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EFFECT OF WARPING DUE TO AERODYNAMIC LOADINGS IN COMPOSITE WINGS

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ABSTRACT

With the advent of composites, the accurate evaluation of the response of deformable lifting bodies when subjected to steady and unsteady aerodynamic loadings becomes an even more challenging issue for the aeroelastic design of aerospace vehicles.

Static response analyses of composite wings subjected to aerodynamic loadings are presented in this paper. Wing structures are modeled via refined finite elements in the framework of the 1D Carrera Unified Formulation (CUF). CUF 1D models have recently been developed for isotropic [1, 2] and composite structures [3]. CUF models exploit arbitrary order expansions of the generalized variables above the cross-section of the structure. In this paper, Taylor-like polynomial expansions are adopted and the order N of the expansion is a free-parameter of the formulation. In other words, any-order models can be obtained with no need of ad hoc formulations by exploiting a systematic procedure to build finite element matrices in a form which is independent of the accuracy of the model. 1D CUF models allow to detect highly accurate shell-like static deformations and modal shapes of thin-walled structures with a significant reduction of computational costs.

1D CUF structural models were coupled to the Vortex Lattice Method, VLM, in [4]. The formulation was extended to the static aeroelastic analysis of lifting surfaces made by metallic and composite materials [5]. The computation of linear steady aerodynamic loads refers to the Vortex Lattice Method presented by Katz and Plotkin [6]. As usually adopted in preliminary aeroelastic design, the aerodynamic computation by the VLM did not consider the airfoil-shaped section. Hence, an analysis tool for airfoils, wings and planes operating at low Reynolds Numbers, XFLR5, is herein adopted in order to accurately describe the aerodynamic field over the wing affected by the airfoil pressure distribution.

In this paper, non-classical effects such as airfoil in-plane deformation and warping are introduced by enriching the displacement field over the cross-section of the wing. A number

of composite wing configurations (by varying aspect ratio, airfoil geometry, dihedral, sweep angle, and lamination lay-up) are analyzed to evaluate the influence of non-classical cross-section deformation on the static response of a typical lifting system. The coupling of XFLR5 and 1D CUF models reveals the capabilities of such refined models in evaluating the aeroelastic behavior of composite wings.

Table 1 shows a typical result from the present formulation. A swept tapered wing exposed to a free stream velocity V_∞ = 50 m/s is considered. The results obtained through a solid Nastran analysis are taken as a reference solution. Results from the present models accurately match those from Nastran shell and solid FEs with a reduced computational costs.

N_{EL}	EBBM	TBM	$N=1$	$N=2$	$N=3$	$N=4$
2	4.2749	4.2829	4.2909	4.4309	4.9598	5.1036
5	3.1768	3.1842	3.1965	3.6408	3.8045	3.8858
10	3.0401	3.0473	3.0605	3.4701	3.5785	3.6316
20	3.0071	3.0144	3.0277	3.4097	3.4854	3.5377
40	2.9990	3.0062	3.0196	3.3920	3.4440	3.4802
	-13.69 %	-13.49 %	-13.10 %	-2.383 %	-0.886 %	+0.155 %

Nastran (solid - sol 101): 3.4748

Table 1: Effect of the expansion order *N* of 1D CUF models on the maximum transverse displacement for different finite element mesh

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