Invited Speaker I

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9:40-10:20, July 14, 2022

TITLE: Temperature and Moisture Content Profiles Through the Thickness of Composite, FGM and Sandwich Structures

Abstract: Structural components in aerospace applications usually undergo adverse environmental conditions. Significant temperature and humidity gradients characterize their application scenarios. The way different materials react to temperature and moisture content strongly differs; their gradients induce thermal and hygrometric stress fields, which sum up to that induced by mechanical boundary conditions. Furthermore, composite materials are led to absorb moisture, which can degrade their structural performances.

Aerospace components are shell type, usually, with a small thickness. A collateral effect is that their boundary conditions are defined on the top and bottom surfaces only. Defining how temperature and moisture content develop across them usually translates into evaluating their profile through the thickness. The Fourier heat conduction equation governs the thermal field, while the Fick diffusion law governs the hygrometric field. The two laws have an identical mathematical formulation, which allows a common discussion.

Three strategies exist under steady-state conditions. Firstly, a 3D solution of the heat conduction and moisture content equations delivers the exact solution of the problem as does not introduce any simplification. The exact lamination scheme is considered, together with the heat/moisture fluxes in the 3D coordinate system. Secondly, In sufficiently thin parts, a 1D solution of the equations is possible: it disregards the heat/moisture fluxes out of the thickness direction but still considers the exact lamination. A further simplification, quite common in the literature, comprises assuming a linear evolution of the temperature/humidity along the thickness between their values at the top and bottom surfaces.

Isotropic and thin components show limited practical differences when comparing these three approaches. However, when the thermal and hygrometric properties change in the thickness direction, the last approach proves to be inadequate. This happens regardless of the source of the anisotropy; whether it is for a specific lamination scheme (in composites or in sandwich parts) or for a functionally grading of the properties (typical of Functionally Graded Materials, FGMs). The 1D solutions overcome this problem; however, disregarding in-plane fluxes makes them inadequate for thicker elements.

Being aware of the field of application and of the limitations of these three solutions is important, especially when they act as field loads. An exact elastic shell solution fails in defining the mechanical behaviour of a structure when the thermal/hygrometric inputs are inaccurate. Integrating these three approaches into an analytical code for static stress analysis allows detecting these differences and limitations in terms of field

profiles such as displacements, strains and stresses. It also allows quantifying the error magnitude they introduce into a stress analysis.

Biography: After earning his degree in Aerospace Engineering at the Politecnico di Torino in 2005, Brischetto received his PhD in Aerospace Engineering (Politecnico di Torino) and in Mechanics (Université Paris Ouest–Nanterre La Défense) in 2009. He won the excellence prize for PhD students in 2008 and the prize for young researchers in 2011 at the Politecnico di Torino. He worked as a Research Assistant at the Politecnico di Torino from 2006 to 2010, and as Assistant Professor from 2010 to 2018; currently he is Associate Professor since february 2018. His main research topics are: additive manufacturing, FFF 3D printing, smart composite structures, multifield problems, hygro-thermal stress analysis, CNTs, inflatable structures, shell 3D and 2D numerical and exact solutions and UAVs. He is the author of 158 articles, 81 of which have been published in international journals, and 1 patent. He serves as a reviewer for more than 100 international journals. He has been Guest Editor for Mechanics of Advanced Materials and Structures, for Technologies, and for Journal of Composites Science. He is a committee member for several international journals and 1 book series, and member of the "Shell Buckling People" web-site. Brischetto is Associate Editor of Curved and Layered Structures, and of Journal of Composites Science. He has been Teaching Assistant at the Politecnico di Torino for courses on computational aeroelasticity, structures for aerospace vehicles, nonlinear analysis of aerospace structures, principles of structural mechanics, aeronautic constructions, aeronautic structures, and numerical modelling and simulation techniques for aerospace structures. He was chair at the Politecnico di Torino for the courses “Aeronautic law and human factors and safety”, "Design and Additive Manufacturing for Aerospace Applications" and currently for "Aeronautic constructions", “Numerical modelling and simulation techniques for aerospace structures” and "3D shell models for composite structures". He is co-founder and co-chair of the group “ASTRA: Additive manufacturing for Systems and sTRuctures in Aerospace”, and also founder and chair of the project “PoliDrone, A multipurpose modular drone produced via 3D printing".