

IUTAM SYMPOSIUM CRITICAL FLOW DYNAMICS INVOLVING MOVING/DEFORMABLE STRUCTURES WITH DESIGN APPLICATIONS

held at the Hotel-Resort De Sol, on Santorini island,
Greece, 18-22 June 2018

Chairpersons : Marianna Braza¹, Kerry Hourigan² and Michael Triantafyllou³

¹CNRS-Institut de Mécanique des Fluides de Toulouse-UMR5502, France

²Department of Mechanical and Aerospace Engineering, Monash University,
Clayton 3800, Australia

³Department of Mechanical Engineering, Massachusetts Institute of Technology,
Cambridge, MA, USA

1 General context of the symposium

The IUTAM symposium on *Critical Flow Dynamics involving Moving / Deformable Structures with Design Applications* (www.smartwing.org/iutam) was held on Santorini island, Greece, during 18-22 June 2018 and chaired by Marianna Braza (CNRS-Institut de Mécanique des Fluides de Toulouse, France), Kerry Hourigan, (Department of Mechanical and Aerospace Engineering, Monash University, Clayton, Australia) and Michael Triantafyllou (Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA). The present symposium hosted 40 oral presentations and a considerable number of the most renowned scientists in the field. The list of Keynote presentations can be found at <http://www.smartwing.org/iutam/?q=node/5>.

The proceedings of the Symposium's full papers, taking into account review remarks and comments arising from the oral presentations, will be published in a dedicated volume under preparation by Springer.

The present IUTAM Symposium concerned an important domain of Theoretical and Applied Mechanics nowadays. It aimed at regrouping the multidisciplinary knowledge coming from the two scientific communities of Fluids and Structures. The symposium emphasized a unified approach which collates the knowledge coming from theoretical, experimental, numerical simulation and modelling in Fluid Dynamics (FD) and Structural Mechanics (SM), involving analysis of critical phenomena crucial for the design in both incompressible and compressible separated unsteady flows around moving and/or deformable structures. Specific attention was focussed on the morphing of aerodynamic / hydrodynamic structures (particularly by using a new generation of electro-active intelligent materials), in order to increase their performances and to prepare new designs in aeronautics, marine hydrodynamics and bio-inspired science. One of the main objectives was the reduction of nuisance phenomena like separation, flutter instabilities, and high-frequency vibrations related to noise, the reduction of drag and increase of lift or thrust.

The subject areas of the symposium covered these important themes in the domains of fundamental research and of industrial applications.

Progress in these areas has received a great deal

of impetus from international research groups and the present symposium stimulated multidisciplinary collaboration among academics and involved key multinational industrial companies, as well as enhanced targeted government programs. This symposium brought together leading international groups of researchers working in the scientific communities of Fluid Dynamics, Structural Mechanics, Sound and Vibration, which have devoted their efforts to understanding and controlling critical phenomena from fundamental and application points of view.

The present symposium included a considerable panel of Keynote speakers, among the most renowned scientists worldwide, who addressed the state of the art and opened new avenues of research in these domains. The present symposium is distinguished by assembling *fifteen invited presentations* as well as target industries in this topic.

Therefore, the present IUTAM symposium has contributed to a better insight into these important topics by means of a synergy between the three main approaches: theoretical, experimental and prediction methods. The main objectives of this symposium have been fulfilled. The chairpersons and the local organising committee received strong endorsement and warm comments from all the participants, among whom there were eminent scientists in the field. We can refer to a *standing ovation* during the gala dinner and best poster award presentation of the Symposium in the videos provided at the symposium website http://smartwing.org/iutam/?q=Closing_address. Furthermore, the symposium carried out a Round-Table discussion among the participants, coordinated by Professor Julian Hunt during the closing address, where a high appreciation of the symposium was given, cf. the video included in the same link of the symposium website. Moreover, we have kept in the archives of this symposium the many comments and remarks of appreciation spontaneously sent by the participants after the conference.

Among the invited lectures, two were devoted to presenting the major outcomes from federative European research programs in aeronautics, related to the symposium themes: the H2020 SMS -Smart Morphing and Sensing for aeronautical configurations European programme and the TFAST (Transition location effects on shock wave boundary layer interaction), co-

ordinated by Marianna Braza and Piotr Doerffer, respectively.

