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Structurally graded core inserts in sandwich panels

Elena Bozhevolnaya *, Anders Lyckegaard

Institute of Mechanical Engineering, Aalborg University, Pontoppidanstræde 105, 9220 Aalborg East, Denmark

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Abstract

Core inserts in sandwich panels substitute parts of the original core material in a sandwich element, and the main purpose of the core inserts is to supply a local reinforcement of the sandwich panel for a subsequent introduction of the external loads. The new design of the core insert substantially diminishes the level of impairing local effects in the faces. The suggested insert is structurally graded by means of shaping insert boundaries to be inclined with respect to the sandwich faces, which provides smoothing of material discontinuities at the junction of different materials. The new design of the core insert is studied experimentally, and the design parameters of the core insert are studied with the help of the finite element modelling (FEM).

Keywords: Sandwich panels; Inserts; Stress concentrations; Junctions

1. Introduction

Sandwich elements in the form of panels are usually comprised of two thin and yet stiff faces, which are separated by a thick, lightweight and compliant core. The faces are usually made from metals or laminated fibre reinforced plastics, while the core is made from polymeric foams, end grain balsa wood, or aramid (nomex) honeycomb. Sandwich panels are used in many applications, where it is important to obtain high strength-to-weight and stiffness-to-weight ratios. The strong faces of a sandwich panel provide a high resistance to external bending loads, while the compliant core offers significant resistance to external and smoothly varying shear loads [1,2]. The application of sandwich structures in spacecraft, aircraft, automotive, marine and building industries is well known.

Practical functionality of structural elements is unthinkable without the possibility of assembling them and introducing fasteners for attachment or rigging of different appliances [3–6]. This at once implies attendance of localised/concentrated loads to which sandwich structures are notoriously sensitive. One practical method to redistribute concentrated loads to a larger area of the sandwich panel is to use so called stiffeners or reinforcing plates or backing plates [4,7,8]. An assortment of various terms is used in this connection. In this paper a term *core insert* is applied to denote a piece of a stiffer core, plywood, wood, polymeric material, metal or the like, which substitutes a part of the original core in the sandwich panel with the purpose of achieving a local reinforcement of the panel. This reinforcement is needed to introduce external transverse loads safely.

A major purpose of the core insert is to facilitate the transmission of the direct and shear stresses through the thickness of the sandwich element without impairment the structural integrity of the whole sandwich. However, any inclusions in a sandwich panel bring about material discontinuities, which results inevitably in local effects in the vicinity of the discontinuities. These local effects manifest themselves in a local rise of stresses in all components of the sandwich panel, and these local stresses may exceed the allowable stresses in the core, insert and faces.

A theoretical modelling of the junction of different cores in sandwich panels due to Skvortsov and Thomsen [9] provides a practical tool for estimation of all stresses locally induced in the sandwich constituents in the vicinity of material discontinuities. The model was experimentally verified by Bozhevolnaya et al. [10], and a method to alleviate the unwanted local stresses at the butt junctions via introduction of intermediate patch cores was suggested. However, usage of patch cores does not seem practical in manufacture, and therefore a new

* Corresponding author. Tel.: +45-96-35-93-23; fax: +45-98-15-16-75.
E-mail address: eb@ime.auc.dk (E. Bozhevolnaya).

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design of core inserts having structurally graded borders of the adjoining core and insert materials is suggested here.

According to the new design, the insert has its borders terminated with an angle different from 90°. This facilitates a smoother change of material discontinuities across junctions and diminishes local effects in the vicinity of those. In the presented paper the new design of the core insert is investigated experimentally, and the measured values of the locally induced stresses are compared with those predicted with the help of the finite element modelling (FEM). Finally, influence of the design parameters on the performance of the inserts is studied numerically.

2. Inserts in sandwich panels

Inserts, which are in some literature called stiffeners or reinforcing/backing plates [4,5,7,8], are widely used in sandwich panels to facilitate the introduction of localised loads. Fig. 1 shows a conventional insert with its borders terminating at an angle of 90° in relation to the faces of the sandwich, and a new type of the insert, whose borders are inclined with an angle α in relation to the faces.

