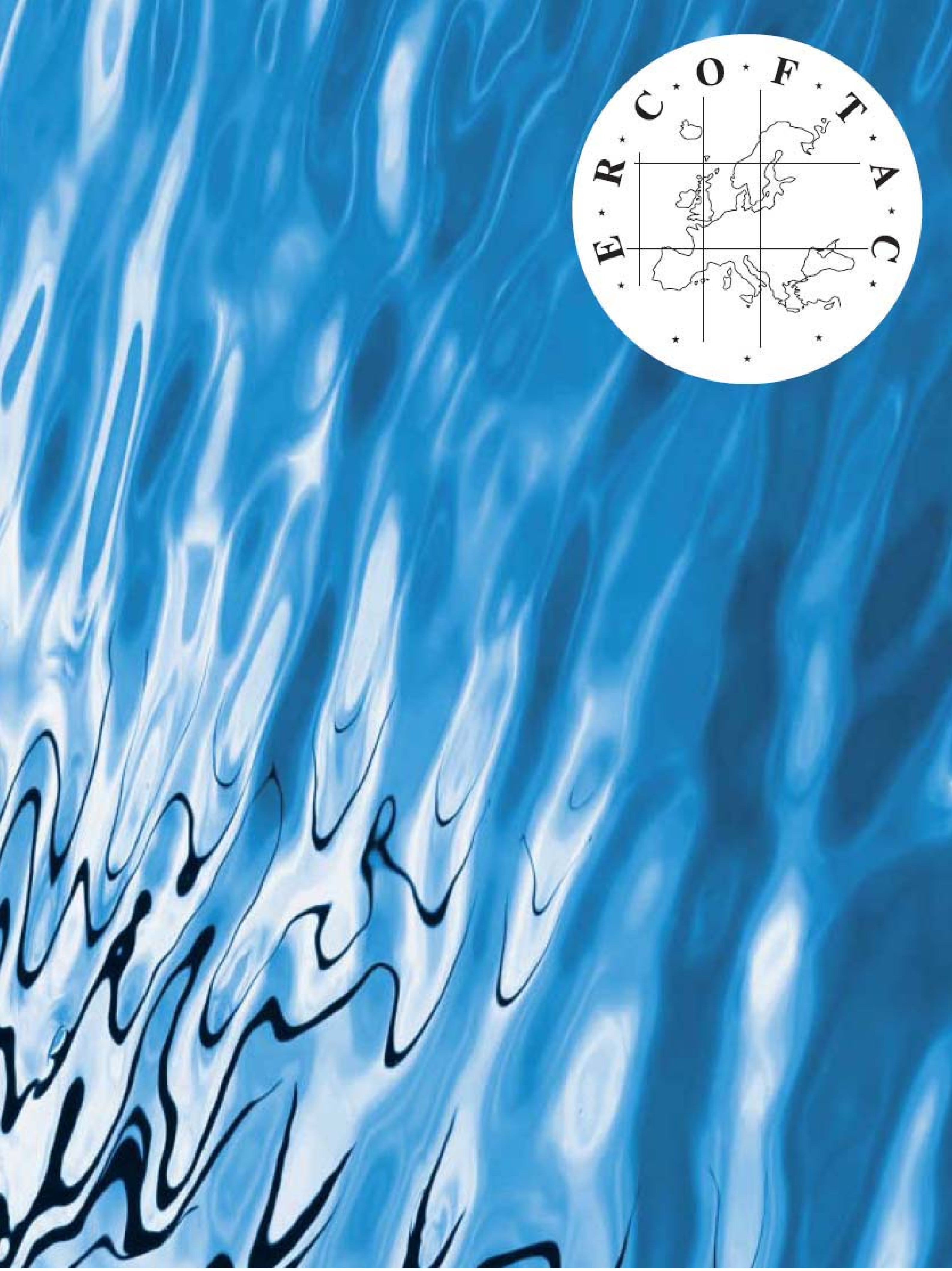

ERCOFTAC Bulletin *June 2011* **87**

European Research Community On Flow, Turbulence and Combustion

ERCOFTAC is a leading European association of research, education and industry groups in the technology of flow, turbulence and combustion. The main objectives of *ERCOFTAC* are: To promote joint efforts of European research institutes and industries with the aim of **exchanging technical and scientific information**; to promote **Pilot Centres** for collaboration, stimulation and application of research across Europe; to stimulate, through the creation of **Special Interest Groups**, well-coordinated European-wide research efforts on specific topics; to stimulate the creation of advanced training activities; and to be influential on funding agencies, governments, the European Commission and the European Parliament.

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SUBMISSIONS

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NEXT *ERCOFTAC* EVENTS

ERCOFTAC Autumn Festival
10^{th} October 2011
TU Darmstadt, Darmstadt, Germany.

ERCOFTAC SPC, IPC & MB-GA Meetings
11^{th} October 2011
TU Darmstadt, Darmstadt, Germany.

JCRH@70

A scientific celebration of Julian Hunt's 70th birthday

7th October 2011

University College London

Sessions:

Turbulence

Environmental Fluid Mechanics

Communication of science into policy

Confirmed speakers:

Keith Moffatt	Paul Linden
Peter Davidson	Richard Perkins
Jerry Westerweel	Lord Desai
Marianna Braza	Elsie Owusu
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Numbers are limited and tickets will be allocated on a first come, first served, basis

Mini Symposium on Current Trends in Modelling and Simulation of Turbulent Flows

Lisbon, Portugal, 14-17 June 2010

Suad Jakirlić[1], Dominic von Terzi[2]

[1] Institute of Fluid Mechanics and Aerodynamics, Technische Universität Darmstadt, Germany

[2] Institut für Termische Strömungsmachinen, Karlsruhe Institute of Technology, Germany

Special Interest Group on Turbulence Modelling - SIG15, ERCOFTAC

In addition to its prime objective, the organization of a series of computational workshops (fifteen workshops have hitherto been organized) aimed at evaluating predictive capabilities of turbulence models at the RANS, LES and hybrid LES/RANS level in a broad range of well-documented flows of scientific and industrial relevance (see e.g. the SIG15 report in the present Bulletin Issue), the ERCOFTAC Special Interest Group on Turbulence Modelling - SIG15 initiated a series of mini symposiums on "*Current Trends in Modelling and Simulation of Turbulent Flows*". The first such symposium was held in Lisbon, Portugal on June 14-17, 2010 in the framework of the "*5th European Conference on Computational Fluid Dynamics - ECCOMAS CFD 2010*". The mini symposium accommodated following fourteen invited presentations:

- *The ERCOFTAC Knowledge Base Wiki - an Aid for Establishing Quality and Trust in CFD*; W. Rodi (Karlsruhe Institute of Technology, Germany);
- *Lessons Learned from the ERCOFTAC SIG15 Computational Workshops: Flow in a 3D Diffuser as an example*; S. Jakirlic (Technische Universität Darmstadt, Germany), D. von Terzi (Karlsruhe Institute of Technology, Germany) and M. Breuer (Helmut Schmidt University, Hamburg, Germany);
- *Reynolds Stress Modelling for Complex Aerodynamic Flows*; B. Eisfeld (DLR - German Aerospace Center, Braunschweig, Germany);
- *Zonal Detached Eddy Simulation for Technical Aerodynamic Flows*; S. Deck (ONERA, Meudon, France);
- *Computational Uncertainty in Turbulent Flow Simulations: Towards a Numerical Error Bar;* D. Drikakis and F. Inok (Cranfield University, U.K.);
- *Aspects of Simulating Synthetic-Jet Injection into Attached and Separated Boundary Layers*; M.A. Leschziner, G.M. Fishpool and S. Lardeau (Imperial College, London, U.K.);
- *Analysis of Unsteadiness in Transonic Shock/Boundary Layer Interactions*; M. Bernardini, S. Pirozzoli and F. Grasso ('La Sapienza' University of Rome, Italy);
- *Lagrangian Methods for Determining the Turbulent Prandtl Number in DNS of Wall Turbulence*; D. V. Papavassiliou and C. Srinivasan (The University of Oklahoma, Norman, USA);
- *Implicit Large Eddy Simulation of Complex Flows*; S. Hickel and N.A. Adams (Technical University Mu-nich, Germany);
- *Reliability of Large-Eddy Simulation of Buoyancy-Driven Turbulent Mixing*; B.J. Geurts (University of Twente, Enschede and Eindhoven University of Technology, The Netherlands);
- *Turbulent Transport Modelling for PANS and other Bridging Closure Approaches*; S. S. Girimaji (Texas A&M University, College Station, USA), B. Basara (AVL List GmbH, Graz, Austria), A. Murthi and D. Reyes (Texas A&M University, College Station, USA);
- *Recent Progress in Hybrid Temporal-LES/RANS Modeling*; R. Manceau, T. B. Gatski and C. Friess (CNRS-University of Poitiers-ENSMA, Futuroscope Chasseneuil, France);
- *Reconstruction of Turbulence Properties for Stochastical Turbulence Modelling*; B. Stoevesandt, R. Stresing (University of Oldenburg, Germany), A. Shishkin, C. Wagner (DLR - German Aerospace Center, Göttingen, Germaany) and J. Peinke (University of Oldenburg, Germany);
- *Symmetry-Preserving Regularization Models of the Navier-Stokes Equations*; R. W. C. P. Verstappen (University of Groningen, The Netherlands).

The full-length papers of the majority of the presented works can be found in the CD proceedings of the ECCOMAS conference. The next mini symposium is going to be organized in the framework of the "6th European Congress on Computational Methods in Applied Sciences and Engineering - ECCOMAS 2012", which is to be held on September 10-14, 2012 in Vienna, Austria (`http://eccomas2012.conf.tuwien.ac.at/`).

n^3l - International Summer School and Workshop on Non-Normal and Nonlinear Effects in Aero - and Thermoacoustics

17th - 20th May 2010, Munich, Germany

Mathieu Zellhuber[1], Gary Jasor[1], Wolfgang Polifke[1]

[1] Lehrstuhl für Thermodynamik, Technische Universität München

1 Introduction

The n^3l Summer School and Workshop on Non-Normal and Nonlinear Effects in Aero – and Thermoacoustics" was held on the premises of the Leibniz-Rechenzentrum (LRZ) in Munich from 17th to 20th May 2010. It was hosted by the Lehrstuhl für Thermodynamik of TU München.

Aero- and thermoacoustic phenomena are a fascinating challenge in fundamental research, and at the same time play an important role in many industrial applications. For example, the stable operation of pipe systems in power plants, or the sound emitted by aircraft can be strongly affected by aero acoustic sources of sound. Moreover, with the introduction of lean premixed, low emission combustion technology, thermoacoustic stability has become a major challenge in gas turbine combustor development, just as it has been for a long time in rocket science.

Acoustic analysis often relies on a linear description, exploiting the superposition principle for orthogonal eigenmodes, which do not couple with each other. However, in situations where nonlinear or non-normal effects become important, such an approach is no longer adequate. For example, it was recently shown by Balasubramanian and Sujith [1], that a linearly stable ducted diffusion flame can go unstable due to interactions between non-normal transient growth and non-linear triggering.

The aim of the n^3l event was to bring together researchers from different backgrounds in order to exchange information on recent developments and explore ideas for the development of a more comprehensive framework of analysis that allows to capture all relevant effects.

2 Participants

Despite the rather narrow scope of the event, the organisers were very happy to welcome about sixty participants from a dozen countries, including overseas (USA & India). Twenty-one research institutions and six industrial companies were represented. The latter give evidence that the possible practical relevance of the ideas discussed during n^3l is considered significant by industry.

3 Event Description

The event was split into two parts, consisting of a Summer School (17-18 May) and a Workshop (19-20 May).

During the Summer School, a series of six invited lectures gave an introduction to the workshop topics and presented the state of the art. The invited speakers were (in order of appearance):

- A. Hirschberg (TU Eindhoven),
- P. Schmid (Ecole Polytechnique, Paris),
- C. Bailly (Ecole Centrale Lyon),
- T. Schuller (Ecole Centrale Paris),
- R.I. Sujith (IIT Madras),
- M. P. Juniper (University of Cambridge).

Each invited lecture was of 90 minutes duration, including discussion. All lectures were recorded, and synchronised streams of the videos and the presentation slides were distributed to the participants. The Summer School set the ground for the following Workshop during the third and fourth day.

For the workshop, contributions of original, recent research results on non-normal and nonlinear effects in the mentioned disciplines had been solicited. A selection of contributions was made on the basis of extended abstracts, which were limited to two pages. In the end, twenty-two abstracts were retained, and the authors were asked to prepare full paper versions, which were made available to the participants on a proceedings CD. The oral presentations during the workshop were allotted 25 minutes each, organised into 5 sessions:

- Methods for the limit cycle prediction of thermoacoustic systems,
- Non-normal and nonlinear effects in Aeroacoustics,
- Non-normal and nonlinear analysis of the Rijke tube,
- Advanced analysis of instability generation in thermoacoustic systems,
- Nonlinear pulsation effects in practical combustion systems.

Furthermore, the organisers were very proud to welcome Prof. Fred Culick from Caltech University for a Special Invited Talk.

