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A Review on Fem Analysis of Structural Response of Sandwich Beam

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Abstract

A composite beam consists of laminate consisting of more than one lamina bonded together through their thickness. Composite materials have interesting properties such as high strength to weight ratio, ease of fabrication, good electrical and thermal properties compared to metals. The equation of motion for the viscoelastic sandwich beam is derived. Different specimens have been modelled by varying the core layers and face layers and studied under the fixed-fixed and cantilever boundary conditions for modal analysis by various researchers. Therefore, this paper reviews the various work done by different authors towards the FEM analysis of structural response of sandwich beam.

Keywords: Sandwich beam, Damping, Vibration analysis, Finite Element Method.

I. INTRODUCTION

Research efforts continuously are looking for new, better and efficient construction materials. The main goal of these researches is to improve the structural efficiency, performance and durability. New materials typically bring new challenges to designer who utilizes these new materials. In the past decades various sandwich panels have been implemented in aerospace, marine, architectural and transportation industry. Light-weight, excellent corrosion characteristics and rapid installation capabilities created tremendous opportunities for these sandwich panels in industry. Sandwich panel normally consists of a low-density core material sandwiched between two high modulus face skins to produce a lightweight panel with exceptional stiffness. Face skins act like flanges of an I-beam. These faces are typically bonded to a core to achieve the composite action and to transfer the forces between sandwich panel components. Sandwich panels have been successfully used for many years in the aviation and aerospace industries, as well as in marine, and mechanical and civil engineering applications. This is due to the attendant high stiffness and high strength to weight ratios of sandwich systems [1]. The use of the sandwich constructions in the aerospace structures can be traced back to Second World War when British De Havilland Mosquito bomber had utilized the sandwich constructions [5]. In the early use, the sandwich structure was very simple in construction, with simple cloth, fabric or thin metal facings were used and soft wood were used as the core. The conventional sandwich construction comprises a relatively thick core of low-density material which separates top and bottom faceplates (or faces or facings) which are relatively thin but stiff. The materials that have been used in sandwich construction have been many and varied but in quite recent times interest in sandwich construction has increased with the introduction of new materials for use in the facings (e.g. fiber- reinforced composite laminated material) and in the core (e.g. solid foams) [2].

Use of Sandwich construction for an aircraft structural component is very common to the present day. One of the primary requirements of aerospace structural materials is that they should have low density, very stiff and strong.

II. TYPES OF SANDWICH PANEL

Detailed treatment of the behavior of honeycombed and other types of sandwich panels can be found in monographs by Plantema [3] and Allen [4]. These structures are characterized by a common feature of two flat facing sheets, but the core takes many generic forms; continuous corrugated sheet or a number of discrete but aligned longitudinal top-hat, zed or channel sections (see Figures 1). The core and facing plates are joined by spot-welds, rivets or self-tapping screws [1].

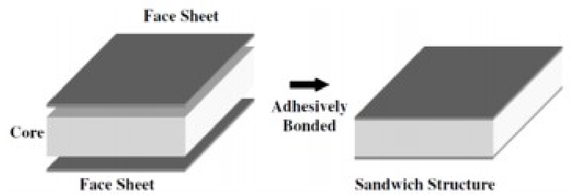

Figure 1: Schematic of sandwich construction**.**

1. Sandwich Construction

Sandwich construction is a special kind of laminate consisting of a thick core of weak, lightweight material sandwiched between two thin layers (called "face sheets") of strong material figure (2). This is done to improve structural strength without a corresponding increase in weight. The choice of face sheet and core materials depends heavily on the performance of the materials in the intended operational environment. Because of the separation of the core, face sheets can develop very high bending stresses. The core stabilizes the face sheets and develops the required shear strength. Like the web of a beam, the core carries shear stresses. Unlike the web, however, the core maintains continuous support for the face sheets. The core must be rigid enough perpendicularly to the face sheets to prevent crushing and its shear rigidity must be sufficient to prevent appreciable shearing deformations. Although a sandwich composite never has a shearing rigidity as great as that of a solid piece of face-sheet material, very stiff and light structures can be made from properly designed sandwich composites.

A useful classification of sandwich composites according to their core properties by respective direction is shown in fig. 2. To see the core effect upon sandwich strength, let us consider the honeycomb-core and the truss-core sandwich composite. The honeycomb sandwich has a ratio of shear rigidities in the xz and yz planes of approximately 2.5 to 1. The face sheets carry in-plane compressive and tensile loads, whereas the core stabilizes the sheets and builds up the sandwich section. The truss-core sandwich has a shear rigidity ratio of approximately 20 to 1. It can carry axial loads in the direction of the core orientation as well as perform its primary function of stabilizing the face sheets and building up the sandwich section [5].

