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3D elasticity analysis of sandwich panels with graded core under distributed and concentrated loadings

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ABSTRACT

Sandwich panels are a type of panel offering weight savings over standard single layer panels, whilst remaining both strong and stiff. However, due to the mismatch of properties between the face sheets and the core, stress concentrations can occur at the face sheet/core interfaces, often leading to delamination. One possible solution to this problem is the introduction of a functionally graded core—a core in which the properties vary gradually from the face sheets to the centre, eliminating any abrupt changes in properties. This paper presents a three-dimensional elasticity analysis for a sandwich panel with stiffness of the core graded in the thickness direction, on the basis of the recently developed 3D elasticity solution. A comparative study of panels with homogeneous and functionally graded cores is carried out to examine the effect of introducing a graded core on the stress and displacement fields under five different loading configurations (uniformly distributed, patch, point, hydrostatic and line).

1. Introduction

Sandwich panels or plates are structures that can be used in place of standard plates or panels, offering weight savings whilst remaining strong and stiff. They are used in a variety of engineering applications particularly in the aerospace industry. Due to the mismatch in stiffness properties between the face sheets and the core, sandwich panels are susceptible to delamination, caused by high interfacial stresses, especially under localised or impact loading [1].

The effect of localised loading on sandwich panels with homogenous core has been examined theoretically by a number of researchers. Polyakov [2] developed analytical expressions for local stresses and displacements under loading by point forces. Using an exact 3D solution for simply supported sandwich panels developed by Pagano [3] and Srinivas and Rao [4], Swanson [5] extended this solution to cover localised loading and compared it to results from higher order plate theory and classical plate theory.

Whitney [6] developed a bending theory for a three-layer sandwich plate subjected to a distributed load and to an end-loaded cantilever plate under cylindrical concentrated bending, modelling the core and face sheets as separate homogeneous plates satisfying equilibrium equations and continuity across the interfaces. Reissner's energy theorem is then used in the development of the solution which is validated through comparison with an available high order theory.

Frostig and Thomsen [7] focused on the non-linear response of sandwich panels in areas surrounding concentrated loads and stiffened core regions. Their analysis uses non-linear high order sandwich panel theory on a panel in three point bending and results show that under localised loading an indentation zone appears beneath the load accompanied by large bending moments and compressive normal stresses. There are also peaks in transverse shear and normal stresses at the upper face sheet core interface. When non-linear effects are considered, it was shown that these effects are magnified and can occur at low load levels.

The effects of localised loading on sandwich panels have also been explored experimentally. Suvorov and Dvorak [8] evaluated the overall and local deflections of a sandwich panel under local contact from a rigid indenter. They concluded that in order to maximise the performance of sandwich panels it is important to minimise the in plane strains in the face sheet at the contact region and the deflections of the face sheet/core interface. It was shown that these factors can cause crushing of the foam core and hence lead to delamination.

Further experiments have been conducted, investigating the effects of a cyclic loading on different foam materials and assessing their suitability for inclusion in sandwich panels [9].

Lolive and Berthelot [10] produced a comparison between experimental data and a finite element analysis into the effects of localised loading on the core material. They were found to be in good agreement with each other under both indentation and 3 point bending.

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