M.C. NOVIELLO, PH.D.

2nd edition

AIRCRAFT MORPHING WING SYSTEMS: ACTUATION, SAFETY AND CONTROL

PHD COURSE (6 CREDITS)

UNIVERSITY OF NAPLES "FEDERICO II", DEPT. OF INDUSTRIAL ENGINEERING
(MULTIMEDIA CLASSROOM, VIA CLAUDIO, 21, NAPLES)

FROM 9.30 TO 12.30 (3-HOUR MEETINGS)

1 OCT - 9 OCT - 22 OCT - 30 OCT
6 NOV - 13 NOV - 20 NOV
(7 CLASSES)

EXAMINATION DATE: 20 NOV (WRITTEN ONLY)

CONTENTS

1. AEROSPACE MORPHING STRUCTURES: STATE OF THE ART OVERVIEW
2. DESIGN PROCESS OF MORPHING STRUCTURES: MULTIDISCIPLINARY APPROACH
3. ACTUATION SYSTEM DESIGN: APPROACH AND PRACTICAL APPLICATIONS
4. MORPHING WING SAFETY AND RELIABILITY ISSUES: FAULT AND HAZARD ANALYSIS

Aircraft Morphing Wing Systems: Actuation, Safety and Control

PhD Course Flyer

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The Italian Aerospace Research Centre (CIRA) - Adaptive Structures Operative Unit

Contents

1. Title

Aircraft Morphing Wing Systems: Actuation, Safety and Control

2. Course meeting times

Lectures: 1 session / week, 3 hours / session (24h)

3. Course language

Material: English

Lessons: English/Italian, based on the PhD students' nationality

4. Prerequisites

Sufficient background in structural mechanics

5. Abstract

The growing interest towards the morphing wing structures in aerospace originates from the ability to adapt their external shape to obtain more aerodynamically efficient structural configurations, if compared to conventional architectures. A camber morphing wing flap, for instance, has largely proven to provide a wide range of aerodynamic benefits during take-off and landing by suppressing the need for flap track fairings. Similarly, while keeping its classical roll control function, a morphing aileron can redistribute spanwise wing loads during cruise and reduce the resulting wing root bending moment. Finally, adaptive winglets are a viable option to implement novel load alleviation capabilities for the outer wing by reducing gust load effects.

Due to their complexity, morphing systems require an interdisciplinary design process, including the architectural concept, the mechanism and the actuation system development, the material selection, the aerodynamic and aeroelastic assessment, also accounting safety issues. Thus, there is an increasing interest in the research and academic field to orientate students towards such design principles, including

both rigid-body linkages and compliant mechanisms, where high reliability, accuracy, and demanding performance are addressed by a multidisciplinary and multi-objective design process.

The intent of this course is to respond to this perceived need, while providing engineering tools to comprehensively address the design of aircraft morphing wing systems. Focus is also given to the evolution of actuation in aerospace, ranging from conventional hydraulic to electromechanical actuators and related control systems and safety issues.

6. Course description

The principal objectives of the course are to:

- Offer an overview of the State-of-the-Art of morphing structures for aerospace applications
- Provide a general prospect of the multidisciplinary design process of morphing structures, related to architectural concepts, mechanism and actuation system development, material selection, aerodynamic and aeroelastic assessment, safety
- Afford advanced understanding in terms of design of morphing systems, with particular focus on:
    - mechanisms, in case of multi-block finger-like and compliant configurations
    - actuation systems, by analysing systems' integration issues, actuation mechanisms and their functions and systematic methods and multibody simulations for synthesis of mechanisms to meet multiple kinematic tasks related to the design of such morphing systems to safety issues, by introducing Fault-and-Hazard analyses

7. Learning objectives

- Looking into the behaviour of morphing systems at mechanism and actuation system levels
- Being able to carry out interdisciplinary design work
- Being able to apply morphing structures principles to a creative design solution
- Understanding both the applications and limitations of morphing systems

24 hours + 3 dedicated to the examination (6 credits)

8. Course structure

The course is divided into four sections.

- In the first section, a general description of the main structural features of the morphing devices for aerospace applications will be provided. The State-of-the-Art of the most relevant morphing structures for aerospace applications will be discussed.
- In the second section, an overview of the multidisciplinary design process of morphing structures will be prospected in general terms, by considering architectural concepts, mechanism and actuation system development, material selection, aerodynamic and aeroelastic assessment, safety aspects.
- In the third section, the morphing systems design will be more detailed in terms of mechanisms and actuation systems. Practical and guided exercises of structural sizing will be performed through computational means during the lessons.
- In the fourth section, safety aspects will be discussed with respect to the design of morphing devices at system level, by introducing Fault-and-Hazard assessment. Guest lecturers will be invited to complement the course through interesting notions and methods.

9. Grading

Students will perform a final group exam and will receive a letter grade for the course.

10. Proposed Calendar

Section	Lecture #	Topic	Key Date	Hour
1	1	Overview of the State-of-the-Art of aerospace morphing structures Main current research projects on aircraft morphing structures	01.10.2025	9.30-12.30 A.M.
2	2	Multidisciplinary design process of morphing structures: ▪ architectural concept ▪ mechanism and actuation system development ▪ material selection ▪ aerodynamic assessment ▪ aeroelastic assessment ▪ safety assessment	09.10.2025	9.30-12.30 A.M.
3	3	Morphing mechanisms: Camber-morphing concept: finger-like Vs. compliant mechanisms	22.10.2025	9.30-12.30 A.M.
3	4	Actuation in aerospace: from conventional hydraulic to electromechanical actuators Actuation system design: approach and practical application for morphing wing structures	30.10.2025	9.30-12.30 A.M.
3	5	Control system design: approach and practical application for morphing wing structures	06.11.2025	9.30-12.30 A.M.
4	6	Morphing wing – Safety and Reliability Issues ▪ Introduction ▪ Safety analysis: general approach ▪ Functional Hazard Assessment (FHA) ▪ System Safety Assessment – Fault Tree Analysis ▪ Active versus Hidden Failures ▪ On Safety Factors ▪ Morphing devices: aircraft level functions ▪ Morphing flap ▪ Morphing winglet ▪ Integrated safety analyses (case study)	13.11.2025	9.30-12.30 A.M.
1:4	7	Final group exam	20.11.2025	9.30-12.30 A.M.
1:4	8	Visit at CIRA facilities	TBD	2.00-5.00 PM

11. Proposed Where & When

Multimedia classroom in Via Claudio, 21, Department of Industrial Engineering, University of Naples "Federico II", from 9.30 to 12.30 (three-hour meetings), from 1 Oct 2025 to 20 Nov 2025.

It will be possible to identify further dates in the abovementioned period for answering special requests for more information by the audience, depending on the availability of the classroom.