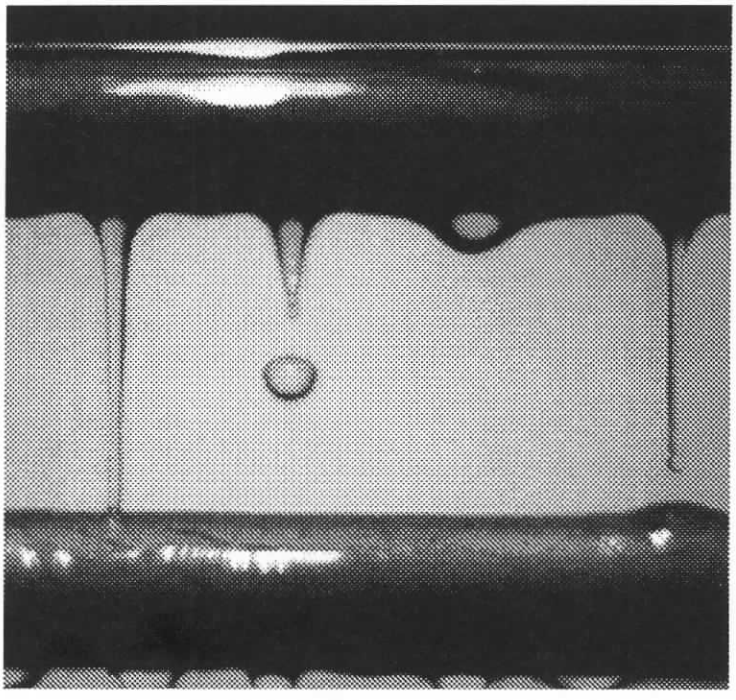

ERCOFTAC bulletin

57

JUNE 2003

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The cover image shows a liquid flowing on a vertical array of horizontal tubes (observed flow mode: Droplet-Column) as part of a study on falling film evaporators and condensers. Photo courtesy of Prof. John R. Thome, D. Gstöhl and J.-F. Roques, Laboratory of Heat and Mass Transfer, EPF-Lausanne, Switzerland.

Call for contributions

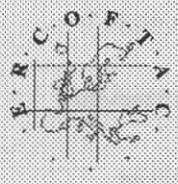
Deadline for submission of papers

July 20, 2003

Next issue scheduled for September , 2003

INTERNATIONAL SUMMERCOURSE ON VARIABLE DENSITY TURBULENT FLOWS

1-5 SEPTEMBER 2003
UPC, VILANOVA I LA GELTRÚ
BARCELONA, SPAIN



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ERCOFTAC SIG 24, 14 & 4
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PRESENTATION AND OBJECTIVES

The Campus Universitari de la Mediterrania at the Vilanova i la Geltru Campus (EPViG) UPC will host the ERCOFTAC summer-course on Variable density turbulent flows. The last scientific event organized by SIG 24 was a conference held in Banyuls in June 2000. The main motivation for the 2003 summer-course is to establish connection with related domains such as compressible turbulent flows and stably stratified and rotating turbulent flows where rather similar processes occur. About 25 hours of core lectures will be given during the week in addition to more specific research presentations.

MAIN TOPICS OF THE COURSE

3D Turbulence
2D Turbulence
Compressible Flows
Experimental Techniques
Baroclinic Instabilities
Rayleigh- Taylor Instabilities
Applications in the Environment
Industrial Applications

XARXA DFTG AND ERCOFTAC SIGS

Representing members of the XARXA TEMATICA DE DINAMICA DE FLUIDS I TURBULENCIA GEOFISICA groups as well as the representatives of the ERCOFTAC Special Interest Groups will be invited to present their main recent research topics in turbulence.

Lecturers of the course include R.A. Antonia (U. Newcastle - Australia), J. Borée (ENSMA Poitiers), C. Cambon (LMFA Lyon), P. Chassaing (IMF Toulouse), P. Fraunié (U. Toulon), L. Joly (ENSICA Toulouse), J.M. Redondo (UPC, Barcelona), S. Sarkar (U. California - USA), D. Souffland (CEA-DAM, Paris), C. Staquet (LEGI Grenoble).

REGISTRATION

The reduced fee of 120 Euro for ERCOFTAC members will cover accommodation and lunch during the week, the Lecture Materials as well as coffee breaks and the course reception. Grants for young research students will be also available

MEETING REPORTS

SCIENTIFIC REPORT ON EUROMECH 440

AERODYNAMICS AND THERMOCHEMISTRY OF HIGH SPEED FLOWS

MARSEILLE, SEPTEMBER 16-19, 2002

J.-P. DUSSAUGE, A. CHIKHAOUI

The objective of this colloquium was to cover the main scientific problems occurring in supersonic and hypersonic flights, in relation with situations found in aeronautics or during the reentry into an atmosphere. The selected papers dealt with the physics of phenomena or with the development of appropriate methods. Theoretical, numerical and experimental contributions have been considered.

For questions related to aerodynamics of high speed flows, presentations about the following topics have been made: compressible turbulence in shear flows, separated or not, including interactions with shock waves; stability and unsteadiness of shock waves, control of jets and of shock systems, stability of compressible flows; the progress of appropriate experimental and numerical methods has been also discussed. Hypersonic flow problems were mainly focused on the thermochemistry of reactive flows, including catalycity effects, radiative transfers and characterisation of radiation downstream of shocks of strong intensity. Diagnostic methods in hypersonic/hyperenthalpic facilities were also examined. Particular attention was paid to questions related to the reentry into Mars atmosphere, in connection with the question of thermal protection of space vehicles.

Some conclusions can be drawn from the works presented during the sessions.

It was confirmed that significant progress have been made by (and can still be expected from) diagnostics methods applied to high speed flows. Results of flow visualizations obtained by filtered Rayleigh scatted enhanced by CO_2 injection used with laser pulsed at a high rate (of the order of 1 MHz) and with an ultra fast camera (also up to 1 MHz) have given remarkable results on the structure of hypersonic boundary layers. Recent progress confirm also that PIV, in spite of the difficulties inherent to the seeding of supersonic flows by particles, can give reliable quantitative results. Finally, experiments in transitional hypersonic boundary layers have shown that, when properly used, traditional hot wire measurements can provide measurements at frequencies up to 500 kHz!

Numerical works on compressible turbulence mainly explored the possibility to compute supersonic flows in different situations with turbulent closures (1 or 2 point closures) essentially designed for solenoidal turbulence. They are essentially related to attempts to solve the difficulties inherent to supersonic flows, due partly to the presence of shock waves, before moving to more physical closures.

Some presentations were dedicated to flow control. The case of supersonic jets and of shock wave intersections was explored. The control of jets was made by small transverse jets; it appears that the effect of the transverse jets is to increase the surface of the main jet and therefore to increase mixing. The control of shock wave intersection (Edney IV) was made by hot spots or by cold plasma; the main effect seems to be in the increase of temperature and the correlative decrease of Mach number, rather than in the change in molecular mass or electrostatic forces.

Stability studies were well represented, in particular by many contributions from numerical simulations. However, analytical and experimental work was still important and well represented for 3-d boundary layer, jets and shock waves. The field is still in development.

Studies on shock/turbulence and shock/boundary layer interactions have shown improvement in the definition of experimental conditions, coming essentially from a better definition of the boundary conditions imposed to the shock.

For reactive flows, a model describing the vibrational and electronic kinetics has been proposed to evaluate the infrared and the ultra-violet radiation, in the case of CO. Moreover a rebuilding method for hyperenthalpic nozzle flows has been presented for CO_2. This method gives a characterisation of such flows, together with indications about the relevant models. Finally, the subsequent result is a gain in accuracy for the prediction of thermal fluxes over the probe during Mars Sample Return mission.

Contribution to the experimental simulation of hyperenthalpic flows was also given. Among them, an arc plasma facility was presented, with which it is possible to match reentry conditions in the Martian atmosphere. Moreover, results were obtained about diagnostics methods applied to the mixture CO_2–N_2, in hyperenthalpic conditions.

This conference has been successful in getting together European experts working on high-speed flow physics. Discussions were numerous and of good quality, so that the conference was a rather vivid one. In particular, the danger of a dispersed interest between purely aerodynamics topics and real gas effects purely connected to chemistry has been mostly avoided. Some prospects can be drawn from the presentations. Progress in particular in experimental methods and in compressible modelling can be expected, and should lead to a better understanding of the effect of compressibility on large scale eddies. Similarly, for reactive flows, some promising prospects can be defined. At this stage, it seems likely that the experts are ready to propose schemes and models to describe the reactive processes and the kinetics in cases of interest for the space missions under examination and definition. Such models should be designed to be incorporated into CFD codes. Another axis to be developed is the study of radiative fluxes, which are of primary importance for reentry phases. They depend critically on kinetics (for Mars atmosphere, of CO_2-N_2 with radical CN, CO and C_2). The expected results should lead to a better optimisation of the heat shields, but for more fundamental issues, this could lead to a control of the rate of ionisation during phases of reentry.

Finally, the meeting has shown that at a European scale, there are a sufficient number of experts for the animation of the scientific live in the field. The skills of this European group has shown that, with the work which is started in the different places, other meetings on similar topics held in a few years will be useful, and will contribute to impulse research on high speed flows.

EUROPEAN RESEARCH COMMUNITY ON FLOW TURBULENCE AND COMBUSTION
THEMATIC NETWORK FOR TRUST AND QUALITY IN THE INDUSTRIAL APPLICATIONS OF CFD

ERCOFTAC / QNET-CFD SEMINAR AND WORKSHOP ON TURBOMACHINERY FLOW PREDICTIONS X

22ND - 25TH SEPTEMBER 2003

Following the successful first nine Workshops held in previous years this tenth Seminar & Workshop is organised by the ERCOFTAC Special Interest Groups in Turbomachinery and Transition, and the QNET-CFD Thematic Area 6, 'Turbomachinery Internal Flows'.

PLACE: CNRS Conference Centre 'La Villa Clythia', at Fréjus, Var, 65 km from Nice, France.

PURPOSE: A forum for comparing the facilities and methods of various computational techniques for turbomachinery flows, including transition and quality assurance issues.

FORMAT: Presentation of test cases with specialist lectures on aspects of turbomachinery CFD. At the Workshop sessions, the Sponsor will present the test case with some computed results, after which presentations of other results will be made, followed by discussion.

TEST CASES: *Test cases are from ERCOFTAC Transition and Turbomachinery SIG's and QNET TA6*

T3L Transition Cases – Sponsor: John Coupland, Rolls-Royce, john.coupland@rolls-royce.com

T106 Turbine Blade Transition – Sponsor: Howard Hodson, University of Cambridge, hph@eng.cam.ac.uk

TA6-02 (R2) NASA Low Speed Centrifugal Compressor – Sponsor: Eric Lorrain, NUMECA, eric.lorrain@numeca.be

TA6-03/05 NTUA Compressor Cascade (tip clearance) – Sponsor: Evangelos Politis, NTUA, vpolitis@ltt.ntua.gr

TA6-04 Hydraulic Pump-Turbine – Sponsors: Florian Menter, AEA Technology and Jean-Louis Kueny, EPFL, Florian.Menter@cfx-germany.com & Jean-Louis.Kueny@epfl.ch

TA6-06 (H1) VKI Turbine Nozzle – Sponsor: Elisabetta Belardini, University of Florence, belardini@ingfi1.ing.unifi.it

TA6-10 Axial Compressor Cascade – Sponsor: Michael Dickens / Bill Clark, STAR-CD, mhd@cd.co.uk

ORIGINATORS AND USERS OF CFD CODES ARE INVITED TO COMPUTE ONE OR MORE OF THE TEST CASES. PLEASE CONTACT THE RELEVANT SPONSOR FOR DETAILS. CONTRIBUTIONS TO BE SUBMITTED BY 1ST SEPTEMBER 2003.

