15th World Congress on Computational Mechanics (WCCM-XV)
8th Asian Pacific Congress on Computational Mechanics (APCOM-VIII)
31 July – 5 August 2022, Yokohama, Japan

Multi-body Rope Approach for the Form-Finding of Shape Optimized Grid Shell Structures

Amedeo Manuello[1*], Jonathan Melchiorre [1], Laura Sardone[2], Giuseppe Carlo Marano[1]

[1]Department of Structural, Geotechnical and Building Engineering Politecnico di Torino, Corso Duca degli Abruzzi, 24 - 10129. Torino, Italy,
*Corresponding author: amedeo.manuellobertetto@polito.it

[2]Department of Civil Engineering and Architecture Sciences. Politecnico di Bari, Via Edoardo Orabona, 4 – 70126. Bari, Italy.

Key Words: *Gridshell, Form-finding, Conceptual Design, Multi-body Rope Approach D'Alembert Principle, Phyton code,*

Over the past decades, different approaches, physical and geometrical, were implemented to identify the optimal shape, reducing the internal stresses, of grid shells and vaults. As far as their original organic shape is concerned, the design of grid shell structures inspired architects and structural engineers in more than one way [1-5]. Along the history time, the solution of the structural form-finding buried its roots on the activity of scientists and designers. In the present paper, the original approach for the form-finding is proposed by the dynamic numerical simulation of hanging net, subjected to gravity load, over the time domain [4]. In particular, the adopted process for the definition of the structural shape is based on a multi-body rope approach (MRA) with masses connected by inextensible ropes characterized by a certain slack coefficient (*sc*) and by the degree of the constraint conditions [4]. The method, originally presented in [4], is here re-developed and extended employing a self-made code based on the dynamic equilibrium, ensured by the d'Alembert principle, of masses interconnected by rope elements in space-time domain. The equilibrium corresponding the optimized shape to be defined, is obtained through an iterative process in the falling masses connected by a net for the definition of the "catenary surface" coinciding with the best shape of the shell (form minimizing the bending moment). The implementation of the method is realized in Python in an interpreted high-level general-purpose programming language. The adopted design philosophy emphasizes the code readability by other languages with respect to the traditional model realized in Visual Nastran 4D. By the use of this code as well as its object-oriented architecture the MRA Python code will be linked to the Grasshopper environment for the direct visualization of the shapes and their fast-parametrization phase.

REFERENCES

[1] Marano, G.C., Trentadue, F., Greco, R. Optimum design criteria for elastic structures subject to random dynamic loads. *Eng. Optimization*, 38(7): 853-871.

[2] Richardson, J.N., Adriaenssens, S.M.L., Coelho, R.F., Buillard, P. (2013) Coupled form-finding and grid optimization approach for single layer grid shell. *Eng Struct*. 52:230–9.

[3] Adriaenssens, S.M.L., Barnes, M.R., Williams, C.J.K. (1999) A new analytic and numerical basis for the form-finding and analysis of spline and grid shell structures. In: Kumar B, Topping BHV, editors. Computing developments in civil and structural engineering. Edinburgh: Civil-Comp Press; 1999. p. 83–90.

[4] Manuello, A., (2020) Multi-body rope approach for grid shells: Form-finding and imperfection sensitivity, *Eng. Struct.*, 221:111029.

[5] Adriaenssen, S., Ney, L., Bodarwe, E., Williams, C.J.K. Construction constraints drive the form finding of an irregular meshed steel and glass shell. *J Architect Eng.* 18(3): 206–13.