Novel Fractional Order Control Strategies for Vibration Suppression in Aeroplane Wings

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Foreword/Summary

- The overall performance of large aerospace vehicles is determined to a great extent by the wings' structure of aircrafts. Vibrations that might occur in these structures may limit their life span and even lead to malfunctioning or system instability.

- The necessity of research on vibration suppression in airplane wings is important from a scientific and technologic point of view:
    - to provide better, more efficient, robust, cheaper solutions to eliminate vibrations effects, which triggers the socio-economic aspect regarding the increase of flight safety and passenger comfort.

    - the main purpose of the project is directed towards the development of novel control strategies for vibration suppression in airplane wings using advanced fractional order control algorithms.

Team members

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Objectives

- **The main overall objective:** to develop novel, robust fractional order control strategies, to offer new solutions for vibration suppression in airplane wings. The project aims at experimenting, testing and the validation of original methods to be applied in one of the most thriving aspects of everyday life: flight safety and comfort.

The specific objectives of the project are as follows:

Objective 1: Development of a complete and up-to-date study of the state of the art regarding vibration suppression in airplane wings (construction, modeling, control);

Objective 2: Design and construction of an experimental unit for the study of vibration suppression;

Objective 3: Development of a dynamic model for airplane wings (using fractional calculus and experimental identification); - original element

Objective 4: Development of novel robust fractional order control strategies for vibration suppression. – original element

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Activities

Objective (PHASE 1)	Activity
Objective 1: Development of a complete and up-to-date study of the state of the art regarding vibration suppression in airplane wings (construction, modeling, control);	Study / analysis of the construction of airplane wings as smart beams and of the problems associated with vibration attenuation
	Study of the existing models and modeling techniques for the dynamics of airplane wings.
	Study of the existing control strategies for vibration suppression in airplane wings.
Objective 2: Design and construction of an experimental unit for the study of vibration suppression	Design of the experimental unit and selection of the necessary components.
	Equipment purchasing and assembly of the final experimental unit.
	Development of the software tool for data acquisition, experimental open loop tests, analysis of the resonance frequencies and material properties of the smart beam, analysis of the positioning of the sensors/actuators on the smart beam.
	Dissemination of results

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Activities

Objective (PHASE 2)	Activity
Objective 3: Development of a dynamic model for airplane wings (using fractional calculus and experimental identification);	Open loop experiments considering various types of excitation signals
	Development of a high order transfer function models for the smart beam
	Development of a fractional order models
	Experimental validation of the two models
	Comparison of the two models in terms of accuracy and selection of the final model that best fits the dynamics of the experimental unit.
Objective 4: Development of novel robust fractional order control strategies for vibration suppression.	Closed loop testing of the most efficient control algorithms studied in simulation. Implementation and validation of the most reliable and robust ones on the experimental smart beam.
	Development of robust fractional order PID control algorithms and optimal fractional order control strategies for vibration attenuation using frequency domain approach. Closed loop testing of the developed control algorithms using simulations. Implementation and validation of the designed fractional order controllers on the experimental smart beam.
	Dissemination of results

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Activities

Objective (PHASE 3)	Activity
Objective 4: Development of novel robust fractional order control strategies for vibration suppression.	Correction, optimization and adjustment of the developed fractional order control strategies, if necessary
	Comparison of the experimental results obtained with novel control strategies, while highlighting the advantages of the proposed fractional order control strategies.
	Dissemination of results

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Milestones

- **Define the key elements to build the experimental unit** (choice of the material the smart beam is composed of, choice of sensors/actuators types, location of sensor and actuator for vibration suppression on the smart structure)

- **Design and construction of the smart beam** (the piezoelectric sensors and actuators, power sources, amplifiers, data acquisition (DAQ) boards, input/output cards)

- **Design of software to monitor and control the experimental unit using LabVIEW**

- **Mathematical modeling** (using fractional calculus/ experimental data) – original element, never tackled before for smart beams

- **Development of novel FO control strategies**
  - Simple FO-PID controllers
  - Advanced FO control strategies
  - Implementation and experimental tests of the developed control strategies

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Challenges

Challenge: Problems regarding the assembly and use of piezoelectric sensors and actuators.
Solution: In this case, other types of sensors and actuators will be used.

Challenge: Problems in obtaining an accurate mathematical model using experimental identification and fractional calculus.
Solution: In this case, finite element modeling (used extensively in modeling smart beams) and fractional calculus will be considered.

Challenge: Numerical errors in the implementation of the FO controllers.
Solution: In this case, numerical errors will be avoided by optimizing the resources allocation on the real time controller

Challenge: Failure of sensing/actuating/control equipment.
Solution: In this case, the budget allows for purchasing additional equipment to replace malfunctioning devices.

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Results

1. A detailed analysis of vibration attenuation problems;

2. Implementation of existing control methods for vibration suppression to assess their limitations;

3. Novel FO model for airplane wings;

4. New and improved control structures suitable for vibration suppression in airplane wings (stability of such systems, increase of passenger safety and comfort)

5. A novel approach in the tuning of FO controllers.

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Thank you!