Currently peer review is under way for the preparation of a special issue of the Int. J. of Spray and Combustion Dynamics (`www.multi-science.co.uk/ijscd`), featuring selected paper contributions from the n^3l workshop.

4 Overview on the discussions

As the session titles indicate, most talks covered the area of thermo-acoustics, which consequently dominated the discussions during the workshop.

In regard to non-linear flame dynamics, significant progress was achieved in recent years. In particular the Flame Describing Function (FDF) ansatz has proven to be very powerful. It allows to capture the subcritical bifurcation of thermoacoustic instabilities, including hysteresis effects (Noiray et al. [2]). Moreover, remarkably accuracy in limit cycle amplitude predictions has been reported. These development are of high relevance for industrial R&D activities. Several methods of nonlinear analysis that go "beyond describing function" were also presented and discussed at the workshop.

Research on non-normal effects in thermoacoustics has started only recently, and is still at an early stage. This leaves the field open for many exciting ideas, especially for the introduction of mathematical concepts and numerical tools that were up to now not used in the field. Considering the contributions to and the discussions at the n^3l workshop, it seems fair to conclude that the non-normal nature of thermoacoustic interactions is accepted within the scientific community. Nevertheless, major open questions remain, e.g. with regard to the definition of a proper norm, which is required for the proper description of transient growth due to non-normality. Also, the significance of non-normal effects for the stability of realistic flame / combustor configurations remains a matter of discussion and asks for the development of advanced analysis tools.

5 Acknowledgements

The organisers gratefully acknowledge the financial support granted by the European Commission in the framework of the FP6 Marie Curie Research Training Network AETHER, by the Sonderforschungsbereich TR40 of the Deutsche Forschungsgemeinschaft, by the Technische Universität München - Institute for Advanced Study, and by Alstom Power. Furthermore, special thanks are addressed to ERCOFTAC support in promoting the event, thus attracting a larger number of interested colleagues.

References

[1] K Balasubramanian and R. I Sujith. Non-normality and nonlinearity in combustion acoustic interaction in diffusion flames. *Journal of Fluid Mechanics*, 594:29–57, 2008.

[2] N. Noiray, D. Durox, T. Schuller, and S. Candel. A unified framework for nonlinear combustion instability analysis based on the flame describing function. *Journal of Fluid Mechanics*, 615:139–167, 2008.

Cardiovascular Fluid Mechanics: From Theoretical Aspects to Diagnostic and Therapeutic Support

June 27-29, 2011. Faculty of Engineering, University of Cagliari, Italy

The fluid mechanics inside the cardiovascular system has been extensively studied in the last decades and many successful results on the hemodynamics is sites of physiological interest are reported in the literature. Nevertheless, the contribution of fluid dynamics to the actual progress in the medical disciplines is still at an early stage. The transfer of the physical, mathematical and engineering concepts into the clinical practice (medical reality), where the information available and the sought answers can be quite different from those commonly required in technical fields, is a current challenging task. This task requires a profound interdisciplinary approach and the careful combination of qualitative fluid dynamics understandings with quantitative techniques of analysis.

The meeting has taken together approximately 60 scientists mostly from the large Europe, including Israel and Russia, and some from USA. The participants represented advanced research teams involved in the subject of cardiovascular fluid mechanics, involving fluid dynamics itself, vortex dynamics, and fluid-structure interaction issues. The meeting has also tempted to stimulate the interdisciplinary interaction with clinical teams, which represented nearly 20% of the participants. To this purpose, also the two invited lectures were given by physicians, leading scientists and involved in cardiovascular fluid dynamics. These interdisciplinary interaction showed that time appears mature for contributions from cardiovascular fluid mechanics modeling to the future clinical practice.

The scientific sessions were dedicated to the major topics of cardiovascular fluid dynamics: Cardiac vortex dynamics, Endovascular devices (stents), Genesis and growth of atherosclerosis, Flow in aneurisms, Basic models and Novel applications of PIV and echo-PIV. A special session with invited speakers was devoted to heart valves. Every presentation was followed by lively discussions demonstrating interest in the subjects and the need of taking together scientists for facing such novel topics. A round table, open to all participants, stimulated a deeply interdisciplinary discussion.

Overall, the presentations and the debates demonstrated how several issues need further advancements and can indeed contribute to a deeper understanding of physiology, and support future clinical applications. At the same time, topics where fluid dynamics is not expected to play a relevant role, or a role not related to clinical interest, were suggested. In summary, the formation of vortices appeared as the principal flow phenomenon requiring fluid dynamics study in cardiovascular systems. The debates also contributed to develop a communication between scientists having mathematical, engineering or physical background with those with a more medical background. It was envisaged that scientist in biological fluid dynamics should have some training into clinical structure to build an understanding of the physics involved and develop a common language with the medical environment where their studies have eventually to find an application.

The event programme was:

June, 27

Invited Lecture, *Cardiovascular inquiry through imaging and modeling*, P. Kilner
Chair: G.Querzoli

Session : *Velocimetry toward application*
Chair: A. Cenedese / C. Poelma

- *Determining the Wall Shear Stress Distribution at a Model of a Stented Vessel by Micro-Particle-Image-Velocimetry with respect to the Non-Newtonian Characteristics of Blood* D. Quosdorf, M. Brede, A. Leder, D. Lootz, H. Martin, K.P. Schmitz
- *Fluid-Structure Interaction and Wall Shear-Stress Measurements in an Elastic, Stenosed Vessel using Time-Resolved PIV* K. Pielhop, K. Kato, M. Klaas and W. Schroder
- *Analysis of the flow field in an ascending aorta by Particle Tracking Velocimetry* U. Gülan, B. Lüthi, M. Holzner, A. Liberzon, and W. Kinzelbach
- *Steady and pulsatile pipe flows in normal and pathological conditions* S. Colonia, P. Larseille, G.P. Romano
- *Ultrasound imaging velocimetry: toward clinical application* C. Poelma, R. van der Mijle, J. M. Mari, M.-X. Tang, P. Weinberg and J. Westerweel

Session : *Cardiac Flow A:*
Chair: L. Agati / P. Verdonck

- *Quantification of blood flow pattern in the left heart and aorta using the exact solution of unsteady-state Navier-Stokes and Continuity equations for Tornado-like flows of viscous media* Bokerya L.A., Kiknadze G.I., Gorodkov A.Y., Bogevolnov A.V.
- *3D Echocardiographic Assessment of Right Ventricular Flow Pattern* J. O. Mangual, F. Domenichini and G. Pedrizzetti
- *Computational Modelling and Analysis of Intracardiac Flows in Normal and Diseased Hearts* Xudong Zheng and Rajat Mittal
- *Fluid dynamics and stresses in prosthetic-valved devices using direct numerical simulations* M. D. de Tullio, G. Pascazio, L. Weltert, R. De Paulis and R. Verzicco
- *A Lagrangian Investigation of the Flow inside the Left Ventricle* S. Espa, M.G. Badas, S. Fortini, G. Querzoli and A. Cenedese

Session : *Advances in Endovascular Devices*
Chair: B. Geurts / U. Morbiducci

- *Evaluation of different stenting techniques in coronary bifurcations* J. García, F. Manuel, Y. Doce, F. Castro, J. A. Fernández, J. Goicolea and A. Crespo
- *A Structural and Fluid Dynamic Approach to Design a New Tapered Balloon Dedicated to Stenting Procedure in Coronary Bifurcations* C. Chiastra, S. Morlacchi, G. Dubini, P. Zunino and F. Migliavacca
- *Hemodynamic Impact of Helical Designed Graft versus Straight Conventional Arterio-Venous Loop Grafts* K. Van Canneyt, G. De Santis, S. Eloot, P. Segers and P. Verdonck

- *CFD analysis of coronary artery with atherosclerosis - pre and post stent-insertion study* Waqas bin Faateh and Naveed Durrani
- *Hemodynamic effects of endovascular procedures*, P. Petruzzo, S. Camparini, L. Pibiri, G. Genadiev

June, 28

Invited Lecture, *Cardiovascular Physiology and Cardiac Flow*, P.P. Sengupta
Chair: G. Pedrizzetti

Session : *Applied Modeling*
Chair: I. Avrahami /S. Chevranov

- *Patient-specific closed-loop multiscale modeling of virtual surgeries for the treatment of congenital heart diseases* Baretta A, Corsini C, Yang W, Marsden AL, Vignon-Clementel IE, Feinstein JA, Hsia T-Y, Dubini G, Migliavacca F, Pennati G
- *Local pressure fluctuations in an occluded artery* O. Korolkova, J. Alastruey, A. Lowe, J. E. Davies, A. D. Hughes, K. H. Parker and J. H. Siggers
- *Shear Induced Platelet Activation and its Relationship with Blood Flow Topology in Hemodynamic Models of Stenosed Carotid Bifurcation* D. Massai, G. Soloperto, D. Gallo, Y. Xu, U. Morbiducci

Session : *Understanding atherosclerosis*
Chair: F. Migliavacca / R. Mittal

- *Effect of retrograde flow on wall shear stress properties in pulsatile flows* Dikla Kersh and Alex Liberzon
- *Tortuosity of Coronary Arteries as a Potential Local Risk Factor for Atherosclerosis* M. Malvé, A. M. Gharib, Saami Yazdani, M. A. Martinéz, Gerard Finet, M. Doblaré, Renu Virmani, R. I. Pettigrew and J. Ohayon
- *A numerical study of pulsatile blood flow in a patient-specific coronary bypass model* J. Vimmr, A. Jonàsova and O. Bublìk
- *Correlation of atherosclerosis progression with structure of disturbed flows in the right coronary artery* S.I. Bernad, C. Brisan, E.S. Bernad, T. Barbat and V. Albulescu
- *Evaluation Of Mechanical Behaviour Of Two Different Carotid Patches Using* "VELOCITY Vector Imaging" C.M. De Filippo, G. Tonti, P. Modugno, E. Caradonna, G. Pedrizzetti, F. Alessandrini

Session : *Cardiac Flow B*
Chair: G. Tonti / P. Sengupta

- *Hemodynamic Effects of Different Pulmonary Artery Banding, Ascending Aorta and Aortic Coarctation Diameters in the Hybrid Norwood Circulation: A Computational Study* Corsini C, Cosentino D , Baker CE, Dubini G, Pennati G, Hsia T-Y, Migliavacca F
- *Three-dimensional flow inside the left ventricle model* S. Fortini, G. Querzoli, S. Espa and A. Cenedese
- *Left Ventricular Vortex in Healthy Hearts, a Clinical Analysis* S. Cimino, G. Pedrizzetti, G. Tonti, E. Canali, V. Petronilli, and L. Agati
- *Blood Flow in the Human Aorta: from In Vivo 4D Phase Contrast MRI to Computational Hemodynamics* U. Morbiducci, R. Ponzini, D. Gallo, G. De Santis, C. Negri, D. Tresoldi, D. Massai, M.A. Deriu, P. Segers, B. Verhegghe, A. Redaelli and G. Rizzo
- *Hybrid repair of thoracic aorta in chronic dissection: changing in the distal perfusion after the procedures.* Pacini D., Careddu L., Di Marco L., Pantaleo A., Barberio G., Leone A., Pilato E., Di Eusanio M., Lovato L., Di Bartolomeo R.

Session : *Modeling Aneurisms*
Chair: P. Kilner, R. Verzicco

- *Simulation of Realistic Pulsatile Flow in Cerebral Aneurysms* J. Mikhal, B. J. Geurts
- *Experimental and Numerical Analysis of the Pressure Field in a Patient-Specific AAA Model with and without Intraluminal Thrombus* R. Antón, C-Y. Chen, M-Y. Hung, E.A. Finol, and K. Pekkan
- *The Dynamics of Flow and Structure in Fenestrated Endografts for Treatment of Abdominal Aortic Aneurysms* Idit Avrahami, Tomer Meirson, Moshe Halak, Zehava Blechman, Moshe Brand

Round Table : *Perspectives of contributions for diagnosis and therapy*

June, 29

Special session : *Mechanics of Heart Valves: from Structure to Flow*
Chair: A. Kheradvar

- *Fluid Dynamic Assessment of Transcatheter Aortic Valve Implantation* A.N. Azadani, H.A. Dwyer, P.B. Matthews, N. Jaussaud, S. Chitsaz, L. Ge, and E.E. Tseng
- *A computational framework for high resolution simulations of patient-specific left heart hemodynamics with aortic valve prothesis* T. Le, I. Borazjani and F. Sotiropoulos
- *Experimental Approaches to Assess Heart Valve Performance using Ultra-High-Speed Imaging Method* A. Kheradvar

Session : *Basic and applied modeling*
Chair: F. Sotiropoulos / G. Pedrizzetti

- *Assesment of the placental blood flow in the growth-restricted fetus* E.S. Bernad, S.I. Bernad, C. Brisan, V. Albulescu and T. Barbat
- *Hydro-Mechanical Foundations for the Blood Swirling Vortex Flows in Cardio-Vascular System* S.G. Chefranov, A.G.Chefranov, A.S. Chefranov
- *Experimental study of the asymmetric heart valve prototype* M. Vukicevic, S. Fortini, G. Querzoli, A. Cenedese G. and G. Pedrizzetti
- *Aging and Hypertension effects on the Aortic Stiffness* A. Guala

Highly Resolved Experimental and Numerical Diagnostics for Turbulent Combustion

May 25-26, 2011 Rouen, France

The objective of this ERCOFTAC conference was to bring together experts in newly developed experimental and numerical techniques for tackling turbulent flames and featuring high resolution; typically high-speed diagnostics (planar laser simultaneous measurements PIV & PLIF) and high-resolution simulations (Direct Numerical Simulation - DNS - or Large Eddy Simulation - LES - with billions points and complex chemistry). Recent progress in computer architecture (massively parallel and high performance computing) renders it possible to envisage "routine" high fidelity simulations running on thousands of processors with billions of cells. As a first consequence, highly refined LES and even DNS of geometries similar the one encountered in industrial devices become feasible. The second consequence is that the current approaches of turbulent combustion modeling need to be revisited. Most of the target experiments that have been used in the past two decennia for the validation of the modeling approaches have been designed with simple geometries and relatively small Reynolds number, to accommodate the computing resources of that period. On the other side, experimental techniques have also enormously progressed (high speed cameras, simultaneous measurements of velocities and temperature with increased spatial and temporal resolution . . .) opening new possibilities for comparisons between simulation and experimental studies. New challenging well-documented experimental set-ups are now emerging to support and complement high-fidelity numerical simulations.