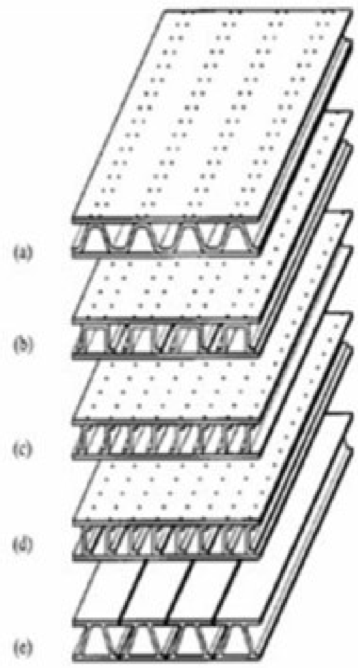

Figure 2: Sandwich panel with (a) continuous corrugated core (b) top-hat core (c) Zed-core (d) Channel core (e) truss-core.

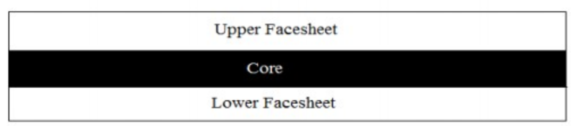

Figure 3: Sandwich Beam.

Sandwich beam consist of three layered like two elastic layer separated by viscoelasticlayer is used to reduce a vibration where viscoelastic material itself act as damping.

Visco-elastic material exhibit properties of both elastic and viscous material. If elastic material is subjected to a load within elastic limit and then removed it will regain its equilibrium position within shortest time but in case of viscoelastic material it will take some time to gain its original position. There are two methods for surface treatment of viscoelastic material to improve its damping capacity i.e. constrained layer [2] and unconstrained layer or free layer treatment.

III. PROPERTIES OF MATERIALS USED IN SANDWICH COSNTRUCTION

No single known material or construction can meet all the performance requirements of modern structures. Selection of the optimum structural type and material requires systematic evaluation of several possibilities. The primary objective often is to select the most efficient material and configuration for minimum-weight design [5].

1. Face Materials

Almost any structural material which is available in the form of thin sheet may be used to form the faces of a sandwich panel. Panels for high-efficiency aircraft structures utilize steel, aluminum or other metals, although reinforced plastics are sometimes adopted in special circumstances. In any efficient sandwich the faces act principally in direct tension and compression. It is therefore appropriate to determine the modulus of elasticity, ultimate strength and yield or proof stress of the face material in a simple tension test. When the material is thick and it is to be used with a weak core it may be desirable to determine its flexural rigidity [4].

2. Core Materials

A core material is required to perform two essential tasks; it must keep the faces the correct distance apart and it must not allow one face to slide over the other. It must be of low density. Most of the cores have densities in the range 7 to 9.5 lb/ft^3. Balsa wood is one of the original core materials. It is usually used with the grain perpendicular to the faces of the sandwich. The density is rather variable but the transverse strength and stiffness are good and the shear stiffness moderate. Modern expanded plastics are approximately isotropic and their strengths and stiffness's are very roughly proportional to density. In case of aluminum honeycomb core, all the properties increase progressively with increases in thickness of the foil from which the honeycomb is made [4].

