A2-NET-TEAM: List of Published Papers - (January 2015)

Paper 1:

Title: Analysis of slender thin-walled composite box-beams including local stiffness and coupling effects
Authors: Giacomo Frulla, Enrico Cestino,
Type: Conference paper submission: *Airtec 2012 conference 7th Int. Conference Supply on the Wing, Frankfurt - Germany, 6-8-Nov. 2012.*

Abstract:
Purpose – Fiber-reinforced laminated composite could play a great role in the design of present and future generation of innovative civil aircrafts and unconventional unmanned configurations. The tailoring characteristics not only improve the structural performance, thus reducing the structural weight, but allow for possible material couplings. Both static and dynamic aeroelastic stability can be altered by those couplings. An accurate and computationally efficient beam model must be used during the preliminary design phase.

Design/methodology/approach – A proper structural beam scheme is adopted as a modification of previously first level approximating scheme. The effect of local laminate stiffness is investigated in order to check the possibility to extend the analytical approximation to different structural configurations. The evaluation of the equivalent stiffness both in the case of isotropic configuration and in simple/thin-walled laminated or stiffened sections proceeds introducing the classical thin-walled assumptions and classical beam theory for equivalent system. Coupling effects are also included. The equivalent analytical and FE beam behaviour is determined and compared in order to validate the considered analytical stiffness relations useful in preliminary design phase.

Findings –The paper analyzed different configurations highlighting the effect of flexural/torsion couplings and local stiffness effect in the global structural behaviour. Three types of configurations are considered: 1) a composite wing box configuration with and without coupling effects 2) a wing box configuration with the presence of sandwich and cellular constructions 3) a wing box with the presence of stiffened panels in coupled or uncoupled configuration. An advanced aluminium experimental test article will be also described in details. A good agreement between theory, numerical analysis and experimental tests was obtained confirming the validity of analytical relations. Practical implications – The equivalent beam behaviour is determined and stiffness calculation procedure is derived for future dynamic and aeroelastic analysis.

Originality/value – the article presents an original derivation of the sectional characteristics of a thin-walled composite beam and the numerical/experimental validation.

Paper 2:

Title: Flutter of flexible plate in a non-uniform thermal field.
Authors: Baghdasaryan G.Y., Mikilyan M.A., Saghoyan R.O. Grigoryan H.S.
Type: Proc. Of NAS RA, Mechanics, 2012, 65 N4, pp. 33-54

Abstract:
In the paper, in linear formulation the problem of stability of long rectangular plate under the influence of both variable along the thickness temperature field and supersonic gas flow (with the unperturbed speed, which directed along the short edges of the plate) is considered. Due to the inhomogeneity of along the thickness temperature field the buckling of the plate is takes place and this state is taken as unperturbed. Conditions of stability of unperturbed state of examined termogasoelastic system are obtained and on its base the stability area is constructed in the space of variables characterizing the value of the flown speed, the temperature at the middle plane of the plate and the temperature gradient along the normal direction of this plane. It is shown that via the combined action of the temperature field and the flowing stream one can regulate the process of stability and with the help of temperature field one can significantly change the value of the flutter critical speed.

Paper 3:

Title: On the Stability of Flexible Orthotropic Rectangular Plate in Supersonic Flow: Amplitude-Speed Dependency in Pre- and Post- Critical Flight Conditions
Authors: Baghdasaryan G.Y., Mikilyan M.A. & Marzocca P.
Type: Journal of Aerospace Engineering, 10.1061/(ASCE)AS.1943-5525.0000246 (Jul. 19, 2012), ISSN: 0893-1321, 2012

Abstract: *This paper provides insights into the stability of flexible orthotropic rectangular plates in supersonic flow, by revealing an amplitude-speed dependency behavior for such panels in pre- and post- critical flight conditions. Flutter and post-flutter behaviors are discussed to highlight the important effect of the structural and aerodynamic nonlinearities inherently present for panels in high speed flows. The influence of transversal shear on stability is also illustrated. Depending on plate's geometrical parameters soft and hard type flutter behaviors are possible and graphical interpretation are provided along with pertinent conclusions.*

Paper 4:

Title: Control Of Forced And Parametric Type Nonlinear Vibrations Of Perfectly Conductive Plate With The Help Of Magnetic Field
Authors: Baghdasaryan G.Y., Danoyan Z.N., Mikilyan M.A
Type: paper submission: Journal Mechanics of NAS Armenia 2012