This meeting gathered researchers from experimental and computational background they have shared the very up-to-date state-of-the-art of both disciplines. Next decade challenges in the context of turbulent combustion were also discussed: advanced design assisted by simulation, prediction of pollutants, inclusion of multi-physics in the models (radiation, soot, spray . . .) and multi-dimensional measurements.

The following points were specifically addressed:

- Partially-premixed and stratified combustion as multi-scale challenge for both high resolution measurements and numerical modeling
- Laser combustion diagnostics at high repetition rates
- Highly resolved numerical simulation of turbulent flame including detailed chemistry
- Advanced laser diagnostics for Kerosene/Air combustion in aero-engines
- Liquid atomization using large-scale numerical simulation

58 scientists from 9 European countries and USA participated to this two-day conference. Keynote lectures were given by Heinz Pitsch (Aachen University, Germany), Andreas Dreisler (Darmstadt University, Germany), Christos Frouzakis (ETH Zurich, Switzerland), Frédéric Grisch (CORIA, France), Simone Hochgreb (Cambridge University, UK) and Olivier Desjardin (University of Colorado at Boulder, USA).

The keynotes lectures were accompanied by 6 sessions, where 18 contributed papers were given, and 9 papers presented in a poster session; leading to a total of 33 contributions collected in a CD available at the conference.

Figure 1: HO2 radical visualization in a detailed chemistry DNS of a lifted turbulent flame (Christos Frouzakis et al., ETH Zurich)

Workshop summary

New methods and modeling approaches were presented for both experiments and simulations. Results obtained from novel time-resolved or multi-dimensional experimental techniques, useful to better understand the physics and provide accurate modeling validation tools, were discussed together with high-fidelity modeling of complex phenomena, as liquid jet atomization, involving high-performance computing.

Striking results, as the direct observation of differential diffusion effects in turbulent premixed flames were also reported and have triggered stimulating discussions.

Comprehensive and reliable experimental data sets are mandatory in the development of new combustion systems. An important outcome of this meeting is the emergence of revisited interactions between the experimentalists and the modelers; unsteady flow patterns are now systematically discussed along with specific features resulting from three-dimensional flow properties, which impose to revisit our views on turbulent flames. For instance, it was shown from experiments how two-dimensional measurements of turbulent lifted-flame bases could be revealed misleading as soon as information on an addition direction is provided. The need to incorporate high-precision numerics, specifically when the physics becomes very complex as with primary atomization, was also clearly demonstrated.

Acknowledgements

The organizers would like to express their gratitude to the ERCOFTAC SIG28 on Reactive Flows and to all the lecturers who participated in the conference.

Statistical Mechanics, Fractals, Instabilities and Turbulence in Fluids and Superfluids

April 13-14, 2011, Institut Henri Poincaré, Paris, France

Frédéric Moisy[1], Marc-Etienne Brachet[2], Claude Cambon[3]

[1] Laboratoire FAST, Université Paris-Sud, France

[2] Laboratoire de Physique Statistique, ENS, France

[3] Laboratoire de Mécanique des Fluides et d'Acoustique, Ecole Centrale de Lyon, France

1 Motivations and objectives

This workshop can be seen as a follow-up of the Winter school at Les Houches, February 22-26, 2010 (ref. S2010-04), but at smaller scale and on a more focused list of topics. This restricted list of topics was also addressed by an informal meeting in Imperial College, London, organized by Christos Vassilicos (active member of the SIG 35) in June 2010, but without explicit label or support from SIG 35, with local financial support.

According to the title of our SIG, 'Multipoint Turbulence Structure & modelling' (MPTSM hereinafter), we continue to address fundamental issues and challenges of turbulence theory and modelling, but we keep in mind practical modelling for engineering and environmental ows. In this sense, a significant overlap exists with the SIG 15, for instance with common interest in 'structure-based modelling' (S. Kassinos and co-workers, C. Cambon and coworkers, among others).

The apparent broad range of themes in the proposed title reflects different domains of competence by the participants but we share the same interest for investigating points of contact between our domains with cross-fertilization. Three themes are chosen more specifically:

1. Revisiting instabilities and turbulence using basic concepts of statistical mechanics and new invariants. The case of the von Kármán flow is mainly addressed, with bifurcations between different flow patterns and transition to turbulence, but other flows, with and without rotation, are discussed.
2. Advances in superfluid modelling. Some studies (M.- E. Brachet, B. Dubrulle, F. Daviaud) are at the cross-road of statistical classical mechanics and quantum mechanics. Very recent aspects are new theoretical and numerical results using a spectral closure (EDQNM, from the Kraichnan and Orszag's legacy) for the dynamics and statistics of superfluid Helium, as a bi-fluid (classical fluid and quantum fluid) medium.
3. Revisiting the 'infrared limit' in connection with decay laws in HIT (homogeneous and isotropic turbulence), and closure models.
4. Fractal approaches. Experiments are carried out in the team of J. C. Vassilicos, which question the 'Kolmogorov's vulgate'. We continue to discuss to what extent this gives new ideas and can suggest a renewed theoretical, but also numerical, approach.

In addition, we continue to share an interest for a global, dynamical, statistical and structural approach to anisotropic flows, with and without rotation. From stable stratification to unstable cases, for instance, new recent elements suggest to consider, with the tools of MPTSM, buoyancy-driven flows such as thermal convection and even Rayleigh-Taylor instability with transition to turbulence. Collaboration with the CEA is particularly encouraging, from spectral approaches (RDT, non-linear closures, supported by high resolution DNS towards LES) and engineering-oriented models, like 'two–structure / two–fluid / two–k–ϵ' [1]. This theme is also important for the SIG 14 (J. M. Redondo).

Our small working group was hosted at 'Institut Henri Poincaré' in Paris, and consisted of 19 active participants, from France and UK. Among them, 5 (Naso / Lawrie / Laizet / Valente / Gomes Fernandez) young scientists are funded by ERCOFTAC scholarships.

2 Talk contents

2.1 Instabilities and turbulence using concepts of statistical mechanics

Aurore Naso (formerly at LP ENS Lyon, now at LMFA, Ecole Centrale de Lyon, Ecully, France) presented 'Statistical Mechanics for the 3D Euler equations in axisymmetric geometry'. The first part of the talk is devoted to the description of the mean states of the von Kármán ow. By using the relative difference of frequency of the impellers as a control parameter, it is shown that the mean flow can bifurcate from a monopolar to a dipolar state. In order to reproduce this behavior theoretically, the most probable flow solutions of the axisymmetric Euler equation in a closed box are computed, using a statistical approach previously derived for 2D turbulence [2, 3]. Good qualitative agreement between theoretical and experimental flows is obtained.

Pierre-Philippe Cortet (CEA Spec / FAST Orsay, France) presented 'Phase transitions in the turbulent Karman flow'. The bifurcation from the mono-polar to the dipolar flow state as the control parameter is varied is analysed in terms of a phase transition, characterized by the divergence of a suitable defined 'susceptibility' at the transition [4]. Here again, the control parameter is the normalized difference of rotation rates of the two propellers. The order parameter associated to this susceptibility is a normalized angular momentum, which is zero in the symmetric (double-cell) state. The transition occurs at an unusually large Reynolds number, of order of 10^5.

Marc-Etienne Brachet (ENS Paris, France) presented 'Dynamo action in the Taylor-Green vortex: The effect of symmetries revisited'. The rotation and mirror symmetries of the Taylor-Green geometry was thought to prevent the spontaneous growth of a magnetic field in this particular geometry. It is shown however that, by subtle arrangements of conducting and insulating boundary conditions, this flow configuration is indeed compatible with a dynamo effect. These results are compared with the VKS flow (von Kármán flow using liquid sodium), in which the dynamo effect has been experimentally obtained.

2.2 Advances in superfluid modelling

Pierre Sagaut (IJLRA, Paris, France) presented 'EDQNM modelling of superfluid turbulence' [5]. Considering the superfluid as a mixing of 'normal' (n) fluid and of '(quantized) superfluid' (s), coupled EDQNM equation for both energy spectra $E_n(k,t)$ and $E_s(k,t)$ are established and solved, with classical dissipation term for the first one. In the second equation, there is no viscous dissipation and a subgridscale viscous term, also derived from EDQNM, allows correct behaviour of the lowest resolved wavenumbers, but with no explicit modelling of quantized eddies and Kelvin waves (next talk) at smallest, unresolved, scales. These EDQNM-type equations are coupled by two interaction spectral terms, F_{ns} and F_{sn} respectively, which express the mutual 'friction' of both fluids, in agreement with L'vov et al. (2006). Results are successively compared with existing DNS, but allow to treat much higher Reynolds numbers, and to phenomenological scaling by Nazarenko and coworkers, for four cases, with either low and high temperature, and either small and strong mutual friction.

Marc-Etienne Brachet presented two results based on the truncated Gross-Pitaevski equation, aiming to model superfluid flows at finite temperature. The first contribution describes thermalization effects of turbulent Bose-Einstein condensates.It is demonstrated that, when large dispersive effects are present, a "self-truncation" of the spectrum appears, which delays the thermalization of the large wavenumbers [6]. In the second contribution, the influence of the thermal fluctuations of Kelvin waves on propagating vortex rings is investigated. These fluctuations, which are generic in finite-temperature superfluid, are shown to decelerate the vortex ring, an effect which could be tested experimentally.

2.3 Deaying turbulence

Antoine Llor (CEA DAM, Bruyéres Le Chatel, France) presented 'Landau's large scale invariants in free turbulent decay'. In this presentation [7], the connection between the large scale structure ($E \approx k^m$ at small k) and the decay exponent is revisited. Exact results, based on the invariance of the angular momentum correlation, are presented. Implications for the decay of inhomogeneous structures (layers, tubes, spots), and for classical "0-dimension" models ($k - \epsilon$) are also discussed.

J. Christos Vassilicos (Imperial college, London, UK) presented 'Decaying turbulence: Theory and experiments'. Self-similar solutions for the free decay of homogeneous and isotropic turbulence are discussed. It is shown that the von Kármán-Howarth equation admits an infinity of possible finite integral invariants depending on conditions at infinity. Given an asymptotic behaviour at infinity for which the Birkhoff-Saffman invariant is not infinite, there are either none, or only one or only two finite invariants. If there are two, one of them is the Loitsyan-sky invariant and the decay of large eddies cannot be self-similar [8]. Implications of these results to turbulence generated by a multi-scale forcing (fractal grids) are discussed. In particular, key quantities such as the ratio L/λ (integral scale to Taylor scale) are found independent of the Reynolds number, instead of $L/\lambda \propto Re_\lambda$ in all self-preserving flows.

Sylvain Laizet (Imperial college, London, UK) presented 'An accurate numerical approach to investigate multiscale-generated turbulence'. First results of direct Numerical Simulations of turbulence generated by fractal grids are presented. These simulations have been performed using a fully parallelised code, Incompact3d, based on an innovative domain decomposition technique. A number of key results in agreement with the experimental findings are presented, in particular the maximum of turbulence production at a distance from the grid governed by the largest mesh size of the grid [9].

2.4 Anisotropic turbulence

Finally, the following five talks illustrated the dynamical, statistical and structural approach to anisotropic flows, in both physical and Fourier space, using very recent experimental and numerical data.

Claude Cambon (LMFA & Centre Henri Bénard PC, Ecole Centrale de Lyon, Ecully, France) presented 'Cascade in anisotropic turbulence: 2 point (physical) and 3 point (Fourier)'. A brief historical survey is given, about the development of closure methods and theories from dynamical equations, Navier-Stokes type, to related dynamical equations for multipoint statistical correlations. It is shown that rather recent analyses starting from equations, Kármán-Howarth type, for two-point second order velocity correlations, are really 'two-point approaches'. On the other hand, techniques formerly referred to as 'two-point closures or theories', developed in Fourier space from Kraichnan's and/or Orszag's legacy, attack the problem of cascade at the deeper level of three-point third-order dynamics: It is suggested to call 'tradic' and not 'two-point' these approaches. After the example of the unavoidable finite Reynolds number effect on the 4=5 Kolmogorov law, illustrated by both (physical) and (spectral) approaches, the interest of spectral, tradic, approach, is discussed for strongly anisotropic turbulence, with rigorous removal of pressure fluctuations and detailed conservation laws, following [10].

