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PII: S0263-8223(16)32895-1
DOI: http://dx.doi.org/10.1016/j.compstruct.2017.01.065
Reference: COST 8199

To appear in: *Composite Structures*

Received Date: 16 December 2016
Revised Date: 17 January 2017
Accepted Date: 28 January 2017

The three-point bending of a sandwich beam with two binding layers – comparison of two nonlinear hypotheses

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Abstract: The paper is devoted to the strength analysis of a simply supported three layer beam. The sandwich beam consists of: two metal facings, the metal foam core and two binding layers between the faces and the core. In consequence, the beam is a five layer beam. The main goal of the study is to elaborate a mathematical model of this beam, analytical description and a solution of the three-point bending problem. The two different nonlinear hypotheses of the deformation of the cross section of the beam are formulated. Based on the principle of the stationary potential energy the two systems of four equations of equilibrium are derived. Then deflections and stresses are determined. The results of the solutions of the bending problem analysis are shown in the tables and figures. The analytical model is verified numerically using the finite element analysis, as well as experimentally.

Keywords: Metal foams; Sandwich beams; Deflections; Stresses, Analytical description and solution; Nonlinear hypotheses.

1. Introduction

Sandwich structures are widely applied since the mid of 20th century in various industrial applications, for example in aerospace, automotive, rail and shipbuilding industry. These structures are characterized by high stiffness in relation to their mass. Allen [1] described the bases of the theory of sandwich structures. Ashby et al. [2] described the mechanical properties of metal foams. Banhart [3] provided a comprehensive description of various manufacturing processes of metal foams and porous metallic structures. Ventsel and Krauthammer [4] presented principles of thin plate and shell theories, emphasized novel analytical and numerical methods for solving linear and nonlinear plate and shell dilemmas. Jasion [5], Jasion and Magnucki [6] studied analytically, numerically and experimentally the global buckling of sandwich beams. Mania [7] analyzed the dynamic response of FGM thin plate structures subjected to combined loads. Malachowski et al. [8] presented the experimental investigations and numerical modelling of closed-cell aluminium alloy foam (Alporas). Magnucka-Blandzi and Magnucki [9] optimized the sandwich beam with metal foam core under strength and stability constrains. Magnucki et al. [10] studied three-layer beams with corrugated core subjected to compression and four point bending. Han et al. [11] carried out analytical and numerical study of foam filled corrugated sandwich beams under three-point bending. Magnucki et al. [12, 13] presented the strength analysis of a simply