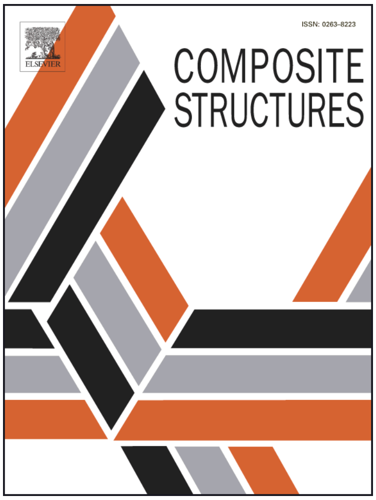

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Atsushi Shitanaka, Takahira Aoki, Tomohiro Yokozeki

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Atsushi SHITANAKA[a*], Takahira AOKI[a] and Tomohiro YOKOZEKI[a]

[a]Department of Aeronautics and Astronautics, The University of Tokyo, Tokyo, Japan
[*]Ph.D. Student, corresponding author:
Department of Aeronautics and Astronautics, The University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, JAPAN
TEL: +81-3-5841-6610
FAX: +81-3-5841-8560
E-mail: shitanaka <at> aastr.t.u-tokyo.ac.jp

Abstract:
Cylindrical lattice structures are types of lightweight structures and can utilize the orthotropy of fiber-reinforced composite materials. Maximization of the buckling loads is important because they dominate the strength of the structures. On the basis of the fact that a hyperboloidal shape deviation increases the buckling loads of cylindrical homogeneous shells, the changes in the buckling loads of cylindrical lattice structures with a hyperboloidal shape deviation are discussed. Further, the buckling loads of both conventional cylindrical lattice structures and shape-deviated hyperboloidal lattice structures with respect to the compressive, bending, and torsional loads are calculated using a finite element method. The results show that the shape deviation decreases the buckling loads, while the change in mass is negligible. The effects of the shape deviation on the buckling loads differ between homogeneous shell structures and lattice structures.

Key Words:
Structural Analysis; Fracture; Lightweight Structure; Composite; Carbon-Fiber-Reinforced Plastics (CFRPs); Aerospace Applications

1. Introduction

1.1. Cylindrical Lattice Structures

The primary reason for using composite materials in the aerospace field is to reduce the structural weight. Conventionally, the manufacturing industry has replaced the metals in existing structures with short-fiber-reinforced composites, woven composites, and composite laminates of long-fiber-reinforced laminae. Cylindrical lattice structures are different from these conventional composite structures in terms of their manufacturability and weight saving capacity. Vasiliev *et al.* [1][2] explained this difference in detail.

Cylindrical lattice structures consist of ribs in the circumferential and helical directions, and the crossing of the ribs creates periodic patterns. Figure 1 shows a typical cylindrical lattice structure with a Kagome lattice pattern.

To manufacture cylindrical lattice structures, manufacturers employ filament winding. Filament winding involves the continuous feeding of fibers from a machine, impregnating the fibers with resin, and winding the impregnated fibers around a mold. Vasiliev *et al.* [1] calculated the manufacturing cost and revealed that filament winding made the manufacture of cylindrical lattice structures cost-efficient.

The weight saving capacity of cylindrical lattice structures comes from their unique load paths. Consider a cylindrical lattice structure subjected to an axial compressive load. The load is transmitted along the helical ribs, and they tend to deflect outward because they are aligned along the cylindrical surface. The circumferential ribs play a role in suppressing the deformation of the helical ribs. What is important is that the load paths are along the longitudinal directions of the ribs. Consequently, the loads are along the stiff and strong directions because the longitudinal directions of the ribs coincide with the fiber-reinforced directions.

Therefore, cylindrical lattice structures are suitable for use in aerospace structures subjected to large axial compressive loads. Even with other loads, the axial compressive strength can be a strength index because other loads consist of local compressive and tensile loads and the buckling caused by the compressive loads dominates the strength of the entire structure. The aerospace industry has adopted cylindrical lattice structures as structural components. Examples include space telescopes [3], spacecraft [2][4][5][6], the interstages of launch vehicles [1][2][7], aircraft fuselage [1][2][7], and conical payload attach fittings [1][2][7][8].

In addition, there are other applications of lattice structures. Lattice structures can be employed in a three-dimensional manner. Hu *et al.* [9] and Liu *et al.* [10] proposed creating the core of a sandwich panel by