Frédéric Moisy (FAST, Orsay, France) presented 'Anisotropic energy transfers in rotating turbulence'. First experimental measurements of the anisotropic energy transfers in the physical space are presented. Large data sets of PIV (particle image velocimetry) have been obtained in grid-generated turbulence in the 'Gyro flow' rotating platform. The measured energy density and energy flux are shown to be consistent with the Karman-Howarth-Monin equation, which is valid in homogeneous anisotropic turbulence [11]. It is observed that the small scales are more anisotropic than the large scales, an effect which is interpreted in terms of helicity cascade.

Fabien Godeferd (LMFA, Ecole Centrale de Lyon, Ecully, France) presented 'Cascade in rotating, stratified and MHD flows'. The review of DNS studies in rotating stratified flows, is given with emphasis on extracting anisotropic statistics, at two point, both in physical and spectral space. Kármán-Horwath (physical) and Lin (spectral) equations are compared as well, and some typical results of statistical theories are shown. Dynamical, structural and statistical approaches are reconciled, at least in axisymmetric turbulence [12].

Andrew Lawrie (LMFA, Ecole Centrale de Lyon, Ecully, France) presented 'Understanding energy conversions in optimal mixing flow'. The role of the baroclinic torque is discussed for trigering the Rayleigh-Taylor instability, and this is illustrated by experimental and numerical results. An indicator to describe the efficiency of turbulent mixing is introduced. It is shown that the Rayleigh-Taylor geometry is the one that yields the maximum efficiency.

Benoît-Joseph Gréa (CEA DAM, Bruyères Le Chatel, France) presented 'Spectral anisotropy of Rayleigh-Taylor turbulence'. In a density-stratified flow, with low Atwood and Boussinesq approximation, statistical homogeneity in the vertical direction is consistent with a constant mean vertical density gradient, whose sign distinguish the 'stable' (conservation of toroidal energy, with gravity waves evolving towards balanced poloidal and potential energy) from the 'unstable' case: Exponential amplification of poloidal energy, at least in the linear, 'Rapid Distortion Theory', phase. This second case offers some remarkable analogy with Rayleigh-Taylor turbulence [13]. It is generalized here by a spectral approach to axisymmetric turbulence with non-homogeneous axial (vertical) direction, with 3D spectra depending on the vertical coordinate and with a new nondiagonal toroidal-poloidal intercomponent for the second-order velocity spectral tensor.

3 General discussions

Very stimulating exchanges are generated, contrasting the 'engineering' and the 'physicist' viewpoint. If a mean flow theory is established (e.g. A. Naso), it is important to look at classical Reynolds decomposition for both equations for 'mean' and 'fluctuating', coupled by the gradient of the Reynolds stress tensor. Use of dynamical equations for two-point and single-point second-order statistics is often closer than expected in both communities, with for instance seminal works by Rotta on Kármán-Howarth equation (J. C. Vassilicos), even if recent studies by physicists often ignore pressure-velocity 'mixed' correlations. Finally, investigation of the infrared limit has important consequences for practical turbulence models (A. Llor), and this merits to be generalized towards anisotropic turbulence with interactions.

4 Supporting organisations, acknowledgements

- Institut Henri Poincaré, Paris, see: `http://www.ihp.jussieu.fr`
- ERCOFTAC ADO, Special budget from SIG 35
- Centre Henri Bénard PC, see: `http://www.lmfa.ec-lyon.fr/henri.benard/`

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6th International SPHERIC
Smoothed-Particle-Hydrodynamics Workshop

Hamburg, Germany, 8-10th June 2011

Introduction

The Institute for Fluid Dynamics and Ship Theory of the Hamburg University of Technology (TUHH) was honoured and pleased to organise the 6th international SPHERIC workshop under the aegis of the ERCOFTAC Smoothed Particle Hydrodynamics European Research Interest Group (SIG40).

Over 100 participants - among them 40 student delegates - followed the invitation to the exciting cosmopolitan city of Hamburg. The enjoyable and successful meeting was held from June 8th to June 10th in a splendid maritime atmosphere at the Rilano Hotel along the shore of the river Elbe.

Importance of Workshop Series

The SPHERIC workshop is the only worldwide event which exclusively focuses on the Smoothed-Particle-Hydrodynamics (SPH) methodology and related simulation approaches. Since SPH has recently gained enhanced attention in the area of scientific computing, the workshop continues to grow and has thus taken a root as the primary annual event on Smoothed-Particle-Hydrodynamics.

The remarkable success of the workshop series is attributed to the strict methodological focus in an interdisciplinary application environment, integrating the know-how of physicist, mathematicians, IT experts and engineers from academia and industry.

Key-Figures of 2011 Workshop

Similar to previous workshops, a record number of abstracts (83 in 2011) were submitted and the amount of workshop delegates increased to 109 with a remarkable 20% share of non-European overseas delegates. This clearly indicates the sustained increase in interest in the SPHERIC workshop. Dedicated to the aim of stimulating a direct exchange of ideas between members of the most active groups in the advancement and dissemination of SPH, it was decided to continue with the workshop ethos of the event and allow everyone to view all presentations. Moreover, a strict quality-assurance policy has been imposed on the accepted workshop presentations based upon at least three reviews of submitted abstracts which were assessed against three equaly important categories, i.e. novelty, applicability & impact and predictive accuracy/improvements over the state of the art. A total of 51 papers have been accepted for presentation, supplemented by 6 poster-presentations. The workshop included three days with 6 one-hour sessions per day. Additional keynote lectures were given in the morning of the first two days.

SPH Training Day

Prior to the workshop, an SPH training day was organised on the campus of TUHH on June 7th. The overture is most suitable for researchers who are familiar with principles of SPH but beginning their work in the field and was attended by 30 participants. The training day comprised two morning lectures followed by a comprehensive introduction into the application of SPH in the afternoon. After an outline of the fundamentals and the mathematical framework of SPH by Prof. Stefano Sibilla from the University of Pavia (Italy), Prof. Rade Vignjevic (Cranfield University, UK) lectured on the application of SPH for solids and structures based on a total Lagrangian formalism in the morning. In the afternoon, the participants were introduced to the open-source SPH software package *SPHysics* under the supervision of Dr. Benedict Rogers (University of Manchester, UK) and Dr. Alex Crespo (University of Vigo, Spain). Focal points of the afternoon were the effects of different approximation strategies, kernel issues, boundary conditions and formulation enhancements in conjunction with practical examples. Supplementary, John Biddiscombe (CSCS, Switzerland) gave an afternoon lecture dedicated to the post-processing and visualisation of large particle simulation data sets using ParaViewmeshless, a tool developed at CSCS in Zürich.

Workshop Programme & Results

Following the opening address by the organisers of the workshop, the chairman of the SPHERIC Steering Committee, Dr. David Le Touze (Ecole Centrale Nantes, France), gave an overview of recent activities and the present status of the growing SPH European Research Interest Community. The scientific part of the workshop was structured into 18 sessions, among them one poster session, which provided an overview of the recent advancements of SPH. Each session involved three 15 minutes oral presentations and a joint 15 minutes discussion at the end of the session. Topic sessions involved Numerical Aspects of SPH, Scale-Resolving Turbulence Simulations, Particulate Flows, Geotechnical Applications, Fluid-Structure Interaction, Hardware Acceleration and GPU Computing, Maritime and Coastal Engineering, Hydraulic and Environmental Flows, Boundary Conditions, Adaptive Resolution Techniques, Complex Applications and Non-Newtonian Flows.

The first days of the workshop were opened by two outstanding keynote lectures. The keynote of Prof. Seiichi

Koshizuka from the University of Tokyo (Japan) was devoted to the recent advancements of the Moving Particle Method - which has strong links to SPH - and grand-challenge applications of particle simulation methods, i.e. nuclear engineering and virtual reality simulations. Prof. Volker Springel from the University of Heidelberg showed us many billion particle simulations of cosmic structure formation problems using SPH and an interesting new approach to combine meshless and mesh-based methods.

At the end of the second day, a conference banquet took place at a shipyard in the harbour. During the banquet, the Larry Libersky student prize was awarded to Mr. Christian Ulrich from TUHH for his paper on a variable resolution technique for water/soil-flows and the organiser of the 7th SPHERIC workshop, Prof. Joe Monaghan from the Monash University (Australia), briefly introduced the location of the next workshop in Prato, Tuscany (Italy).

Scientific Conclusions

It was clearly seen that the method has considerably matured and the range of practical SPH applications to sub-micro-scale to macro-scale problems is rapidly growing. Prominent examples outlined during the workshop referred to tsunami and flooding simulations, cosmic structure formation, wave-energy generation, slamming loads on maritime structures, geotechnical multi-physics problems, virtual reality simulations, swimming fishes, material fracture, lavastream flows, explosion simulations and simulations of pedestrian crowds. Due to the large computational effort, a significant portion of the presentations was concerned with high performance computing with emphasis on GPU computing and the use of multiple GPU arrays. A number of contributions did show noticeable advancements on the formulation of appropriate boundary conditions for both fundamental and practical applications, such as RANS-based complex multi-physics flows at very large Reynolds numbers. Improvements were also reported for scale-resolving, direct and large-eddy turbulent flow simulations . Moreover, an increase of activities was observed in the area of variable and dynamic resolution as well as dimension reduction approaches, both aiming at drastic reductions of the computational cost.

Acknowledgements

In line with the constant growth of the SPHERIC workshop, the organisation certainly became more demanding. The 6th SPHERIC workshop was made possible by the generous financial support provided by Deutsche Forschungsgemeinschaft (DFG) which is greatly acknowledged. We are also indebted to the ERCOFTAC organisation for sponsoring the student participations.

Instabilities and Transition in Three-Dimensional Flows with Rotation

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Motivations and objectives

Shear flows are known to display a variety of spatiotemporal instabilities and complex transition scenarios. The route from a laminar flow to a fully turbulent regime cannot be understood without taking into account three-dimensional efects. Particularly interesting efects are observed in the presence of rotation either external, through rotating bodies, or internal, through largescale vorticity. Recently, our understanding of such flows has been improved by technical advances in analysis and experiment and a vast increase in computing resources. This allows to consider increasingly complex mean flow distortions, in which the additional complexity brought by three-dimensional coupling is approached with diferent techniques in the communities of hydrodynamic stability and turbulence, which can however be compared and, whenever possible, linked.

By bringing together experts in experimental, numerical and analytical approaches, this colloquium aimed at clarifying the global picture prevailing near transition and to narrow the gap between stability and turbulence analyses. It is expected that the development of modern analytical tools will suggest new experiments, and that novel experimental observations will in turn inspire more theoretical work.

Contributions have been received, among others, from the following topics:

- Three-dimensional boundary layers
- Flows around or inside rotating bodies
- Vortex breakdown
- Spatio-temporal development of perturbations
- Transition scenarios
- Control
- Transient phenomena
- Inhomogenous and anisotropic turbulence

A hardcopy of the book of abstract was handed out during the colloquium. It is now available as open archives [1]. The complete programme can be viewed on the colloquium's website [2].

Contents of the talks

The colloquium took place in Ecole Centrale de Lyon, and attracted more presentation proposals than could fit in the available time slots. The number and quality of submitted abstracts was such that the organizing committee decided early on to have the colloquium over three full days. Finally, the programme could accomodate six keynote lectures and thirty-eight regular presentations, in six half-day sessions. As expected, contributions spanned a wide range of themes related to flows three-dimensionality and the effect of rotation, giration, swirl, etc., in fluids. Various approaches were presented, from theoretical hydrodynamic stability analyses looking at the evolution of small perturbations in different base flows and the global or local nature of the possible instability to fully turbulent flows in various settings. Some talks were devoted to the passage from laminar flows to turbulent states, regarding complex transition scenarios. In addition to analytical methods, numerical and experimental approaches were also exposed. Several contexts were considered: homogeneous or shear flows in academic settings were used as simplied models permitting refined dynamical analyses, while 'natural' contexts were of course studied, since rotation plays a role in environmental and geophysical flows. More applied or industry-related flows also lead to a number of interesting studies.

Figure 1: Photograph of the participants during the colloquium

The colloquium began with rotating disks and other three-dimensional boundary layer instabilities. Rotating disks generate boundary layers that bear lots of similarities with swept wing boundary layers, and can be set up experimentally, thus allowing direct measurement of the different stages of the developement of the instability. In addition, the convective/absolute character of the instability has been fully characterized, and the rotating disk boundary layer is now amenable to active control. An interesting question was raised however during the colloquium about the influence of the boundary conditions at the outer edge of the disk, which may act on the upstream flow.

