

International Symposium on "Novel Structural Skins: Improving sustainability and efficiency through new structural textile materials and designs"

Unprecedented structural skins. Experiments towards an intelligent tensegrity skin.

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Abstract

Pin-jointed prestressable structures -known as tensegrity systems- have been largely studied for over six decades, untouched in their complexity and fascination. Prior research has marginally offered interactive toolsets to design tensegrity: none without tedious procedures embedded in their resolution. Restrictions in terms of simultaneous design's topology and optimization - aggravated by lacking effective means to automate manufacturing and specially assembly of such system - have greatly disrupted and cornered their current applicability. We present results of unprecedented processes extending tensegrity systems applicability. Employing a novel approach to design's topology and optimization of arbitrary tensegrity systems, we developed means to automatically design and manufacture them. With advantages in tailoring design and production costs, we explore some speculative scenario.

Therefore we present experiments towards novel processes and products aimed to revolutionized the market of lightweight structural systems, both in static and dynamic applications. Moving from tensegrity systems and their intrinsic transportability, material-economy, easy manufacture, customization and assembly -the latest expanded within our research- we propose a new standard for structural performing skin. We aim for an intelligent skin: free-form, lightweight, widely adaptable in use, and capable of embedding complex design features and functionalities. Central in addressing economical solutions to nowadays challenging tasks we present our findings, analyzing production processes and potential challenges further suggesting relevant scenarios of pertinence.

Highlights: ► Tensegrity automated production is possible linking design topology, optimization, manufacturing and assembling.
► Two automated manufacturing approaches are outlined according to scale, functionality and use. ► Injection moulding is

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nowadays proofed for structural performances, cost competitiveness, easy multifunctional layer implementation.►3D printing will favor in future robust automated customized production.

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1. Introduction

1.1. Tensegrity: past, present and undergoing research

In 1864 Clerk Maxwell anticipated what a century later R. Buckminster Fuller - looking at the work of a young artist called Snelson - would have named tensegrity. Since then, six decades of research have expanded our understanding of such system, stimulated by the aerospace industry's quest for deployable lightweight systems. Again in the last decades new discoveries have flourished and progressed thanks to improvements in numerical methods and symbolical computation. Where Snelson had emancipated the native definition of tensegrity rethinking them as *endoskeletal prestressed structures*, Motro disengaged the patent based definition from the principle. "*Tensegrity system is a system in stable self-equilibrated state comprising a discontinuous set of components inside a continuum of tensioned components*".

While traditional trusses structures have quickly encountered technological development and market demand, tensegrities further challenged designing both static and dynamic configurations, sunk in tedious manufacturing and assembling processes. We believe that further achievements in these fields are needed step-stones to reach concrete market applicability.

With renew interest among relevant properties demonstrated by tensegrity, we would like to recall their scalability, unparalleled lightweight and material efficiency [16]. Their intrinsic deployability gained them a central role among deployable structures for space application. Needless to say, a larger investigation from static behavior (Hernández and Mirats [7]) to dynamic response (Mirats and Hernández [11]); from the deployable configurability and dynamic control (Mirats and Hernández [11]; Adam and Smith [2]) to form finding design (Chandana et al. [5]) and design optimization (Masic et al. [10]) ; from biological similarities in modeling natural organism (Ingber [8]) to structural-material efficiency (Lieber [9]), gives just a taste of potential applicability and complexities inherently embedded in such lightweight system (Fig. 1).

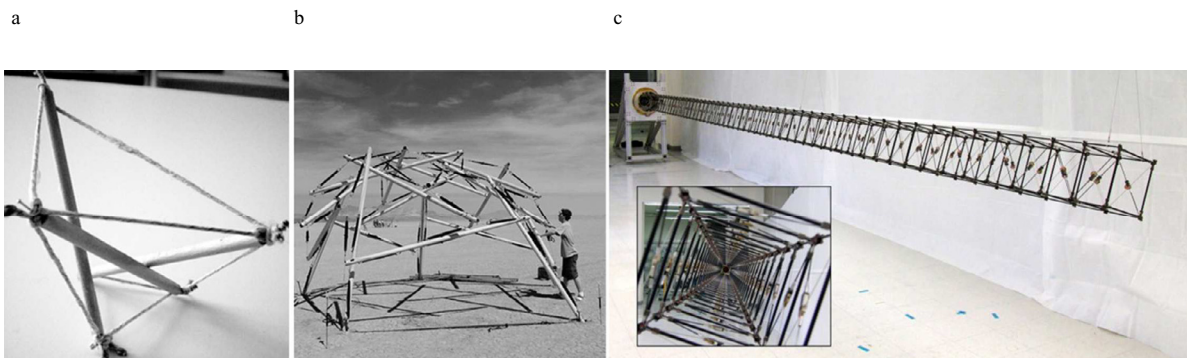


Fig. 1. (a) tensegrity model; (b) geodetic tensegrity dome; (c) deployable tensegrity masts for space application.

To clarify the underneath principle, Hanaor distinguished pin-jointed skeletal structures composed of bar and cables in two major classes: *not prestressable* (statically determinate structure and mechanism) and *prestressable*

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