Equilibrium and Stability of Lobed Inflatable Structures

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Inflatable membrane structures provide significant benefits because of their low mass and easy storage but they also pose special challenges. The internal pressure in inflatable structures must be sufficiently high to maintain the desired shape but the stress in the membrane must be low to avoid rupturing the membrane.

The membrane tension for an inflatable structure is directly proportional to the radius of curvature of the surface. Increasing the curvature of the surface causes a decrease in the tension thus providing a strong incentive to produce highly curved surfaces. One way to produce highly curved surfaces is to use lobes.

Using lobed shapes for inflated structures reduces tension and allows the use of a thin membrane to maintain the desired low mass and high flexibility. Lobed structures come in various shapes but most resemble a spheroid or a column. Different spheroidal shapes lead to different stress patterns, enclosed volumes, surface area, and stability characteristics. A simple shape is a membrane column with circumferential lobes and restrained in length. This simple structure demonstrates many of the important aspects of the structural mechanics of lobed membrane structures.

A shape of particular interest is the lobed isotensoid. This structure is spheroidal with membrane lobes spanning between load-bearing tapes that span meridionally between the apex points. If the lobes have stress only in their circumferential direction then the tapes will adopt the shape of a cross-section of an isotensoid. The isotensoid is a spheroidal shape that has no circumferential stress and carries all load in the meridional direction. The lobed isotensoid is of significant interest currently because of its use in high altitude scientific ballooning and its potential for inflatable spacecraft. It resembles the shape of many habitats proposed for space exploration either as bases or as parts of space vehicles.

The choices of basic parameters for the structure influence the membrane stress, surface area, enclosed volume, and the stability of the structure. This paper examines these characteristics for example lobed structures to show the influence on the structure of choices in geometric parameters. These geometric parameters include the number of lobes, angle enclosed by the lobes, radius of curvature of the lobes, and the shape of the structure at the intersection between adjacent lobes. Results of particular interest to analysts and designers are the geometric limits on the number of lobes, the effect of excess material in the lobes, and the relationship between the number of lobes and stability. Understanding the effects of changing basic parameters will help researchers, analysts and designers to gain a better appreciation of the behaviour of inflatable structures.