The scientific discussions were continued at the evening cocktail on Monday 18th June 2018 during the boat trip to Santorini's Volcano, as well as during the gala dinner held at Nomikos Conference Centre in Fira, the capital town of the island.

Considering the participants' comments, this symposium was highly successful and all the objectives were completely achieved. The main outcomes of the symposium are summarised as follows :

Instability and transition related to VIV (Vortex Induced Vibrations), MIV (Movement Induced Vibrations) and TIV (Turbulence Induced Vibrations), wall rotation effects and dynamic stall have been investigated by DNS, LES and experimental studies, including highly resolved PIV, as well as analytical approaches and Reduced Order Modelling for the fluid-structure interaction of moving / deformable structures. Configurations of spheres, tandem cylinders and of flows around flexible or moving cylinders were considered, including numerical studies of flexible bodies leading to very complex wake structures in the context of fluid-structure interaction.

New strategies involving multiscale aspects and forecasting of chaotic systems modeling have been presented. Lattice-Boltzman simulation methods applied in moving-deformable boundaries as well as poroelasticity and homogenisation methods to model complex multi-scale interfaces including also biomedical applications have been addressed.

Progress of physics and modelling in turbulence and control have been made, enabling scientists to improve aerodynamic and hydrodynamic performance in reducing drag, increasing lift or thrust and reduce noise under critical conditions corresponding to strong separation, vortex dynamics, amplification of harmful instabilities (flutter, buffet) and movement-induced vibrations. The symposium has investigated new insights into turbulence interacting with moving or deformable structures, leading to new ways of adapting and controlling the configurations to respond to these critical conditions.

Theory together with large computer simulations and experiments have shown new features of turbulent flows in boundary layers over wings and in thin shear layers immediately downstream, lying between the turbulence and the external flow. Natural and artificially generated fluctuations have proven efficient in affecting the dynamics of turbulence structure which, after suitable manipulation, lead to reductions of noise and drag. Efficient turbulence modelling methods have been addressed in the domain of advanced URANS (as for example stochastic forcing to capture thin shear-layer interfaces), LES (including grid-independent length-scale modelling) and hybrid RANS-LES (Delayed Detached Eddy Simulations improving model-stress depletion). These approaches were associated with coupling strategies in CFDSM (Computational Fluid Dynamics-Structural Mechanics). Specific achievements of LES by using appropriate near-wall turbulence modelling have been reported, and which are able to capture crucial phenomena, as for example strongly separated flows in the high Reynolds number range.

Compressibility effects leading to critical phenomena arising in the context of unsteady shock-boundary layer interaction (SBWLI), as for example

transonic buffet and flutter, have been investigated by experimental, theoretical and numerical approaches and methods for their control have been analysed. The study of these effects contributes to the fundamental research of compressibility phenomena arising in aeroelasticity as well as for the wings of future design.

Electromechanical conversion was shown to be efficiently achieved by using a variety of mechanisms available from a range of novel smart actuators to perform morphing. Smart, bio-inspired materials, compliant surfaces and actuators were examined together with new dynamically controlled aerodynamic and hydrodynamic shapes in order to attenuate harmful effects and to improve performance and safety. The symposium addressed improvements in aerodynamic/hydrodynamic performance by using compliant surfaces and intelligent scilia, porous layer coatings with feather-like actuators, as well as electroactive morphing by means of shape memory alloys, piezo-actuators and polymers, among others.

Efficient passive and active control studies using theoretical, numerical and experimental approaches have been presented. Biomimetic flows around fishes and natural flyers have been also studied, and the dynamics of beating cilia has been investigated experimentally and numerically. Fluid-structure interaction mechanisms actively controlled in fish-like bodies have been investigated in order to optimise their locomotion and maneuvering performance.

Progress in these areas have been effectively presented, enabling multidisciplinary collaborations among international research groups participating in the symposium, developing fruitful exchanges and building future research projects involving academic research and design applications. This symposium brought together the leading international groups of researchers working in the aforementioned scientific communities. It included advanced theoretical approaches, experiments and simulations, as well as including Artificial Intelligence that showed how, in synergy, smart designs lead to considerable benefits compared with more conventional ways. The present symposium has provided a forum for the presentation of scientific advances in the state of the art and important outlooks of research concerning these topics.

