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Letter

The optimum layer number of multi-layer pyramidal core sandwich columns under in-plane compression

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HIGHLIGHTS

- The effect of layer number on the in-plane compressive property of columns is investigated.
- The analytical calculations agree well with the simulations.
- One facesheet-thickness to core-height ratio corresponds to one optimum layer number.

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ABSTRACT

The effect of the face thickness to core height ratio on different multi-layer pyramidal core sandwich columns under in-plane compression is investigated theoretically and numerically. Numerical simulation is in good agreement with theory. Results indicate that one specified face thickness to core height ratio corresponds to one optimum layer number of multi-layer pyramidal core sandwich columns in consideration of engineering application. This result can guide the sandwich structure design.

All-metallic sandwich panels consisting of low density cores and thin facesheets have impending application as ultra-light load bearing panels in aerospace and other fields. Several open cell topologies have been proposed based on truss lattices with pyramidal [1], tetrahedral [2], 3D-Kagome [3], and other topologies [4]. Usually, sandwich panels are loaded by various modes of loading (in-plane compression, out-of-plane compression, bending, shear, etc.) [5–8], and their strengths depend upon the compressive strength of the core and the cell size (which controls the face sheet deformation periodicity) [9]. Thus, while pyramidal and tetrahedral topology systems usually offer significantly superior structural performance, improvements appear feasible, based on the following limitation in relation to unit cell size: the thicker core leads to larger intervals between the point rows where the lattice truss core contacts the face sheets, and this weakens the resistance to local buckling of the face sheets [10].

In order to address the limitation, Cote et al. [6] proposed a multi-layer pyramidal core sandwich column. The peak in-plane compressive load increases accordantly with the layer number when the face sheet is thin. The reason is that the increasing of layer number might increase the resistance to wrinkling of the face sheet.

In this paper, the in-plane compressive properties of the multi-layer pyramidal core sandwich columns are investigated theoretically and numerically. The effects of the face thickness to core height ratio and the number layer on the in-plane compressive properties are analyzed. And the numerical simulation is compared with the theory analysis.

The multi-layer pyramidal core sandwich structure is, along the in-plane direction of core, the lattice is periodic pyramids, and along the thickness direction of core, the lattice is a stack of the single layer pyramids facing each other, as seen in Fig. 1. Since the multi-layer pyramidal lattices are constructed from the single layer pyramidal unit cell, they have the same relative density. Consider the 3D single layer pyramidal unit cell indicated in Fig. 2(b). Geometrical parameters of the pyramidal truss lattice are sketched. Note that for the square cross section truss, $t = w$, and its length is equal to l. In the present paper take the angle $\omega = 45^\circ$. By calculating the volume of regions occupied by materials, and scaling this by the unit cell volume, the relative density, $\overline{\rho}$, of

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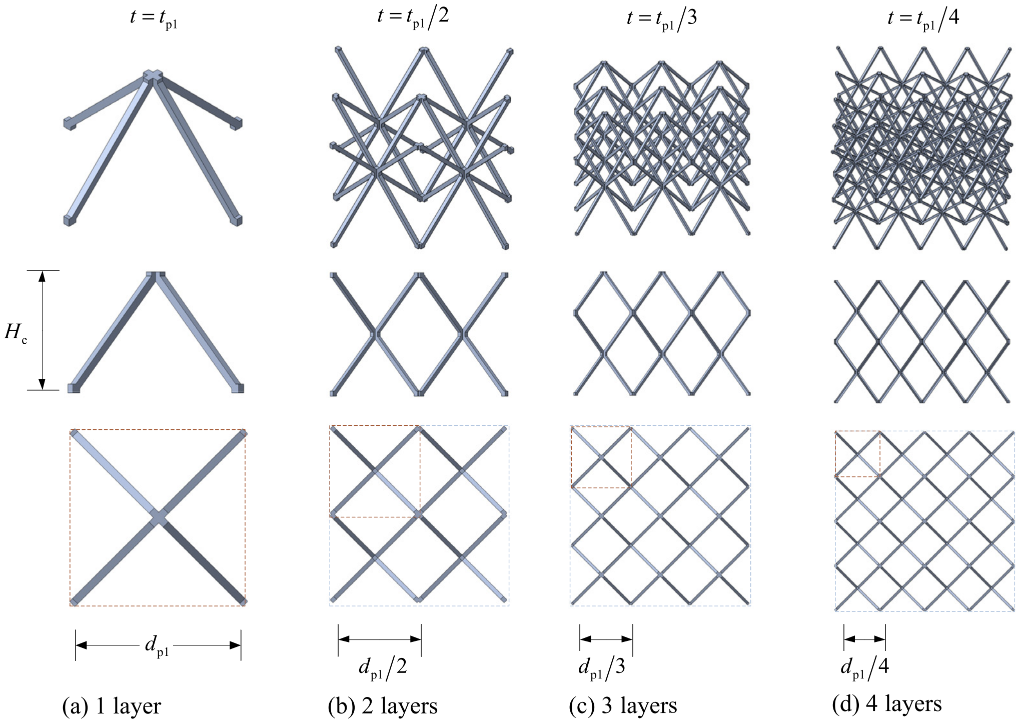