Another category of flows in which rotation effects are felt includes swirling flows, and the breakdown of vortices. Spiral vortex breakdown was studied by, and the effect of density onto vortex breakdown was also presented. As regards shear flows, the case of the jet was especially investigated, including the swirling jet by a local linear analysis, or Large Eddy Simulations of a jet, including the modelling of the nozzle. Compressible effects and the acoustic emission of flow structures were also considered in some talks. A lively presentation by demonstrated intriguing patterns during the segregation of particleladen flows, in an experimental study, while sophisticated numerical techniques for computing rotating cylindrical flows with embedded solid particles were also presented.

An important feature present in rotating or swirling flows, is helicity or helical motion, which certainly deserves an increased attention from the scientific community. Helicity is of course of great importance in magneto-hydrodynamics and in the context of dynamo action, and can also be studied from the point of view of symmetries or serve as grounds for developping new theory.

Several contributions to the colloquium showed state-of-the art analyses of instability growth, thus demonstrating that the corresponding theory is rather advanced and well-developped. Among others, one could follow the instabilities in a rotating torus, in Taylor-Couette-Poiseuille flows. Thermal effects can also be considered in some settings, as in vertically differentially rotating cylindrical annulus with radial temperature gradient or the detection of baroclinic wave interactions in thermally driven rotating annulus. At larger scales, as in geophysical flows, instabilities are also important with three-dimensional inertial effects, as in the sub-mesoscale ocean.

On the other end of the rope, turbulence sumitted to rotation has been studied for decades and is still a somewhat controversial subject, regarding its structure and dynamics, and how to account for the anisotropy generated by the Coriolis force. Experiments or numerical approaches were presented for grid turbulence and regarding flows forced by mobile boundaries, most often enclosed in containers, either in the context of the now famous von Kármán flow (the "french washing machine") or in Taylor-Couette flow.

Finally, another flow category which is extensively studied is internal shear flows, especially the channel flow case (plane Couette or Poiseuille case), in which the addition of rotation can be either in the transverse direction in that case the background vorticity adds up algebraically to the vorticity contained in the mean shear, or in the streamwise or wall-normal direction. Channel flow simulations were thus presented for fully turbulent regimes as well as for transitional regimes.

Final comments

The colloquium was focused on rather fundamental studies of the role of rotation and three dimensional coupling in laminar and turbulent flows. Classical hydrodynamic stability is indeed already diffcult when considering idealized contexts, so that complex geometries are less in the scope of such a meeting. However, the motivations of several of the participants stemmed from industrial preoccupations, and parts of the mechanisms found in e.g. rotating channel flows, Taylor-Couette flows with temperature gradients, or even homogeneous turbulence boxes with Coriolis effect, have direct implications in the modelling of rotating flows. Three-dimensional boundary layers over rotating disks, although studied in an academic context, have the same kind of instability mechanisms as boundary layers over three-dimensional topographies. Thus, we expect that models of less idealized flows, industrial or geophysical, will benefit from the rotating and stability community efforts.

Acknowledgements

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The Germany West Pilot Centre Report

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Organisation

As the successor of Prof. Norbert Peters, Prof. Schröder from RWTH Aachen University took the office as the Coordinator of the Germany West Pilot Centre in 2006.

The Pilot Centre Germany West mainly concentrated on advisory functions, e.g., for scientific events, promotion of young scientists, and fundamental fluid mechanics research.

The following list gives an overview of the activities of the PC Germany West.

Activities of the Centre

Participation in Scientific Events

The ERCOFTAC Pilot Centre Germany West was involved in several scientific events in a consultative function during the last five years. In the following, a list of exemplary scientific events with participation of the PC Germany West is given. Please note that, in general, the conferences were organized by the respective organizations.

2008 *DGLR STAB Fachsymposium of the German Society for Aeronautics and Astronautics, November 3-4, 2008, Aachen.*

On the initiative of the German Society for Aeronautics and Astronautics, the "Deutsche Strömungsmechanische Arbeitsgemeinschaft, STAB" was founded in 1979. Its primary goal is to boost the German research on fluid mechanics, aerodynamics, and aerospace engineering in German universities and industry. In the two-day event, 140 scientists participated in 24 sessions. The major topics having been addressed are: computational aeroacoustics, biofluid mechanics, experimental analysis and measurement techniques, vehicle aerodynamics, flow control, transition, computational fluid dynamics, and turbulence.

2009 *2nd Aachen Symposium on Natural and Artificial Respiration in the context of the DFG Research Program "Protective Artificial Respiration" November 23-24, 2009, Aachen.*

In 2005, the German Research Association DFG launched the research program "Protective Artificial Respiration" which is a joint initiative of scientists from medicine and fluid mechanics. The main long-term objective of this program is the development of a more protective artificial respiratory system to reduce the physical stress of patients undergoing artificial respiration. To satisfy this goal, 14 projects were defined in the proposal. In each of these projects scientists from medicine and fluid mechanics do collaborate in several experimental and numerical investigations to improve the fundamental knowledge on respiration and to develop a more individual artificial breathing concept. The event was attended by 60 participants from all over the world.

2010 *TMFB International Workshop of the Cluster of Excellence "Tailor-Made Fuels from Biomass", June 23-24, 2010, Eurogress Aachen.*

The Cluster of Excellence "Tailor-Made Fuels from Biomass" adopts an interdisciplinary approach towards research of new, biomass-based synthetic fuels to reduce the dependence on fossil energy sources. Optimized synthesis processes will be applied and the potential of the fuels especially with regard to modern combustion technologies will be investigated. The long-term goal is to determine the optimal combination of fuel components and their production processes, which are based on renewable raw materials and new combustion processes. The 3rd workshop consisted of 17 presentations and more than 50 scientists participated in the discussions.

2011 *2nd Joint Korean-German Workshop on Aeroacoustics, February 18, 2011, Aachen.*

The Workshop is part of the bilateral cooperation "Numerical Investigation of Active/Passive Controls for Airframe Noise Reduction". The main objective of this cooperation is to develop an outstanding expertise in noise reduction concepts via a long-term bilateral cooperation between German and Korean Universities. The Workshop included presentations from RWTH Aachen University, DLR, and the Korea University in the field of noise prediction, noise generation, and aeroacoustic design.

Cooperation/Young Scientists

In 2008, the Ministry of Innovation, Science, Research and Technology of the German federal state North Rhine-Westphalia (NRW) established the "NRW research schools" to set up structured training programs for graduate students. One primary focus of this initiative is on cluster-programs in energy research. The NRW research school "Fuel production based on renewable resources" started in October 2008 and focuses on the interdisciplinary education of young scientists in the fields of biology, chemistry, and engineering with a special focus on fuel production and fuel efficiency. The 2011 summer school of the research school will be organized in close cooperation with the PC West.

Activities of Members

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

- fundamental and applied fluid mechanics (turbulence, aerodynamics, vortex dynamics);

- bio-medical flows;
- multiphase flows;
- measurement methods;
- computational fluid dynamics and computational aeroacoustics;
- simulation of premixed combustion in Otto engines;
- simulation of Diesel-engine combustion;
- Engine Experiments;
- energy and process engineering;
- contact heat transfer;
- combustion in engines;
- heat transfer in falling films;

Outlook

In 2010, Prof. Nicolas Gauger, coordinator of the ERCOFTAC Pilot Centre North, moved to RWTH Aachen University and now is Head of the Computational Mathematics Group in the Department of Mathematics and Center for Computational Engineering Science (CCES) of RWTH Aachen University. Up to now, Prof. Gauger is still acting on behalf of DLR as coordinator of the PC Germany North. Prof. Gauger and Prof. Schröder agreed to join the two PCs Germany North and West with Prof. Gauger as the coordinator of the new PC. After the merger of the two Pilot Centres, the new Pilot Centre will re-organize its structure and website according to the new ERCOFTAC template.

The Italian Pilot Centre Report

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1. Introduction

In respect of the ERCOFTAC scientific objectives, the creation of pilot centres (PC) in many European countries is an essential tool for the fulfilment of the exchanging of technical and scientific information concerning basic and applied research and the development, the validation and maintenance of numerical codes and databases, and thus strongly promoted. According to the previous mentioned objectives the Italian Pilot centre was proposed in the early 1999 and started its activities in the late 2000 year. This document represents the second presentation of the PC since the establishment.

2. PC organisational structure

The Italian Pilot Centre includes most of the major Italian research centres active in the fields of interest normally sponsored by the ERCOFTAC, ranging from fluid dynamics, aerodynamics to combustion. These centres, with the related scientific leaders are:

- Energetics Dept. - University of Florence (DE); Prof. Francesco Martelli; Prof. Gian Paolo Manfrida; Prof. Maurizio de Lucia
- Dipartiamento di Ingegneria Meccanica per l'Energetica, Universitá degli Studi di Napoli "Federico II,"; Professor Marcello Manna
- Mechanical Engineering Dept. - University of Trieste (UNITS); Prof. Carlo Poloni
- Energetics Dept. - University of Genova (DIME); Prof. Pietro Zunino; Prof. Ferruccio Pittaluga
- Mechanical Engineering Dept. - University of Roma I (DIMEI); Prof. Renzo Piva; Prof. Franco Rispoli

Together with these research centres, and in co-operation through contracts and common research projects, industrial partners are present, mainly involved in Gas Turbine steam production and power plants:

- " ENEL Engineering and Innovation"; Eng. Nicola Rossi, Eng. Iarno Brunetti
- CIRA - Italian Aerospace Research Center; Eng. Francesco Capizzano

Italian Pilot Centre is coordinated by Prof. Francesco Martelli, Energetics Dept. of the University of Florence, since the PC establishment in year 2000.

The following PC representatives are appointed to the ERCOFTAC managing bodies:

- Managing Board: Prof. Francesco Martelli (Research), Carlo Poloni
- Scientific Programme Committee: Prof. Franco Rispoli
- Industrial Programme Committee: Dr. Carlo Poloni

3. Research activities and expertise of the PC members

3.1 Energetics Department, University of Florence

Staff: 3 Full Professor, 3 Assistant Professor, 3 Research Assistant, 5 Post Doc Researchers, 10 PhD Students.

The TEEG (Turbomachinery, Energy and Environment Group) activity ranges from turbomachinery to environment, while MTB (Measurement Technique Branch) group focuses on advanced measurement systems for turbomachinery component investigation.

Turbomachinery

Most part of the CFD activity is based on the in house Advanced solver, *HybFlow*, a new generation unstructured code for internal and external aerodynamics. This code is continuously improved with up to date turbulence models and heat transfer facilities. The other in-house developed code HybFlowCHT is able to analyse both fluid and metal.

One of the most important topics in turbomachinery analysis is the study of the unsteady interaction in turbine stages. Due to the limits imposed by the classical scaling approach, the code has been modified to manage with unfavourable blade counts by means of a phase lag approach based on the theory by Erdos and He. The method has been tested and validated on a 2D case representing the mid-span of a transonic stage experimentally tested at the von Karman Institut.

Film cooling analysis represents another important task to be addressed. The increase of turbine inlet total temperature generates hot spots whose redistribution across the high pressure stages is harmful for rotor thermal cycle. Then, this point has been extensively analyzed in collaboration with international partners. The film cooling configurations are also addressed from an aerothermal point of view. For this reason the interaction between the cooling flow on the suction side of a vane and the oblique shock coming from the adjacent blade has been studied in a simplified environment. Furthermore, the cooling system of a turbine vane has been studied considering showerhead and trailing edge cooling configurations. The performances of a platform cooling configuration proposed by EPFL have been also studied to individuate its effectiveness and the accuracy of steady CFD when reproducing this kind of geometrical solutions.

Talking about accuracy, the importance of individuating the quality of the performed CFD is another key point of the upcoming numerical activities. A study on the geometrical effects has been realized with special attention to the presence of fillets and the tip clearance shape, and a methodology based on a statistic approach has been proposed. Also blade fillet and cavity flows problems are addressed.

Considering flow control, the possibility of governing the flow behaviour in the gap region of turbine stages by means of trailing edge cooling is under investigation on a simplified case. Numerical and experimental analyses on a real blade are also under consideration. Investigation on the control of boundary layer development is a promising strategy to obtain improvement in performance. Passive and active devices are common technologies investigated to this purpose. The synthetic jet (SJ) is a zero-net mass flow control active device which is meant to re-energize the boundary layer in order to render it more resistant to the adverse pressure gradient.

In the Field of hydraulic machine the Group is still active in analysing Complex Pumps Geometries and Regenerative Compressors, in steady and unsteady condition.

In the Field of hydraulic machine the Group is still active in analysing Complex Pumps Geometries (residual axial thrust and the cavitation problems) and designing Regenerative Compressors (by using in-house and commercial tools), in steady and unsteady condition.

We also carry out theoretical and experimental analysis on noise emissions of civil aircraft engines. Namely, through the development of new engine architectures (high by-pass ratio) noise from the fan and jet has been reduced significantly and the contribution from low pressure turbine (LPT) has become relevant. In such a scenario the experimental investigation plays a fundamental role to improve the physical understanding of the noise generation and transmission mechanisms, as well as to support the validation of numerical analysis tools. These reasons motivated the development of a wind tunnel in order to investigate the noise generated by a turbine stage; for the purpose, advanced noise measuring techniques and data processing tools have been developed.

