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Title

A 3D aeroelastic beam modelling approach for time domain non-uniform lifting structures flutter analysis

Authors

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Abstract

The aim of this work is to present an alternative 3-dimensional beam finite element for rapid time-domain flutter analysis of non-uniform wings equipped with distributed trailing edge control surfaces. The presence of control surfaces strongly affects the aeroelastic behaviour of the wing, usually reducing its flutter boundary, expecially when non-linearities on the hinge stiffness, such as free-play, are present [1]; it follows that a rapid numerical tool for preliminary aero-servo-elastic design is needed in order to avoid inefficient structural configurations for the desired flight envelope. Nowadays the most popular tool for aeroelastic verification of wing structures is the combination of the Finite Element Method, used to model the structural system, coupled with the Doublet Lattice Method [2], used to model the aerodynamic system, and the connection between structure and aerodynamics is performed by means of splines. Anyway, this kind of aeroelastic model presents high computational costs and it is better suitable for the verification phase of the project than for the preliminary aeroelastic assessment of the design. Moreover, aero-servo-elastic time domain analyses of aeroelastic models in ppresence of non-linearities are more suitablein order to assess if there exists any coupling between the flight control system and the aeroelastic behaviour of the structure that can lead to undesired dynamic phenomena [3]. In this work a reduced order modelling approach of the aeroelastic system is proposed taking advantage of three-dimensional Euler-Bernoulli beam theory, De Saint Venant torsion theory and 2D unsteady aerodynamics [4]. The aerodynamic loads, expressed in time domain by means of the Duhamel formulation and Sears approximation of the Wagner function [5], are directly incorporated in the beam element matrices that are computed from the governing equations weak form [6]. As the two-noded aeroelastic beam finite element is defined in the 3D space each node has six structural Degrees Of Freedom DOF, an aerodynamic lag state DOF (introduced to model the aerodynamics in time domain), and the control surface rotation DOF, for a total of eight degrees of freedom per node. Moreover, the proposed 3D beam element allows to model variations of elastic axis position along the span connecting the adjacent wing stations with rigid rod elements. The finite element equivalent beam model equations can be finally cast in the convenient state space form in order to carry out the stability analysis of the wing for increasing speed values to identify its flutter boundary. The method proposed is validated with commercial code aeroelastic results of non-uniform lifting structures with and without control surfaces.

References

[1] Vindigni, C. R., Esposito, A., & Orlando, C. (2022). Stochastic aeroservoelastic analysis of a flapped airfoil. *Aerospace Science and Technology*, *131*, 107967.
[2] Albano, E., & Rodden, W. P. (1969). A doublet-lattice method for calculating lift distributions on oscillating surfaces in subsonic flows. *AIAA journal*, *7*(2), 279-285.
[3] Vindigni, C. R., & Orlando, C. (2022). Simple adaptive V-stack piezoelectric based airfoil flutter suppression system. *Journal of Vibration and Control*, 10775463221085854.
[4] Theodorsen, T. (1949). *General theory of aerodynamic instability and the mechanism of flutter* (No. NACA-TR-496).
[5] W.R. Sears, A systematic presentation of the theory of thin airfoils in non-uniform motion, PhD dissertation, California Institute of Technology, 1938.
[6] Vindigni, C. R., Mantegna, G., Esposito, A., Orlando, C., & Alaimo, A. (2022). An aeroelastic beam finite element for time domain preliminary aeroelastic analysis. *Mechanics of Advanced Materials and Structures*, 1-9.