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EUROMECH 9TH EUROPEAN TURBULENCE CONFERENCE

JULY 2ND-5TH, 2002

UNIVERSITY OF SOUTHAMPTON

IAN P CASTRO

SCHOOL OF ENGINEERING SCIENCES, UNIVERSITY OF SOUTHAMPTON

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EUROMECH's European Turbulence Conference (ETC9) held in Southampton was the 9th in the series begun in Lyon in 1986. At that meeting, which had significantly less than half the number of participants than were present in Southampton, the late Professor George Batchelor predicted in his opening remarks that turbulence specialists could look forward to many happy years of enquiry without the fear that announcement of some new development would render their efforts unnecessary. Despite (or perhaps because of!) the continually increasing numbers of papers on turbulence, appearing in an every-growing variety of academic journals, it seems that not only has his prediction been amply fulfilled but that a similar prediction could be made even now - 16 years later. Fundamental understanding, although clearly greater than it was and reasonably well summarised by the proceedings of the intervening conferences, has largely only proceeded incrementally, without any really startling breakthroughs.

Nonetheless, as at previous meetings in the series, ETC9 was characterised by a wide range of high quality and interesting contributions, covering a range of basic issues in various contexts. The objectives remained the same as ever: to bring together mathematicians, engineers and physicists working on fundamental aspects of turbulent flows. Note that the aim was not to discuss turbulence modelling - other conferences do that very well and with well over 100 Reynolds-averaged turbulence models now in existence such conferences clearly have an important role. Rather, the emphasis was on fundamentals, with a view to broadening basic understanding of turbulent flows, including those of specific industrial or environmental importance. The papers presented, whether oral (172 plus 8 plenaries) or poster (62), reflected this emphasis and were grouped under various themes. Some of the themes were reviewed by the eight invited speakers, who provided an excellent background against which the various sessions could be viewed. As usual, the papers were chosen by the EUROMECH Turbulence Conference Committee, currently chaired by Prof Leonhard Kleiser, at its meeting in January 2002. They were selected from a total of 322 abstracts, which was rather fewer than submitted for the previous conference. Sadly, this was probably a reflection more of the infamous 11.09.01 events (abstracts were due a month later) and the lack of guaranteed sun (cf. Barcelona in July), rather than any reduction in European turbulence activity, but at least it meant perhaps that in Southampton there was a solid collection of genuinely committed turbulence researchers!

There were about 275 registered delegates representing nearly 30 countries although, as often happens, a number of the Eastern Europeans were, mostly at the last moment, unable to attend, despite having received some financial assistance. To fit all accepted papers (orals of 15 minutes) into the 38 sessions over three-and-a-half days it was necessary to use parallel sessions but although these were mostly 'three-parallel', more than in any of the previous conferences in the series, this did not seem to detract from delegates' enjoyment of the meeting.

For such a large conference it is clearly impossible to comment on individual contributions. It could also be invidious, perhaps implying that all the others were less noteworthy! But to give a flavour of the scientific programme the session titles, (numbers of oral contributions) and names of the invited speakers are summarised below. Some additional remarks, made by Prof Frans Nieuwstadt in his final summary statement at the Conference itself, are included (in italics) for each topic.

- Instabilities & Transition (8). J.-M. Chomaz (CNRS, open flows) and B. Eckhardt (Marburg, internal flows) gave invited talks.

  Considerable theoretical progress has been made since Lyon.

- Intermittency & Scaling (17). L. Biferale (Rome) gave an invited talk.

  This topic arose out of the original 'Chaos' topic at Lyon. It helps to keep the physicists and engineers talking.

- Structures & Vortex Dynamics (31).

  Since Lyon, structures in turbulence have become fully accepted as being dynamically significant, but quantifiable description remains a problem. Wavelet techniques (featuring in a number of paper) may be the way forward.

- Transport & Mixing (17).

  Considerable progress since Lyon, with now a reasonably good understanding of mixing processes in turbulence.

- Geophysical Turbulence (17). E. Lindborg (KTH, Stockholm) gave an invited talk.

- Two-Phase Flows (11).

  First introduced at the Lausanne conference (1996) and clearly of continuing interest and importance.

- Turbulence Control (8). T. Bewley (UCSD) and J. Kim (USLA) gave invited talks.

  Important results now being produced but the real step towards practical application has still to be taken.

- DNS/LES (25).
  (See below).

- Compressible Turbulence (4).
  A loss of interest in this topic since its first introduction.

- Separated Flows (5).

- Boundary Layers and Pipe Flows (4).

- Jets (3).

- Reacting Flows (4). N. Peters (Aachen) gave an invited talk.
  Technologically important and in which advanced measuring techniques and numerical simulations will lead to much progress.

- Acoustics & Turbulence (7). A. Dowling (Cambridge, UK) gave an invited talk.

- Miscellaneous (11).

Just one talk will be mentioned individually. Inclusion of a topic on Acoustics & Turbulence was a new feature in the ETC series. In her invited presentation Prof Ann Dowling confirmed the Turbulence Committee's view that with the increasing interest in aero-acoustics, of the kind in which turbulence plays a crucial role, it was important that the (so far) largely separate acoustics and turbulence communities should interact more positively. Despite the relatively low number of contributions in this area, it is hoped that the topic will remain a feature of future ETCs. It was also evident that practically all the DNS contributions in the DNS/LES sessions could have been positioned in one or another of the alternatively-titled sessions. DNS has now largely become 'simply' a tool, to be used (like laboratory experiments) for probing the nature of turbulent flows. It might be anticipated, for example, that work in the Turbulence Control area will increase further and a number of the DNS talks could certainly have been included in those sessions. In his closing summary Frans Nieuwstadt suggested that DNS/LES has in fact 'been the success story of the last 16 years'. He pointed out that the ratio of the number of papers on laboratory experiments to those on numerical simulation has changed completely, with the latter now forming a clear majority. However, whilst numerical simulation has led to a much better insight into the structure and dynamics of (low Reynolds number) turbulence, Prof Nieuwstadt also suggested that a point of saturation is perhaps being reached - i.e. the ratio 'increase of insight to increase in available computer power' is tending to zero rather than a usefully non-zero constant. This emphasises the importance of the current trend to establish genuinely high Reynolds number laboratory facilities - a good, new example being the proposed Nordic Wind Tunnel, which Prof Bill George discussed in a poster at the meeting.

Unlike all other EUROMECH-sponsored meetings, the ETCs produce a published version of all the collected papers in time for the meeting itself. ETC9 was no exception - CIMNE published the 908-page book 'Advances in Turbulence IX', edited by three of the organisers. This contains all presented papers (eight pages for invited talks, four pages for orals and one page for posters). There are copies available for purchase at the special conference price, direct from the author (£25 plus p. & p.) to whom enquiries should be directed.

Although two years seems a rather short time to expect major developments in turbulence understanding, the increasing popularity of these conferences suggests that much is still to be gained by the personal interactions and discussions generated at the ETCs, as well as by the paper preparation and presentation processes themselves. ETC9 seemed no exception and its success augurs well for the next meeting, which will be held at the Norwegian University of Science & Technology in Trondheim in early July 2004.

PIVNET 2 T6/ERCOFTAC SIG 32
5TH WORKSHOP ON PIV
LISBON JULY 5-6 2002

The Fifth Workshop of Pivnet 2 task 6/ERCOFTAC Sig 32 took place in Instituto Superior Technico in Lisbon on Friday the 5th and Saturday the 7th of July 2002. This Workshop was linked to the 11th International Symposium on Laser Techniques Applied to Fluid Mechanics which took place from the 8th to the 11th of July in Lisbon.

The aim of this series of Workshop is to enhance cooperative activity and exchange of information between the participating teams around the validation and the improvement of PIV.

For that purpose, a list of topics of interest has been identified by the organizing Committee.

The preceding workshop was joint to the first International PIV challenge, which took place in DLR Göttingen on September 14th and 15th 2001.

The present workshop has gathered 19 contributions and 46 participants. Attention was focused on Advanced PIV, Applications, two phase flows and turbulence, seeding, hardware and software.

It comes out from this workshop and from the following Symposium that PIV is now a mature technique with well founded basis and theory. The workshop did show that some significant improvements can be gained on the hardware side, with the introduction, for example, of CMOS cameras which allow to perform time resolved PIV. The extension of the PIV methodology to other fields like BOS or surface motion is also of interest. The application to two phase flows looks quite promising, although some technical difficulties have to be overcome.

During the workshop, the organization of the second PIV challenge, which will take place in Corea in September 2003, was also discussed, in preparation to the discussion with the representatives of the Visualization Society of Japan.

It was proposed to have less test cases than in the first challenge, to try to focus the test cases on the assessment of turbulence by PIV and to simplify the challenge data format.

The CD-ROM containing the full minutes of the workshop is available to ERCOFTAC members by Pr Stanislas at pivnet-sig32@univ-lille1.fr

AGENDA OF THE WORKSHOP

Friday the 5th

9h00 Welcome and presentation of T5/SIG 32, *M. Stanislas*

9h15 Presentation of PIVNET 2, K. Schroeder

9h30 Invited lecture : Advanced PIV algorithms, A. Lecuona

10h00 T5/SIG 32 Workshop and PIV Challenge 2003 organization, M. Stanislas

10h30 Coffee break

11h10 **Session 1:Advanced PIV, chairman: M. Riethmuller**

- Image quality, aberrations and noise in particle holography – approaches in 3D displacement measurements obtained from real images, *K.D. Hinsch, S. Herrmann*
- Measuring 3-D velocity fields with ESPI recordings, *J. Lobera, N. Andrés, P. Arroyo*
- Application of 3D-PTV to track particles moving inside heterogeneous porous media and lakes, *A. Cenedese, J.H. Cushman, M. Moroni*
- High speed cameras for PIV, *T. Nicholls*

12h30 Lunch

14h30 **Session 2 : Applications , chairman: C. Kaehler**

- Experimental study of incompressible flows in grooved channels, *F. Billy, G. Pineau, M. Arghir, L. David*
- Formation of streamwise vortices in a flat plate wake, *T. Pärssinen*
- How to obtain local density information by the Background Oriented Schlieren (BOS) method, *F. Klinge*
- PIV in large wind tunnels, *S. Kallweit*

15h50 Coffee break

16h30 **Session 3 : Two phase flows & Turbulence chairman: M. Stanislas**

- Calibration of PIV to measure void fractions in bubbly flows., *M. Honkanen, P. Saarenrine*
- Understanding of Dynamics of a two-phase flashing jet using PIV, *D. Yildiz, J.P.A.J. van Beeck, J.M. Buchlin, M.L. Riethmuller*
- Simultaneous PIV and Shadowgraphy measurements in Slug flow, *S. Nogueira, R. Sousa, M.L. Riethmuller*
- Application of the window deformation technique to synthetic PIV images from DNS, *B. Lecordier, M. Trinité*

17h 50 End of day 1

Saturday the 6th

9h30 Invited lecture : General design and operating rules for seeding generators, *C. Kaehler*

10h00 **Session 4 : Hardware & software, *chairman: A. Lecuona***

- On the accuracy of PIV signals, *C. Westergaard*
- Determination of high-order statistical moments of tur bulence fluctuations using new algorithms for filtration of PIV data, *B. Ilyushin, D. Markovich*
- Progress in hybrid PIV-PTV methods, *A. Stitou, M.L. Riethmuller*
- Shape and 3D-Deformation of Free Surfaces, *B. Wieneke*
- Possibilities in time resolved PIV, *C. Westergaard*

11h40 Coffee break

12h10 Discussion : PIV challenge 2003, *manager: M. Riethmuller*

13h10 End of meeting

J.M Burgers Centre & Ercoftac
Summerschool
on

Mathematical Techniques and Tools for Data Analysis and Modelling of Intermittent Structures

23-27 June, 2003,
Lorenz Centre, Leiden
the Netherlands

PROGRAM

Monday 23 June	J. Delville. Proper Orthogonal Decomposition S. Balachandar. Linear Stochastic estimation
Tuesday 24 June	J. Lewalle. Continuous Wavelets and Data Analysis J.C.R. Hunt. Flow topology
Wednesday 25 June	M Farge. Wavelet Methods for Coherent Vortex Extraction T. Bohr: Localized structures in laminar and turbulent flows
Thursday 26 June	W. van de Water. Intermittency and Similarity in Turbulence C. Vassilicos. The Fractal Structure of Turbulent Diffusion
Friday 27 June	Contribution by participants

The summerschool is given in the Lorenz center of the University of Leiden which offers excellent accommodation (**http://www.lc.leidenuniv.nl/**). There is no fee to participate in the summerschool but the costs for travel and accommodation has to be borne by the participants

During the course hands-on training with various analysis techniques is provided and participants are invited to bring their own data sets.