Fluid mechanics

Current Reynolds-averaged Navier-Stokes (RANS) simulation methodology for high speed turbulent flows lacks important capabilities in predicting the physical behavior of several flow configuration. High Reynolds number (Re) turbulent flows contain a broad range of scale of length and time. The largest length scales are related to the flow configuration geometry and boundary conditions whereas it is principally at the smallest scales thet energy is dissipates by molecular viscosity. Subgrid scale models are needed to ensure the accurate computation of the largest scale (grid-Scale) resolved motions responsible for the primary jet transport and entrainment. Simulation that capture all the relevant length scales of motion thought numerical solution of the Navier-Stokes Equation (NS) are termed Direct Numerical Simulation (DNS). DNS is prohibitively expensive, now and for the foreseeable future for most practical flows of moderate to high Re. Large Eddy Simulation (LES) is an alternative both to RANS and DNS methods which provides to prediction smaller vertical structures. TEEG group focuses his attention in developing a Large Eddy Simulation algorithm converting an operative in-house Unsteady-RANS solver, widely validated for applicative purpose, into higher-accuracy DES and LES, in order to face turbulence computation of turbomachinery technical cases.

Renewable energy

The research was performed under contract with En-Eco, a small company starting production of a small (H-rotor) Vertical Axis Wind Turbine. A computer code for the design of VAWTs was developed, based on the aerodynamic coefficients and allowing selection of different approaches to flow modelling (Single/Multiple Steam Tube, Double Actuator Disk, Cascade Model; including effect of Reynolds on the variation of aerodynamic coefficients and dynamic stall). The predicted performance was compared to existing published data. An original measurement technique for verification of performance in a downscaled (1:3) operating wind tunnel model was developed, and validated against open-field test data. Systematic research on different airfoil profiles, aerodynamic appendices etc. was run in the wind tunnel. The experimental research was performed in the CRIACIV environmental wind tunnel facility (Prato, Italy).

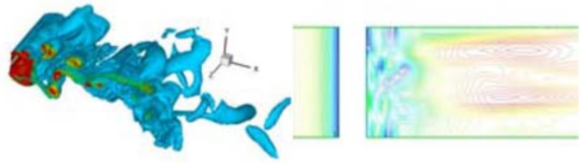

Figure 1: Iso-vorticity around square cylinder and Mach number iso-lines in spanwise direction

The research group is developing a design tool for the preliminary design of radial turbo-expanders, to be employed in small CHP system using low-grade heat and Rankine (organic or engineered fluid) cycles. The model includes loss correlations working also with backswept blades, extending thus the traditional design rules based on NASA experimentation, which have led most producers of these equipments to radial inlet blades. This advanced design can lead to significant improvements of these machines, which in the low power range offer much better performance than the traditional scroll or volumetric expanders. Develop and Experimental analysis on concentrated solar system for hybrid Photovoltaic and Thermal applications.

Combustion

The research activity regards mainly detailed study on specific components with special attention to the gas turbine combustion chamber. Numerical simulation, code development and experimental activity, cooperating with industrial partner, are the main tools employed.

The activity can be summarised in the following points:

- Study of power plant thermodynamic cycle fired by renewable fuel
- Retrofit of heavy-duty gas turbine combustion chamber to reduce pollutant emissions
- Retrofit of micro gas turbine combustion chamber to use biofuel
- Optimisation of modern gas turbine combustion chamber equipped with premixing burners
- Application and development of research of 3-D CFD for non-reactive and reactive aerodynamic simulation
- Development of reactor network approaches focused on detailed chemistry to be used coupled with CFD numerical simulation and/or experimental activity
- Development and improvement of dedicated codes as tools to the design of sub-component for gas turbine combustion chambers

- Modifications for combustion chamber 100% hydrogen fired in dry operation in order to reduce the NOx production, development of new injection system using CFD RANS

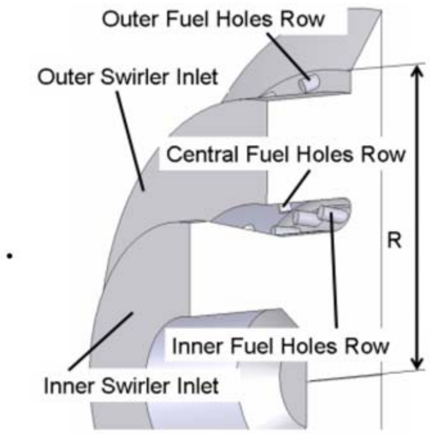

Figure 2: Injection system of Modified combustor

- Development of a prototype hydrogen fuelled premixer using CFD and experimental analysis. Study of different injection system: cross-flow and co-flow types, effect of dimension of dimension and position of injection holes, Swirl configuration

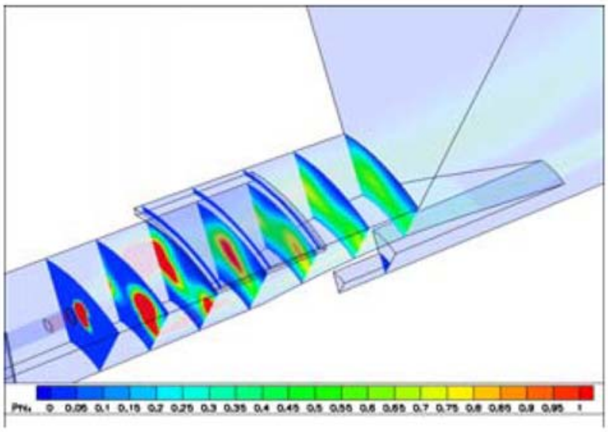

Figure 3: Equivalence ratio maps on several crossing sections of the burner prototype

- Study of the aerodinamics of micro gas turbine to individuate the modifies for the using of bio-fuel like vegetal oil or pyrolysis oil
- Evaluation of quality of modifies development of combustor, evaluation of NOx emission
- Instability analysis of an industrial combustor prototype: define a 1D numerical procedure for thermoacoustic analysis with good agreement with experimental data

Experimental

An experimental activity exists, aiming to perform analysis and interpretation of the experimental data in conjunction with the numerical simulation results. These may be summarised in the following points:

- Aerodynamic test on cold-flow through industrial combustors

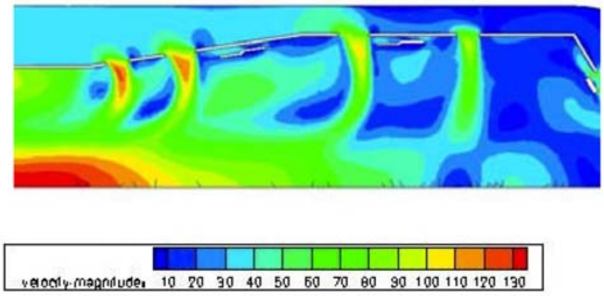

Figure 4: Field of velocity magnitude in Micro gas turbine combustor

- Experimental activity on atmospheric pressure and full-pressure combustor test rigs to test heavy-duty gas turbine combustion chambers
- Experimental activity on micro gas turbine fuel by bio-fuel
- A recent activity regards the operating conditions effect on a gas turbine DLN burner performances aiming to evaluate the impact of hydrogen contents of fuel on the combustion instability and emissions of NOX, about the flash-back events.

3.2 Dipartimento di Ingegneria Meccanica ed Energetica - Università di Napoli Federico II

Staff: 2 Professor, 1 Research Assistant, 1 PhD Students

Spectral-multi-domain methods in cylindrical geometries

- Trigonometric polynomials in azimuthal and axial directions
- Chebyshev polynomials in radial direction
- Analytic expansion of the harmonic extension
- Pole singularity
- Direct Numerical Simulation
- Large Eddy Simulation

Preconditioned spectral-multi-domain methods in cartesian geometries

- Weak Legendre method
- Iiterative solution of the Schur complement matrix
- A nearly optimal method in terms of condition number behavior
- Direct Numerical Simulation

Spiral Taylor-Couette flows

- Direct numerical simulation
- Torque reduction phenomenon

3.3 Energetics Department, University of Genova

Staff: 3 full professors, 3 research assistants, 5 post-doc research engineers, 5 phD students

The main research activities in which the group is involved are hereafter listed:

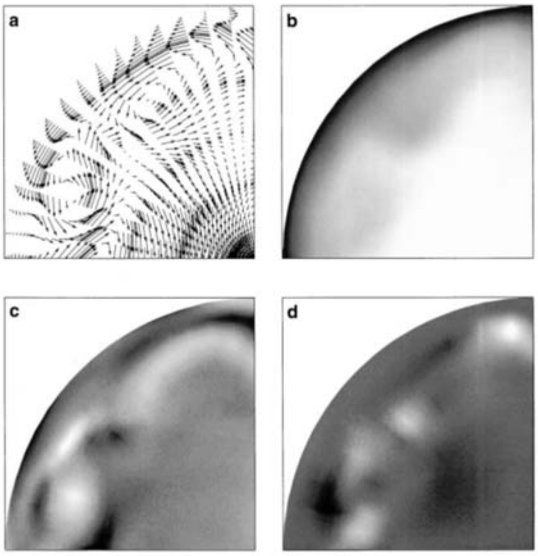

Figure 5: Equilibrium Turbulent pipe flow at Rb=2500. Instantaneous velocity vectors (a), streamwise velocity u (b), streamwise vorticity wz (c), and shear stress uv (d)

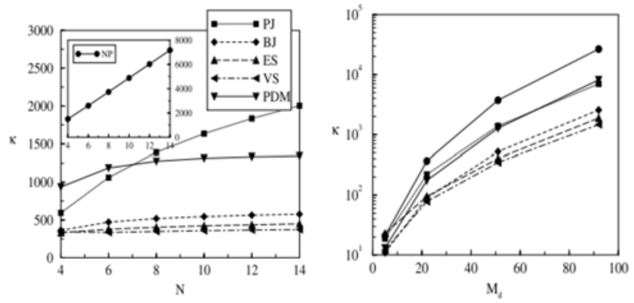

Figure 6: Condition number versus the number of Legendre modes for Md =51 (left) and versus the number of subdomains for N=8 (right). Unpreconditioned (NP). Point Jacoby preconditioner (PJ). Block Jacoby preconditioner (BJ). Edge-Space preconditioner (ES). Vertex-Space preconditioner (VS). Projection Decomposition method (PDM)

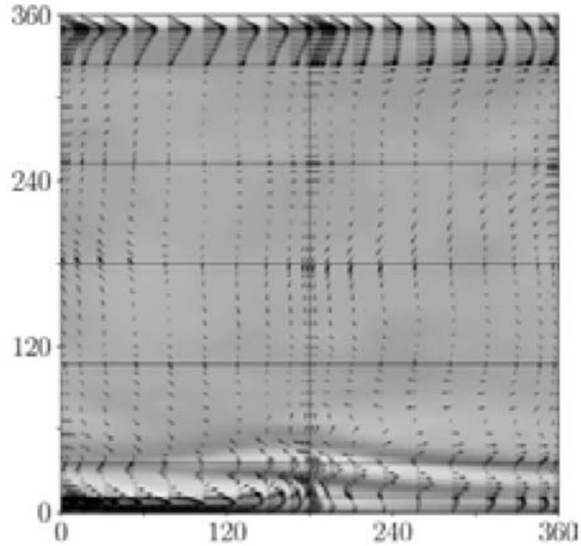

Figure 7: Equilibrium turbulent channel flow Rt=180; instantaneous velocity fluctuations superposed to spanwise vorticity shaded contours in an x-y plane.

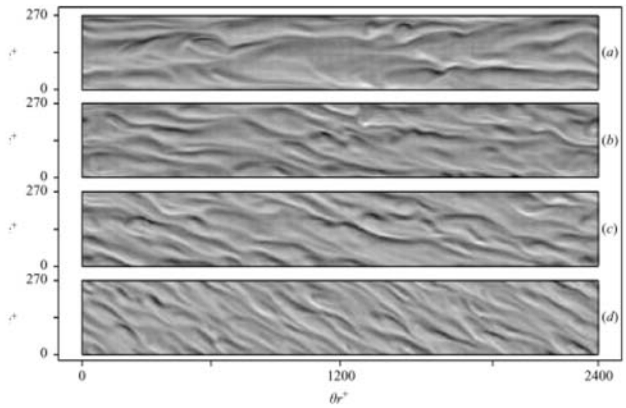

Figure 8: Instantaneous shaded map of ωr+ in the θ-z plane in inner coordinates at y+ = 5 (Ta = 1500): (a) Re = 0, (b) Re = 50, (c) Re = 100, (d) Re = 200.

Experimental investigation and control of boundary layer transition and separation processes under strong adverse pressure gradients, typical of new generation Ultra-High-Lift low pressure turbine blade profiles (in cooperation with Avio, in the framework of TATMo European Project and the Research Project of National Interest PRIN 2007):

- Study of the separated flow transition process to identify instability mechanisms inducing transition
- Investigations of the unsteady transition induced by upstream periodic wakes
- Boundary layer laminar separation control by means of synthetic jet (active device with zero net mass flow rate)
- Analysis of the interaction mechanisms between jet and main flow under steady inflow
- Study of the syncronized forcing effects due to both incoming wakes and synthetic jet, aimed at further reducing the unsteady separation growing between adjacent incoming wakes without control.

