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Marianna Braza · Jean-François Rouchon ·
George Tzabiras · Franco Auteri · Pawel Flaszynski
Editors

Smart Morphing and Sensing for Aeronautical Configurations

Prototypes, Experimental and Numerical Findings from the H2020 N° 723402 SMS EU Project

Springer

Editors
Marianna Braza
CNRS
Institut de Mécanique des Fluides de Toulouse
Toulouse, France

Jean-François Rouchon
Laboratoire Plasma et Conversion d'Energie
Institut National Polytechnique de Toulouse
Toulouse, France

George Tzabiras
School of Naval Architecture and Marine Engineering
National Technical University of Athens
Zografou, Greece

Franco Auteri
Dipartimento di Scienze e Tecnologie Aerospaziali
Politecnico di Milano
Milan, Italy

Pawel Flaszynski
Institute of Fluid-Flow Machinery
Polish Academy of Sciences, IMP PAN
Gdańsk, Poland

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Preface

The present book contains a detailed description and analysis of the results including new findings obtained from the H2020 N° 723402 European research project SMS, *Smart Morphing and Sensing for Aeronautical Configurations*, https://cordis.europa.eu/project/id/723402 and http://www.smartwing.org/SMS/EU.

In the recent decades, a considerable effort has been devoted to improve the aerodynamic performance and to reduce noise by means of different methods. Most of them involve vortex generators and riblets enabling drag reduction, as well as hydromechanical actuators and microelectromechanical systems, among other. The majority of these devices are heavy and characterized by a rather slow response. Few attempts had been made to employ electrical actuators, able to deform specific parts of the wings. Furthermore, there do not exist to our knowledge approaches permitting a *simultaneous* reduction of the noise sources, together with a considerable aerodynamic performance increase. Besides, the majority of existing concepts were focusing on actuation of upstream parts of the wings, to obtain laminarisation. They do not take benefits that would be obtained by *feedback effects* through modification of the *downstream* wing's part and its surrounding turbulent vortex structures.

This book presents innovative and highly efficient *Morphing* concepts for an optimal and smooth modification of the wing's shape and its vibratory character, operating *at different time and length scales*, according to the turbulence nature surrounding the lifting body. The topics of the book present therefore the ways of "*Smart wing design through turbulence control*", enabled by "*hybrid electoractive-morphing*." This operates simultaneously high deformations in low frequencies and slight deformations in higher frequencies. It creates an interaction with the turbulence vortex structures that in turn modify the structural properties, thus composing an efficient fluid-structure interaction system. Its high efficiency in lift increase, drag reduction and noise sources reduction has been demonstrated by the SMS project in laboratory scale, *as well as near "scale one".*

Advanced wing prototypes have been built on this purpose and presented in detail in this book. They embedded different classes of *electrical actuators* under the "skin" of the lifting surface controlled by an appropriate *multi-point pressure system* that measures the unsteady pressure on strategic areas of the wing surface. These areas, together with optimal wing shapes have been identified by adjoint-based sensitivity matrix evaluation, among other optimisation approaches in the project. The present electrically based morphing leads to much lighter and efficient wing design than other approaches in the state of the art. It is in-line with the priorities fixed by the aeronautics industry toward "*a More Electric Aircraft*", *MEA*.

This disruptive wing design is partly bio-inspired, regarding the different scales of large—span hunting bird wings that operate high cambering of the main wing's part and simultaneously actuate small deformations and higher frequency vibrations of their ailerons and feathers. These actuations are guided from the pressure sensing of the bird that captures the aerodynamic pressure distribution. This enables the bird to optimally actuate all this arsenal of multiple-scale structures. It will be remembered the ability of the owl to simultaneously increase its aerodynamic performance and practically suppress noise when flying toward its prey.

However, the electroactive morphing concepts studied in the SMS project are only partially bio-inspired because they have been adapted in realistic aircraft speeds that never these birds reach. The efficiency in aerodynamic performance increase is demonstrated in all flight phases, take-off, landing and cruise, by means of refined wind tunnel experiments, Hi-Fi numerical simulations and modeling. In many cases of the studies presented in this book, the simulations *dictated* the optimal parametric ranges followed by the experiments. An appropriate controller's design studied by ONERA—Toulouse SMS partner under the responsibility of Dr. Carsten Döll—enabled the application of the optimal actuations on the prototypes to reach these performances.

Thanks to the obtained performances, the SMS project prepares future wing design for aeronautics industrial applications aiming at saving energy and at reducing the pollution through these new *multiscale morphing concepts.* These open new ways in the design enable a considerable reduction of emissions, meeting the targets fixed by

the European Commission, DG MOVE/DG RTD, Flightpath 2050: Europe's Vision for Aviation: Maintaining global leadership and serving society's needs.

Toulouse, France — Marianna Braza
Toulouse, France — Jean-François Rouchon
Zografou, Greece — George Tzabiras
Milan, Italy — Franco Auteri
Gdańsk, Poland — Pawel Flaszynski

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"Future Smart Wing design", thus contributing to a significant part of the Hi-Fi simulations of the SMS project. Their dedicated two "Success Stories" articles to our project, https://prace-ri.eu/future-aircraft-wings-will-be-able-to-adapt-their-shape-mid-flight/ and https://prace-ri.eu/news-media/publications/prace-fact-sheets/success-stories-in-engineering/ are highly acknowledged. A deep acknowledgement is also addressed to the French Supercomputing Centres CINES, TGCC and CALMIP for the substantial CPU allocation that made possible part of the Hi-Fi numerical simulations of the coordinator's Institute in the SMS project. Moreover, warm thanks are expressed to CALMIP under the Direction of Jean-Luc Estivalezes, for having launched the Data Management Plan and the data access of the SMS project respecting the FAIR principles fixed by the European Commission, by means of the specific dataverse platform "CALLISTO"—"*CALmip Launches an Interface for Semantic Toolbox Online*", developed by Thierry Louge. Thanks to this platform, data access, exchange, interoperability and reuse has been made possible for the SMS partners thanks to development of a specific ontology and workflows, described in Chap. 5 of this book.

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The publication of the book is a result of the collective effort by the contributors and authors of the chapters.

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Picture from the 30th month SMS meeting at Politecnico di Milano, Aerodynamics Laboratory, in front of the Large Scale prototype of the project. Last project's meeting in presence before COVID restrictions

Toulouse, France — Marianna Braza
Toulouse, France — Jean-François Rouchon
Zografou, Greece — George Tzabiras
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Gdańsk, Poland — Pawel Flaszynski
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