IV. REVIEW OF PAST WORK

Sandwich structures can be defined as a subset of multilayered composite structures, optimized for the anticipated lifetime loading conditions. A typical sandwich structure consists of the outer facings and the core embedded between them. Below where two facings are clearly identified. While in this figure, the sandwich structure has a tetrahedral truss core, numerous alternative core designs have been employed, including foam, honeycomb, corrugated core, various bio-inspired cores, etc. The facings are built of stiff and strong materials and they are much thinner than the light and relatively compliant core. Accordingly, a typical sandwich structure is somewhat similar to an I-beam where the flanges carry the lion share of bending and in-plane loads, while the web sustains transverse shear, redistributes concentrated normal to the surface forces and maintains the integrity of the structure. The thickness of the facings found in typical structural applications seldom exceeds several millimeters, while the core may be over 50 mm thick, although usually it is thinner. Exceptions to the dimensions referred to here can be found, but they seldom necessitate a development of an alternative theory for the analysis. Neither the facings nor the core of a sandwich structure have to be homogeneous. While the facings can consist of a single metallic layer, laminated or woven composite materials are also broadly employed. The core designs are even more diverse, including honeycomb, cellular, lattice and truss designs or web-reinforced options. The facing-core interface is often the most vulnerable part of the sandwich structure. This interface is often bonded (e.g., graphite epoxy facings joined to an aluminum honeycomb core). Alternatively, the facing-core interface can be blended or functionally graded as is sometimes suggested for ceramic-metal sandwich structures. The choice of sandwich materials depends on the function of the structure, lifetime loading, availability and cost. Graphite-epoxy and carbon-epoxy multilayered facings are typical in aerospace applications, while glass-epoxy or glass-vinyl ester are used in the facings of civil and marine structures. The core of aerospace structures is often aluminum or Nomex honeycomb. In civil engineering the core is often a closed-cell or open-cell foam, while balsa of various density is a typical choice in ship sandwich structures. Even though this review is concerned with the most recent developments in sandwich structures, the major steps outlining the theory and analysis methodologies are listed to present a comprehensive picture. Those include the books by Plantema [1], Allen [2], Zenkert [3] and Vinson [4]. A comprehensive review of the studies of sandwich structures covering the early developments was published by Noor, Burton and Bert [5]. Chai and Zhu reviewed research on low-velocity impact of sandwich structures [6]. Non-destructive testing of thick composite and sandwich structures was reviewed by Ibrahim [7] and Hsu [8]. The features and methods of control of sandwich structures using magneto rheological and electro rheological fluids in the core were reviewed in Ref. [9]. The analyses of bending, buckling and free vibrations of sandwich beams using equivalent single layer theories, layer wise theories, zigzag theories and exact elasticity were outlined in Ref. [10]. Abrate and Di Sciuva presented a review of equivalent single layer theories, including the classical, first, second and third order formulations, and polynomial and non-polynomial displacement methods [11]. Langdon et al. reviewed experimental and numerical studies of sandwich structures subject to air blast [12]. Asymptotic methods of the homogenization of composite and sandwich structures evaluating their effective properties were considered by Kalamkarov et al. [13]. Acoustic response of sandwich panels was reviewed in Ref. [14]. The recent book of Carlsson and Kardomateas provides an insight in the modern methods of analysis and testing of sandwich structures [15].A LW analysis of free vibrations of sandwich beams with damping using the classical lamination theory for the cross-ply facings and FSDT for the core was employed to both evaluate natural frequency and specify the modal loss factors [16]. Vibrations and damping of cylindrical sandwich panels containing a viscoelastic flexible core were analyzed using HSDT and validated through a comparison with a LW approach solution [17]. This paper can be considered in conjunction of the static analysis of cylindrical sandwich shells conducted by the same authors [18,19]. The effectiveness of cork layers as a damping treatment for sandwich structures was demonstrated both numerically (FEA) and experimentally in Ref. [20]. This study concentrated on sandwich plates with aluminum facings and cork compound cores. Impact analysis of cylindrical sandwich shells subjected to impact was conducted by HSDT and successfully compared to experimental data [21]. The solution was obtained by assumption that the in-surface stiffness of the core was negligible. Accordingly, the facings were modeled by the classical theory, while the displacements and stresses in the core were found from the theory of elasticity. This approach has also been applied to other mechanical loading cases [22]. The layer-wise analysis of a geometrically nonlinear behavior of a sandwich beam with viscoelastic core and elastic facings using FSDT theory for each layer was published in Ref. [23]. Guided wave propagation in composite and sandwich strips was considered using a LW approach [24]. The waves were generated by a piezoelectric actuator, their monitoring is potentially important in health monitoring applications. Static and dynamic problems of sandwich plates were analyzed and favorably compared to the three-dimensional elasticity benchmark solutions and FEA results using the refined zigzag theory [25], [26]. Brischetto employed a LW approach to study free vibrations of cross-ply sandwich shells and plates [27]. The LW third-order shear deformation theory was employed in Ref. [28] to analyze delamination in sandwich panels subject to slamming loads.

V. CONCLUSION

Modeling of sandwich structures requires progressively sophisticated methods accounting for the three-dimensional effects, physical and geometric nonlinearities and constitutive relations for the newly developed materials. Pressing needs include addressing new or previously underexplored phenomena, such as environmental effects on the engineering constants, interaction of failure modes, and multiscale response of the material, from nanoscale to macroscale. Two principal directions of macro-mechanical modeling are a layer wise and equivalent single layer approaches. New sandwich designs and concepts are actively investigated and introduced into practice. Many such concepts are developed for the core aiming at improving its functionality both transferring and distributing applied loads among the facings as well as enhancing toughness of the structure. In addition to widely used honeycomb, cellular and balsa cores, various truss-core designs are extensively investigated. Among recent developments is using functionally graded core enabling a better tailoring of the response of the structure and an enhanced integrity? Functionally graded, z-pinned or stitched sandwich structures can provide an enhanced resistance against face/core deboning as well as a higher toughness. Multi-functionality of sandwich structures is a natural design objective. Such features as heat transfer management, radar wave absorption, and noise and fire insulation are considered in diverse industrial settings. New material concepts are studied for sandwich structure applications. Examples of materials incorporated into new sandwich designs include, but not limited to, annotates, shape memory alloy and piezoelectric, while the aims may vary from enhanced strength, stiffness and toughness to sensing internal damage. One of the consequences of introducing such materials in the facings and core is the adaptation of available or development of new micromechanical theories capable of an accurate capturing of the structural behavior.

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