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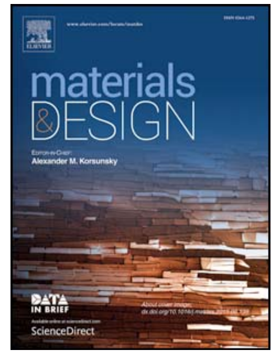

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Development of melt-stretching technique for manufacturing fully-recyclable thermoplastic honeycombs with tunable cell geometries

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Abstract

Honeycomb sandwich panels of several cell geometries were created by stretching polycarbonate melts between opposing platens. Perforations for air ingress through one of the platens were employed to enable and direct the formation of cells within the honeycomb, demonstrating a simple means to produce complicated architectures. Platen temperature, consolidation pressure, and platen movement speeds were each investigated to establish a range of effective process parameters. Honeycomb panels were successfully produced with areal densities of $0.18\,\mathrm{g\,cm^{-2}}$ to $0.42\,\mathrm{g\,cm^{-2}}$ and panel thicknesses ranging from 6 mm to 32 mm. The cell geometries were found to be effectively modeled by Voronoi diagrams seeded by the perforations used for air ingress. This model was validated by the successful production of hexagonal-, square-, and triangular-celled honeycombs, as well as an architecture combining all three cell shapes. Analysis of several samples via computed tomography provided insight into the internal distribution of material. Out-of-plane compressive testing was used to probe the mechanical performance of the structures. Minimal variation in buckling strength was found between the different honeycomb geometries, but post-failure behavior was dependent on cell shape.

Keywords: honeycomb, thermoplastics, sandwich structures, sustainable materials

1 Introduction

Sandwich panels - consisting of a core region bounded by face sheets - are a vital configuration within the field of composite structures. The primary purpose of sandwich panels is to resist bending or buckling loads, which typically place the face sheets under in-plane tension and/or compression while the core experiences shear and out-of-plane stresses. As compared to monolithic beams or fully-dense panels, sandwich constructions can offer improvements of up to two orders of magnitude in mass-specific strength and stiffness [1]. Amongst potential core materials, honeycombs generally produce sandwiches with higher mass-specific mechanical performance than wood, foams or fully-dense materials - the other common core sandwich materials used in industry. However, honeycombs are also much more expensive.

Honeycomb-core sandwich panels are used extensively in the aerospace, automotive, and transit industries [2]. In addition to their bending stiffness and strength, a major application of honeycombs is for energy-absorbing structures, in which the presence of honeycomb topologies within panels or tubes acts to increase the energy-absorption capacity of the structure [3]. Graded honeycombs - those in which webs vary in thickness and/or distribution - have recently been the subject of much study, as they offer improved mass-specific performance when optimized for a particular load case [4] and can more efficiently absorb crash energy [5, 6].

A major shortcoming of most commercial composites - especially honeycomb sandwich panels - is sustainability; the prevalence of thermoset matrix materials and the mixed-material nature of composites makes recycling or re-use difficult [7–9]. Honeycombs are manufactured commercially by several processes.

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