Abstract:
On the basis of non-linear theory of magnetoelasticity of thin plates the governing equations and boundary conditions of non-linear dynamics of perfectly conductive plate in an inclined magnetic field are obtained. Besides the usual third-order nonlinear term (typical for the classical problems of elastic vibrations of flexible plates) these equations contain also a new square nonlinear member of magnetoelastic origin. The appearance of this nonlinear term is due to the occurrence of longitudinal force in the middle plane of the plate. The noted occurrence is a result of the interaction of longitudinal component of the induced current with the transverse component of external magnetic field. This means that the character of nonlinear magnetoelastic vibrations of the plate is qualitatively identical to the character of nonlinear elastic vibrations of flexible shells. The special case of here stated problem (the problem of natural non-linear magnetoelastic vibrations) was investigated in [2,3]. A formula is obtained to determine the frequency of the nonlinear magnetoelastic vibrations as a function of the amplitude of the vibrations and the intensity of external magnetic field. It is shown that, depending on the orientation of external magnetic field, the character of nonlinear magnetoelastic vibrations of the plate, unlike the classical case, can be soft. In the presented work the approximate solution of the addressed problem is obtained in the cases of non-linear, forced and parametric type vibrations. The influences of as orientation, as well as the intensity of the given magnetic field on the behavior of forced vibrations, on the weight of dynamic instability boundary and on the amplitude of non-linear forced and parametric vibrations are investigated. It is shown that the existence of resonant type vibrations near the multiple frequencies is conditioned only by the presence of the inclined magnetic field.

Paper 5:

Title: Analysis of slender thin-walled anisotropic box-beams including local stiffness and coupling effects

Authors: Frulla G., Cestino E.
Type: Journal of Aircraft Engineering and Aerospace Technology - AIRCRAFT ENGINEERING AND AEROSPACE TECHNOLOGY, vol. 86 n. 4, pp. 345-355. - ISSN 1748-8842

Abstract:

Purpose – Fiber-reinforced laminated composite could play a great role in the design of present and future generation of innovative civil aircrafts and unconventional unmanned configurations. The tailoring characteristics not only improve the structural performance, thus reducing the structural weight, but allow for possible material couplings. Both static and dynamic aeroelastic stability can be altered by those couplings. An accurate and computationally efficient beam model must be used during the preliminary design phase. Design/methodology/approach – A proper *structural beam scheme is adopted as a modification of previously first level approximating scheme. The effect of local laminate stiffness is investigated in order to check the possibility to extend the analytical approximation to different structural configurations. The evaluation of the equivalent stiffness both in the case of isotropic configuration and in simple/thin-walled laminated or stiffened sections proceeds introducing the classical thinwalled assumptions and classical beam theory for equivalent system. Coupling effects are also included. The equivalent analytical and FE beam behaviour is determined and compared in order to validate the considered analytical stiffness relations useful in preliminary design phase. Findings –The paper analyzed different configurations highlighting the effect of flexural/torsion couplings and local stiffness effect in the global structural behaviour. Three types of configurations are considered: 1) a composite wing box configuration with and without coupling effects 2) a wing box configuration with the presence of sandwich and cellular constructions 3) a wing box with the presence of stiffened panels in coupled or uncoupled configuration. An advanced aluminium experimental test article will be also described in details. A good agreement between theory, numerical analysis and experimental tests was obtained confirming the validity of analytical relations.*

Paper 6:

Title: Aeroelastic Design of Propellers with Optimized Load-Distribution Characteristics
Authors: Jurij Sodja, Radovan Drazumeric, Tadej Kosel, Pier Marzocca
Type: Conference paper submission: 54th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference

Abstract:
The mathematical model and experimental verification of deformable propeller blades is presented in this paper. The propeller aerodynamics model is based on an extended blade-element momentum model while the Euler-Bernoulli beam theory and Saint-Venant theory of torsion are used to account for bending and torsional deformations of the blades, respectively. The proposed blade-element momentum model extends the standard blade-element momentum theory with the aim of providing a quick and robust model of propeller action capable of treating propeller blades of arbitrary geometry. Based on the proposed mathematical model a propeller blade aeroelastic design procedure and its associated analysis algorithm are established. Verification with experiment investigations are also proposed to evaluate the performance of the developed algorithm and design strategy. Both theoretical and experimental results are presented along with pertinent concluding remarks.