Participation is by invitation (the amount of participants is limited to about 30)
Request for participation should be sent **before April 1** to prof. F.T.M. Nieuwstadt.

f.nieuwstadt@wbmt.tudelft.nl

J.C.R. Hunt
J. Lewalle
F.T.M. Nieuwstadt

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

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

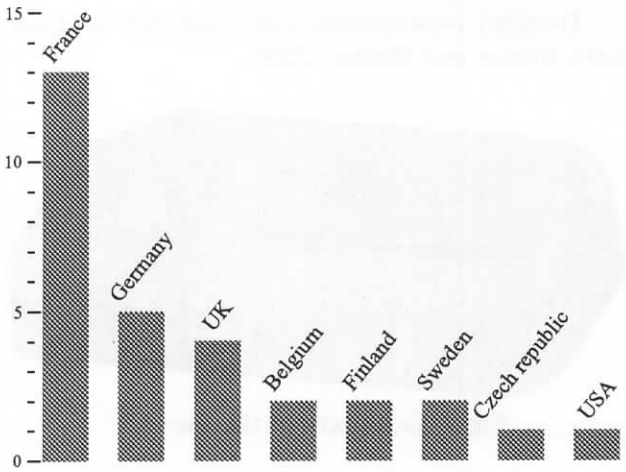

Fig. 1: Repartition of the participants

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.

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.

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 (Jakirlić, Jester-Zürker, Tropea, 2001): the complexity of the underlying mechanisms and the challenge they represent for turbulence models have led to the renewal of these test cases.

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.

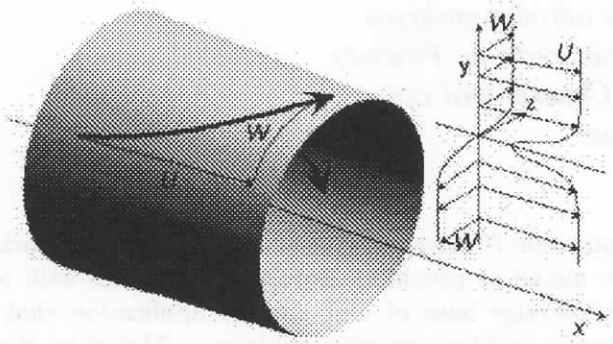

Fig 2: Sketch of the wake/mixing layer interaction test case

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 (Béharelle, Delville, Bonnet, 1997) 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.

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 (Temmerman, Leschziner, 2001).

Fig 3: Geometry of the case 9.2

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.

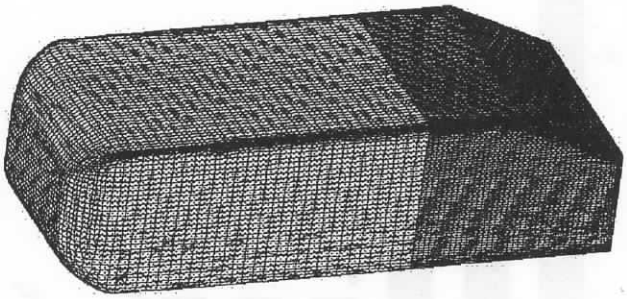

Fig 3: Geometry of the case 9.2

PROGRAMME

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.

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.

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.

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 hardly 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.

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:

Manceau, R., Bonnet, J.-P., 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

ACKNOWLEDGEMENT

Beside ERCOFTAC and IAHR, the workshop was supported by the CNRS, the university of Poitiers, CD-Adapco and CFX.

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Temmerman, L., and, Leschziner, M., A., Large Eddy Simulation of separated flow in a streamwise periodic channel construction, *Int. Symp. on Turbulence and Shear Flow Phenomena, Stockholm, June 27-29, 2001.*

Lienhart, H., Stoots, C., Becker, S. Flow and Turbulence Structures in the Wake of a Simplified Car Model (Ahmed Model), *DGLR Fach Symp. der AG STAB, Stuttgart University, 15-17 Nov., 2000.*

SIG 28 Combustion Activities Revived

Prof. Ali Turan

As expressed by its name, ERCOFTAC is a community dedicated towards research in the fields of **F**low, **T**urbulence **a**nd **C**ombustion. While there are widespread activities focusing on CFD and turbulence modelling for aerodynamic applications, combustion has been largely neglected in the framework of ERCOFTAC. This becomes obvious when looking at the list of the currently 24 special interest groups (SIGs) only one of which (SIG 28) is dealing with combustion. Unfortunately, SIG 28 «Combustion» has been mostly inactive during recent years.

On April 11th 2003 a meeting was held at UMIST (Manchester) to revive the activities within SIG 28. The participants, that constituted the SIG panel members, were: Prof. A. Turan (Manchester), Prof. M. Pfitzner (Munich), Prof. E. Hassel (Rostock), B. Merci (Gent), Prof. J. Warnatz (Heidelberg), Prof. D. Thevenin (Magdeburg), J.-C. Larroya-Huguet (SNECMA), B. Wegner (for Prof. Janicka, Darmstadt), Prof. A. Tomboulides (Thessaloniki), R. Prosser (Manchester), Y. Zhang (Manchester), D. Laurence (Manchester/Paris).

Initially, Prof. N. Peters (Aachen) and Prof. A. Turan (UMIST) were designated as the co-ordinators for the combustion activity. Then the focus and orientation of future activities were discussed. During the course of this discussion, it was decided to change the SIG name from «Combustion» to «Reactive Flows» stressing the generic nature of many combustion-related problems. Three main themes were identified by the panel to be currently of predominant interest for combustion researchers in general and for this SIG in particular:

- combustion instabilities,
- multiphase flow in combustion and
- the use of large eddy simulation for combustion modelling.

Related questions are how to enable quality and trust in CFD for combustion (inspired by the well-accepted activities of QNET-CFD which originates from a former ERCOFTAC-SIG) and the special requirements imposed on validation experiments by LES. Furthermore it was agreed to build a database of validation test cases for combustion.

The next meeting of SIG 28 is proposed to be held as a side meeting of the ECM 2003 in Orleans, France (October 25th to 28th). Forthcoming events are a joint workshop with the Darmstadt based collaborative research centre «Flow and Combustion in Future Gas Turbine Combustion Chambers» (http://www.sfb568.de) which is planned for February 2004 as well as a Summer School in Summer or in the Fall 2004.

People interested in the activities of SIG 28 can find more information at www.ercoftac.org.

The Summer School on Recent Developments in Design and Computations of Gas Turbines September 25-27, 2003 Olsztyn, Poland

The School will be devoted to experimental and numerical methods applied to design of gas turbines. The content of the programme will include topics on aerodynamics of blading of compressors and turbines with special reference to steady and unsteady computations of blading and combustion modelling. The present School is the extension to industrial area of two previous Schools organised in Poland in 1999 and 2001. The goal of the Summer School is to transfer knowledge from leading European centres to Polish scientists working in the field of CFD applications to gas turbines. The audience foreseen is mainly the young scientists and PhD students from Polish universities and research centres but participants from all over Europe are encouraged to attend.

THE ORGANISING INSTITUTIONS ARE THE FOLLOWING:

- Fluid Mechanics Section of the Polish Academy of Sciences,
- Polish Pilot Centre of ERCOFTAC,
- University of Warmia and Mazury in Olsztyn.

The School was approved as the official ERCOFTAC event. The school will be held in Olsztyn - a capital of Warmia, a region of lakes in the North-East part of Poland in the period 25-27 September 2003. All the organisational matters will be handled by the University of Warmia and Mazury.

THE MEMBERS OF THE SCIENTIFIC COMMITTEE OF THE SCHOOL:

- Prof. Albin Bölcs (EPFL Lausanne)
- Prof. Tadeusz Chmielniak (Silesian Technical University) – Chairman
- Prof. William Dawes (Cambridge University)
- Prof. Piotr Doerffer (Institute of Fluid-Flow Machinery, Gdansk)
- Prof. Stanislaw Drobniak (Technical University of Czestochowa)
- Prof. Jaroslaw Mikielewicz (Institute of Fluid-Flow Machinery, Gdansk)
- Prof. Norbert Peters (RWTH Aachen)
- Prof. Marian Trela (Institute of Fluid-Flow Machinery, Gdansk)

LOCAL ORGANISING COMMITTEE (UNIVERSITY OF WARMIA AND MAZURY):

- Prof. Eustachy Burka (Honorary Chairman)
- Dr. Tomasz Nalecz (Chairman)
- Prof. Ryszard Michalski (Faculty Dean)

DURING THE FIRST DAY OF THE SCHOOL (SEPT. 25TH) THE FOLLOWING LECTURES WILL BE GIVEN (IN POLISH):

- Prof. Chmielniak - «Gas Turbine in Modern Energy Systems»
- Prof. Mikielewicz - «Methods of Convective Heat Transfer»
- Prof. Trela - «Convective Heat Transfer»
- Prof. Drobniak, Prof. Doerffer - «Results of Research Within Selected Gas Turbine Projects»

ON SEPT. 26TH AND SEPT. 27TH THE INVITED SPEAKERS WILL GIVE LECTURES ON THE FOLLOWING TOPICS:

Prof. Peters – «Turbulent Combustion Modelling»

- o Turbulent Combustion – the State of the Art
- o Premixed Turbulent Combustion – Regimes and Previous Models, The Level-Set Approach
- o Non-premixed Turbulent Combustion – the Flamelet Concept, Simulation Results for Diesel Engines and Gas Turbine Combustion Chambers
- o Partially Premixed Turbulent Combustion

Prof. Boelcs – «Fundamentals of Transonic Flow in Axial Compressors»

- o Flow in a compressor cascade at high subsonic Mach number
- o Compressor cascades with supersonic inlet velocities
- o Supersonic inlet flow with attached and detached shock wave
- o Three-dimensional flow effects, Stator-rotor interaction.

Prof. Dawes – «Steady and Unsteady Computations of Fluid-Flow Machinery Blading»

- o Overview of turbomachinery CFD (the blade-blade/throughflow model; the 1D/2D/3D modelling hierarchy; modern developments, especially in whole engine optimisation)
- o Blade-blade simulations (steady fully 3D blade-blade; unsteady & multirow/multistage blade interactions; design optimisation; current trends, especially noise prediction, and future opportunities)
- o Complex geometries (the importance to performance of shrouds, leakage gaps, overlaps, internal cooling etc...; hierarchies of modelling approaches, including geometry management - current status and future prospects)

Dr. R. Howell (Alstom Power)

- o HP and LP gas turbine aerodynamics
- o Rolls-Royce ultra high lift turbine blades
- o HP turbines, aerodynamics, cooling and life considerations
- o Design implications and differences between industrial and aeroengine turbines
- o Measurement techniques employed in industry and the laboratory

The registration fee which covers accommodation costs and lecture materials is **250 EURO**. Additional information about the School may be found at the website:

http://rie5.ise.polsl.gliwice.pl/konfer/szkolaletnia/szkola%20letnia1%20ang.html

REGISTRATIONS SHOULD BE DIRECTED TO:

University of Warmia & Mazury
ul. Oczapowskiego 11
10-957 Olsztyn, Poland
tel./fax: +48 (89) 523 32 55
email: FALKA@UWM.EDU.PL

The School was granted the **3000 EURO** scholarship from ERCOFTAC authorities. The organisers intend to give a certain number of scholarships to PhD students who would like to participate in the Summer School. Requests for the grants should be directed to Dr. D. Asendrych (DAREK@IMC.PCZ.CZEST.PL), secretary of Polish Pilot Centre until **June 1st 2003.**

REPORT ON THE EXECUTIVE COMMITTEE MEETING

KRAKOW, MAY 10, 2003

D. ROBINSON
ERCOFTAC COORDINATION CENTER

EXECUTIVE COMMITTEE ACTIONS

The minutes of previous meetings were reviewed as well as a list of action items generated after the ERCOFTAC meetings in Aachen held on October 2002. Professor Oliemans mentioned that a 2nd accounts auditor (in addition to Dr C. Cambon) must be identified. Dr. Gustav Amberg of the Nordic Pilot Centre volunteered to take the position. Professor Oliemans mentioned that 4 positions were still available in the Managing Board. He asked that names of nominees be sent to the Coordination Center so that they could be considered at the Managing Board meeting in London, October 2003. The issue of a VAT number for ERCOFTAC was considered. Professor Hirsch said that maintenance of a VAT number would likely require professional accounting and other non-negligible administrative work. Professor Redondo requested that Professor Hirsch write an official letter stating that ERCOFTAC does not have a VAT number, and as a non-profit association, it is not required to have one according to Belgium law. This letter is to be present to Professor Redondo's university (UPC Barcelona) so that UPC Barcelona will not delay reimbursement of workshop/summer school scholarship expenses due to lack of a VAT number for accounting purposes. Professor Hirsch agreed to write this letter.

