A2-NET-TEAM
Advanced Aircraft Network for Theoretical & Experimental Aeroservoelastic Modeling

On 1st of January 2012, the project A2-Net-Team was initiated, It is coordinated by the Politecnico di Torino and is a concrete example of collaboration in an international network for the study of innovative aircrafts aeroelasticity

Partners

- Politecnico di Torino
- Clarkson University
- The Armenian Academy of Science
- Budapest University of Technology and Economics
- University of Ljubljana

Summary of Project Objectives

Next generation of composite civil aircrafts and unconventional flexible flight vehicles, such as High Altitude Long Endurance HALE-UAV, exhibit aeroelastic instabilities quite different from their rigid counterparts. Consequently, one has to deal with phenomena not usually considered in classical aircraft design. Alternative design criteria are needed in order to maintain the safety levels imposed by the regulations and required for certification. The study of the nonlinear aeroservoelastic behaviour of these aircrafts is extremely complex and requires the integration of a variety of disciplines including solid mechanics, fluid mechanics, and controls. Only by integrating these disciplines is possible to develop a comprehensive model truly representative of the aircraft dynamics and its aeroservoelastic behaviour. The A2-Net-Team project aims to build a multi-disciplinary network of researchers with complementary expertise to develop analytical methods used for a better understanding and assessment of the factors contributing to the occurrence of critical aeroservoelastic instabilities. Finally test articles will also provide the opportunity to modify and calibrate theoretical models, with the goal of showing the effect of theoretical approximation and their limits, and the necessity of model modifications and future investigations. To pursue such an ambitious goal, the project is divided into three working packages: *WP 1: Overall Management And Dissemination* The objective of this work package is to ensure the coordination of the whole A2-Net-TEAM project; *WP2: Aero-elasto dynamic of slender wing Configurations* i) Development of analytical methods capable of providing a better understanding and estimation of factors contributing to the occurrence of aeroelastic instabilities of high aspect ratio wings; ii) Design and manufacture of a multifunctional aeroelastic test model; iii) Development of test techniques; iv) Experimental activities for the validation of theoretical and numerical models. *WP 3: Flight dynamic & control of flexible aircrafts:* The main object is the study of coupling between aeroelasticity and flight dynamics in the case of highly flexible aircraft. Control strategy development is also studied within this WP.

Scientific Coordinator: Ing. Enrico Cestino – Assistant Professor
Politecnico di Torino – DIMEAS - Corso Duca degli Abruzzi, 24 – 10129 Torino, Italy
Tel: +39 011 564.6818   fax: +39 011 564.6899 - e-mail: enrico.cestino@polito.it

First period main scientific results achieved:

During the first part of the project 12 researchers were in mobility for a total of 21 months of secondments. Main research activities performed during this period were:

- A static aeroelastic analysis and design procedure of propeller blades was proposed, implemented and experimentally validated. The result of this preliminary study shown the potential to significantly expand the efficiency envelope of propeller performance as compared to the fixed-pitch rigid propellers. Results have been published in [1] [2].
- A combined structural and aerodynamic model for high aspect ratio wings has been developed based on a consistent nonlinear beam model. A parametric analysis was performed using the reduced order nonlinear beam model to assess the sensitivity of the structure to angle of attack, stiffness, and radius of gyration. Predicted flutter speeds and frequencies are validated using an experimental wind tunnel model. Results have been published in [3] [4].
- Application of innovative adaptive $\mathcal{L}_1$ techniques to control flutter phenomena affecting highly flexible wings and to evaluate the efficiency of this control algorithm and architecture by performing the following tasks: i) adaptation and analysis of an existing simplified nonlinear plunging/pitching 2D aeroelastic model accounting for structural nonlinearities and a quasi-steady aerodynamics capable of describing flutter and post-flutter limit cycle oscillations, ii) implement the $\mathcal{L}_1$ adaptive control on the developed aeroelastic system to perform initial control testing and evaluate the sensitivity to system parameters, and iii) perform model validation and calibration by comparing the performance of the proposed control strategy with an adaptive back-stepping algorithm. The effectiveness and robustness of the $\mathcal{L}_1$ adaptive control in flutter and post-flutter suppression is demonstrated. Results will be presented in [5].
- Development of a multibody model of flexible wing aircraft. The developed model is suitable to simulate the effect of both structural flexibility and flight dynamics and maneuvering on the wing deformation, and can be used to help developing control strategies for air vehicles with highly deformable wings. Results in this field will be presented in [6].
- The nonlinear stability of flexible plate immersed in a high speed gas flow is also considered. It is shown that the inclusion of quadratic aerodynamic nonlinear components can lead to the appearance of “amplitude-frequency” phenomena in both the pre-critical as well as in the post-critical flow speed regimes. The developed nonlinear plate model will be improved in order to study subsonic flow speed regimes and the effect of ferromagnetic or magnetostrictive materials. Some preliminary results will be presented in [7].
- Extraction of aeroelastic coefficients from small-scale wind tunnel tests to be used to perform efficient flutter analysis and evaluate reduced order unsteady aerodynamic models.

Selected Publications

1. Sodja J.; Drazumeric R.; Kosel T.; Marzocca P. "Aeroelastic Design of Propellers with Optimized Load-Distribution Characteristics" 54th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 2013.
2. Sodja J.; Drazumeric R.; Kosel T.; Marzocca P. “Aeroelastic Design of Propellers with Optimized Load-Distribution Characteristics” Journal of Aircraft, OI: 10.2514/6.2013-1560, April 18, 2013.
3. Cestino E., Frulla G., Marzocca P. "A Reduced Order Model for the Aeroelastic Analysis of Flexible Wings" SAE-AEROTECH-2013.
4. Frulla G., Cestino E. "Analysis of slender thin-walled anisotropic box-beams including local stiffness and coupling effects" Aircraft Engineering and Aerospace Technology 2013
5. Cassaro M., Battipede M., Marzocca P., Cestino E., Behal A. "$\mathcal{L}$1 Adaptive Flutter Suppression Control Strategy for Highly Flexible Structure" SAE-AEROTECH-2013.
6. Nagy A., Gati B., Cestino E., Marzocca P."Improved Multibody Model of Flexible Wing" SAE-AEROTECH-2013.
7. Baghdasaryan G., Mikilyan M., Saghoyan R., Cestino E., Frulla G." The Influence of Supersonic Stream on the Dependence “Amplitude-Frequency” Of Nonlinear Vibrations of Flexible Plate " SAE-AEROTECH-2013.

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Tel: +39 011 564.6818 fax: +39 011 564.6899 - e-mail: enrico.cestino@polito.it