Paper 7:

Title: Design of Flexible Propellers with Optimized Load-Distribution Characteristics

Authors: Jurij Sodja, Radovan Drazumeric, Tadej Kosel, Pier Marzocca

Type: Journal of Aircraft, 2014, Vol.51: 117-128, 10.2514/1.C032131

Abstract: *The mathematical model and experimental verification of flexible propeller blades are presented in this paper. The propeller aerodynamics model is based on an extended blade-element momentum model, while the Euler–Bernoulli beam theory and Saint–Venant theory of torsion are used to account for bending and torsional deformations of the blades, respectively. The proposed blade-element momentum model extends the standard blade-element momentum theory with the aim of providing a quick and robust model of propeller action capable of treating high-aspect-ratio propeller blades with a blade axis of arbitrary geometry. Based on the proposed mathematical model, a static flexible propeller blade design procedure and its associated analysis algorithm are established. Dynamic aeroelastic phenomena like propeller flutter and divergence are not covered by the presented mathematical model, design, and analysis algorithm. Experimental validation was carried out with an objective of evaluating the performance of the developed mathematical model and the design strategy. Both theoretical and experimental results are presented along with pertinent concluding remarks.*

Paper 8:

Title: A Reduced Order Model for the Aeroelastic Analysis of Flexible Wings
Authors: Enrico Cestino; Giacomo Frulla; Pier Marzocca
Type: SAE-AEROTECH-2013& SAE INTERNATIONAL JOURNAL OF AEROSPACE, vol. 6 n. 2. - ISSN 1946-3855

Abstract: *The aeroelastic design of highly flexible wings, made of extremely light structures yet still capable of carrying a considerable amount of non-structural weights, requires significant effort. The complexity involved in such design demands for simplified mathematical tools based on appropriate reduced order models capable of predicting the accurate aeroelastic behaviour. The model presented in this paper is based on a consistent nonlinear beam model, capable of simulating the unconventional aeroelastic behaviour of flexible composite wings. The partial differential equations describing the wing dynamics are reduced to a dimensionless form in terms of three ordinary differential equations using a discretization technique, along with Galerkin's method. Within this approach the nonlinear structural model an unsteady indicial based aerodynamic model with dynamic stall are coupled. Only three degrees of freedom in edgewise, flapwise, and torsion, are needed to describe efficiently the dynamics of the wing and to evaluate the sensitivity to system parameters, such as stiffness ratio, aspect ratio, and root angle of attack. Interesting design indicators will be highlighted. In addition to analytical results, a wind tunnel test article will be introduced to assess the validity of the proposed model.*

Paper 9:

Title: The Influence of Supersonic Stream on the Dependence "Amplitude-Frequency" Of Nonlinear Vibrations of Flexible Plate
Authors: Gevorg Baghdasaryan, Marine Mikilyan, Rafayel Saghoyan, Enrico Cestino, Giacomo Frulla
Type: SAE-AEROTECH-2013-Technical paper

Abstract: *The stability analysis of plates and shells in high speed flow deals with the determination of the flutter instability boundary. A linear analysis is made using the basic principles of the theory of aero-elasticity of isotropic bodies, the theories of flexible plates, the stability equations and associated boundary conditions obtained through a linear formulation. Herein, the nonlinear stability of flexible plate immersed in a high speed gas flow is considered. The model takes into account quadratic and cubic aerodynamic nonlinearities as well as cubic geometric nonlinearities. 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 influence of the free stream flow speed on the "amplitude-frequency" dependence phenomena is also presented.*

Paper 10:

Title: $\mathcal{L}1$ Adaptive Flutter Suppression Control Strategy for Highly Flexible Structure
Authors: Mario Cassaro, Manuela Battipede, Piergiovanni Marzocca, Enrico Cestino, Aman Behal
Type: SAE-AEROTECH-2013 & SAE INTERNATIONAL JOURNAL OF AEROSPACE, vol. 6 n. 2. - ISSN 1946-3855

Abstract: *The aim of this work is to apply an innovative adaptive* $\boldsymbol{\mathcal{L}_1}$ *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* $\boldsymbol{\mathcal{L}_1}$ *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* $\boldsymbol{\mathcal{L}_1}$ *adaptive control in flutter and post-flutter suppression is demonstrated. Results and discussion will follow with pertinent conclusions and future outlooks.*

