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Abstract

In this paper, we propose an original FEM strategy to consider stiffening honeycomb-shaped cells, filled or not, to the simulation of sandwich plates and shells. The strategy combines three-dimensional membrane elements (called active face) with solid prismatic elements. This approach is different from the usual ones that use solid elements to discretize all parts of a panel or use equivalent macroscopic properties to simulate honeycomb-shape laminated composites. In the proposed technique, the composition of elements is done by means of direct nodal correspondence, defined in the mesh generation procedure, not interfering in the number of degrees of freedom of the models. Thus, introduction of reinforcements does not increase the number of degrees of freedom, which makes the technique highly economical from the numerical point of view. Positional finite element (Positional FEM) procedure is adopted, resulting in a total Lagrangian description that allows general applications including large displacements of laminated plate and shell problems. Positional FEM adopts as main variables the current nodal positions instead of displacements as classical finite elements do. The proposed stiffening cell element is tested regarding stress and displacements calculations, comparing results with literature. Results for large displacements in reinforced honeycomb laminated shells are also presented.

Keywords: Finite element method; positional formulation; active face prismatic element; honeycomb-shape reinforcement; sandwich plates and shells

1 Introduction

Sandwich laminate is a class of composite material made by joining two thin rigid facesheets separated by a thick, lightweight core. The core may have several compositions, for example, be composed of simple foam (metal or polymeric), truss-like structure or lattice structure, corrugated sheet, prismatic honeycomb cells, also filled or not by foams, as can be seen in Fig. 1.

The properties of the facesheets and of the core are chosen according to the mechanical loads to be carried and the acoustic or thermal insulation to be achieved. Regarding the mechanical behavior, the facesheets have the main function of resisting the bending and membrane stresses, while the core is responsible to bear shear stresses, preventing the facesheets from relative sliding and, consequently, ensuring the efficiency of the mechanical bending stiffness, that is, it contributes to the performance of the facesheets.

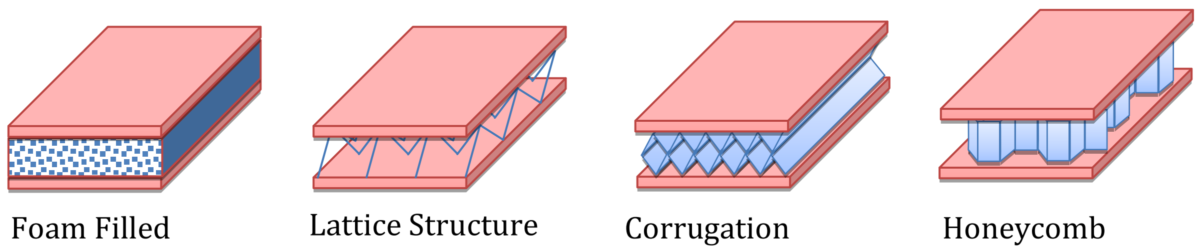

Fig. 1. Usual sandwich cores.

Due to its high stiffness/weight ratio and thermal and acoustic insulation properties, laminated sandwich plates have various applications as secondary structural elements in the naval, aeronautical, civil, space, transport, among others industrial fields. In secondary applications, only the overall behavior of the component is sufficient to evaluate the possibility of its proper use. However, the current growth in the use of laminated sandwich panels, as components of primary structures, requires more attention in the