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Collapse mechanism maps for the hollow pyramidal core of a sandwich panel under transverse shear

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ABSTRACT

The finite element method has been used to develop collapse mechanism maps for the shear response of sandwich panels with a stainless steel core comprising hollow struts. The core topology comprises either vertical tubes or inclined tubes in a pyramidal arrangement. The dependence of the elastic and plastic buckling modes upon core geometry is determined, and optimal geometric designs are obtained as a function of core density. For the hollow pyramidal core, strength depends primarily upon the relative density $\bar{\rho}$ of the core with a weak dependence upon tube slenderness. At $\bar{\rho}$ below about 3%, the tubes of the pyramidal core buckle plastically and the peak shear strength scales linearly with $\bar{\rho}$. In contrast, at $\bar{\rho}$ above 3%, the tubes do not buckle and a stable shear response is observed. The predictions of the current study are in excellent agreement with previous measurements on the shear strength of the hollow pyramidal core, and suggest that this core topology is attractive from the perspectives of both core strength and energy absorption.

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1. Introduction

Metallic sandwich plates bring structural benefit over their monolithic counterparts due to increased structural stiffness and strength, and the potential for multifunctional application. For example, sandwich plates have potential application as structural armour in land, sea and air vehicles for providing structural stiffness, and resistance to crash, blast and ballistic attack. Typically, sandwich panels are loaded by spatially varying transverse loads, and consequently the core of the panel must possess adequate compressive strength and longitudinal shear strength. The properties of the core are sensitive to both material choice and topology, and in the current study we shall explore the use of hollow tubes made from stainless steel as candidate core material. Stainless steels have both high ductility and corrosion resistance, and a wide range of yield strengths (200–1000 MPa), depending upon the alloy and heat treatment.

Lattices are mechanically competitive alternatives to prismatic (corrugated) and honeycomb structures when configured as the core of a sandwich panel. There has been significant recent activity in the invention, manufacture and testing of new core topologies, see for example the review by Fleck et al. (2010) and Wadley et al. (2003a). Lattice sandwich structures are of particular interest because of their fully open interior structure which facilitates multifunctional applications (Evans et al., 1998a,b; Wadley, 2006). For example, lattice core sandwich panels are capable of supporting significant structural loads while also facilitating cross flow heat exchange (Kim et al., 2005). Sandwich panels with lattice cores made from hollow stainless steel tubes are well-suited for structural heat exchangers: stainless steel combines structural and thermal performance along with high corrosion resistance. The lattice topology may also alleviate some of the delamination and corrosion concerns associated with the use of traditional closed cell honeycomb sandwich panels (Blitzer, 1997).

Early experimental studies on lattice-cored sandwich panels were limited to the manufacturing route of investment casting, and this restricted the material choice to high fluidity casting alloys such as high Si-content aluminium alloys (Deshpande and Fleck, 2001; Sugimura, 2004; Zhou et al., 2004) and to non-structural alloys such as the casting brasses (Chiras et al. (2002), Wallach and Gibson, 2001). However, the tortuosity of the lattices and ensuing casting porosity made it difficult to fabricate high quality structures at low relative densities (2–10%) identified as optimal for sandwich panel constructions (Chiras et al., 2002). In these early investigations, premature failure occurred from casting defects. The resulting tensile ductility was sufficiently low (a few percent) that shear loading of sandwich panels gave rise to brittle failure of the tensile struts rather than to elastic or plastic buckling of the compressive struts (Sugimura, 2004).

Efforts to exploit the inherent ductility and toughness of many wrought engineering alloys led to the development of alternative

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