REFINED AND ADVANCED MODELS FOR THE RATIONAL DESIGN OF MULTILAYERED FUNCTIONALLY GRADED MATERIAL PLATES AND SHELLS

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Abstract (Topic: Structures)

Functionally Graded Materials (FGMs) are composite materials made up two or more constituent phases with a continuously variable composition. FGMs are usually associated with particulate composites where the volume fraction of particles varies in one or several directions. One of the advantages of a monotonous variation of volume fraction of constituent phases is the elimination of stress discontinuity that is often encountered in laminated composites and accordingly, avoiding delamination-related problems [1], [2]. FGMs present a number of advantages that make them attractive in potential future applications, such as a reduction of in-plane and transverse through-the-thickness stresses, an improved residual stress distribution, enhanced thermal properties, higher fracture toughness, and reduced stress intensity factors [3]. For these reasons, an accurate evaluation of displacements, strains, stresses and vibration modes can be fundamental in the design of such structures. This paper analyzes the bending response of several multilayered plates and shells embedding functionally graded layers. The mechanical load is bi-sinusoidal in the plane and applied at the top surface in the thickness direction. Refined and advanced Equivalent Single Layer (ESL) and Layer Wise (LW) models, with linear to fourth order of expansion in the thickness direction, will be employed. The functionally graded properties of FGM layers will be approximated by means of Legendre's polynomials. The ESL and LW theories have been developed according to the Principle of Virtual Displacements (PVD) and Reissner's Mixed Variational Theorem (RMVT); in the latter case, both displacements and transverse shear/normal stresses are assumed as primary variables. Among the proposed multilayered FGM structures, of particular interest are sandwich plates and shells with a functionally graded core. The use of a core in Functionally Graded Material can, in fact, offer some advantages with respect to classical cores that have been widely employed in open literature. Benchmarks are proposed which consist of sandwich plates/shells with two isotropic faces and various functionally graded cores. That benchmarks could be useful to assess future refined computational models. In order to obtain refined and advanced two-dimensional models for multilayered structures with FGM layers, Carrera's Unified Formulation (CUF) [4], [5] has been extended to materials with properties that are functionally graded through the thickness direction. This extension of CUF to FGMs was made for the refined models (PVD) in Carrera et alii [6] and for the advanced mixed ones (RMVT) in Brischetto and Carrera [7]: applications were only made for single-layered FGM structures. In this paper, the models will be validated for multilayered FGM plates as already done in Brischetto [8], and then for shell geometries. The main aim is to propose a rational design of sandwich structures with an FGM core. The refined and advanced models will be employed to investigate the more appropriate functionally graded cores in order to avoid the main problems related to classical sandwich structures: the use of FGM cores can represent a valid alternative to classical materials, because they permit particular performances e.g. the continuity of in-plane stresses in the thickness direction, that conventional cores do not permit. In

the full paper several functionally graded cores will be investigated in order to define the best solution in the design of sandwich structures.

References

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