Fig. 1. Four layer numbers of multi-layer pyramidal core sandwich columns with the same relative density $\overline{\rho}$ and core height H_c.

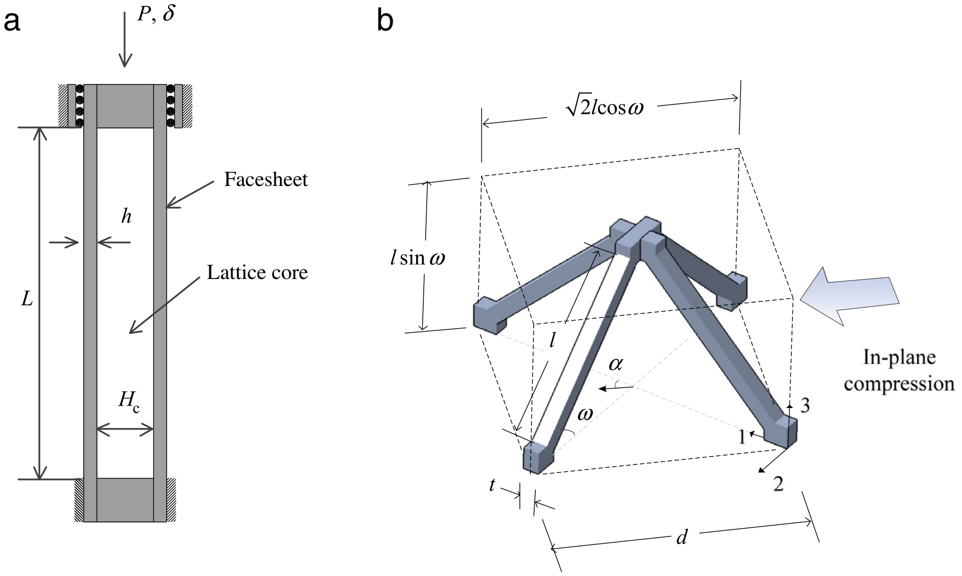

Fig. 2. (a) Sandwich columns subjected to in-plane compression. (b) Unit cell of single layer pyramidal core.

pyramidal unit cell is given by

$$\overline{\rho} = 4\sqrt{2}\left(\frac{t}{l}\right)^2, \tag{1}$$

where the inter-node spacing d is equal to the width of the unit cell. The predicted relative density is calculated in the limit of vanishing node size.

In order to compare the properties of different layer number sandwich columns, the values of both relative density $\overline{\rho}$ and core height H_c need to be fixed. In this case, for the multi-layer pyramidal sandwich column, there is a one-to-one correspondence among the side length of the strut t, the inter-node spacing d, and the number of the pyramidal layer numbers N, which can be seen by Eq. (1) and Fig. 2(b).

Uniaxial compression test of 304 stainless steel samples that have underwent the same thermal cycle used for fabrication of the brazed sandwich structures are performed and used to determine parent alloy properties and the tangent modulus, E_t, for the face sheet under in-plane compression. Three compression-repeated tests are performed according to ASTM E8-01. The compressive stress–strain response and its fitted curve by modified Ramberg-Osgood model [11] are shown in Fig. 3. The 304L stainless steel alloy had a 0.2% offset yield strength $\sigma_y = 212$ MPa and $E_s = 213$ GPa. The elastic Poisson's ratio for steel $\nu = 0.3$. Also, the tangent modulus E_t (given by the slope of the true stress–true