Experimental investigation of coolant-main flow aerodynamic interaction in turbomachinery components:

- Secondary flow field analysis and control in a large scale high-pressure turbine cascade with advanced endwall effusion cooling system (in cooperation with Avio in the framework of AITEB-2 European Project)
- Rotor-stator aerodynamic interaction on a large-scale two-stage axial research turbine with coolant ejection from cut-back blade trailing edges (supported by MIUR "Italian Ministry of Education, University and Research" through the PRIN 2007 Research Program)

Analysis of the wake shed from a high-lift low-pressure turbine blade under steady and unsteady inflow conditions (in cooperation with Avio):

- Study of the influence of the suction side separation bubble on the wake development under steady inflow conditions

- Investigation of the effects induced by the upstream row wakes on the vane wake development under different operating conditions

Active and passive wake control on turbine blades aimed at tone noise reduction (in cooperation with Avio, in the framework of the VITAL European Project). We carried out a detailed experimental investigation of the effects induced on the wake by:

- the application of a crenulated trailing edge
- the injection of air through discrete holes applied at the blade trailing edge
- the boundary layer suction along the suction side rear part

Numerical and experimental investigations on combustion instability phenomena in gas-turbine premixed burners for heavy duty and aero-engine applications:

- Experimental investigations on fluid-dynamical and thermo-acoustical stability characteristics of the combustion-process taking place within the heavy duty AE64-3A gas turbine burner-combustor systems (in cooperation with Ansaldo Energia)
- Numerical (NastComb code) and experimental characterization of fluid-dynamics-driven combustion instabilities within a prototypical Avio-designed LPP burner (Lean Premixed Prevaporised) for aero-engine applications (in cooperation with Avio, and also in the framework of TLC European project)
- Quasi-inverse design of different premixed burners, gas- or liquid-fueled, characterized by stable flame processes
- LRPM (Liquid fuel Rapid Pre-Mix) ultra-low NOx burner, designed at DIMSET/SCL, taking advantage of indications from the University of Leeds, Department of Fuel and Energy (in cooperation with Ansaldo Energia)
- GRPM (Gas fuel Rapid Pre-Mix) ultra-low NOx burner, designed at DIMSET/SCL
- Avio LPP premixed prevaporised burner (in cooperation with Avio)

Wood thermal pre-treatments, combustion and gasification technologies for enhanced renewable energy generation:

- Experimental investigation on wood torrefaction processes for increasing the heat value of wood and enhancing its utilization as an energy-rich fuel (supported by Liguria Region)
- Theoretical and experimental characterization of wood (and torrefied wood) gasification technologies for distributed energy generation (supported by Liguria Region)
- Micro- and nano-particulate emissions from biomass combustion and inceneration processes (supported by IIT, Italian Institute of Technology, in the framework of INESE Project)

3.4 Fluid Mechanics, Dipartimento di Ingegneria Meccanica e Aerospaziale (DIMA), Università la Sapienza di Roma

Staff: 3 Full Professors, 1 Associate Professor, 1 Assistant Professor, 1 Research associate, 4 PhD students.

Our research interests include:

Particle-laden turbulent flows

Pipe flow:

- DNS of a spatial developing particle-laden pipe flows
- Analysis of the turbophoresis (mean drift of small particles towards the wall) both in the developing phase and in the asymptotic state of a pipe flow

Incompressible Jets:

- DNS of a particle-laden jet
- Analysis and description of particle transport in turbulent jets
- Effect of the particulate phase on

Premixed turbulent flames:

- DNS and experiments of a particle-laden Bunsen premixed flame
- Analysis and description of particle transport in flames
- Determination of appropriate PIV-seeding characteristics for accurate velocity measurements of premixed flames

Homogeneous Shear Flows:

- DNS and experiments of particle-laden homogeneous shear flows
- Analysis of the geometrical properties of particle clustering and of particle relative velocity

Microbubbles in Turbulent Flows

- Experimental investigation in a towing tank for ship drag reduction
- Experimental analysis of turbulence modulation in a homogeneous shear flow

Turbulent reactive Flows

Premixed regime:

- DNS and experimental investigation on the geometrical (fractal) features of premixed flames
- LES modelling of premixed flames using the fractal features of the premixed front
- Interaction between turbulence and flame front
- DNS of 3D Bunsen flames with detailed chemistry

Micro/Nano fluidics

Binary flow interfaces:

- Macroscopic simulations using diffuse interface methods
- Analysis of contact angle effects on the flows
- Molecular Dynamics simulation of binary mixtures

Liquid slippage in nano/microchannel:

- Molecular Dynamics simulation of liquid slippage on hydrophobic surfaces
- Slippage on nano/micro patterned surfaces
- Cassie-Wenzel transition for super-hydrophobic surfaces

Transport in nanochannels:

- Molecular Dynamics simulation of liquid transport through nanochannels
- Protein and polymer translocation thought nanopores

3.5 Thermo-Fluid Dynamic of Thermal Machines, Sapienza Università di Roma

Staff: 1 full Prof., 2 Associate Professors, 1 researcher, 3 Post-Docs.

In the last two years, the research activity at DIME has been focussed on different topics of fluid turbulence, namely:

Numerical Methods for Turbomachinery CFD

Stabilized Finite Element Methods:

- Petrov-Galerkin techniques for advection-diffusion SUPG/PSPG and a SPG for reaction
- Variational Sub-Grid-Scale model for compressible and incompressible flows

Finite Volume Method and High Performance Computing:

- Development of unstructured parallel solvers in F90 and C++ language
- Tailoring of Open Source HPC libraries and solver (LIBMESH, OpenFOAM)

Turbulence Modelling and Simulation for Turbomachinery Related Flows

LES Large Eddy Simulation:

- LES of flow and heat transfer in complex geometries of turbomachinery interest using second order accurate (in space and time) numerical solver and dynamic Smagorinsky SGS
- Analysis and development of innovative mixed similarity SGS schemes

URANS:

- URANS and heat transfer simulation of turbomachinery flows using innovative elliptic-relaxation based eddy viscosity closure ($k - \epsilon - \zeta - f$)
- Development of a non linear (quadratic or cubic) elliptic relaxation $k - \epsilon - \zeta - f$ model

Hybrid LES/RANS and 2nd generation URANS:

- Development of an innovative seamless hybrid LES/RANS closure based on $k - \epsilon - \zeta - f$ URANS model and dynamic SGS
- Analysis and development of Partially Averaged Navier Stokes and Instability Sensitized SAS models for turbomachinery applications

Analysis of Particle Laden Flows, Deposit and Erosion Mechanisms

Development of a Lagrangian Solver for Two-Phase Flows (solid-fluid):

- Analysis and development of numerical tools for the solid fuel combustion and the related emission of heat, hot gases and solid ashes
- Particle tracking of ashes in biomass furnaces using statistical cloud approach and tracking of single particles

Modelling and Simulation of Deposit and Erosion Mechanisms in Industrial Equipments:

- Analysis and implementation of advanced impact models of particles on solid surfaces
- Fouling and erosion mechanisms in biomass furnaces, compressor cascades and axial flow compressors
- Erosion in induced draft boiler heavy duty fans

CFD analysis of industrial turbomachinery flows

- CFD analysis and design of an improved geometry of a Integrated Collector Storage solar system
- Investigation on stall-resistant Wells turbine rotor under pulsating inflow
- U-RANS of industrial fans

Aero-acoustic analysis of turbomachinery

- Development of passive noise control blade-tip technologies
- Development of measurement technique for aeroacoustic noise source detection in turbomachinery rotors
- Acoustic stall warning in a low speed axial fan
- Tonal noise prediction in transonic high pressure turbines

3.6 Mechanical Engineering Department, University of Trieste

Staff: 1 Associate Prof., 1 Researcher, 1 Reserch assistant, 2 Phd students.

The main Research activities of the Group relates to Optimisation Methods for multidisciplinary Design, with particular attention to:

- Multiobjective Evolutionary algorithms and classical algorithms
- Interpolation/Approximation techniques (Neural Networks, Gaussian Processes, etc.)
- Game Theory applied to Design Problems
- Decision Making tools
- Optimization under uncertainties
- Visualization in multi dimensional space

3.7 ENEL Produzione-Ricerca

CFD modelling applied to industrial power plants issues

Commercial and homemade codes with RANS/URANS approaches are used for the applications listed below:

Gas turbine combustors

- Development of Low NOx hydrogen combustors
- Improvement of environmental performances and combustion stability of natural gas fired combustors

Furnaces and steam power plants

- Validation of homogeneous and heterogeneous combustion sub-models (with both air and oxygen comburent) on the base of experimental data coming from pilot-scale furnaces and drop tube reactor owned by Enel

- Improvement of environmental performances of coal/oil large-scale steam boilers
- Fluidynamic optimization of flue gas ducts and components for both large-scale coal and geothermal power plants

Experimental investigations

Several experimental facilities, installed in two research areas located in Tuscany, are used to perform investigations on:

Gas turbine combustors

- Development, characterization and verification of gas turbine burners in full-scale full-pressure conditions
- Application of optical diagnostic techniques for the characterization of aerodynamics, mixing and flame structure in atmospheric conditions for several gaseous and liquid fuels

Steam boiler combustion

- Steam boiler burners are tested in a semi-industrial scale furnace with the aim to improve the environmental performances of combustion systems, to characterize innovative fuels (rdf, biomass, bio-oils) and to develop new combustion techniques (like oxy-combustion) aimed at reducing CO2 emission from fossil fuel power plants
- Solid fuels characterization by means of a drop-tube reactor
- Characterization of liquid fuel atomizers

3.8 UTTEI-COMSO (Sustainable Combustion Laboratory) - ENEA

Staff: 21 researchers,16 technicians, 2 internships.

Research domains include:

Plants and Processes

- 100 kWt MICOS plant, equipped with a Trapped Vortex Combustor (burning natural gas)
- 100 kWt IDEA plant (burning hydrogen)
- 1 MWt COMET plant (up to 8 bar), equipped with the ANSALDO V64-3A burner (burning hydrogen)
- ZECOMIX plant, for CCS technologies analysis and development

Experimental Diagnostics of Turbulent Combustion

- Laser velocimetry (LDA, PIV, PDA)
- Laser spectroscopy (CARS, RAYLEIGH, LIF) for temperature and species measurements
- Synchronized PIV-LIF system
- Instability detection and monitoring by means of ODC (Optical Diagnostics of Combustion - ENEA's patent) based on photo-diodes

Modelling and Simulation of Turbulent Combustion

- RANS (based on the FLUENT platform) and LES (based on the in-house HeaRT code) methodologies
- HeaRT (Heat Release and Turbulence)
- compressible and incompressible, subsonic and supersonic, single- and multi-phase flows, reacting and not
- accurate modelling of molecular properties and transports
- chemical mechanisms in CHEMKIN format
- spark ignition module
- staggered finite difference - finite volume schemes
- structured grids in cylindrical and cartesian coordinates
- immersed volumes and boundaries for complex geometry treatment
- development of subgrid scale models
- domain decomposition methods & parallel solution techniques

3.9 CIRA Italian Aerospace Research Center

The mission of the laboratory is to define, develop and validate computational methodologies for fluid dynamics at subsonic, transonic and supersonic, hypersonic regimes including multidisciplinary effects (e.g. propulsion, ice, flow control). The final goal is to apply computational fluid dynamics (CFD) to the following research fields:

- Study of basic fluid dynamics phenomena to develop accurate modelling
- Compute aerodynamic performances of generic aircraft & rotorcraft including multidisciplinary effects
- Support Wind Tunnel Tests Preparation and Realisation and Extrapolation to Flight of Aerodynamic Data
- Develop technologies to improve aircraft aerodynamics performances (decrease drag, improve high lift performances, etc.)