In the following the conventional type of insert is called a butt insert, while the new type of insert is called a scarf insert. This follows the terminology exploited in the technical literature in relation to composite structures [4,5,11]. Note, that an in-plane shape of the insert may be rectangular, circular or any other practically sensible contour.

The core insert is placed in the sandwich as a substitute for the original core and is usually made of stiffer foam, plywood, wood, polymeric material, metal or the like. Local reinforcement of the core may also be achieved, for example, by filling the cells of the honeycomb core with epoxy in a special way, as was done by Daniel and Abot [12]. Edge inserts of an optimised shape, whose purpose is to minimize local stress concentrations at the beam supports, were suggested by Miers et al [13]. Both the former [12] and the latter [13] designs provide more levelled transition zones between the core and the insert.

In the case of the conventional design (Fig. 1(a)) an abrupt change of shear moduli takes place at the junction, which causes local effects to appear. The local effects manifest themselves in significant rise of normal stress σ_f in the faces, normal σ_c and shear τ_c stresses in the core. These locally induced stresses are proportional to the shear stress resultant τ_0 at the junction

$$\sigma_f = \tau_0 f_1\left(\sqrt{G_{core}/G_{ins}},\ \text{parameters}\right)$$
$$\sigma_c = \tau_0 f_2\left(\sqrt{G_{core}/G_{ins}},\ \text{parameters}\right)$$
$$\tau_c = \tau_0\left(1 + f_3\left(\sqrt{G_{core}/G_{ins}},\ \text{parameters}\right)\right)$$

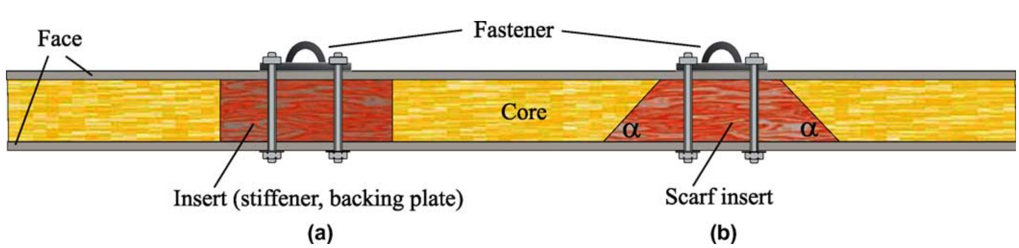

Fig. 1. A conventional design (a) and a new design (b) of the core inserts in sandwich panels.

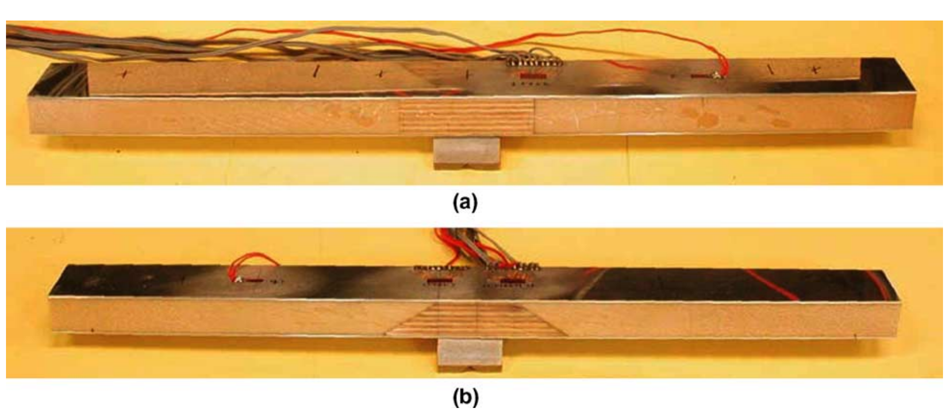

Fig. 2. Sandwich beams with two types of core inserts: (a) a beam with the conventional butt insert; (b) a beam with the structurally graded scarf insert. Material data are given in Table 1 and geometry is illustrated in Fig. 3.