FINANCIAL REPORT

Professor Hirsch presented the financial report of ERCOFTAC to the Executive Committee. For calendar year 2002 the income due to memberships, interest on the account holdings, and SIG payments was balanced by the expenditures due to scholarships, bank charges, and operation of the Administration and Development Office and the Coordination Center. The value equaling the expenditures and income for 2002 was € 109,351.15. The global reserve of ERCOFTAC as of the end of 2002 is roughly € 342,000. Expenditures through the first 4 months of 2003 total € 2,908 and income within the same time period total € 21,670.

REPORT FROM ADMINISTRATION AND DEVELOPMENT OFFICE

The financial report and report of the administration and development office was presented by Professor Hirsch. The expenses of the Administration and Development Office for 2002 were € 24.946,49, which was over the budget of € 20,000. This was largely due to higher than usual travel expenses incurred because of extra meetings concerning the «Networks of Excellence» in the 6th European Framework. Professor Hutton presented the summary of the Quality and Trust SIG accounts. The membership status of ERCOFTAC was discussed. Meeting attendees volunteered to contact certain ERCOFTAC members who are late in membership payments.

REPORT FROM COORDINATION CENTER

Dr. Robinson reported on the activities of the Coordination Centre. Concerning the ERCOFTAC web site, recent improvements to the web site now include the ability to download logistical information for upcoming ERCOFTAC administrative meetings as well as the questionnaire for the Industrial Consultation Initiative. The Table of Contents of the Best Practice Guidelines is now available on the web site. Requests have been sent out to update the SIG web sites, as some have not been updated for some time. Other web site improvements were discussed, including the design for a standard web page template for Special Interest Group and Pilot Centre pages. It was mentioned that perhaps a page be dedicated to FTAC–related job postings. Furthermore, the idea of presenting previous issues of the bulletin in PDF form on the web site was suggested. Professor Hutton expressed concern that making issues of the bulletin available on the web would be giving away free one of the benefits of ERCOFTAC membership. It was agreed that a time lag of 1 or 2 years would be suitable.

The expenditures of the Coordination Center were balanced by the income for 2002 to within 710 CHF (approximately 475 Euro). Therefore, Dr. Robinson requests that the current subsidy to the coordination center remain the same as the annual contribution for each of the last 3 years (37,500 Euros). Dr. Robinson mentioned that he will leave the post of ERCOFTAC secretary at the end of June 2003. Dr. Thierry Ursenbacher, another research engineer within the laboratory of Heat & Mass Transfer at EPF-Lausanne, will replace him, or in the event that he is not available, lab director Professor J. Thome will be responsible for finding a suitable candidate.

EU RELATED ACTIVITIES (EUROPEAN COMMISSION, 6TH FRAMEWORK PROGRAMME, «NETWORKS OF EXCELLENCE»)

Professor Hirsch had discussed EU activities concerning Networks of Excellence (NoE) at the SPC/IAC meeting of the previous day. A working party consisting of Professors Oliemans, Hutton Laurence and Hirsch had submitted an Expression of Interest in summer 2003 (see bulletin 55, December 2002) and made a presentation before the European Commission in October. Even though the commission thought that the proposed topic of study would be worthy of funding, they expressed some concern about whether or not the proposed network of excellence would remain active after the end of the framework. The delegation was advised to apply for the second round, end of 2003, as the monies for the first round were already mostly allocated. Professor Hirsch suggested that ERCOFTAC continue to try to convince the Commission to support an ERCOFTAC network of excellence. He was in regular contact and felt that the Commission's attitude toward EERCOFTAC was

evolving positively after the somewhat discouraging first meeting. A discussion ensued about how to properly present a case for support of a network of excellence without forcing activities of members, necessarily excluding them, or compromising ERCOFTAC areas of interest. The issue is that the bid for a network of excellence must be made in a specific sector (e.g. Aerospace). Professor Laurence pointed out that it would be awkward to have half the SIGs left out of a network of excellence (e.g. environmental). There is a new deadline for proposals in March 2004. The participants proposed that Professor Hirsch and others members of the network of excellence working party continue to explore options to enhance the attractiveness of a proposal from ERCOFTAC.

Professor Hirsch mentioned that there are many other EU opportunities that ERCOFTAC could consider. A surveillance group consisting of Professors Redondo, Hirsch, and Drobniak (while Dr. Filippone was suggested for the UK) will monitor these opportunities.

REPORT FROM SCIENTIFIC PROGRAM COMMITTEE

During the SPC/IAC meeting of the day before, future potential meetings were discussed. One workshop and 1 summer school (both during 2004) were proposed by the newly invigorated SIG 25 (Combustion) and considered by the SPC. They were both accepted for the ERCOFTAC label and scholarship funding.

ERCOFTAC publications had been also discussed. The issues of software difficulties with bulletin contributions and lateness of contributions were mentioned. It was decided in the SPC/IAC meeting of the day before that the Editorial Board would be contacted to provide suggestions for resolving these problems with the bulletin. It was mentioned that the deadline of the bulletin has been moved to 10 days earlier (e.g. April 20 for the June bulletin) to improve timeliness of contribution submission. The next theme issue (September) will be on aeroacoustics, and will be organized by Dr. Bendiks Jan Boersma of Delft University of Technology. Potential subjects for future themes were discussed. It was decided that 'Geophysical and Environmental Turbulence Modeling,' to be organized by Professor J. Redondo of UPC-Barcelona would be the theme for March 2004. 'New Developments in Numerical Methods for CFD,' was suggested by Professors Hirsch and Laurence for September 2004.

The activities of SIGs were reviewed. A meeting in summer 2003 will be organized with SIG 1. Certain attendees of the SPC/IAC meeting volunteered to contact potential candidates to reactivate SIG 2. Dr. Pierre Compte, the new coordinator of SIG4 mentioned that he would like to organize a workshop in 2004. Aeroacoustics was mentioned again as a topic for a SIG. It was suggested to contact the future contributors for the aeroacoustic theme issue to ask if any of them are interested in organizing a new aeroacoustics SIG. Professor Rodi said that he had a candidate in mind concerning reinvigorating activity in SIG 5. Professor Hirsch reported that SIG 8 is active. SIG 10 had an organizational meeting recently planned but was canceled. Professor Laurence mentioned that SIG 12 is active. SIG 14, coordinated by Professor J. Redondo is quite active and is organizing two meetings this year. Professor Laurence reported activities of SIG 15 and mentioned the meeting in 2004 to be held in the USA, organized by D. Gatski in association with SIG 15. SIG 19 is inactive. Professor Hutton had commented on potential creation of a SIG on standards and protocols for the exchange of CFD data. He mentioned that despite previous enthusiasm on the subject, there does not appear to be any interest in creation of such a SIG after contacting potential coordinators and holding an exploratory meeting with NAFEMS in London. Professor Hirsch said that a European view and voice on international standard setting committees in this area was important. He surmised that European Commission money may be available to support a small highly focused team, and agreed to investigate further. SIG 20 is active. SIG 21 has not been active recently. SIG 24 is co-organizing a summer school in Barcelona, September 2003. SIG 25 is inactive but may reactivate soon. SIG 28 has reactivated under the leadership of Professor A. Turan of UMIST. They have held an organizational meeting and will organize a workshop and summer school in 2004. Professor Oliemans had spoken with Professor G. Stelling of TU Delft, who agreed to take over coordination of SIG 30. SIG 32 is quite active. Dr. Florian Menter of AEA Technology GmbH had presented slides on recent activities of SIG 34. The SIG organized an introductory course on design optimization in April 2003 which was attended by 65 people. It was proposed that ERCOFTAC members could present a licensed version of the course elsewhere, e.g. the UK. Dr. Cambon mentioned that a meeting will be organized with coordination of SIG 35 and that SIG 36 will also organize a meeting in the near future. SIG 37 is new and active.

Pilot Centers were discussed. Dr. Robinson mentioned correspondence with Professor Hendrik Kuhlmann who expressed interest in organizing an Austrian PC, beginning in Autumn 2003 when he is established in Vienna. Dr. Robert Castilla had presented a list and activities of the Spanish Pilot Centre. Professor Hutton had reported on UK PC's 1st Osborne Reynolds Research Student Award Seminar, where there were several high quality PhD research presentations made. Professor Rodi agreed to contact Professor Schilling of Technical University Munich to gauge interest in creation of a Pilot Center in Hungary.

REPORT FROM INDUSTRIAL ADVISORY COMMITTEE

During the previous day's IAC meeting, Professor Hutton reported on the progress of sales of the Best Practice Guidelines. 638 copies have been sold, at an average rate of 13 per month. Professor Hutton had arranged a vote for a new IAC Chairman. Two people, Paul Gallagher and Chris Carey, were nominated. P. Gallagher was elected, winning 15 votes from the 24 cast by the industrial membership. Professor Hutton spoke with Professor R. Karlsson and they both decided that Professor Hutton would become Deputy Chairman (replacing Professor Karlsson) to ease the new Chairman into his position.

During the IAC meeting, Professor Hutton gave a presentation concerning the future direction of the IAC and how ERCOFTAC could make itself more valuable to industry. He proposed revitalizing and further developing the Quality and Trust Initiative.

He emphasized that the Quality and Trust initiative would very likely be attractive to large product producing companies, engineering service, and engineering consultancy companies. In addition, he suggested that ERCOFTAC could provide a technology watch service (e.g., web-based product, special awareness seminars), sector focused benchmark exercises, and establish mechanisms for small and medium sized enterprises to gain access to know-how/ solutions (e.g. CFD 'surgeries', Technology Yellow Pages). As an added attraction, he expressed support for a suggestion previously made by Professor L. Kleiser of

ETH-Zürich that ERCOFTAC should consider a reduced membership fee for small and medium sized enterprises.

Professor Hutton discussed the new schedule for production of the previously proposed turbulence workbook. Professor Laurence has said that he can now make time to take a sabbatical to write the workbook this summer, completing a draft by 31 August 2003. It will be sent out to a panel of reviewers, where the reviews will be returned 30 November, and a final version to be submitted for printing in Spring of 2004.

Professor Hutton suggested again the idea of setting up a dedicated publication office to handle the increasing number of projects that ERCOFTAC is assuming. He drafted a list of duties and reponsibilities associated with publications and data bases. ERCOFTAC members will be invited to submit a proposal for hosting the publication office, setting out the resources they intend to commit and the costs of these resources as well as some justification of their competency.

OTHER BUSINESS

The next SPC/IAC and Managing Board meetings will be held in London the 24th and 25th of October, 2003. It was suggested that the Spring 2004 meetings should be held in Madrid, Spain with Professor J. Redondo and Dr. Robert Castilla as the points of contact.

Professor Hutton noted that it was the last meeting for the current ERCOFTAC secretary, Dr. Douglas Robinson. He thanked Dr. Robinson for his service on behalf of ERCOFTAC. Professor Laurence noted that it was the last meeting for Professor Hutton as IAC Chairman. Professor Laurence and Professor Oliemans thanked Professor Hutton for his many accomplishments and years of service to ERCOFTAC.

The ERCOFTAC Industrial Consultation Initiative

Part of the remit of the ERCOFTAC Industrial Advisory Committee (IAC) is to pose the big flow, turbulence and combustion (FTAC) questions from the industrial point of view and then promote and enable FTAC research programmes which match innovation to industrial need.

In order to strengthen its role in this area, the IAC is initiating a dialogue with industry so as to establish their priority needs. After consultation and analysis, these needs will be translated into targeted research programmes. Researchers will then be encouraged and supported by the IAC to pursue such programmes using funds from the EU and other sources. As a first step, a questionnaire is being circulated to European industrial organisations with interests in flow, turbulence and combustion. This can be found on the ERCOFTAC web page (www.ercoftac.org, under the left side menu window, «Industrial Consultation Initiative»). The response to this questionnaire will be analysed and themes which need further development will be identified. Workshops will then be held in each country to explore these themes with the aim of refining them into key elements of industrial need which can then be readily translated into targeted research programmes.