Paper 11:

Title: Improved Multibody Model of Flexible Wing
Authors: Andras Nagy, Balazs Gati, Enrico Cestino, Piergiovanni Marzocca
Type: SAE-AEROTECH-2013-Technical Paper

Abstract: *In the development of High Altitude Long Endurance (HALE) UAVs and their control the flexibility of the wing must be taken into account. The wing of this type of UAVs, usually made of highly flexible composite materials, has high aspect ratio with significant bending-torsional deformation during flight. The NASA Helios, as an example, has tragically shown that wing deformation coupled with control and power operation can cause serious problem in flight, instability can suddenly occur and can be quite difficult to foresee. In this paper the mathematical description of a flexible wing multibody model is presented. It 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. The paper will present simulation results for a typical HALE (High Altitude Long Endurance) wing with control surfaces and the effect of flexibility on the flight dynamic will be explored.*

Paper 12:

Title: Piezo-Aeroelastic modeling and flutter prediction of flexible composite wings
Authors: Bruni C, Cestino E, Frulla G

Type: AIRTEC 2013 & (**under review** AIRCRAFT ENGINEERING AND AEROSPACE TECHNOLOGY).

Abstract: *The design of highly flexible aircraft, such as high altitude long endurance (HALE) configurations, require a dedicated aeroelastic analysis which is not usually considered in traditional aircraft design. Wing flexibility, coupled with high wing span lead often to large deflection during normal flight operations, associated with aeroelastic instabilities. The discussion addressed in this paper is restricted, among the various aeroelastic phenomena, to the flutter condition only. Aeroelastic flutter of wings and structures is typically considered a dangerous self-starting instability phenomenon that must be avoided by properly designing the mass, stiffness, and inertia properties of structures and by restricting the flight envelope of the aircraft. Classical modeling procedures usually refer to aero-structural systems where the undeformed state is taken as the reference point. This assumption is not longer suitable for slender wing configuration where, due to the high structural flexibility, a proper beam model, capable of describing the structural flight deflections, needs to be adopted. A reduced order model, including only three degrees of freedom in edgewise, flapwise and torsion, of a thin-walled composite beam has been proposed to study the flutter phenomenon of a such wing configuration. Besides, the possibility of acting on the restriction of the flight envelope, postponing the flutter instabilities onset, have been investigated by coupling to the composite beam a piezoelectric passive circuit. The governing equations of the expanded structural element, beam and PZT, have been coupled with an aerodynamic model for incompressible unsteady flow. The effect of composite bending/torsion couplings terms have been analyzed as well as the optimum electrical load value as a function the model flutter speed.*

Paper 13:

Title: Issues of Dynamics of Conductive Plate in a Longitudinal Magnetic Field
Authors: Baghdasaryan G.Y., Danoyan Z.N., Mikilyan M.A.
Type: International Journal of Solids and Structures, Available online 12 June 2013, DOI: 10.1016/j.ijsolstr.2013.06.003

Abstract: *On the basis of Kirchhoff hypothesis the problem of vibrations of conductive plate in a longitudinal magnetic field is brought to the solution of the singular integral-differential equation with ordinary boundary conditions. The formulated boundary-value problem solved and the influence of magnetic field on the characteristics of vibration process of the examined magnetoelastic system is investigated. Via the analysis of obtained solutions it is shown that the presence of magnetic field can: a) increase essentially the frequency of free magnetoelastic vibrations of the plate; b) decrease essentially the amplitude of forced vibrations if* $r \le 1$*, where* $r = \theta / \omega$*,* θ *- is the frequency of acting force,* ω *- is the frequency of own vibrations of the plate magnetic field is being absent; c) increase essentially the amplitude of forced vibrations if* $r > 1$*; d) decrease essentially the width of main areas of dynamic instability. It is shown that: 1)* *in the case of perfectly conductive plates magnetic field constricts essentially the width of main area of dynamic instability; 2) if plate's material has the finite electroconductivity, then the certain value of the intensity of external magnetic field exists, exceeding of which excludes the possibility of appearance of parametric type resonance. It is shown also that in dependence on the character of initial excitements the plate can vibrate either across the initial non-deformable state, or across the initial bent state.*

Paper 14:

