Shape and mechanics of asymmetric inflatables

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Abstract

Inflatables are particularly popular shape-morphing materials. Their simple, purely mechanical actuation allows for fast deployment and reusability. Moreover, just as the overall shape and stiffness of a party balloon are directly linked to its internal pressure, inflatable objects offer an elegant example of the coupling of elasticity and geometry.
We study networks of parallel inflatable tubes obtained by welding two elastic sheets. Composite tubes presenting two sides of distinct stiffness are made by using two sheets of different thicknesses. Upon inflation of such tubes, the torque balance at the junction of two asymmetric sheets results in the rotation of the seam line connecting two neighbor tubes. This local misalignment allows for enormous displacements when integrated across large networks. We present experimental results on the mechanics of inflation of one or several connected tubes.

The shape of one tube throughout inflation is determined using a minimal Kirchhoff beam model, for which analytical solutions are given in the asymptotic limits of low and high pressures. In the latter case, a boundary layer at the edge of the seam line fully determines the rotation between two connected tubes. We highlight as well how contact between neighboring tubes limits in practice the overall curvature of our inflatables.
We then formulate and solve an inverse problem to design a wide variety of objects that can be described as a two-dimensional curve normal to the direction of the tubes. The stiffness of such structures is discussed as well. We finally present several applications of asymmetric tubular inflatables to more complex geometries: axisymmetric surfaces, *kirigami*, and curved folding.

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