IASS Annual Symposium 2019 - Structural Membranes 2019
Form and Force
7–10 October 2019, Barcelona, Spain

Lightweight Rigidly Foldable Canopy using Composite Materials

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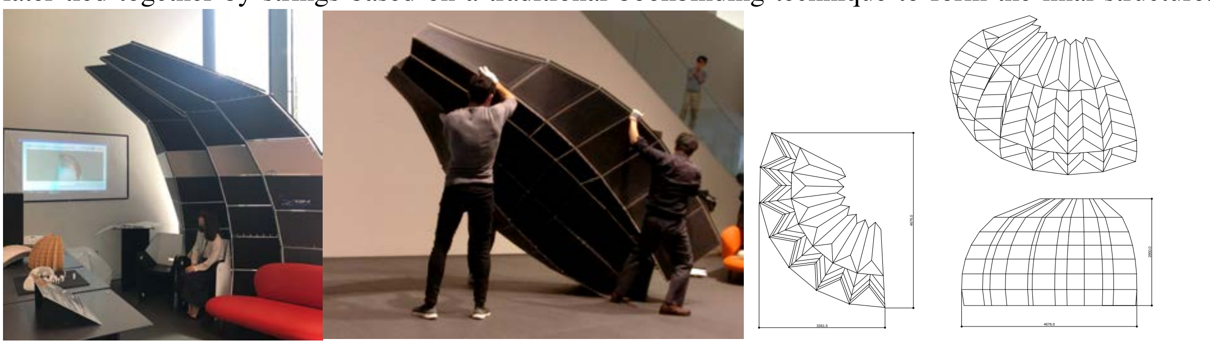
Abstract

Application of rigidly foldable origami to a design project using actual materials require simultaneous considerations of the function of the space, kinematics, stability, and fabrication. In this work, we show the design process of a novel portable deployable canopy and acoustic reflector using composite materials. (1) We explored a modular family of one-DOF rigidly foldable, flat-foldable, non-developable origami structures by extending the geometry of tubular construction [1]. The structure is composed of multiple developable strips, so each strip can be produced in a plane. (2) Design parameters such as the section polyline, the rail curve and the number of corrugations are explored by identifying the Pareto optimal solution for minimization of both the deflection and acoustic concentration under the constraints on the minimum size of the enclosing space and the maximum size of each developable strip. (3) The resulting structure underwent nonlinear implicit analyses to find the structure's buckling behavior in the deployed state and the process of nonlinear folding coupled with bending of panels; The analyses showed the necessity of tension elements for additional stability realized by triangular foldable fins on the backside of the structure. (4) The pattern of hinges and rigid panels on each developable strip was created by cutting and laying out prepreg composites sheets. Specifically, we used multi-step curing, first making each rigid panel from 1mm carbon fiber reinforced plastic sheet and each hinge element from glass fiber sheets patterned with a thin strip of silicone matrix creating a gap between rigid panels as in [2], and then combining them together into a single planar sheet. Each developable sheet was later tied together by strings based on a traditional bookbinding technique to form the final structure.



References

[1] T. Tachi, "One-DOF cylindrical deployable structures with rigid quadrilateral panels," in *Proceedings of the IASS Symposium 2009*, 2009, pp. 2295–2306.

[2] L. Jimenez and S. Pellegrino, "Folding of fiber composites with a hyperelastic matrix," *International Journal of Solids and Structures*, vol. 49, pp. 395–407, 2012.