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Geometry-induced rigidity in pressurized elastic shells

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We study the indentation of pressurized thin elastic shells, with positive Gauss curvature. In our precision desktop-scale experiments, the geometry of the shells and their material properties are custom-controlled using rapid prototyping and digital fabrication techniques. The mechanical response is quantified through load-displacement compression tests and the differential pressure is set by a syringe-pump system under feedback control. Focus is given to the linear regime of the response towards quantifying the geometry-induced rigidity of pressurized shells with different shapes. We find that this effective stiffness is proportional to the local mean curvature in the neighborhood of the locus of indentation. Combining classic theory of shells with recent developments by D. Vella et al. (2011), we rationalize the dependence of the geometry-induced rigidity on: i) the mean curvature at the point of indentation, ii) the material properties of the shell and iii) the in-out differential pressure. The proposed predictive framework is in excellent agreement with our experiments, over a wide range of control parameters. The prominence of geometry in this class of problems points to the relevance and applicability of our results over a wide range of lengthscales.

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