ABSTRACT

The finite inflation and stability of a toroidal membrane, inflated from a flat geometry, is studied. The uninflated geometry consists of two identical equatorially bonded flat annular membranes which results a closed toroidal structure upon inflation. Two different hyperelastic material models, namely, Mooney-Rivlin model and Gent model, are used to describe the isotropic incompressible membrane material with a relaxed strain energy density function. The inflation problem, involving both geometric and material nonlinearities, is solved numerically. Wrinkling is observed along the outer equator of the torus at low inflation pressures. A pressure limit is found to exist which can be linked with the material and geometric parameters of the torus through an empirical relationship involving two universal constants. Next, the possibility of joint peeling at the equatorial joints is investigated. This is based on the energy release rate calculations at the joints. The stability of peeling in terms of the spontaneity of debonding is determined over the range of inflation. The response of the inflated membrane against radial in-line force distribution along the inner equator is studied under two different forcing conditions, namely, constant pressure forcing and forcing with constant amount of enclosed gas. The first type of loading leads to wrinkling instability, whereas the second one results a pull-in instability of the torus beyond a critical force value. The stability of the torus as the outer rim of an inflatable reflector/antenna model is investigated. The conditions under which the reflecting membrane surface can be approximated as paraboloid are found out. The study of geometric symmetry breaking of the toroidal membrane is presented using perturbation technique. Beyond a critical level of pressurization, the torus undergoes a spontaneous symmetry breaking through a super-critical pitchfork bifurcation, which is later restored back by a reverse sub-critical pitchfork bifurcation. The corresponding asymmetric shapes and the symmetry breaking zones are determined. The effect of temperature change on the inflated toroidal membrane is also discussed.

Keywords: Flat torus, Finite inflation, Stability, Hyperelastic material, Wrinkling, Limit point pressure, Joint Peeling, Pull-in instability, Symmetry breaking.