Vibration Characteristics Research of Sandwich Structure with Octet-truss Lattice Core

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Abstract. Lattice sandwich beams are often subjected to vibrations when they are used. The aim of this study was to explore the vibration characteristics of the octet-truss lattice core sandwich beam by translating discrete octet-truss core to the continuous homogenization material. The natural frequencies of which are obtained by theoretical calculation and numerical simulation. The theoretical solutions are in good agreement with the numerical results. It demonstrates that the theoretical approach is effective to compute the natural frequency. Furthermore, the influences of truss member radius and thin sheets ply on the natural frequencies are also discussed. The outcomes indicate that the octet-truss lattice core sandwich beam’s natural frequencies are controlled via selecting the appropriate truss member radius and the face sheets thickness.

1. Introduction
Lattice sandwich structures have received much focus in recent years on account of its high specific strength, excellent designability, and multifunctional characteristics [1], which offer important application value. The sandwich structure comprises double thin face sheets with a lattice truss core between them. More potentials of sandwich structures will be explored by the development of mechanical metamaterials with novel lattice truss topologies [2]. When sandwich structures are utilized in aviation, aeronautics, national defense and vehicles, which are usually enslaved to vibrations, so it is of great importance to explore their vibration characteristics. Lou et al. [3] transformed the porous pyramidal-truss lattice core to a continuous homogenization material to explore the freedom vibration performance of lattice sandwich beams with simply supported condition. Guo et al. [4] further investigated free vibrations of pyramidal-truss lattice core sandwich beams under different common benchmark boundary conditions by utilizing normal mode equations and analytical formulations of natural frequency. However, the vibration characteristics of the relative complicated octet-truss core sandwich beam have been rarely researched. Among this work, we investigate the free vibrations of aluminum alloy sandwich beam with octet-truss lattice core under simply supported boundary conditions. Inherent frequencies of octet-truss sandwich beams are computed via theoretical analysis and numerical simulation. Finally, the influences of the truss member radius and the face sheet thickness on natural frequencies are investigated.
2. Geometrical model

Figure 1(a) exhibits an octet-truss unit cell. The relative density of octet-truss lattice core could be expressed as follows:

$$\rho = \frac{\rho_m}{\rho} = \frac{6\sqrt{2} \pi r_m^2}{l^2}$$  \hspace{1cm} (1)

where $r_m$ represents the truss member radius and $l$ represents the truss member length, $\rho_m$ is the lattice core’s equivalent density, and $\rho$ denotes the density of mother material. The equivalent shear modulus of the octet-truss lattice core is formulated as follows [5]:

$$G_m = \frac{\pi r_m^2 E_s}{\sqrt{2} l^2}$$  \hspace{1cm} (2)

where $E_s$ denotes the constituent material’s elastic modulus.

![Figure 1](image1.png)

Figure 1. Geometrical model: (a) Octet-truss unit cell, (b) Schematic diagram of sandwich beam

Figure 1(b) shows a schematic diagram of a sandwich beam with octet-truss core. The center line of the beam is coincided with the $x$-axis, and $z$-axis is perpendicular to it. $H$ represents the total height, $h$ denotes the interval between mid-surfaces of the thin solid face sheets, $h_m$ denotes the height of the lattice core, and $h_s$ indicates the thickness of the thin solid face sheet.

3. Numerical validation

The vibration characteristics of aluminium alloy sandwich beams with octet-truss core are studied by the finite element simulation. The geometric parameters shown in figure 1(b) about sandwich beam contain: $h_s = 1$ mm, $h_m = 14.14$ mm and $r_c = 1$ mm. The material properties conclude: $E_s = 71$ GPa, $\gamma = 0.33$ and $\rho = 2779$ kg/m$^3$. 50 unit cells is arranged along the $x$-axis and 4 unit cells is placed along the width direction. The natural frequencies and modal shapes of the octet-truss beam can be acquired by finite element software NASTRAN. The first three order inherent frequencies of the octet-truss beam are respectively 69.01 Hz, 271.64 Hz and 594.42 Hz. Figure 2 demonstrates the corresponding modal shapes.
A comparison between theoretical results by MATLAB and numerical solutions by NASTRAN is depicted in Table 1, in which, $f_1$, $f_2$ and $f_3$ respectively denote the first-order, second-order and third-order natural frequencies. The theoretical results are in good agreement with numerical solutions, and the relative error is less than 5%. It demonstrates that the theoretical approach is effective to compute the intrinsic frequencies of octet-truss beams.

### Table 1. Inherent frequencies of the octet-truss sandwich beam.

|          | $f_1$  | $f_2$  | $f_3$  |
|----------|--------|--------|--------|
| Theoretical results (Hz) | 70.71  | 280.00 | 619.83 |
| Numerical solutions (Hz)  | 69.01  | 271.64 | 594.42 |
| Relative error            | 2.40%  | 2.99%  | 4.10%  |

4. **Influences of geometric parameters on the inherent frequencies**

4.1. **Influences of the truss member semidiameter on the natural frequency**

Influence of the truss member semidiameter on the inherent frequency is obtained by theoretical derivation and finite element simulation (FES), which is shown in figure 3(a). The natural frequencies decline as the radius of the truss increase, on account of that the equivalent density of the octet-truss lattice core rises.

4.2. **Influences of the face sheet ply on the inherent frequency**

Influence of the face sheet ply on the inherent frequency is also obtained by theoretical derivation and FES, which is shown in figure 3(b). The inherent frequencies increase as the thin face sheet ply increases, in view of that the equivalent stiffness of the sandwich beam elevates.
5. Conclusion
Vibration characteristics of the octet-truss beams are explored in this paper. Theoretical results are in good agreement with numerical solutions, which proves that the theoretical approach is suitable to the relative complicated octet-truss sandwich beam. Influences of the truss member radius and face sheet thickness on natural frequencies are also investigated, and the inherent frequencies of the octet-truss sandwich beam can be controlled by selecting the appropriate truss member radius and the face sheets thickness.

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