

# Computational Design of Cylindrical Honeycomb Cores

*S. Ishida*

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## Abstract

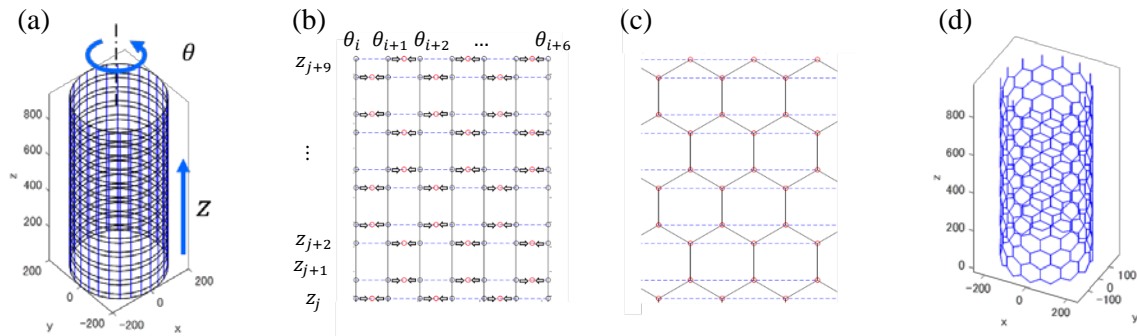
In this study, a computational method to design cylindrical honeycomb cores with radial core height directions is demonstrated. The method is based on a conventional construction of flat honeycomb cores and applied to a cylinder segmented with longitudinal and latitudinal lines. Finally, an obtained physical model confirms that the method works to construct desired core shapes. As the core height direction affects core rigidity against load to be applied, the cores are expected to be used for application to undergo radial load.

## 1. Introduction

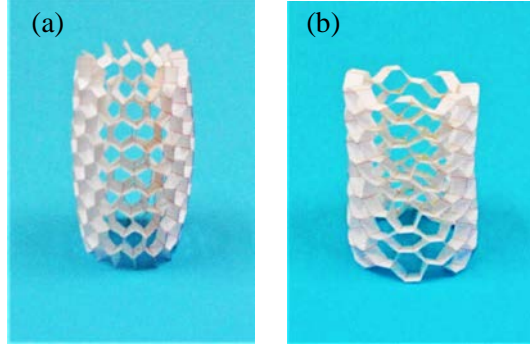
Honeycomb cores are widely used to construct industrial structures such as airplanes and railway vehicles with an advantage of light-weight but rigid characteristics. As these structures possibly have complex curved surfaces, the cores are required to follow the shape. In general, curved honeycomb cores are manufactured by cutting flat honeycomb cores to the desired shape. However, from a mechanical point of view, the core height direction is a key parameter to define rigidity of the cores; the core height direction should be designed in parallel to the load direction to be applied. In this study, design of cylindrical honeycomb cores with radial core height directions are discussed for the purpose of use under radial load conditions.

## 2. Computational Approach

In the construction process of conventional flat honeycomb cores, straight strips are folded in zigzag manner and two adjacent strips are glued to construct hexagonal hollows. Because the adjacent strips are placed symmetrically, the cores are deployable in the perpendicular direction



**Figure 1:** Segmentation of cylindrical surface, (a): With straight longitudinal and latitudinal lines, (b): Vertex shifting, (c): Construction of hexagons by zigzag longitudinal lines, (d): Hexagonal segmentation generated in the regular manner.



**Figure 2:** Physical models of cylindrical honeycomb cores.

to the axis of symmetry as long as the zigzag strip is reversible to the initial straight shape. To consider a cylindrical surface, it is parametrized as a function of  $(r, \theta, z)$  in the cylindrical coordinates, where  $r$  is a radius of the cylinder,  $\theta$  is azimuth and  $z$  is altitude. Thus, a cylinder is segmented by longitudinal (in blue) and height (in black) lines shown in Fig. 1 (a).

### 3. Cylindrical Honeycomb Cores

As the straight strips are folded zigzag, the straight longitudinal lines are modified zigzag on the cylindrical surface. Denote the vertex located at  $i$ -th longitude and  $j$ -th latitude  $V_{ij}(r, \theta_i, z_j)$ . The azimuth  $\theta_i$  for the vertex  $V_{ij}$  is shifted to  $(\theta_i + \theta_{i+1})/2$  or  $(\theta_{i-1} + \theta_i)/2$  without changing both  $r$  and  $z_j$  according to the regular pattern shown in Fig. 1 (b). The shifted vertices are still on the cylindrical surface, because the radius  $r$  is fixed. Thus, zigzag longitudinal lines are generated by connecting the  $i$ -th vertices (Fig. 1 (c)), which make hexagonal shapes on the cylindrical surface (Fig. 1 (d)). Now, it is obvious that the latitudinal lines are not necessary and suppressed on the figure. Next, a zigzag longitudinal line is extracted from the cylindrical surface. The vertices on the extracted line are connected perpendicularly to the central axis of the cylinder to generate radial lines to be used to define the directions of core height on each vertex. Finally, a physical model of the cores (see Fig. 2 (a)) is obtained according to the designed cylindrical honeycombs. Similarly, the altitude  $z_j$  for the vertex  $V_{ij}$  can be shifted to  $(z_j + z_{j+1})/2$  or  $(z_{j-1} + z_j)/2$  with fixing both  $r$  and  $\theta_i$ . Figure 2 (b) shows a physical model of the method, but detailed description is omitted for lack of space in this abstract.

### 4. Conclusion and Future works

In this study, the computational method to design cylindrical honeycomb cores is demonstrated and it is confirmed that the method works to construct desired cores with radial core height directions. They are expected to be used for application to undergo radial force such as liquid pressures including reinforcements of vehicle tires and pressure containers. A future study is to verify the effects of the core height directions to rigidity. Especially, the cylindrical honeycomb cores are anti-clastic structures such that they are curved in opposite ways in two orthogonal directions as well as standard flat honeycomb cores. Effects to the orthogonal directions to radial pressures applied must be studied carefully, because the cylindrical honeycomb cores are closed in azimuth direction. Furthermore, this computational method is to be applied to general axisymmetric structures including a sphere.