2 Sessions of the IUTAM Symposium “ Critical flow dynamics involving moving /deformable structures with design applications ”

The Symposium consisted of single plenary sessions with invited lectures, selected oral presentations, discussions on special topics and posters.

- Flow - Induced Vibrations
- Numerical simulation of oscillating/vibrating flows around bodies
- Fluid-Structure Interaction arising in aerodynamics and flow control
- Theoretical aspects, simulation and reduced-order modelling of fluid-structure interaction for deformable structures
- Rotating effects, fish motion, swimmers, energy harvesting
- Compressibility effects in fluid-structure interaction

- Fluid-Structure Interaction, Morphing and Control

- Bifurcations and analytic modelling in FSI

The detailed Symposium programme can be found at <http://www.smartwing.org/iutam>.

3 Scientific Committee

Dr. M. Braza, Co-Chairperson CNRS- IMF
Toulouse, UMR 5502 – France

Prof. K. Hourigan, Co-Chairperson Monash
University – Australia

Prof. M. Triantafyllou, Co-Chairperson Mas-
sachusetts Institute of Technology – USA

Prof. A. Bottaro Università di Genova – Italy

Prof. B.J. Geurts University of Twente – Nether-
lands

Prof. G. E. Karniadakis Brown University –
USA

Prof. J.F. Rouchon INPT-LAPLACE – Toulouse

Prof. B. B. Schrefler University of Padova – Italy

4 Invited speakers

Prof. E. de Langre LadHyx, Ecole Polytech-
nique, Paris – France

Prof. B. Geurts University of Twente – The
Netherlands

Prof. E. Wesfreid Ecole Supérieure de Physique
et de Chimie Industrielles, Paris – France

Prof. Y. Zhou HIT - Harbin Institute of Technol-
ogy – China

Prof. A. Bottaro Università di Genova – Italy

Prof. J.F. Rouchon INPT LAPLACE UMR 5213
– France

Prof. Y. Ventikos UCL-University College Lon-
don – U.K

Prof. J. Hunt UCL-University College London –
U.K.

Prof. H. Hangan Wind Engineering, Energy and
Environment (WinEEEE) Research Institute – USA

Dr. P. Ern CNRS, Institut de Mécanique des Flu-
ides de Toulouse – France

Prof. J. Morrison Imperial College – U.K

Prof. H. Choi Seoul National University – South
Korea

Prof. P. Doerffer Polish Academy of Sciences,
Gdansk – Poland

Dr. A. Fontaine Airbus and Pegase Co – France

Dr. E. Liberge LaSIE, University La Rochelle –
France

5 Host Institution

The symposium was organised by the “Institut de Mécanique des Fluides de Toulouse”- (IMFT), directed by Professor Eric Climent and affiliated with the “Centre National de la Recherche Scientifique”- (CNRS), the “Institut National Polytechnique de Toulouse” - (INPT), the “Ecole Nationale Supérieure d’Electrotechnique, Electronique, Informatique, Hydraulique et Télécommunications” , (ENSEEIH) and the “Université Paul Sabatier” - (UPS).

Acknowledgement: The chairpersons of the symposium are grateful to IUTAM for having attributed the IUTAM label and financial support, as well as for having contributed to the advertisement of the symposium. The contribution of the congress department of Toulouse Institut National Polytechnique (Mrs Marlene Giamporcaro) was essential for the organisation of this Symposium.

6 Epilogue

A friendly atmosphere was created among the participants, helped by the organisation of the social events: the boat trip to Santorini’s Volcano on Monday 18th June, the dinner on 19th June at Nomikos Conference Centre, the visit of the archaeological city ” ‘Akrotiri’ and the gala dinner on 21th June at Monolithos vil-
lage.

A general impression from this symposium was that the scientific communities working on experi-
mental, theoretical and numerical approaches related to the symposium topics have learned a lot from one another and the meeting has brought new research ideas to everyone, as well as unforgettable memories from the attractive Santorini island.

Marianna Braza, Kerry Hourigan and Michael Tri-
antafyllou