The IAC welcomes the participation of all industrial organisations in this initiative and we invite key technical personnel to spend a few minutes completing the questionnaire (www.ercoftac.org, under the left side menu window, «Industrial Consultation Initiative»).

Please return to:

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Report on the ERCOFTAC Conference on Small Particles in Turbulent Flows

Seville, 11-13 March 2002

Javier Dávila[1] & Julian C.R. Hunt [2]

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The first Ercoftac Conference on Small Particles in Turbulence was held in Seville, Spain, on March 11-13, 2002. This conference was organised to meet a small group of researchers interested in the field, to stimulate the interaction between the participants. The aim of this meeting was more fundamental than the "Workshops on Two-Phase Flow Predictions" organised by M. Sommerfeld (SIG on Dispersed Turbulent Two Phase Flow), but should be complementary to them.

During three days twenty-one talks were given. Experimental and theoretical approaches as well as numerical works were presented to an audience of about 30 participants from European countries and the USA, with British and Spanish participants being the most numerous. About 90% of them belong to the academic world.

The oral presentations included the following themes: dynamics of inertial particles in turbulent flows, turbulent dispersion, disperse two-phase flow modelling, and experimental techniques for turbulent flows laden with particles. Two lectures were given by invited speakers:

- "Turbulence modification by particles", by S. Elghobashi
- "Particle interaction with turbulent structures - the application of random walk models", by M.W. Reeks,

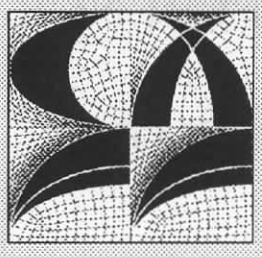
Current advances on the knowledge of the behaviour of small particles in turbulence were reviewed and several experimental results were discussed. There was enough time for informal discussion to stimulate the interaction between the participants. Very representative works on the current research on turbulent modification by small particles, disperse two-phase flow modeling, settling of small particles in turbulent flows, wall effects, experimental techniques for turbulent flows laden with particles, and turbulent dispersion were presented. Some of the questions addressed in this meeting were: exact formulation of the forces acting on small particles, description of the fluxes of particles (e.g. deposition or initial conditions), distributions (forces, turbulence, deformations), coalescence, finite void fraction effects, mean field approaches, etc.

Publication

The conference proceedings will be available from the University of Seville (Dr. Javier Dávila, Escuela Superior de Ingenieros, Camino de los Descubrimientos s/n, 41092 - Sevilla, Spain). Also at the conference web site: http://eurus2.us.es/actividad/congresos/Seville2002.html

Acknowledgement

The Ercoftac Conference on Small Particles in Turbulence was organised by the Escuela Superior de Ingenierios at the University of Seville. The support of this meeting by the staff of this organisation is gratefully acknowledged.



CONFERENCE ON MODELLING FLUID FLOW (CMFF'03)

THE 12TH INTERNATIONAL CONFERENCE ON FLUID FLOW TECHNOLOGIES

September 3-6, 2003
Budapest University of Technology and Economics
Budapest, Hungary

The next event in the series of
International Conferences on Fluid Machinery held every fourth year in Budapest

INVITATION

It is our privilege to invite you to attend the 12th International Conference on Fluid Flow Technologies, entitled «Conference on Modelling Fluid Flow», the next event in the series of International Conferences on Fluid Machinery held every fourth year in Budapest since 1959. The aim of the Conference is to respond to challenges in the rapidly developing field of fluid mechanics: numerical simulation of flows and physical modelling of flow processes using advanced measurement methods. The Conference aims at defining the state of the art in CFD and advanced measuring methods, inspiring both research and practical applications by promoting interaction between scientists and practitioners.

This Conference, like the previous ones, will provide an ideal venue for the development of new partnerships.

We look forward to welcoming you to Budapest.

Univ. Prof. Dr.-Ing. habil.
Rudolf Schilling
Chairman of International Scientific
and Programme Committee

Professor
Tamás Lajos
Chairman of Local Organising
Committee

CONFERENCE ORGANISATION

International Scientific and ProgrammeCommittee (ISPC)

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Univ. Prof. Dr.-Ing. habil. Rudolf Schilling, Munich (D)

Co-chairman:
Prof. Tibor Czibere, Miskolc (H)

Secretary:
Dr. János Vad, Budapest (H)

Members (Invitations accepted so far):
Prof. Reza Abhari, Zürich (CH)
Dr. László Baranyi, Miskolc (H)
Prof. René Van Den Braembussche, Sint-Genesius-Rode (B)
Prof. Dr. Dr. h.c. Franz Durst, Erlangen (D)
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Dr. Tamás Gausz, Budapest (H)
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Prof. Takashi Kubota, Yokohama (J)
Prof. Michael Leschziner, London (UK)
Prof. Ivan R. Lewis, Newcastle-upon-Tyne (UK)
Dr. Elemér Pap, Magdeburg (D)
Prof. Franco Rispoli, Rome (I)
Prof. Ryszard Rohatynski, Zielona Góra (PL)
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Secretary:
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Members:
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Dr. László Kullmann, Budapest (H)
Ákos Szabó, Budapest (H)
Dr. Szilárd Szabó, Miskolc (H)
Dr. János Vad, Budapest (H)

Co-operating Organisations

Scientific Society of Mechanical Engineers (Flow Technology Section)
Budapest University of Technology and Economics
  Department of Fluid Mechanics
  Department of Hydraulic Machines
University of Miskolc
  Department of Heat and Fluid Engineering
Committee of Fluid Mechanics and Thermodynamics of the Hungarian Academy of Sciences

Conference Secretariat

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CONFERENCE TOPICS

The scope of the Conference includes both the theoretical and practical aspects of numerical simulation of flows and physical modelling of flow processes using advanced measurement methods.

The main thematic areas of the Conference are

- Turbomachinery
- Internal Flows
- External Aerodynamics
- Combustion and Heat Transfer
- Environment
- Heating, Ventilating and Air Conditioning
- Chemical and Process Engineering
- Fluid Power

Each thematic area covers research, development, design, new applications and equipment, case studies and future trends with particular emphasis on the use of CFD and advanced measurement methods.

CONFERENCE FRAMES (TENTATIVE)

Tentative structure of the Conference

Wednesday, September 3: Registration, welcome reception (afternoon, evening)

Thursday, September 4: Plenary session: Opening, 3 keynote speeches: issues and trends in

- turbulence modelling, by Prof. Michael Leschziner, London (UK)
- CFD application, by Univ. Prof. Dr.-Ing. habil. Rudolf Schilling, Munich (D)
- advanced measuring techniques, by Prof. Dr. Dr. h.c. Franz Durst, Erlangen (D)

Thursday, Friday September 4-5: Parallel sessions, presentation of papers, poster sessions, and workshops. Closing plenary.

Saturday, September 6: Post-conference workshops, visits to research laboratories, social programs.

OFFICIAL LANGUAGE

The language of the Conference is English.

CALL FOR PAPERS

Abstracts of papers or technical notes (between 200 and 300 words in English) are required before November 20, 2002 for review and selection. Authors whose abstracts are accepted will be notified by December 20, 2002, and requested to submit the full-length papers or technical notes by March 20, 2003 for review with deadline of May 20, 2003. The revised camera-ready papers must be submitted no later than June 20, 2003. The correspondence should be sent to the Conference Secretariat.

PUBLICATIONS

Authors are expected to submit either 6-page papers or 2-page technical notes in English. The Proceedings of the Conference includes the papers reviewed and accepted by the International Scientific and Programme Committee as well as technical notes. Upon registration, delegates will receive the printed materials which will also be available on CD-ROM.

CALENDAR

The aim of this announcement is to bring the Conference to your attention. If you expect to attend the Conference, please respond to the Conference Secretariat via mail, fax or e-mail using the form attached, or register yourself on the Conference web site. This ensures that you will receive all future Conference information.

The Calendar of the Conference is as follows:

- November 20, 2002 Deadline for submission of abstracts
- December 20, 2002 Notification of abstract acceptance
- March 20, 2003 Deadline for papers and technical notes
- May 20, 2003 End of paper review, communication
- June 20, 2003 Deadline for submission of camera-ready papers
- September 3-6. 2003 Conference in Budapest

For further details on the program, please visit the conference web site http://www.cmff03.hu.

BUDAPEST

Budapest, «the pearl of the Danube» is one of the truly historic European capitals with its past stretching back over one thousand years. The eight picturesque bridges spanning the river Danube, the churches and architecture, the sculptures, the wooded hills, the Hungarian cuisine and wine, and the warm hospitality of Hungarian people all ensure that no guest can leave here without longing to return. Walking down streets hosting several open-air programs, those who attend the Conference will have the opportunity to enjoy the refreshing breeze and gentle sunlight of our late summer.

Budapest University of Technology and Economics, the largest technical university in Hungary with its eight faculties, was established in 1782. The Central Building of the University, the venue for the Conference, is beautifully located near a bend in the Danube with views across the Hill Gellért and several historical bridges.

The conference programme also includes optional social programmes and tourist events.

First Announcement and Call for Papers http://www.cmff03.hu

THE ERCOFTAC SUMMERSCHOOL
PHYSICAL AND NUMERICAL ASPECTS OF TURBULENCE MODELLING
26 JUNE - 2 JULY, 2002
UMIST, MANCHESTER, UK

K. BREMHORST, UNIV. OF QUEENSLAND, & D. LAURENCE, UMIST

CONTENT OF THE SUMMERSCHOOL

The theme consisted of two interlinked topics, one to introduce participants to the physical nature of flow modelling and the other the numerical realization of models in turbulent flows. This was achieved over a five day period in addition to one day of refresher courses for those not fully familiar with computational techniques. The audience ranged from commencing postgraduate students who have had little contact with turbulence models or even turbulence theory to practitioners from government and industry right through to internationally recognized scholars in the field. Presenters were drawn from present and ex UMIST staff, software developers and invited guest speakers.

Topics covered included,

- Phenomenon of turbulence
- Modelling philosophies
- Zero-, one- and two-equation models
- Reynolds stress models
- Wall functions
- Unsteady RANS modelling
- Large eddy simulation
- Realizability of closures
- Modelling of heat transfer and force fields
- Software validation
- Turbulence models used in commercial codes
- Limitations of standard models
- Anisotropy resolving models for shock affected flows
- Introduction to the FLOMANIA project
- Tutorials and computer sessions.

PHYSICAL ASPECTS OF TURBULENCE MODELLING

Professor Joel Ferziger (Stanford) provided the introduction to the school with an overview of the phenomenon of turbulence, its time dependent, three dimensional nature and the problems of dealing with complex flows. Participants were reminded of the instabilities leading to turbulence and the mechanisms which maintain them. A review of turbulence modelling followed with special emphasis on LES. The case was made that LES is sufficiently refined to give reliable and accurate results for averaged quantities as well as the larger structural features which are resolved on a time basis. Dynamic models are considered to be the best choice but it is not possible at this point in time to name a unique best model. To illustrate the power of LES, Professor Ferziger undertook a detailed comparison of measurements and LES predictions of flow past a cubic obstacle. In order to achieve excellent agreement with measurements, a new procedure was developed which removes high wavenumbers from the dynamic calculation of model coefficients.

Professor Laurence reviewed the basic concepts of RANS modelling. The presentation introduced the roles played by mean strain rates and mean vorticity and how these are incorporated into modern eddy viscosity models. Limitations of the k-epsilon model were reviewed and the derivation of the proportionality constant for eddy viscosity, C_μ, historically from shear flow data, was shown to be inadequate in complex flows, in particular in the production term of the k equation [1]. The need for Reynolds stress models for complex flows was highlighted together with reassurance that numerical convergence of Reynolds stress models is no longer an issue.

Dr Apsley reviewed the details of two equation models and highlighted the limitations of linear eddy viscosity models. While convenient and widespread in their use, linear eddy viscosity models were shown to fail badly in prediction of flows with anisotropy in simple shear flows with large irrotational strains such as stagnation flows and in the presence of body forces. In order to address these issues, quadratic, cubic and non-linear eddy viscosity models [2] were introduced and reviewed with special emphasis on the strain sensitive cubic model by Craft-Launder-Suga.

