SYNCLASTIC AND ANTICLASTIC: WIN – WIN INTERACTION OF PRESSURIZED AND TENSIONED MEMBRANES

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***Summary**. The proposed work aims to draw attention to a rarely investigated problem – the mechanical interaction between pre-stressed tensile membranes and high-pressure inflated elements. Particular emphasis is placed on to the possibility of buckling stabilization of inflated beams by conbyning them with tensioned membranes. Structural stabilization of curved compressed elements is also studied. This research generates a proposal for new optimized air beam supported structures. It draws parallels with tensegrity principles.*

1 INTRODUCTION

In the world of building construction and engineering inflatable structures are a relatively new phenomenon. Fuller gives them a theoretical definition in the same breath as tensegrities, in his seminal Synergetics. Their practical use, outside of lighter than air craft is less than a half century affair. In rather the same way, as a particular expression of tensioned structures, membranes were a rarity until a couple of decades ago. Outside the roofs of roman arenas and their application in wind powered shipbuilding they had little use in the advanced construction culture of the Western world. The 'hybrid' membrane structures i.e. air beam supported tents have been around for around forty years. Curiously, the interaction between their inflatable and tensioned parts has barely been studied. Such structures are viewed as combined separate subassemblies: the supporting inflatable tubular frame and the textile cladding. A possible reason for this omission is inertia: a membrane is assumed to be an element that needs to be supported, not an element having the capacity to support. This paper deals with cases where pressurized and pre-stressed by contour tension membranes and inflatable members are combined in a common structure. Both parts of the membrane are analyzed simultaneously as a system. This seems only natural because of the similarity of the mathematical models.

2 SYNERGETIC INTERACTION

The spokes of an old-fashioned western style umbrella made out of U shaped steel are designed to deflect under the pressure of tensioned umbrella fabric. The ribs are attached to the tensioned canopy and thus forced to follow its curvature. The fabric tension loading the ribs axially on one side enters into dynamic stability with the elastic stress in the ribs, evading buckling. A similar approach is applied in structures where the arch is laterally stabilized by a tensile membrane, which the arch in turn supports.

It is a well-known fact that when the membrane and its support structure are modeled together, calculated stresses are significantly less. The substantive question is how to predict and utilize this effect. We believe that airframe supported tensile membrane structures bring us to the threshold of a fruitful field for research. Inflatable structural elements are capable of withstanding high compressive forces, while mechanically prestressed membranes need tension to achieve structural rigidity. The idea is to connect the membrane and its support structure in a hybrid, which will allow us to introduce pre-stress by pressurizing its pneumatic part

3 DEFLEGRITY INFLATABLE

An interesting side effect of pressurized and tensioned membranes in interaction is their capacity to overcome the simple geometries restriction distinctive for pneumatics. Of special interest are membranes balancing internal pressure and external tension along the perimeter. The use of stiff compression elements modifies the equilibrium geometry of the membrane. The “antigravity” toy provides an early example. It is made out of spherical sectors and a compression ring. The same configuration is employed in a series of space deployable antennas, designs for a stratospheric aerostat and lens-like roof structures. The recently trendy cushions could be regarded as tensioned inflatables, or membranes subject to boundary restrains. The compression ring could be a highly pressurized pneumatic structure. The potential of multi-chamber inflatable structures with variable chamber pressure is much bigger.

4 EXAMPLES

We shall illustrate our approach with the construction of an inflatable aerostat fin [Fig. 1]. Aerodynamically shaped inflatable fins bear a resemblance to an airfoil approximating mattress. In our design the flattening of the membrane surface is achieved by combining a high-pressure pneumatic arch with tensioned fabric. The fin base achieves the geometry of a plausible airfoil. Prestress is introduced by pressurizing the pneumatic arch. Additionally a ram nozzle crates differential pressure in the chamber enclosed by the tensioned membrane. Para-gliders and some kites utilize ram pressure to give shape to the airfoil but it doesn't work below a certain critical speed. Pressurizing of a synclastic boundary prestressed membrane provides further engaging research opportunities.

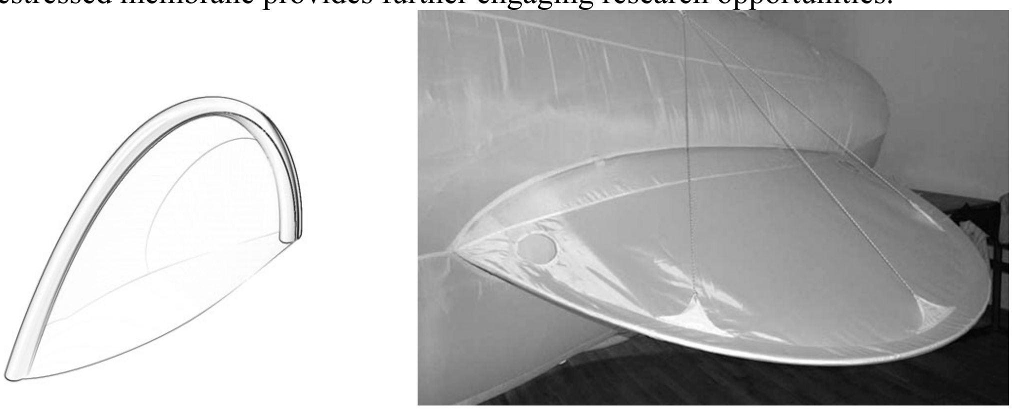

Fig 1. Tensile membrane fins for tethered aerostat

5 FURTHER WORKS

Experimental data from physical modeling will be compared with a simple analytical model and finite element analysis.

6 CONCLUSIONS:

- The hybrid structures made up of tensioned and pneumatic membranes should be studied holistically, as an entity from the very level of form-finding.
- The elements of such hybrid structures should be connected and dimensioned so that pneumatic pressurization introduces boundary prestress and tensioned add that tension shall be applied for structural stabilization.

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