Tension-induced giant actuation in unstructured elastic sheets

Marc Suñé*†[1], Kexin Guo[2], Mingchao Liu‡[2,3], K Jimmy Hsia§[2], and Dominic Vella¶[4]

[1]Mathematical Institute, University of Oxford – United Kingdom
[2]Nanyang Technological University [Singapour] – Singapore
[3]University of Birmingham [Birmingham] – United Kingdom
[4]Mathematical Institute [Oxford] (MI) – Mathematical Institute University of Oxford 24-29 St Giles' Oxford, OX1 3LB UK, United Kingdom

Abstract

Buckling in compression is the archetype of elastic instability: when compressed along its longest dimension, a thin structure such as a playing card will buckle out-of-plane accommodating the imposed compression without a significant change of length. However, recent studies have demonstrated that tension applied to sheets with microscopic structure leads to out-of-plane deformation in applications from 'groovy metasheets' for multi-stable morphing to kirigami grippers and edge-clamped graphene sheets. In this talk, I will explain how this counter-intuitive behaviour - a large transverse motion actuated by a relatively small imposed longitudinal tension - occurs also in unstructured sheets of isotropic material. Reflecting both the mode of actuation and its surprising effectiveness, we refer to this as 'Tension indUced Giant' (TUG) actuation. Our work shows that TUG actuation occurs because of an efficient transfer of applied tensile load into compression - a geometric consequence of a localized applied tension. We determine scaling results for the actuation angle as a function of applied strain in agreement with both experiments and simulations. The generic nature of TUG actuation suggests that it might be utilized in a broader range of materials and structure than previously realized.

*Speaker
†Corresponding author: marc.sunesimon@maths.ox.ac.uk
‡Corresponding author: m.liu.2@bham.ac.uk
§Corresponding author: kjhsia@ntu.edu.sg
¶Corresponding author: dominic.vella@maths.ox.ac.uk