Low Reynolds number eddy viscosity models with their inherent limitations and multiplicity of refinements were reviewed by Dr Craft with illustrations of comparative performance data of a selection of such models applied to the near wall region. The wall limiting conditions of various flow variables were presented to illustrate the limiting behaviour of acceptable models. This led to the two component limit of turbulence at flow interfaces where the velocity component normal to the interface vanishes [3]. The similarity to near wall behaviour was noted together with the realizability of such models to ensure that unphysical values are not returned by a model calculation. Development of this model introduced the anisotropy invariants parameter which formed the basis of many subsequent model developments.

Professor Launder gave a history of the development of wall treatments and reviewed current approaches to prediction of the near wall region. The inadequacy of this approach was noted. Participants were then introduced to a radically new approach based on two schemes developed at UMIST based on considerations of production and dissipation of turbulent kinetic energy in the near wall region [4]. The first scheme, also referred to as the analytical one, uses an analytical solution of the simplified x-momentum and energy equations with full allowance of changing thermal properties when non-isothermal flow exists. The approach is a two-layer model for the wall region with the assumption that the velocity and thermal sublayer thicknesses are the same. Model parameters were determined from data with fluids of Prandtl numbers 0.7 and 7. Application to much higher Prandtl number fluids or to mass transfer with high Schmidt number fluids still needs to be verified. The second scheme, referred to as a subgrid wall function, uses simplified boundary layer type equations together with grid refinement in the near wall cell of a coarse grid solution. When combined with a nonlinear eddy viscosity model, it was shown that this scheme gives excellent agreement for

heat transfer predictions in difficult cases such as jet impingement. The computational cost is less than one tenth that of low Reynolds number models.

Professor Launder also gave an overview of the effect of heat transfer and force fields on turbulence modelling. A clear preference was established for second moment closure of the momentum field with a generalized gradient diffusion model for heat transfer. The reason is that in most problems, the main difficulty lies in correct modelling of the pressure-strain correlation rather than in inadequacies of the generalized gradient hypothesis for the thermal field. Second moment closure with a realizable model for pressure containing terms was considered to be the best option in the presence of force fields.

Dr. Manceau (CNRS Poitiers) reconsidered the blocking effect of walls on turbulence by examination of the fluctuating pressure equation. This was shown to lead to an elliptic relaxation model and Durbin's derivation of the v2f model [5]. The clear theoretical derivation, the confirmation of by DNS two-point correlation data of the distant effect of a solid wall, and the ability of the elliptic relaxation model to predict near wall behaviours led to the recommendation that more use should be made of this model in industrial computations.

NUMERICAL ASPECTS

Professor Laurence discussed discretization methods including body fitted coordinates, finite volume discretization with arbitrary control volumes and error estimation. An outline was given of the effect of periodic strains, inlet conditions, the use of unsteady RANS modelling and convergence of higher order statistics. This section concluded by speculating what the next decade may bring and gave notice of the possible emergence of Smoothed Particle Hydrodynamics (SPH) as a powerful tool which is used extensively in astrophysics but is yet to be embraced by the CFD community.

Limitations of standard turbulence models was discussed by Dr Craft who also gave proven methods of overcoming a range of limitations. Dr Apsley presented methods of implementation of turbulence models in CFD and discussed some useful observations relating to ways of stabilizing solutions and dealing with diffusive and non-diffusive terms in the equations.

Numerical methods for large eddy simulation, as distinct from sub-grid scale modelling, was dealt with by S. Benhamadouche with special reference to collocated grids for finite volume methods. Useful tests for the effect of model constants, time discretization and interpolation were discussed and illustrated by application within an industrial flow solver.

Professor Leschziner gave two sessions on anisotropy-resolving models for shock affected aerodynamic flows. Special attention was focussed on turbulence modelling, the effect of compressibility and the presence of shocks [6].

CODE VERIFICATION AND APPLICATIONS

Dr Werner Haase (EADS-Munich) set the scene for this section by giving an overview of the FLOWMANIA project and of the type of CFD applications of interest to the aerospace industry [7]. The need for accuracy involving quite complex flow situations ranging from subsonic to supersonic was stressed together with the ability of simulating time dependent flows during aircraft maneuvers. The current benefits and needs of advanced turbulence models combined with high resolution grids was illustrated for example by a dramatic improvement of the drag prediction for a complete fighter jet when the near-wall grid is successively refined down to y+ = 12, 5 and then 1 (resulting in a 9 Million node grid however). Another challenging example is that of an oscillating airfoil where the lift vs. angle oval shaped curve (returning two different values for one angle depending on the phase).

S. Benhamadouche gave an overview of code development and validation at Electricite De France. A number of reasons for independent code development were given. Amongst these are safety concerns, type of flows to be simulated and knowledge of what is in the code: the best training for CFD users is found by involving them in code development.

Professor Laurence and Dr Craft also outlined the importance of validation and introduced participants to the large ERCOFTAC data base now available to any user by simply registering on the ERCOFTAC website. The range of test cases available from the AGARD database was also shown.

Dr Cokljat from FLUENT Sheffield outlined the FLUENT suite of turbulence models and gave details of the introduction of the Wilcox k-? models in FLUENT 6.0. The presentation highlighted the difficulty faced by code marketers of which turbulence models to incorporate or recommend. The presentation then focused on k-? variants, enhanced wall functions and also showed the superior performance of Re Stress Transport models for the cases of the aerodynamics of a prolate spheroid and a cyclone separator. Current developments in turbulence modeling concern Detached Eddy Simulation and the V2F model.

Dr Menter outlined the use of turbulence models in CFX and showed a distinct preference for the k-? models and specifically the SST version, which blends a near wall, k-??approach with a k-? model for the bulk of the flow. Sensitivity of the standard wall functions to near wall grid refinement is shown to be a serious issue and corrections such as «scalable wall functions» are proposed [8]. The SST model fitted with scalable wall functions is shown to be the least sensitive to grid effects, including for heat transfer predictions. Applications of RSTM and LES are shown, but industrial users are still reluctant to use these advanced models. An invitation was issued to submit challenging problems to help extend the boundaries of commercial codes.

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THE ERCOFTAC BEST PRACTICE GUIDELINES FOR INDUSTRIAL COMPUTATIONAL FLUID DYNAMICS

The Best Practice Guidelines (BPG) were commissioned by ERCOFTAC following an extensive consultation with European industry which revealed an urgent demand for such a document. The first edition was completed in January 2000 and constitutes generic advice on how to carry out quality CFD calculations. The BPG therefore address mesh design; construction of numerical boundary conditions where problem data is uncertain; mesh and model sensitivity checks; distinction between numerical and turbulence model inadequacy; preliminary information regarding the limitations of turbulence models etc. The aim is to encourage a common best practice by virtue of which separate analyses of the same problem, using the same model physics, should produce consistent results. Input and advice was sought from a wide cross-section of CFD specialists, eminent academics, end-users and, (particularly important) the leading commercial code vendors established in Europe. Thus, the final document can be considered to represent the consensus view of the European CFD community.

Inevitably, the Guidelines cannot cover every aspect of CFD in detail. They are intended to offer roughly those 20% of the most important general rules of advice that cover roughly 80% of the problems likely to be encountered. As such, they constitute essential information for the novice user and provide a basis for quality management and regulation of safety submissions which rely on CFD. Experience has also shown that they can often provide useful advice for the more experienced user. The technical content is limited to single-phase, compressible and incompressible, steady and unsteady, turbulent and laminar flow with and without heat transfer. Versions which are customised to other aspects of CFD (the remaining 20% of problems) are planned for the future.

The seven principle chapters of the document address numerical, convergence and round-off errors; turbulence modelling; application uncertainties; user errors; code errors; validation and sensitivity tests for CFD models and finally examples of the BPG applied in practice. In the first six of these each of the different sources of error and uncertainty are examined and discussed, including references to important books, articles and reviews. Following the discussion sections, short simple bullet-point statements of advice are listed which provide clear guidance and are easily understandable without elaborate mathematics. As an illustrative example, an extract dealing with the use of turbulent wall functions is given below:

- Check the lower limit of y^+. In the commonly used applications of wall functions, the meshing should be arranged so that the values of y^+ at all the wall-adjacent integration points is only slightly above the recommended lower limit given by the code developers, typically between 20 and 30 (the form usually assumed for the wall functions is not valid much below these values). This procedure offers the best chances to resolve the turbulent portion of the boundary layer. It should be noted that this criterion is impossible to satisfy close to separation or reattachment zones unless y^+ is based upon y^*.
- Check the upper limit on y^+. In the case of moderate Reynolds number, where the boundary layer only extends to y^+ of 300 to 500, there is no chance of accurately resolving the boundary layer if the first integration point is placed at a location with the value of y^+ of 100.
- Check the resolution of the boundary layer. If boundary layer effects are important, it is recommended that the resolution of the boundary layer is checked after the computation. This can be achieved by a plot of the ratio between the turbulent to the molecular viscosity, which is high inside the boundary layer. Adequate boundary layer resolution requires at least 8-10 points in the layer.
- Exercise care when calculating the flow usingdifferent schemes or different codes with wall functions on the same mesh. Cell centred schemes have their integration points at different locations in a mesh cell than cell vertex schemes. Thus the y^+ value associated with a wall-adjacent cell differs according to which scheme is being used on the mesh.
- Check that the correct form of the wall function is being used to take into account the wall roughness. An equivalent roughness height and a modified multiplier in the law of the wall must be used.

All such statements of advice are gathered together at the end of the document to provide a 'Best Practice Checklist'. The examples chapter provides detailed expositions of eight test cases each one calculated by a code vendor (viz FLUENT, AEA Technology, Computational Dynamics, NUMECA) or code developer (viz Electricité de France, CEA, British Energy) and each of which highlights one or more specific points of advice arising in the BPG. These test cases range from natural convection in a cavity through to flow in a low speed centrifugal compressor and in an internal combustion engine valve.

Copies of the Best Practice Guidelines can be acquired from

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The price per copy (not including postage) is:

Non-ERCOFTAC Members	150EUR (discount price for academics 75EUR)
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ACTIVITIES OF THE ERCOFTAC SPANISH PILOT CENTRE

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UNIVERSITAT POLITECNICA DE CATALUNYA

In the past year, the Spanish ERCOFTAC Pilot Centre has extended its activities in order to maintain communication and interaction between the members, and increase their number. We have organised courses, such as the **Summerschool on Numerical Methods on Environmental Prediction**. Based on this course, a textbook on Geophysical Fluid Dynamics and Environmental Turbulence is being prepared. Next September, the Campus Universitari de la Mediterrania, in Vilanova i la Geltru, will host the **International Summercourse on Variable Density Turbulent Flows**. This Course is also co-organised by the ERCOFTAC SIG 24, 14 and 4 and the Universitat Politecnica de Catalunya. ERCOFTAC SIG 14 and 21 and the UPC are also preparing the **13th International Couette-Taylor Workshop, Nonlinear Dynamics in Fluids** (www.fa.upc.es/personals//index.html), which will be held in Barcelona next July. In March, Dr. Javier Davila, from the Department of Fluid Mechanics, Universidad de Sevilla, and Prof. Julian Hunt from University College in London, organised the **ERCOFTAC Conference on Small Particles in Turbulent Flows**. From the 3rd to the 5th July 2003, the **13th International Couette-Taylor Workshop, Nonlinear Dynamics in Fluids** will be held in the Campus Nord of the U.P.C. in Barcelona.

