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Karlstad Applied Analysis Seminar (2022)

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September 14, Wednesday, 14:30-15.30

Design of 3D printable thin composite panels featuring an extension-bending coupling

Abstract

Materials capable of changing their shape in response to external stimuli open new prospects for e cient and versatile design and shaping of three-dimensional objects. During this presentation, I intend topresent two strategies for the design of thin micro-architectural panels with the intent of controlling theircomplete macroscopic elastic behavior, and in particular the extension{bending coupling e ects. I will primarily present a novel class of microstructures, that can be harnessed as an elementary building block for shape-shifting panels. They are built with a single material as a network of undulated ribbons, parametrized by B-splines. The deformations mechanisms of both single and connected undulated ribbons are analyzed using the nite element method to explain the main features of the EBC mechanism. For a particular micro-structure of the proposed class, the elastic response is investigated both under small strain assumption combining two-scale homogenization with Kirchho {Love plate theory, and at nite strains relying on numerical analysis. The range of achievable EBC ratio is then assessed with respect to the geometric parameters of the unit cell. Patterned specimens are mechanically tested at nite strain up to 20%: the displacement measured by point tracking match the predictions from the nite element simulations and indicate that the structure maintains its properties at nite strain. Moreover, a tensile test load with point-like boundary is proposed to highlight exceptional out of plane displacement. In a second part, building upon our previous work, we devise a topology optimization procedure

[redacted] case of elastic panels in order to control their macroscopic behavior, simultaneously taking into account in-plane sti ness, out-of-plane sti ness and extension{bending coupling e ects. Our topology optimization method combines inverse homogenization, the Hadamard shape derivative and a level set method in the di use interface context to systematically capture within the unit cell the optimal micro-architecture. The e ciency of the solution method is illustrated through four numerical examples where the designed shape yields an important extension{bending coupling. The deformation responses under tensile loading are assessed numerically both on the complete periodic panel and on its homogenized twin plate. The results demonstrate that the simultaneous control of the in-plane, out-of-plane and their coupled behavior enables to shift a at panel into a dome or a saddle shaped structure. In both cases, the obtained unit cells are elementary blocks that can be harnessed to directly create 3D printable objects with shape-morphing capabilities. Furthermore, they can be combined with active materials for the actuation of shape shifting structures, like soft robots, control systems and power devices.

[1] F. Agnelli, M. Tricarico, A. Constantinescu. \Shape-shifting panel from 3D printed undulated ribbon lattice". Extreme Mech. Lett.42 (2021)

[2] F. Agnelli, G. Nika, A. Constantinescu. \Design of thin micro-architectured panels with extension-bending coupling e ects using topology optimization" Comput. Meth. Appl. Mech. Eng. 391 (2022)