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Effects of gaps between discontinuous wire woven kagome cores upon bending of sandwich panels

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Abstract

WBK (Wire-woven Bulk Kagome) is a periodic cellular metal assembled of helical wires. The mechanical behavior under compression or shear, optimal design of a sandwich panel with WBK core, and characteristics of heat dissipation media have been studied, which proves feasibility of WBK as core material with multi-function capability. When WBK is used as the core material in a large scale sandwich panel, gaps between discontinuous cores are inevitable in their fabrication or building even larger scale structures using them. In this study, the effects of the gaps on mechanical behavior of sandwich panels are investigated. Theoretic analysis, experiments with three-point bending, and numerical analyses are performed to predict the strength and to analyze the results

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1. Introduction

Truss PCM (Periodic Cellular Metal) are a kind of cellular metals composed of miniaturized truss-like cells (Zok (2004), Chiras (2002)). Their regular and optimized structures with open cells have several benefits and potentials in terms strength or stiffness for a given weight (Zok (2004)), Chiras (2002)) and multi functionality such as heat dissipation media (Tian (2004), Wadley (2006)) or actuators (Lu (2001)). However, fabrication processes for mass production are yet to be established. Contrarily, conventional cellular metals, i.e., metal foams have irregular

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stochastic structures, and consequently their strength or stiffness are likely to be inferior to truss metals, but a number of fabrication processes of metal foams are well established.

A few years ago, WBK (Wire-woven Bulk Kagome) was introduced as a truss PCM fabricated using wires (Lee (2007)). Namely, helically formed wires are spin-inserted in six directions evenly-distributed in space to assemble a regular 3D truss. Because the structure of WBK is similar to Kagome truss, one of the best structures to give high strength per a given weight, and it is composed of wires which have merits for achieving high strength without defects, WBK is regarded as a mass producible truss PCM. WBK was evaluated to determine its performance as a core material for sandwich panels and the optimal design methodology of WBK-cored sandwich panels was studied to obtain its maximum bending strength for a given weight or the least weight for a given bending load (Lee (2009)).

According to a standard procedure for fabricating composite sandwich panel (Bitzer (1997)), if large core pieces or cores composed of two or more different materials are desired, small pieces can be spliced together. For a typical core material, i.e., honeycombs, a splice adhesive strip is usually placed between the two core slices and cured at the same time as the facings are bonded to the core. For another typical core material, i.e., foams, separate cores are usually adhesively bonded with a butt or inclined core junction.

Truss PCMs with various cell architectures including pyramid, Kagome, and octet truss have been investigated on feasibility as a metallic sandwich core (Zok (2004), Chiras (2002), Wadley (2003), Cote (2007)). They were fabricated by investment casting or crimping of expanded metals or perforated sheets, and their performances have been proved under bending or in-plane compression. In general, multi-layered structures with fine cells are preferred for homogeneous material properties and vibration suppression. However, contrarily to a single-layered structure or 2D structure like a honeycomb, a multi-layered truss structure including WBK has a zone on lateral sides where the struts do not support the external load.

Recently, the authors have performed a large industry-university joint research on the feasibility of application of WBK-cored sandwich panels for ship building (Kang (2012)). In order for sandwich panels to be joined to build a large scale structure like a ship, only face sheets can be welded together, but the cores cannot. Hence, discontinuous cores with small gaps are inevitable. Therefore, it is necessary to elaborate the effects of the gaps to establish a standard procedure of engineering design of WBK-cored sandwich panels with discontinuous cores. As a part of the results of investigation, this article elaborates the effect of gap between discontinuous WBK cores on bending properties of mild steel sandwich panels.

2. Theory

The standard sandwich specimen with continuous WBK core failed by Core-shear mode-B. For discontinuity of the core, two new failure modes are expected in addition to the four modes mentioned above. Fig. 1 depicts Core-shear mode-B, the modes of Double hinge mode and Hinge and crush at gaps. For Core shear mode-B, the critical load is given by

$$P_B = \frac{4Bt_f^2}{S-2a}\sigma_o^f + 2BH_c\tau_o^c \quad (1)$$

Here, H_c is the core height, S is the span between the two lower supporting points, t_f is the face sheet thickness, B is the face sheet width, D is the overhang, τ^o_c is the equivalent shear strength of WBK core, and σ^f_c is the yield strength of the face sheets. For the mode of double hinge at gaps, balance between externally applied energy and internal energy dissipation gives:

$$P_h \times \delta = 8 \times M_p \times \theta$$

Where δ, e, and θ are the displacement of the applied load, gap and the rotation angle at the hinges. They are related by $\theta = \frac{\delta}{e}$. M_p is the limit moment for a plastic hinge in the face sheets and it is given by $M_p = \frac{Bt_f^{\ 2}}{4}\sigma_o^f$. Hence, the critical loads, P_h, for the mode of double hinge at gaps is given by:

$$P_h = \frac{2Bt_f^{\ 2}}{e}\sigma_o^f \quad (2)$$