One of the most important activities in 2002 has been the organization of the **First Workshop on Research in Turbulence**, held in CIMNE, the Spanish Pilot Centre of ERCOFTAC, on the 6th of February 2003. This was a national workshop, which intended to create a discussion forum for the Spanish groups researching on turbulence. The attendees came from a variety of turbulence related backgrounds: basic research, numerical implementation, industrial application, environmental research, etc. The workshop began with a conference by professor Ramon Codina, from CIMNE, on problems of computer implementation of the turbulence models. He pointed out the difficulties that complex models have for converging, and the low capacity of certain models to capture mass forces, e.g. Coriolis, or centrifugal forces. Professor Jose Manuel Redondo, from the Department of Applied Physics, in the Universitat Politècnica de Catalunya presented the research of his group in reference to the turbulent dynamics of oil slicks in the sea, relating it to the Coriolis forces, stratification and Richardson's Law. Professors Javier Dàvila and David Gutiérrez, from the Department of Fluid Mechanics of the University of Seville presented their investigations on particle dynamics in homogeneous and isotropic turbulence as well as on dispersion and sedimentation, using Kinematic Simulation as Direct Numerical Simulation. Jordi Piera, from the Department of Theory of Signal and Communications of the U.P.C. and Jordi Catalán, from the Advanced Studies Centre, CSIC, presented their investigations on vertical transport in aquatic ecosystems using nonlocal models. Professor J. A. Ferré, from the Department of Mechanical Engineering of the University Rovira i Virgili, in Tarragona, presented his research group and the activities that they carry out and described numerical experiments of flow between parallel layers with his own software. Dr. Angel Velázquez, from the company SENER, in Madrid, gave the point of view of industry in the field of the turbulence and described some of the projects that they are working on in the division of Aeronautics. Dr. Velázquez is the new Spanish Industrial Representative to the Managing Board of ERCOFTAC. The first part of the Workshop finished with the presentation of Professor Guillermo Hauke, from the Area of Fluid Mechanics, of the University of Zaragoza. He described turbulence models and the implementation of a combined statistical model with FEM for the determination of pdf for chemical concentrations. The second part of the Workshop started with the conference of professor Javier Jiménez, from the E.T.S. Aeronautics Engineering of the Polytechnical University of Madrid, and from the Centre for Turbulence Research in Stanford University. Professor Jiménez presented a very interesting lecture about Large Eddy Simulation and Direct Numerical Simulation stating that there is a real possibility to obtain a DNS at high Reynolds numbers for a simple geometry in the not-so-distant future. Dr. Elena Roget, from the Group of Environmental Physics of the Universitat de Girona, presented the investigations of her group in dynamics of turbulence in the sea. Professor Eugenio Oñate, from CIMNE, presented his research group of investigation and described a model of turbulence based on the denominated «finite calculus» technique. Professor Henar Herrero, from the Faculty of Chemical Sciences, in the University of Castilla La Mancha showed results from the studies of her group in problems of thermal convection. Dr. Guillaume Houzeaux and Oriol Guasch, from CIMNE presented the investigations of their group in convection in rooms and buildings and on computational aeroacoustics. Finally, Dr. Roberto Castilla, from LABSON, Department of Fluid Mechanics in the Universitat Politècnica de Catalunya, described the studies of his group in the numerical and experimental analysis of the flow of oil in diverse oleohydraulic components. The Workshop concluded with an open discussion between the participants and a very positive evaluation of the experience. This workshop will be organised annually. Next meeting has been planned to take place at the Polytechnical University of Madrid in February 2004. More details of the workshop can be found in the web page of the Spanish Pilot Center of ERCOFTAC at **http://www.cimne.upc.es/Sociedades/ercoftac/home.htm,** or at **www.ercoftac.org,** under «Pilot Centres,» «Spain.»

NORDIC PILOT CENTER

GUSTAV AMBERG, COORDINATOR OF THE NORDIC PILOT CENTER.

The Pilot Center gathers members from the Nordic countries, i.e. Sweden, Denmark, Norway and Finland. We have also recently had some attendance from Estonia. The number of participating academic departments/organizations is 16 (7 from Sweden, 5 from Denmark, and 2 each from Norway and Finland). There are 11 industrial partners (6 from Sweden, 3 from Finland and 1 from Norway and Denmark). The areas of interest of these partners include fundamental research in fluid dynamics and turbulence, such as DNS, turbulent separation, onset of turbulence, flow control, development of turbulence models, influence of swirl, rotation etc, as well as studies of increasing applicability on heat transfer, two-phase flows, etc. Examples of applications are wind power engineering, hydropower, aerodynamics, flow problems in automobile design, combustion, with all of the related two-phase flow problems, and other 'complex' flow problems in process industry. CFD is naturally a very important component in this, as a tool for flow analysis, as well as development of solution algorithms and software.

One main objective of the center is to promote exchange between academic institutions and industry in the different Nordic countries, in the subject area covered by ERCOFTAC. Unlike perhaps most other Pilot Centers, the NPC covers quite a large geographical area and several countries. One of the successes of the center so far is that it has created bonds and collaborations between groups in the different Nordic countries, and it remains one of the most important tasks for the NPC to maintain and enhance such activities further.

NPC organizes an annual meeting that is hosted in one of the four countries, typically in late August. This series of meetings began in 1996, and has been maintained since, so that this year the 8th annual meeting will be held in Göteborg in August. The typical attendance is 30-35 people. The program usually fills two days, with most of the time being taken on hearing short presentations on ongoing research. Short reports from each of these meetings are collected on the NPC website. These annual meetings are perhaps the most important activity of the NPC in creating a good exchange of ideas and information between the participants. There is an ongoing discussion on how to make sure that these meetings remain attractive, where various ideas for modifying the format have been put forward.

NPC partners are active in several of the special interest groups, notably SIG 2 Turbulent Boundary Layers; SIG 15, Turbulence Modeling; SIG 33, Transition Mechanisms, Prediction and Control; and SIG 34, Design Optimisation.

Rolf Karlsson, as a member of NPC, has actively been marketing the Best Practice Guidelines for Industrial CFD, by numerous presentations in different meetings in the Nordic countries.

Since the previous report, a few workshops have been held under the auspices of ERCOFTAC and the NPC. On April 25-27, 2001, the 4th SIG 33 Workshop on Flow Control was held in Abisko northwest of Kiruna in Lappland, Sweden. This is a remote location, well above the polar circle, which offers excellent conditions for outdoors activities. This workshop followed three successful previous workshops organized by SIG 33 on special topics of interest in stability and transition, with the topic of this fourth workshop being flow control. The purpose of the workshop was to bring together people working in the area of flow control to present the state of the art in sensing, actuation, theory, computations and experiments. Future perspectives in the area were emphasized, both in terms of novel basic research as well as technological needs and applications. The topics of special interest was recent theoretical advances and advances in methodology, linear control and estimation theories applied to flow control, non-linear optimal control, applications and experiments in instability, transition and turbulence control. The form of the small (28 participants) workshop was presentations by the attending experts followed by informal discussions. The local environment gave ample opportunity for after-session discussions. A more detailed report from the workshop was given in number 55 (December 2002) of this bulletin by Håkan Gustavsson.

The second workshop on draft tube flow, Turbine 99-2, was held in June 18-21 2001 in Älvkarleby, Sweden, gathering 32 participants. This is the follow-up to the workshop Turbine-99, held in Porjus, Sweden in June 1999. Turbine-99 was a challenge to determine the state-of-the-art in predicting the flow in hydraulic turbine draft tubes. In the Turbine-99 - Workshop 2 the investigation of the draft tube flow was continued, now with emphasis on turbulence models and addressing a non-optimal flow case. For this workshop, a structured grid with about 700,000 cells was distributed for all participants to use. In this way, it was possible to disregard the effects of the grid when comparing different simulations. The unknown inlet boundary conditions, known to have a noticeable influence on the results, were also specified. The proceedings from the workshop will be available from the University of Luleå, Prof. Hakan Gustavsson, (see http://www.luth.se/depts/mt/strl/turbine99). The outcome of the workshop was also reported briefly by Håkan Gustavsson and Rolf Karlsson in number 55 of this bulletin.

A EUROMECH and ERCOFTAC colloquium on swirling flows was held 16 - 20 September 2001, in Bergen-Tromsø, NORWAY, organized jointly by the Norwegian University of Science and Technology (NTNU) in Trondheim and Institute of Thermophysics (Russian Academy of Sciences) in Novosibirsk. The event took place onboard a vessel while sailing northwards along the scenic west coast of Norway all the way from Bergen to Tromsø (above the Arctic Circle). Thus, the Colloquium eventually turned into the most northerly ERCOFTAC and Euromech event ever.

The aim of the Colloquium was to provide an opportunity for European scientists to present and discuss the outcome of their latest research on swirling motions in inviscid, viscous and turbulent fluid flow. Swirling flows occur in a wide range of applications, both in geophysics and engineering. The intention of the Colloquium was to bring together people from different fields of applications, as well as a mix of theoreticians, experimentalists and computationalists, in order to highlight unresolved issues and enhance the understanding of the complex flow physics associated with swirling flow phenomena. On the basis of submitted abstracts some 40 contributions were accepted for inclusion in the Colloquium programme. Eventually 38 scientists from 11 countries participated. The 37 oral presentations, of which 4 were extended keynote lectures, were grouped into thematic sessions according to their subject area, i.e. vortical flows; rotor-stator flows; Stability and vortex breakdown; confined flows; system rotation; coherent structures; applications. A more detailed report by Helge Andersson and S.V. Alekseenko from this meeting is available at the NPC website (www.mech.kth.se/ercoftac/, or link at the ERCOFTAC webpage).

Profile of the Pilot Center Germany South

Dr.-Ing. Florian Menter: Coordinator of PC

1 Introduction

The ERCOFTAC Pilot Center Germany South was founded in 1991. It currently has thirteen members from university institutes, eight members from industry and three members from research centers.

The center is coordinated by Dr. Menter from ANSYS-CFX since January 1998.

Prof. Rodi represents the center in the Scientific Programme Committee and Dr. Menter represents the center in the Industrial Advisory Committee. Both are members of the Managing Board and Prof. Rodi is also member of the Executive Committee of ERCOFTAC, as well as one of the four editors of the ERCOFTAC Journal "Flow, Turbulence and Combustion".

The pilot center supports its own Homepage under the web address:

http://www.flm.mw.tu-muenchen.de/ERCOFTAC-PCGS

The Homepage gives information on the organisation of the PC and on all events organised by the center.

2 Organisational Structure

The Pilot Center is organized in the following way. There is a yearly meeting of the members which is called by the coordinator, who, together with two deputies, is elected by the members for a period of three years.

3 Members

The members of the Pilot Center are:

- Members from Universities:
  - Institut für Hydromechanik, Universität Karlsruhe.
  - Interdiszipliäres Zentrum für Wissenschaftliches Rechnen, Ruprecht-Karls-Universität Heidelberg.
  - Lehrstuhl für Strömungsmechanik Erlangen-Nürnberg.
  - Institut für Strahlantriebe, Universität der Bundeswehr München.
  - Lehrstuhl für Technische Thermodynamik, Universität Erlangen-Nürnberg.
  - Institut für Aerodynamik und Gasdynamik, Universität Stuttgart.
  - Fachgebiet Strömungsmechanik, Technische Universtät München.
  - FG Energie- und Kraftwerkstechnik, Technische Universität Darmstadt.
  - Institut für Kernenergetik und Energiesysteme, Universität Stuttgart.
  - Fachgebiet Hydraulische Maschinen, Technische Universtät München.
  - Lehrstuhl für numerische Methoden im Maschinenbau, Technische Universität Darmstadt.
  - Lehrstuhl für technische Simulation, Universität Heidelberg.
  - FB Strömungslehre und Aerodynamik, Universität Darmstadt.
- Members from Research Centers:
  - Gesellschaft für Anlagen und Reaktorsicherheit mgH, München.
  - DLR, Institut für Verbrennungstechnik, Stuttgart.
  - Kernforschungszentrum Karlsruhe, GmbH.
- Members from Industry:
  - ANSYS-CFX GmbH, Otterfing.
  - Astrium GmbH, München.
  - Bosch Rexroth AG, Lohr a. Main.
  - DaimlerChrysler AG, Stuttgart.
  - EADS Deutschland GmbH, Militärflugzeuge, München.
  - NEC Deutschland GmbH, Stuttgart.
  - Silicon Graphics Computer GmbH, Grasbrunn.
  - Voith Hydro GmbH.

4 Activities of the Center

4.1 Special Interest Group on Design Optimisation

The main scientific activity of the PC Germany South is the organisation of the SIG-34 on Design Optimisation. The goal of the SIG is to introduce and support the use of advanced optimisation techniques in CFD. This is achieved through the organisation of workshops and scientific meetings on a regular basis. In addition, a web-page has been set-up to allow interested parties to get the latest information and to interact continously. It can be accessed through the PC Homepage. The members of the organising committee are:

- Prof. R. Schilling, TU München (Coordinator)
- Prof. R. van den Braembussche, VKI Rhode Saint Genese.
- Prof. K.C. Giannakoglou, TU Athens.
- Dr. F. Menter, ANSYS-CFX, München.
- Dr. W. Haase, EADS München.
- Prof. C. Poloni, Univ. Trieste.

The organising committee is supported by S. Thum (TU München), who has accepted the responsibility for the SIG web-page and also supports the local organisation of the workshops.

