Bending-driven Dynamic Corrugation for a Funnel Shell Design

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Abstract

Funicular shells are known to be an efficient design paradigm for self-weight-driven structural surfaces [1]. Nevertheless, the rules that govern funicularity offer a fairly constrained design spectrum, limiting the scope of application for these structures [2]. The principle of corrugation has proven to be an effective approach to enable efficient structural performance in non-funicular thin shells [3]. The research presented in this paper explores the use of corrugation methods for shells in the context of a computational and structural design workflow. As an extension to existing methods, the authors introduce work on Dynamic Corrugation, a strategy for increasing bending and buckling performance on non-funicular global designs by modulating the undulation of their surfaces according to bending stress distribution.

The bending-driven dynamic corrugation method was developed during the Form and Structure seminar of the ITECH programme at the University of Stuttgart and was evaluated through the design of a non-funicular funnel shell in textile concrete. The method consists of a two-step Shape Optimization workflow that integrates NURBS-based surface generation with FEA and a Multi-Objective Genetic Algorithm (MOGA). In a first step of the design workflow, the initial design surface is analyzed to give its bending energy vector field. This field then serves as the source to generate a modulation curve passing through the areas of peak bending stresses. This curve then regulates the frequency, amplitude, and influence of local bending on the corrugation. The MOGA is given control over these variables and attempts to minimize both bending moment and displacements, offering a wide spectrum of performances and expressions along the emerging Pareto front. Simultaneously, the introduction of local curvature is evaluated on its capacity to improve the buckling resistance and to allow reductions in material thickness. The presented iterative approach is incorporated in a computational design framework.

A series of Dynamic Corrugation-optimized shell samples are then compared with the initial non-corrugated design showing great structural (improved bending and buckling resistance), as well as economical and ecological (material savings) potential. Further, the expressive value of dynamically corrugated shells is deemed as a contribution to the aesthetic value of a design proposal for a small infrastructural building.

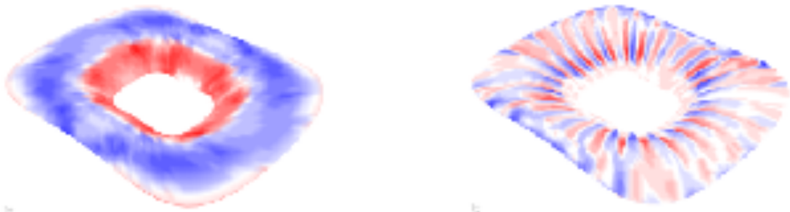

Fig 1. Utilization of the initial non-funicular shell (left) and a shell optimized with dynamic corrugation (right)

References

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