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ORIGINAL PAPER

Numerical evaluation of two-dimensional micromechanical structures of anisotropic cellular materials: case study for polyurethane rigid foams

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Abstract This paper deals with evaluating the elastic response of several micromechanical structures used for simulating cellular materials under compression. For this study polyurethane rigid foams were investigated, having three relative densities: 0.085, 0.124 and 0.256. Their microstructure was analysed using SEM images, determining four types of cells that were consequently designed using specialized CAD software: square cells with circular, quadratic and/or hexagonal orifices and hexagonal cells. An interdependent variation of the cells' geometrical parameters of the proposed structures was determined to obtain geometrical variations at a required relative density. Finite element analysis simulations were performed on the designed microstructural models using a linear elastic material model for the cell struts, resulting in the variation of the elastic modulus of the structure with the variation in cell geometry parameters. The final objective of this work was to determine anisotropic bi-dimensional micromechanical models for the studied cellular material that provides accurate results in compression on both loading directions. The anisotropic models for the proposed cell structures were obtained by generating irregular geometries which provided extra variables for the cell geometry parameters. It was determined that some cell geometries are suitable for simulating lower relative density materials while other cell geometries provide good accordance with experimental data for higher relative density materials.

Keywords Finite element analysis · PUR foams · Micromechanical structures · Compression · Anisotropy

Introduction

Cellular materials represent an interconnected matrix of solid layers having a well-defined shape of the edges and facets [1]. Through their light specific weight, good impact resistance and high-energy absorption in dynamic loading scenarios, cellular materials represent one of the most frequently used materials as cores in sandwich structures with numerous applications in aerospace, naval and terrestrial transportation [2, 3]. Through their structure, cellular materials can provide a wide range of mechanical properties which vary with a number of parameters such as the materials' intrinsic properties like relative density, orientation, microstructure as well as with loading conditions such as strain rate or temperature [4, 5].

Considering the properties of this class of materials, an important objective consists of predicting the mechanical properties of these structures at a microlevel, based on the geometry of the structure and the properties of the solid.

Micromechanical models are able to describe the multiaxial properties of cellular materials, which in general present anisotropy in elasticity, yield point and plateau stress with regard to the loading directions [6–8]. Finite element analysis represents a useful tool in describing the mechanical behaviour of cellular structures [9], which in some cases are difficult to determine experimentally but are generally required in designing cellular and sandwich structures [10]. A first requirement for the numerical simulations of micromechanical structures

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