LMS Seminar

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Nonlinear mechanics and configuration dependent homogenized properties of straw-based truss metamaterials

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ABSTRACT

Truss metamaterials are structures comprised of repeated or spatially varying unit cells that are composed of elastic struts, which collectively define the effective mechanical properties at the operative macroscale. A careful design of the geometrical and physical properties of the struts as well as their connectivity can lead to superior mechanical performance such as exceptional strength-to-weight ratios and tailored anisotropy, as well as dynamic properties such as customized band gaps and energy absorption. Despite the vast and versatile design space of truss metamaterials, their mechanical properties are typically predetermined and cannot be changed without introducing irreversible plastic deformations. To enrich the nonlinear characteristics achievable by truss metamaterials and allow post-production change of shape and properties, we supplement them with novel multistable struts inspired by drinking straws. In the planar case discussed here, these struts are modelled as serial interconnections of segments which can be stabilized in two axisymmetric and two bent configurations. These multiaxial stable equilibria provide the multistable struts and the lattices they form with a myriad of complex stable configurations, a vital capability for shape morphing and deployable structures, as well as soft robots. The large number of stable configurations further allows changing the local stiffness and effective density of the lattices, which results in programmable static and dynamic properties.

We introduce a numerical scheme describing the mechanical behavior of planar truss metamaterials that incorporate straw-inspired struts, considering their multistability and the nonlinear holonomic constraints they introduce between the nodes of the structures. This formulation spans a wide design space allowing to change the arrangements of the struts as well as the local properties of their constituent multistable segments, to achieve a desirable performance. Indeed, based on the numerical scheme we demonstrate the effect of the internal parameters and microstructure as well as the structure's configuration, on nonlinear properties such as the Poisson function and energy absorption capabilities. We further show the effect of reconfiguration on the linear anisotropic elasticity of straw-based periodic lattices. This is done by homogenization of the linearized formulation of their corresponding unit cells, around different stable configurations.

BIOGRAPHY

Dr. Dotan Ilssar did his PhD at the Technion – Israel institute of technology and is currently a Postdoctoral researcher at the Mechanics and Materials Laboratory in ETH Zürich. In ETH, his research focuses on the mechanics of reconfigurable metamaterials