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Mechanical behaviour of tube-woven Kagome truss cores under compression

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ABSTRACT

Wire-woven bulk Kagome (WBK) has recently been used to fabricate multi-layered truss-type cellular metals. A tube WBK structure is fabricated of tubes instead of solid wires. In this work, tube WBK specimens with various combinations of slenderness ratio and inner-to-outer diameter ratio of the tubular struts were tested under compression to investigate the effects of geometric factors on peak strength, equivalent Young's modulus and energy absorption capability. To aid in the physical interpretation of the results and the development of a design methodology, numerical simulations of single tubular struts were performed with a wide range of slenderness ratio and inner-to-outer diameter ratio. The tube WBKs outperformed most cellular metals, but they were inferior to hollow trusses, especially those with a diamond configuration. However, energy absorption of the tube WBKs was comparable to that of hollow trusses because of stable deformation of the tube WBKs after initial yielding or maximum strength.

1. Introduction

Periodic cellular metals (PCM) are useful sandwich core materials in terms of strength and lightness. PCMs are classified as prismatic or truss-based [1]. The open cell structure of the latter is an advantage because the interior space is accessible for additional functions such as heat transfer media [2,3] or catalyst supports [4]. To enhance resistance against strut buckling (a main failure mechanism of truss PCMs), tubes can be used as raw material because they increase the second moment of inertia of the cross-sectional area for a given weight. The "hollow truss core" developed by Queheillalt et al. [5–7], is a good example. Using tubes has additional benefits. Tubes give the flexibility of changing density without changing unit cell size and enhance the bonding strength between the cores and face sheets through large surface interfacial area nodes. A multi-layered hollow truss core can be simply fabricated by aligning tubes in collinear layers with an alternating orientation of successive layers to create a lattice truss architecture [6]. Despite excellent performance in terms of specific strength and energy absorption capability, hollow truss cores have high anisotropy; that is, the material properties are quite sensitive to orientation.

Wire-woven bulk Kagome (WBK) is a multi-layered truss PCM fabricated by a three-dimensional (3-D) assembly of wires rather than by stacking multiple single-layered truss structures [8]. Helically-formed wires are screw-inserted in six evenly distributed directions in space to fabricate a Kagome truss-like structure in which the wires cross one another with minimum deflection. Consequently, the strength is only slightly degraded compared to an equivalent ideal configuration composed of straight struts and the material anisotropy is minimized. Moreover, WBK has good potential for mass-production. The effects of geometric factors such as wire diameter and pitch on the compressive strength of WBK has been investigated [9]. WBK composed of high strength steel and filled with brass has been developed to attain ultra-high specific strength [10]. Heat transfer characteristics under forced convection [11] and the methodology for optimal design [12,13] for sandwich panel cores were reported. In addition, it was recently shown that WBK could be fabricated using tubular wires and the strength was as good as that estimated using an analytic solution derived for equivalent Kagome truss PCMs with an ideal configuration composed of straight tubular struts [14].

In this work, tube WBK specimens with nine different combinations of slenderness ratio and inner-to-outer diameter ratio of tubular struts were tested under compression to investigate the effects of geometric factors on peak strength, equivalent Young's modulus and energy absorption capability. To aid in the physical interpretation of the results and the development of a design methodology, numerical simulations for single tubular struts were performed using a wide range of slenderness ratio and inner-to-outer diameter ratio. A map was created showing contours of the relative densities and the normalized peak strengths of tube WBKs and the domains of their failure modes plotted as functions of d_o/c and d_i/d_o. Another map was constructed showing relative densities and equivalent Young's moduli of tube WBKs. The measured results of the tube WBKs were compared to other cellular metals with respect to strength and energy absorption capability.

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