Title: On bimodal flutter behavior of a flexible airfoil

Authors: Radovan Drazumeric, Bojan Gjereka, Franc Kosel,Pier Marzocca

Type: Journal of Fluids and Structures Volume 45, February 2014, Pages 164–179

Abstract: *The dynamic aeroelastic behavior of an elastically supported airfoil is studied in order to investigate the possibilities of increasing critical flutter speed by exploiting its chord-wise flexibility. The flexible airfoil concept is implemented using a rigid airfoil-shaped leading edge, and a flexible thin laminated composite plate conformally attached to its trailing edge. The flutter behavior is studied in terms of the number of laminate plies used in the composite plate for a given aeroelastic system configuration. The flutter behavior is predicted by using an eigenfunction expansion approach which is also used to design a laminated plate in order to attain superior flutter characteristics. Such an airfoil is characterized by two types of flutter responses, the classical airfoil flutter and the plate flutter. Analysis shows that a significant increase in the critical flutter speed can be achieved with high plunge and low pitch stiffness in the region where the aeroelastic system exhibits a bimodal flutter behavior, e.g., where the airfoil flutter and the plate flutter occur simultaneously. The predicted flutter behavior of a flexible airfoil is experimentally verified by conducting a series of systematic aeroelastic system configurations wind tunnel flutter campaigns. The experimental investigations provide, for each type of flutter, a measured flutter response, including the one with indicated bimodal behavior.*

Paper 15:

Title: Development of an Aeroelastic Wing model with piezoelectric elements for gust load alleviation and Energy Harvesting

Authors: Bruni C., Cestino E., Frulla G., Marzocca P.

Type: ASME-2014 International Mechanical Engineering, Montreal (Canada) 14-20 November 2014

Abstract: *The lifting surfaces of next generation of flying vehicle exhibits enhanced flexibility, particularly for high aspect-ratio solutions needed for high-altitude long endurance aircrafts needed for 24/7 operations. Often the wing of these vehicles is designed as slender body with an aeroelastic behavior distinctive of cantilever beam. Based on this typical assumption the governing equations of a thin-walled beam modified to account for surface mount piezoelectric elements and subjected to deterministic external gust loads have been derived and its dynamic behavior examined. This paper assesses the effectiveness of piezoelectric elements to carry out load alleviation function over the slender structure invested by atmospheric disturbances along with the evaluation of the amount of the power density harvested via a suitable electric circuit connected to the piezoelectric elements.*

Paper 16:

Title: A Multi-Objective Nonlinear Piezoaeroelastic Wing Solution for Energy Harvesting and Load Alleviation: Modeling and Simulation

Authors: Claudia Bruni, Giacomo Frulla, Enrico Cestino, Pier Marzocca

Type: 56th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference (AIAA 2015-1188)

(doi: 10.2514/6.2015-1188)

Abstract: *The model of a geometrically nonlinear wing hosting piezoelectric patches with the dual purpose of suppressing aeroelastic vibration and harvesting vibrational energy is presented in this paper. The nonlinearities are introduced in order to consistently reproduce the behavior of the flexible structure, since moderate to large displacements can occur in response of external loading conditions. A nonlinear shear underfomable 3-D Euler-Bernoulli beam theory is used to model the displacements field and structural nonlinearities up to the third order are retained in the model of a straight untapered composite wing. A linear indicial functional representation of the unsteady aerodynamic loads in an incompressible flowfield is adopted. The extended Hamilton principle is used to derive the aeroelastic equations of motion. The composite cantilever wing includes two piezoelectric elements, perfectly bonded on its lower and upper longitudinal surfaces in the proximity of the wing root, and electrically connected by a resistive load, functioning as energy harvesting devices. During the state of deformation the piezoelectric components induce electric charges to be stored for future use as a supplementary power source. The piezoelectric layers also function as damping elements with desired load alleviation properties. The effectiveness of such a solution, both in terms of the amount of energy harvested and load alleviation characteristics, for a well defined wing configuration have been evaluated in this paper. Numerical results and discussions are followed by pertinent conclusions and directions for future work.*

Paper 17:

Title: Aeroelastic System Control by a Multiple Spoiler Actuation and MRAC Scheme (AIAA 2015-1851)

Authors: Mario Cassaro, Manuela Battipede, Pier Marzocca, Goodarz Ahmadi

Type: 56th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 2015, 10.2514/6.2015-1851

