CRITICAL PRESSURE OF A LOBED BALLOON

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Buckling is normally associated with structures that carry loads in compression, and it is generally assumed that tension structures cannot buckle. This paper is concerned with a particular type of tension structure that is prone to buckling, namely a lobed balloon consisting of many stiff tendons that constrain a thin, highly curved plastic surface. Between the tendons, the surface bulges out and it is expected that the balloon will take up a symmetric shape, with n identical lobes of large transverse curvature, Figure 1; this type of balloon design is known as "pumpkin design". In practice, non-symmetric shapes were first observed by Nott [1], in an actual balloon and it has been recently shown that the symmetric shape becomes unstable at a certain pressure.

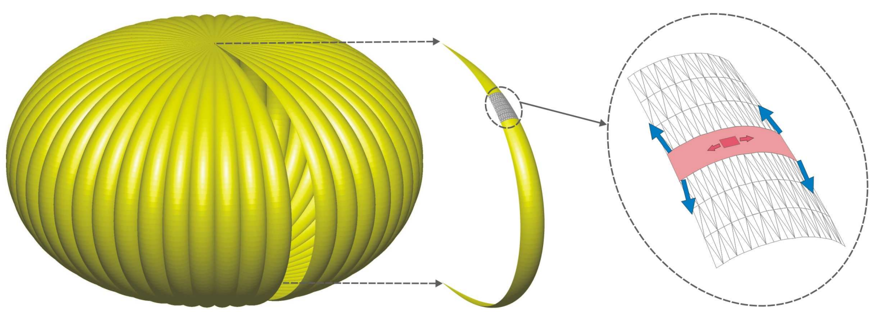

Figure 1: Perspective view of 48 lobe balloon showing the primary load-carrying mode

Here we present a computational study of this buckling problem. We begin by introducing a closed form solution of symmetry transformation matrices, Pagitz [2]. These matrices are used to set up the tangent stiffness matrix of the balloon in block diagonal form which makes a classical stability analysis with varying n, based on the computation of the eigenvalues of the tangent stiffness matrix, possible without using parallel computers.

A key result from our stability analysis is that the buckling pressure versus n can be expressed in terms of a power law

$$p \propto n^{-x} \tag{1}$$

where p is the buckling pressure, n the number of lobes and x a variable depending on the design of the lobes.

References

[1] J. Nott, "Design considerations and practical results with long duration systems for manned world flights," *Advances in Space Research* **33**, 1667–1673, 2004.
[2] M. E. Pagitz, "Symmetry Transformation Matrices for $\mathbf{C_{nv}}$ and $\mathbf{D_{nh}}$ Groups," *to be submitted*.

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