The organising committee has decided to hold an Introductory Course on Design Optimisation in Munich on a bi-yearly basis. This course will cover the

basic concepts and techniques behind todays optimisation tools. In order to increase the attractiveness for beginners, the courses will allow the participants to gain hands-on experience on training cases set-up by the organisers and volunteers. The courses will also offer a platform for software demonstrations and interaction with commercial vendors.

In addition to the Introductory Course, it is planned to hold scientific meetings/workshops in the intermediate years. These events will be held at different locations and will be organised locally.

Since the last presentation of the PC Germany South in the ERCOFTAC Bulletin, two Introductory Courses have been held in Feb. 2001 and in April 2003. Both events have enjoyed a large audience, with more than 60 participants at the 2003 meeting.

The Introductory Course 2003 covered the following subjects:

- Introduction to Design Optimisation.
- Geometry Handling and Parametrisation.
- Gradient-based Methods.
- Decision Making Tools.
- Neural Networks / RSM.
- Design of Experiments.
- Evolutionary Strategies.
- Sensitivity Analysis.
- Adjoint Methods.
- Automatic Differentiation.
- Genetic Algorithms.
- Applications.
- Presentation of Commercial Tools.
- Hands-on training.

All details of these meetings, including the technical program can be found on the web-page given above.

4.2 Activities of the Members

The members of the PC are actively engaged in a wide range of topics:

- General Fluid mechanics / aerodynamics / hypersonics.
- Transition and turbulence.
- Combustion research.
- Multiphase flows.
- Chemical processes.
- Propulsion.

In October 2001 the Department of Fluid Mechanics and Aerodynamics at the Universität Darmstadt organized the 9th joint ERCOFTAC/IAHR Workshop on Refined Turbulence modelling. The following testcases have been used in the model comparison:

- Swirling flow in a model combuster.
- Periodic flow over a 2-D hill.
- Periodically perturbed flow over a backward-facing step.
- Flow around a simplified car body.

The workshop was attended by 52 participants from 10 countries from Europe and Asia (Austria 2, Belgium 1, Finland 2, France 8, Germany 25, Greece 1, Japan 1, Swiss 2, The Netherlands 4 and United Kingdom 6). 27 computational contributions from 21 groups were submitted.

A large variety of turbulence models ranging from the Spalart-Allmaras one-equation model, standard linear and non-linear $k-\varepsilon$ and $k-\omega$ models, via the Durbin's three equations $k-\varepsilon-v^2$ model, explicit and implicit algebraic Reynolds-stress models up to differential Reynolds-stress models (RSM) and LES were used in this workshop.

The proceedings of the workshop (two volumes with about 600 pages) containing a summary of the test cases with all details necessary for their computations, a review of turbulence models and numerical methods used by each participant, as well as cross-plots of results for all four test cases were distributed to all participants. The contributors were offered a possibility to correct or refine their results and to re-submit them after the workshop. Only few took advantage of this opportunity. The updated proceedings are available on the workshop www-site:
http://www.sla.maschinenbau.tu-darmstadt.de/workshop01.html.

Some of the testcases have been revisited at the 10th joint ERCOFTAC-IAHR-QNET/CFD workshop in Poitiers (http://www.iahr.org/newsweb/conferences/10thercoftac.htm).

4.3 Participation in Special Interest Groups

Members of the center participate in the following Special Interest Groups:

- Large Eddy Simulation.
- Quality and Trust in Industrial CFD/(QNET-CFD).
- Turbulence in Compressible Flow.
- Transition Modelling.
- Turbomachinery.
- Turbulence Modelling.
- Design Optimisation.
- Combustion.

5 Organisation of ERCOFTAC Events

- Feb. 2001, Introductory Course on Design Optimisation, TU München.
- December, 2002, Yearly PC Germany South members meeting.
- April 2003, Introductory Course on Design Optimisation, TU München.
- August 2003, Workshop on Direct and Large Eddy Simulation (http://www.flm.mw.tum.de/dles5/), TU München.

6 Contact Address:

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5TH ERCOFTAC WORKSHOP ON DNS AND LES

AUGUST 27-29, 2003

FACULTY OF MECHANICAL ENGINEERING
MUNICH UNIVERSITY OF TECHNOLOGY, GERMANY

http://www.flm.mw.tum.de/~dles5/

ORGANIZED BY: R. FRIEDRICH, B. GEURTS AND O. MÉTAIS

Invited speakers:
G. Coleman (Southampton Univ.)
C. Härtel (ALSTOM Power)
K. Hanjalic (TU Delft)
D. Henningson (KTH Stockholm)
D.D. Holm (NL, Los Alamos)
S. Lele (Stanford Univ.)
K. Squires (Arizona State Univ.)
D. Thévénin (EC, Paris)
A.E.P. Veldman (Groningen Univ.)
S. Zaleski (UPMC, Paris)

Deadlines :
March 1, 2003 : Two-page abstract
August 1, 2003: 8-page manuscript

Publication: Proceedings will appear in the Kluwer ERCOFTAC SERIES

Fees:
EUR 300, EUR 150 (Ph.D. students)
After July 1, 2003 : Higher rates

This is the 5th Workshop of a series that originated at the University of Surrey in 1994 under the auspices of ERCOFTAC. Subsequent workshops were held in Grenoble in 1996, in Cambridge in 1999 and in Enschede in 2001. The 5th workshop, *DLES5*, continues to provide a platform for the exposition and discussion of state-of-the-art modeling and simulation approaches for transitional and turbulent flows in many areas, including acoustics, aerodynamics, atmospheric and oceanic sciences, chemical engineering, combus-tion and magnetohydrodynamics. It aims at promoting the exchange of ideas, problems and solution strategies from both industrial and academic background paying attention to mathematical, physical and engineering aspects.
To guarantee your accommodation during this three-day workshop you should register before July 1, 2003

2ND ANNOUNCEMENT

13TH INTERNATIONAL COUETTE–TAYLOR WORKSHOP

Nonlinear Dynamics in Fluids

July 3-5, 2003 – Barcelona, Spain

The conference is sponsored by

Ministry of Science and Technology of Spain (MCYT)
Generalitat, Government of Catalonia (DURSI)
European Research Community On Flow, Turbulence And Combustion (ERCOFTAC)

The conference is organized by

Technical University of Catalonia (UPC), Barcelona
International Center for Numerical Methods in Engineering (CIMNE), Barcelona
Applied Physics Department, UPC.

SCIENTIFIC PROGRAM

The meeting is devoted to fundamental problems in fluid mechanics, with particular emphasis in nonlinear dynamics. Papers are invited in the following areas:

- Taylor Couette flows
- Rotating flows
- Dean vortices
- Pattern selection
- Geophysical flow instabilities
- Transition
- Rayleigh-Benard instabilities
- Magnetohydrodynamics and dynamo effect
- Spherical and planar Couette flows
- Goertler vortices
- Centrifugal instabilities
- Chaos
- Instability control
- Absolute and convective instabilities
- Shear flows
- Vortical flows

Promoting interaction and collaboration between the international participants is a key aspect of the workshop, therefore there will not be parallel sessions: all the sessions will be plenary. Depending on the number of participants, there may be a poster session if necessary, to keep the conference within a three-day time frame.

Invited Speakers

- Prof. **Friedrich Busse**, Chair of Theoretical Physics IV, University of Bayreuth. *Convection in rotating spherical shells and its dynamo action.*
- Prof. **Edgar Knobloch**, University of Leeds and University of California, Berkeley.
- Prof. **Tom Mullin**, Director of the Manchester Centre for Nonlinear Dynamics, University of Manchester. *Taylor-Couette Flow; the long and the short of it.*

PRESENTATION OF PAPERS

To submit an abstract title or simply indicate the intention to assist to the conference, send and email to the Secretariat tc2003@cimne.upc.es or to the Conference Manager marques@fa.upc.es. Abstracts up to four pages should be submitted before May 5 in order to appear in the abstract's book; recommended formats are pdf and tex files.

For additional information, look at the conference web page:

http://www-fa.upc.es/personals/fluids/TC2003/index.html

NEXT ERCOFTAC EXECUTIVE MEETINGS

The ERCOFTAC Executive meetings will be held on the following dates:

SCIENTIFIC PROGRAMME COMMITTEE AND INDUSTRIAL ADVISORY COMMITTEES:

October 24, 2003
London, England

May, 6, 2004
Madrid, Spain

EXECUTIVE COMMITTEE MEETING:

May 7, 2004
Madrid, Spain

MANAGING BOARD AND GENERAL ASSEMBLY MEETING:

October 25, 2003
London, England

Please note that the meetings in Cracow are on Friday and Saturday.

For further information contact Dr. Douglas Robinson at the ERCOFTAC Coordination Centre (contact details inside the back page of the Bulletin).

BULLETIN THEMES AND PC REPORTS

PAST AND FUTURE

The ERCOFTAC Bulletin aims to publish news of, and of interest to, the ERCOFTAC Community every 3 months. Every second issue (March and September) is dedicated to a scientific theme. Pilot Centres are supposed to report occasionally on their activities, and the non-theme issues (June and December) since March 1996 should contain two Pilot Centre reports.

We list below the Themes and PC reports of past and planned future issues from 2000 to 2003. PC chairmen are asked to note when their report is due. A complete list of Bulletin themes can be found in the Bulletin section of the ERCOFTAC web server. Those interested in organising a theme issue or in contributing to planned theme issues are invited to contact the Coordination Centre.

2000

March	*Theme:*	Turbulence Control (K.-S. Choi)
June	*PC reports:*	France West PC Germany South PC Portugese PC (failed to report)
September	*Theme:*	Eddy Structures Identifi cation (J. Delville)
December	*PC reports:*	Belgian PC Spanish PC

2001

March	*Theme:*	Large Eddy Simulations (B.J. Geurts)
June	*PC reports:*	Polish PC Swiss PC Greek PC (delayed)
September	*Theme:*	Parallel Computing (D.R. Emerson)
December	*PC reports:*	Italian PC Greek PC

2002

March	*Theme:*	Fluid Dynamics Databases (P. Voke)
June	*PC reports:*	Germany West PC UK North PC (delayed) Portugal PC (failed to report)
September	*Theme:*	Transition (M. Savill)
December	*PC reports:*	UK PC France South PC (failed to report) Portugal (failed to report)

2003

March	*Theme:*	Complex Flow Problems (I. Eames)
June	*PC reports:*	Germany South Nordic Spain (R. Castilla) France South PC (failed to report)
September	*Theme:*	Aeroacoustics (B. Boersma)
December	*PC reports:*	France West Germany North

Special Interest Groups

1. Large Eddy Simulation (LESig)
B.J. Geurts, University of Twente, NL
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Fax 31.53.489.4888
b.j.geurts@math.utwente.nl

2. Turbulent Boundary Layers
B. Aupoix, ONERA - CERT, Toulouse, F
☎ 33.5.62.252.804
Fax 33.5.62.252.583
Bertrand.Aupoix@onecert.fr

4. Turbulence in Compressible Flows
P. Comte, ULP, Strasbourg, F
IMFS
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5. Environmental CFD
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8. Turbomachinery
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10. Transition Modelling
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12. Dispersed Turbulent Two Phase Flow
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Martin.Sommerfeld@iw.uni-halle.de

14. Stably Stratified and Rotating Turbulence
J.M. Redondo, UPC, Barcelona, E
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15. Turbulence Modelling
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20. Drag Reduction and Flow Control
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21. Vortex Dynamics
P. Orlandi, Universita di Roma, I
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24. Variable Density Turbulent Flows
F. Anselmet, IMST, Marseille, F
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Fabian.Anselmet@irphe.univ-mrs.fr

25. CFD for Ship Hydrodynamics
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28. Combustion
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30. Wind over Waves
G. Stelling, Delft University of Technology
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32. Particle Image Velocimetry
M. Stanislas, Ecole Centrale de Lille, Villeneuve d'Asq, F
☎ 33.3.20.337.170
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stanislas@ec-lille.fr

33. Transition Mechanisms, Prediction and Control
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34. Design Optimisation
R. Schilling, TU München, D
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35. Multipoint Turbulence Structure and Modelling
C. Cambon, ECL Ecully, F
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36. Swirling Flows
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FACULTY POSITION IN AEROTHERMODYNAMICS OF TURBOMACHINES

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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