Abstract: *A novel wing configuration to control flutter and post-flutter limit cycle oscillations is proposed. The new wing consists of a multiple spoiler control surface, with a predefined and coordinated actuation strategy. The proposed architecture, optimized through CFD analysis, is fabricated and tested in the wind tunnel to validate the aerodynamic properties of the wing section. The experimentally obtained nonlinear aerodynamic database is implemented in a simulation environment, which is used to investigate the dynamic response of the proposed wing configuration aeroelastic model. The coupled, two degree of freedom, structural model has nonlinear plunging/pitching characteristics, which allow the system to exhibit LCOs above flutter speed. The open and closed loop responses of the system are investigated and compared to a trailing-edge flap solution of the same wing section. The regulation problem is obtained for a normalized MRAC scheme, modified for performance improvement. The same algorithm is applied to both plants and results validate the robustness and the adaptation capabilities of the implemented control scheme. Further sensitivity analyses to external disturbances, which are different gust distributions, demonstrate the efficacy and solidity of the overall configuration investigated.*

Paper 18:

Title: Comparison of Adaptive Control Architectures for Flutter Suppression

Authors: M. Cassaro, M. Battipede, P. Marzocca, A. Behal

Type: Journal of Guidance, Control, and Dynamics, 2015, Vol.38: 346-355, 10.2514/1.G000707

Abstract: *The evaluation of the nonlinear flutter instability of slender wings represents a critical condition to test and validate control algorithms; [1–4] are case in point. On a benchmark 2-D aeroelastic model, several linear and nonlinear active controllers [5–7] as well as various adaptive control schemes [2,3,7,8] have been tested. In spite of the recent years' flourishing literature on aeroelastic adaptive controls, there is a noted lack of robustness and sensitivity analysis with respect to structural proprieties degradation, which might be associated with a structural failure. Structural mode frequencies and aeroelastic response, including limit cycle oscillations (LCOs) characteristics, are significantly affected by changes in stiffness. This leads to a great interest in evaluating and comparing the adaptation capabilities of different control architectures subjected to large plant uncertainties and unmodeled dynamics. The contribution of this Note lies in the derivation and implementation of state feedback model reference adaptive control*

(MRAC) solutions for a 2-D aeroelastic nonlinear system and in evaluating the robustness of different control strategies to damage leading to the deterioration of the structural stiffness characteristics. The standard MRAC, a modified MRAC, and the L1 adaptive controller are the three model reference adaptive control solutions analyzed. The standard direct MRAC solution [9] serves as the threshold to assess whether or not the more complex algorithms are an effective improvement to it. Both modified model reference [9] and L1 [10] adaptive controllers, which embody different modifications to the standard scheme with the intent to improve robustness and performance at the same time, are proposed in this work. For consistency of the analysis, all the adaptive scheme solutions are derived for the same control objective [11–14] and are applied to the same aeroelastic plant, which is a two-degree-of freedom (2-DOF) structurally nonlinear plunging and pitching lifting surface in a quasi-steady aerodynamic flow. The model has pitch polynomial-type structural nonlinearities and uses a single trailing edge control surface. The proposed aeroelastic model exhibits a supercritical Hopf-bifurcation behavior, that is, stable LCOs obtained past the flutter speed [15]. Investigation results and pertinent comments on the adaptation performance and robustness of the three schemes are presented.

Paper 19:

Title: High- and Low-Fidelity Investigations of Flexible Propeller Blades

Authors: J. Sodja, D. Nozak, R. Drazumeric, P. Marzocca,

Type: (AIAA 2014-0410) Proceedings of the AIAA SciTech Conference, 52nd Aerospace Sciences Meeting, 13-17 January 2014, NATIONAL HARBOR, MARYLAND.

Abstract: *High- and low-fidelity fluid-structure interaction analyses of flexible propeller blades are compared in this paper. High-fidelity fluid-structure interaction analysis consists of a coupled computational fluid dynamics and computational structural dynamics commercial codes, whereas low-fidelity analysis is composed out of coupled extended blade element momentum model and nonlinear beam theory. The comparison is performed in the case of flexible propeller blades. Three different blade geometries are analyzed: straight, backward swept and forward swept blades. Backward swept and forward swept blades are designed to emphasize the influence of the blade flexibility on the blade performance. Straight blade was selected in order to serve as a reference. In the course of the study, integral thrust and breaking power as well as their respective distributions along the blades are compared at different advancing ratios. Blade deflections are also analyzed.*

Paper 20:

Title: Aeroelastic Characteristic of an Airfoil Containing Laminated Composite Plate

Authors: R. Drazumeric, B. Gjerek, F. Kosel, P. Marzocca

Type: Proceedings of the AIAA SciTech Conference, 52nd Aerospace Sciences Meeting, 13-17 January 2014. NATIONAL HARBOR, MARYLAND.

