A NOVEL OPTIMIZATION STRATEGY FOR FORM-FINDING AND STRUCTURAL STABILITY ENHANCEMENT OF DOME-TYPE GRID-SHELL STRUCTURES

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Domes are highly efficient structures designed to span long distances while effectively resisting gravity loads. Traditional domes can be categorized into two types: continuous shells, which are typically constructed from monolithic concrete or masonry, and grid-shells, which utilize lattice members to create depth throughout the shell thickness. Although grid-shells have gained popularity in recent years, the integration of topology optimization and size optimization for the form-finding of these structures remains relatively unexplored.

This paper presents a novel framework for optimizing deep grid-shell structures through topology and size optimization techniques. The framework is structured as a multi-phase process. Initially, a deep grid-shell structure and the associated load type are defined. Subsequently, an equivalent continuous shell structure is established and subjected to an optimization process aimed at minimizing strain energy to determine the optimal grid arrangement. This arrangement is then utilized for size optimization to identify the optimal member sizes. Finally, a linear elastic analysis is conducted to compare the structural performance of the initial grid-shell, the topology-optimized continuous shell, and the grid-shell inspired by structural optimization.

Two case studies demonstrate the framework's capability to generate innovative and practical grid-shell structures. In test case 01, a ring load of 1 N was applied at the apex of a deep dome with a radius of 12 m, resulting in a corresponding structural optimization-inspired grid-shell. The buckling capacity increased from 3.5 MN to 31.5 MN, while maximum stress decreased from 4.2 Pa to 3.0 Pa, and maximum displacement was reduced from 31.5 nm to 25.3 nm when compared to the initial defined grid-shell. In test case 02, a total point load of 1 N was applied to the same deep dome, yielding another structural optimization-inspired grid-shell. The buckling capacity improved from 8.5 MN to 10.1 MN, maximum stress decreased from 0.9 Pa to 0.2 Pa, and maximum displacement was reduced from 10.1 nm to 2.5 nm compared to the initial defined grid-shell.

The results indicate significant enhancements in material efficiency and structural performance, with optimized designs achieving over a hundred percent increase in buckling capacities and reductions in stresses and displacements exceeding seventy percent. Future work will investigate the complexities of topology optimization for shallow versus deep shells, assess the impact of more realistic load applications on structural stability, and explore the flexural capacities of grid-shells with topology-optimized continuous arrangements. Additionally, potential challenges related to node connections due to wider members resulting from optimization will require further investigation to refine the framework for broader applications.

Keywords: Buckling capacity, Form-finding, Grid-shells, Size optimization, Topology optimization

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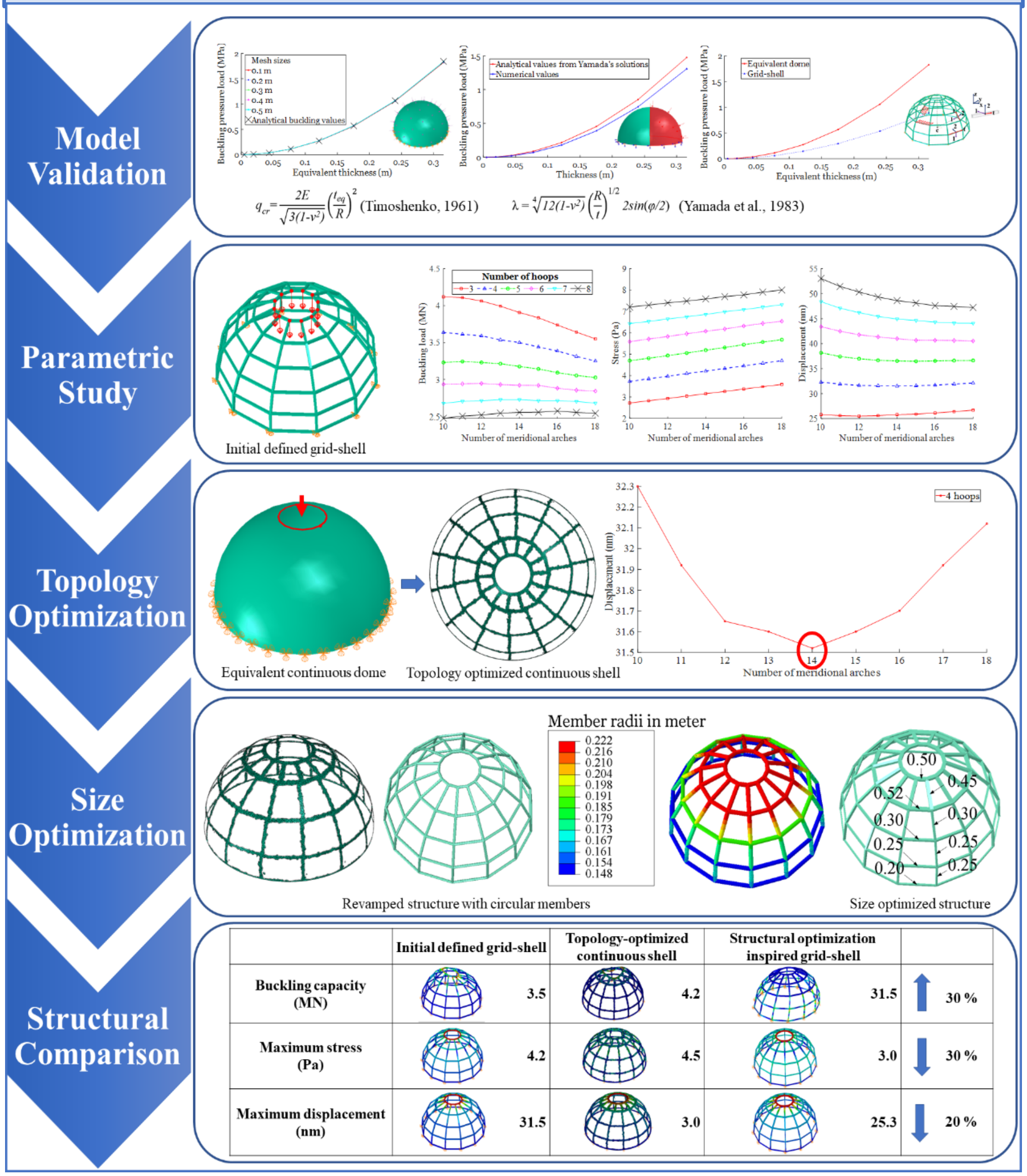

	Initial defined grid-shell	Topology-optimized continuous shell	Structural optimization inspired grid-shell	
Buckling capacity (MN)	3.5	4.2	31.5	30 %
Maximum stress (Pa)	4.2	4.5	3.0	30 %
Maximum displacement (nm)	31.5	3.0	25.3	20 %