Numerical methods for CFD

- Boundary elements (BEM)
- Inviscid analysis (EULER, Full Potential)
- Viscous analysis (BL, VII, TLNS, RANS, U-RANS)
- Rapid flow analysis (Immersed Boundaries)
- Turbulent flows simulation (LES, DNS)
- MDO environment and procedures
- Ice Accretion analysis (Euler and Lagrangian approaches)
- Surface/Domain modellers, Grid generators
- Post-processors (forces and moments book keeping)

4. Main RTD contracts/projects and international cooperations in the last two years

4.1 Energetics Department, University of Florence

- PRIN project number 2007R3AXLH supported by Italian Ministry of the University and Scientific Research (MIUR)

- 2005-2009: BIOMGT innovative small scale polygeneration system combining biomass and natural gas in a micro gas turbine
- Progetto FP6 REACt (Self-sufficient Renewable Energy Air-Conditioning system for Mediterranean countries), CREAR-UNIFI, DLR, Solitem and CDER (Marocco), NERC (Giodania) e ALMEE (Libano), two SC prototype plant in Mediterranean country with PTC and chiller H2O-NH3
- 2007-2009 Progetto di Ricerca - MATT "Sviluppo di cicli zero emission a combustione di Idrogeno" Progetto di Ricerca - MATT
- 2009-2011 Engine and turbine combustion of bioliquids for combined heat and power production (BIOLIQUIDS-CHP) - Funded under 7th FWP (Seventh Framework Programme)
- Progetto S.A.L.T.O (Solar Assisted CooLing Toscana) a prototype of PTC sola field for medium temperature application. The goal is to make SHC technology economically competitive without grant
- Progetto PRIN2007 SOLIDE, Partners (DE - UNIFI, Università di Bergamo and Università di Lecce) Comparison among SHC system based on various collector technologies: PTC and flat collector, NH3 and LiBr chiller
- ASsisted SolAr CooLing - Università di FirEnze, a SHC prototype based on commercial available technologies
- Progetto FP7 ALONE (smAll scaLe sOlar cooliNg dEvice), CREAR-UNIFI, RIELLO, EURAC, CLIMATEWELL, DLR, SOLITEM, SONNENKLIMA and AOSOL for SHC demostrating plant based on different technologies both for collector both for chiller. Bulding and monitoring of 2 demo plant with chiller NH3-H2O, H2O-LiBr and H2O-LiCl, coupled with flat and PTC sola field. Plant realized in Italia (Firenze e Bolzano). `www.aloneproject.eu`
- Progetto CESARE (Concentrated PV combinEd SolAR Energy system) a TPV prototype collector with fuel cells energy storage Progetto VITAL is an integrated Project co-funded by the European Commission within the sixth framework programme (2005-2010) under Thematic Priority 4: Aeronautics and Space
- 2009/2010: Contract with GE Oil&Gas "New working fluids for centrifugal compressor test stands", S.R. (Scientific Responsible) Prof. Giampaolo Manfrida
- 2009/2010: Contract with En-ECO SRL "Wind tunnel testing and models for small VAWT prototypes", S.R. (Scientific Responsible) Prof. Giampaolo Manfrida
- Contacts are active with the most important Research Institutes, Industries and Universities such as Von Karman Institute, Rolls-Royce, Muenchen Universitaet and Alston University

4.2 Energetics Department, University of Genova

- 2005/2010: UE Research Project AITEB2 "Aerothermal Investigations on Turbine Endwalls and Blades", S.R. Prof. Pietro Zunino
- 2005/2010: UE Research Project VITAL "EnVIronmenTALly Friendly Aero Engine", S.R. Prof. Pietro Zunino
- 2006/2010 UE Research Project TATMo "Turbulence and Transition Modelling for Special Turbomachinery Applications" , S.R. Prof. Marina Ubaldi
- 2008/2010 : Italian Relevant National-Interest Research Project 2007 "Experimental investigation of the boundary layer separation control on high-lift low-pressure turbine profiles by means of synthetic jets", S.R. Prof. Pietro Zunino
- 2008/2010 : Italian Relevant National-Interest Research Project 2007 "Experimental investigation of the aerodynamic interaction between trailing-edge cooling flow and main flow in a two-stage experimental turbine", S.R. Prof. Marina Ubaldi
- 2009/2012: UE FP7 Research Project H2-IGCC "Low emission gas-turbine technology for hydrogen-rich syngas", S.R. Prof. Ferruccio Pittaluga
- 2006/2012: Research contract with Ansaldo Energia on "Advanced lean-premixed, dry low-NOx combustor systems characterized by stable flame processes", S.R. Prof. Ferruccio Pittaluga
- 2010/2012: Research project INESE, supported by IIT, the Italian Institute of Technology, on "Impact of Nanoparticles in Environmental Sustainability and Ecotoxicity"

4.3 Fluid Mechanics, Dipartimento di Ingegneria Meccanica e Aerospaziale (DIMA), Università la Sapienza di Roma

- 2007-: Cooperation in "Particle in Turbulence", COST-Action MP0806
- 2009-: Grant winner PRIN (National Research Project Grant)

4.4 Thermo-Fluid Dynamic of Thermal Machines (TFDTM), Sapienza Università di Roma

- 2007/2010: Marie Curie Chair Project "COMSITA - Computational Modelling and Simulation for Industrial Thermo-Fluids Applications", Chair Holder Prof. Kemal Hanjalic, S.R. (Scientific Responsible) Prof. Franco Rispoli
- 2010/2011: Ricerca 2010 Grant-Sapienza Università di Roma "Development of integrated LES/particle laden flows modelling for the simulation of fouling and erosion in high temperature axial flow fan", S.R. (Scientific Responsible) Dr. Domenico Borello, Ph.D.
- 2006-2009, Development of new end-plate concepts for improved aero-acoustic signature in industrial fans, Fläkt Woods Ltd. Scientific Responsible, Prof Alessandro Corsini
- 2010-2011, Blade erosion prediction in heavy duty boiler fans. Fläkt Woods AB. Scientific Responsible, Prof Alessandro Corsini.

4.5 ENEL Produzione-Ricerca

- Project: "Development of hydrogen combustion zero-emission cycles" coordinated by ENEL with the involvement of GE Oil&Gas-Nuovo Pignone and several italian Univesities, partially funded by Regione Veneto

- Project: "Demonstration of large scale biomass co-firing and supply chain integration" (DEBCO project), European FP7 program UTTEI-COMSO (Sustainable Combustion Laboratory) - ENEA
- 3 Natioanl Projects with the Italian Ministery of Economic Development on Coal Technologies (CO2 capture and storage) and Combustion
- 2 National Projects INDUSTRIA 2015: Ecoappliances (INDESIT) about diagnostic and early detection of malfunction in operation; and MILD (ENEL) about application of MILD combustion technologies to different industrial fields
- Project CARBOMICROGEN about microgeneration
- Collaboration with Prof. C. Bruno (Univ. "Sapienza" of Rome) in 2 European projects: LAPCAT II on supersonic combustion and TIMECOP on LES of spray combustion.

4.6 CIRA Italian Aerospace Research Center

- 2007/2010 - CESAR: "Aerodynamics Optimization of a wing-nacelle-fuselage configuration" âĂŞ Mr. E. Iuliano
- 2008/2010 - DRAGON: contract with Airbus-Spain and CIMNE: "Development of an library for aerodynamics optimization" Scientific responsible - Dr. D. Quagliarella
- 2007/2012 Project funded by the EU commission EXTICE:" The objectives of EXTICE project is twofold. One objective is to reduce aircraft development cost by improving tools and methods for aircraft design and certification in an icing environment. On the other hand, since the proposal will address the development and validation of Means of Compliance and tools for aircraft icing certification, this research activity will also have a direct impact on aircraft safety, allowing future aircraft to be designed safer with respect to the icing and the SLD environment." Scientific responsible G. Mingione
- 2009/2013 Project financed by the EU commission DESIREH:" DeSiReh focus on both, the numerical design tools and the experimental measurement techniques for cryogenic conditions, with the objective to improve the industrial high lift system design process in terms of product quality, efficiency, and development cost reduction" Scientific officer P. Iannelli
- 2009/2012 Project financed by the EU commission ALEF:" ALEF: Aerodynamic Loads Estimation at Extremes of the Flight Envelope: ALEF's long term objective is to enable the European aeronautical industry to create complete aerodynamic models of their aircraft based on numerical simulation approaches by reducing the amount of required experimental data" Scientific officer P. Iannelli
- 2007/2011 Project financed by the Italian Minister for research NACELLE: "Ice accretion studies on engine air intakes, In detail problems related to laminar-turbulent transition on air inlet nacelle in presence of thermal ice protection system will be addressed spa s air inlet ice accretion and wetting factor calculation" Scientific officer G. Mingione
- 2009/2013 Project financed by the EU commission PLASMAERO "Development and implementation in the CIRA CFD tools of models for the simulation of the discharge barrier devices on wing models in order to control boundary layer shock interaction. In addition some wind tunnel tests will be performed in the transonic PT1 wind tunnel on a model designed by CITA in order to house DBD actuators developed by other partners (EPFL)" scientific officer R. Donelli
- 2005/2010 Project financed by the EU commission VCELL 2050 "Study of a flow control device based on the trapped vortex concept" R. Donelli
- 2008/2012 Project financed by the EU commission SADE "Morphing concept for high lift devices" G. Mingione
- 2008-2015 Project financed by the EU commission JTI-GRA "Study of innovative Low noise aircraft"
- 2008-2017 Project financed by the EU commission JTI-GRC "Study of innovative helicopter concept"
- 2009-2012 Project financed by the EU commission FAST20X "Future High-Altitude High-Speed Transport 20XX. The objectives are to study high-speed high-altitude air transport vehicles" Marco Marini
- GARTEUR-AG44 Research group: "Application of transition criteria in Navier-Stokes computations, phase II", Dr. R. Donelli
- GARTEUR-AG49 Research group: "Scrutinizing Hybrid RANS-LES Methods for Aerodynamic Applications", Dr. P. Catalano

5. Scientific events organised by the Italian PC

- Alfieri, A., Borello, D., Delibra, G., Hanjalić, K. and Rispoli, F., 2008, RANS and Hybrid RANS/LES computations of flow in a 3D diffuser, 13th ERCOFTAC SIG 15 Workshop on Refined Turbulence Modelling, 25-26 Sept., Graz Univ. of Technology, Graz, Austria.
- Nucara P., Borello D., Delibra G., Rispoli F. and Hanjalić K., Development of non linear elliptic relaxation $k-f$ model for the prediction of flow in a 3-D diffuser, In S. Jakirlic, G. Kadavelil, E. Sirubalo and D. Borello (Eds) Proc. 14th SIG15 ERCOFTAC Workshop on Refined Turbulence Modelling, 18 September 2009, Roma, Italy.
- First "Sustainable Fossil Fuels for Future Energy" (S4FE), Rome, Italy, 6-10 July, 2009.
- Second "Sustainable Fossil Fuels for Future Energy" (S4FE) in collaboration with The Italian Section of The Combustion Institute, Ischia, Italy, 6-10 July, 2010.
- XXV Event of the Italian Section of the Combustion Institute, Rome, 3-6 June, 2002.
- 4th HTACG (High Temperature Air Combustion and Gasification), Rome, Italy, 26-30 November, 2001.

6. The involvement of the Italian PC in ERCOFTAC SIG activities

SIG 34 "Design Optimization" The collaboration with SIG 34 was initiated since its formation back in 2000 and involves directly University of Trieste. Since then

Prof. Poloni was part of the organizing committee. The University of Trieste group contributed to both introductory and advanced courses that the SIG has organized in Munich and Manchester. In 2007 the introductory course will be organized in Trieste. Ansaldo is interested in taking part in the near future in the present SIG.

7. Future activities of the Italian PC

The Italian PC activity is intended to further stimulate the collaboration between scientists-academic research centres and industrialists in the wide range of application field promoted up to now to meet the objectives of the ERCOFTAC association. The activity will include the organisation of further international congresses, meetings, conferences, summer school, research groups and anything else could be useful to meet the goals of the Italian PC.

Moreover Italian PC activity times up with EUROTURBO in organization of several events scheduled in foreseeable future.

Some groups of PC-Italy will be also present to the next 15th Workshop to be held on October 17-18, 2011, in EDF at Chatou, France

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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 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.
- 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 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 $y*$.
- Exercise care when calculating the flow using different 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 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.

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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Best Practice Guidelines for Computational Fluid Dynamics of Dispersed Multi-Phase Flows

Editors

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&
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The simultaneous presence of several different phases in external or internal flows such as gas, liquid and solid is found in daily life, environment and numerous industrial processes. These types of flows are termed multiphase flows, which may exist in different forms depending on the phase distribution. Examples are gas-liquid transportation, crude oil recovery, circulating fluidized beds, sediment transport in rivers, pollutant transport in the atmosphere, cloud formation, fuel injection in engines, bubble column reactors and spray driers for food processing, to name only a few. As a result of the interaction between the different phases such flows are rather complicated and very difficult to describe theoretically. For the design and optimisation of such multiphase systems a detailed understanding of the interfacial transport phenomena is essential. For single-phase flows Computational Fluid Dynamics (CFD) has already a long history and it is nowadays standard in the development of air-planes and cars using different commercially available CFD-tools.

Due to the complex physics involved in multiphase flow the application of CFD in this area is rather young. These guidelines give a survey of the different methods being used for the numerical calculation of turbulent dispersed multiphase flows. The Best Practice Guideline (BPG) on Computational Dispersed Multiphase Flows is a follow-up of the previous ERCOFTAC BPG for Industrial CFD and should be used in combination with it. The potential users are researchers and engineers involved in projects requiring CFD of (wall-bounded) turbulent dispersed multiphase flows with bubbles, drops or particles.

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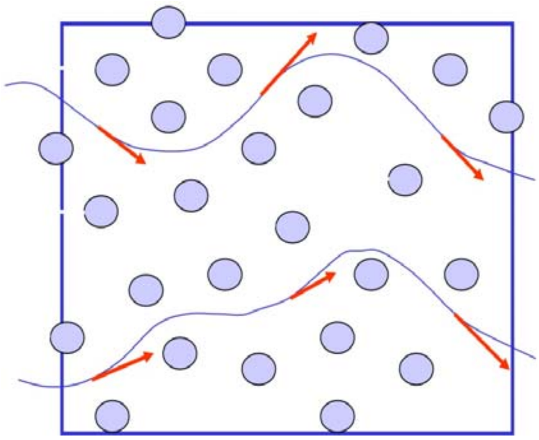

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