Abstract: *The aeroelastic behavior of an elastically supported airfoil is studied in order to investigate possibilities of increasing critical speed by exploiting its chord-wise flexibility. The flexible airfoil concept is implemented using a rigid airfoil-shaped segment, and laminated composite plate conformally attached to its trailing edge. The aeroelastic behavior is studied in terms of the number of laminate plies used in the composite plate for a given aeroelastic system configuration. Such flexible airfoil is characterized by three types of aeroelastic response, the airfoil divergence, the classical airfoil flutter, and the plate flutter. The analysis shows that a significant increase in the critical speed can be achieved in the region where the aeroelastic system exhibits a bimodal behavior, e.g. where two types of the aeroelastic response occur simultaneously. The predicted aeroelastic behavior of a flexible airfoil is experimentally verified by conducting a series of wind tunnel flutter campaigns.*

Paper 21:

Title: Novel Active Control Strategy for LCO and Flutter Suppression by a Coordinated Use of Multiple Distributed Surface Actuators

Authors: M. Cassaro, A. Nágy, P. Marzocca, M. Battipede, G. Ahmadi,

Type: IMECE2014-36905, Proceedings of the ASME 2014 International Mechanical Engineering, 14-20 November 2014, Montreal, Canada.

Abstract: *The effectiveness of a novel actuation architecture developed to control flutter and post-flutter is investigated in this paper. To this purpose, the performance of an active control strategy in various operational conditions is experimentally examined. A physical prototype, consisting of a wing section with multiple spoilers mounted on an aeroelastic apparatus, has been designed and assembled to carry out open- and closed loop operations. Wind tunnel aeroelastic testing are performed with a plunging and pitching apparatus specifically designed to simulating wing sections with prescribed stiffness characteristics, including torsional structural nonlinearities responsible of a stable nonlinear post-flutter limit cycle behavior. Five surface mounted spoilers located at 15% of the chord from the leading edge are used to control aeroelastic vibrations in pre- and post-flutter. The spoilers design, including selection of best size and chord position and considering the geometrical constraints, has been carried out by CFD simulation, with the objective of maximizing the aerodynamic pitching moment used to stabilize the lifting surface at the various speeds. The spoiler actuations are commanded by an active control system as to extend the flight region in the natural post-flutter condition. A simple PID algorithm is implemented to test the efficiency of the control system design to suppress flutter oscillation. A trial and error tuning of the gain has been executed on-site during the experimental campaign. Only the pitch angle is used as state feedback in the control laws to stabilize the system above the open-loop flutter velocity. Results and pertinent conclusions are outlined.*

Paper 22:

Title: Numerical and Experimental Investigation of Membrane Wing for Micro Aerial Vehicle Applications

Authors: I. Petrovic, S.P. Shea, I.P. Smith, F. Kosel, P. Marzocca

Type: IMECE2014-38581, Proceedings of the ASME 2014 International Mechanical Engineering, 14-20 November 2014, Montreal, Canada.

Abstract: *Micro-Air-Vehicles (MAV) flight regimes differs significantly from larger scales airplanes. They are operating at low Reynolds numbers of approximate 104, cruising at speed about 12m/s, and are capable of agile maneuvers in limited space environment. They are compact and easily stowable to facilitate transportation. However, due to the small size, they are usually more vulnerable to the wind gusts with significant complexities associated to their flight mechanics, stability and control, which also makes difficult to quantify flight qualities and performances. Furthermore, complex aerodynamics can produce loading scenarios leading to the destruction of the vehicle during flight operation. To minimize the size of the MAV when not in use, their wings are stowed within the body of the vehicle, and are deployed during operation. To supplement the bulk of knowledge in MAV aero-mechanics, the study of the aerodynamic characteristics of a deformable membrane MAV wing is carried out in this paper. The analysis of the membrane airfoil is performed using a fluid-structure interaction 2D model, to select a set of optimal airfoil parameters for the intended flight regime. Numerical simulations are supplied and validated with an MAV model tested in the wind tunnel.*