Exploration of Compliant Hinges in Origami-based Structures

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Abstract

The term "origami" is usually associated with the outcome of a given folding process rather than the process itself. Once we focus on the folding, every piece of origami becomes a (more or less intricate) mechanism and can provide a wealth of inspiration to efficiently design kinematic structures from flat sheets.

A critical point for origami-based structures made for real-world applications that need to be produced from thicker materials is the availability of practical hinge concepts that need to meet several requirements, including ease and economy of manufacture, robustness, and longevity. Compliant hinges show promise with regard to these requirements [1, 2]. Recently introduced plastically annealed lamina emergent origami (PALEO) combines this concept with non-trivial programmable states to which a given structures will return elastically without any additional actuators or external stimuli [3].

This paper will explore potential of PALEO structures intended for use as façade elements, which are one focus of the Collaborative Research Centre 1244 "Adaptive Skins and Structures for the Built Environment of Tomorrow" at Stuttgart University. Issues of design, manufacturing, scalability, longevity and feasibility of origami-inspired structures in an architectural context will be addressed and augmented by data gathered from finite element analysis and real-world mechanical testing of selected structures. Figure 1 shows an example made from a single 2mm thick polycarbonate, with integral hinges that are generated by a simple milling process in the flat sheet.

Figure 1: PALEO prototype made from 2mm polycarbonate with integral hinges, in two different deployment states

References

[1] Ohshima, Tachi, Tanaka, and Yamaguchi. "*Analysis and design of elastic materials formed using 2D repetitive slit pattern*". In Proceedings of the International Association for Shell and Spatial Structures (IASS), 2015

[2] Nelson, Lang, Pehrson, Magleby and Howell: "*Facilitating deployable mechanisms and structures via developable lamina emergent arrays"*. Journal of Mechanisms and Robotics, (3), Mar., pp. 031006–031006–10, 2016

[3] Y. Klett, "*PALEO: Plastically Annealed Lamina Emergent Origami*" in IDETCIE 2018, Québec, Canada, http://dx.doi.org/10.1115/DETC2018-85983, 2018