Progressive Deflection Element / Strain-Stiffening

Technology Offer

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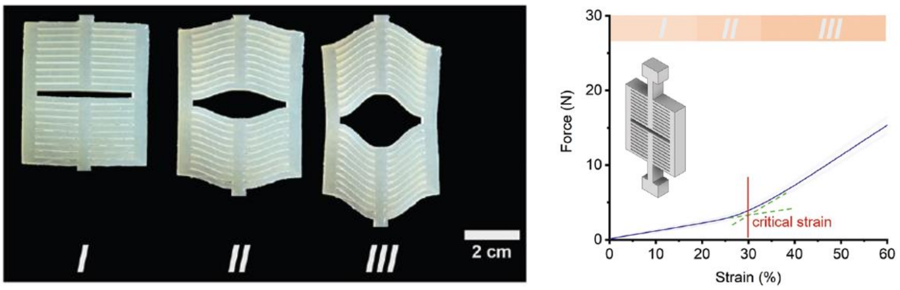

Source: Taale, M., Schmidt, M., Taheri, F., Timmermann, M. and Selhuber-Unkel, C. (2023), A Minimalistic, Synthetic Cell-Inspired Metamaterial for Enabling Reversible Strain-Stiffening. Adv. Mater. Technol., 8: 2201441 // DOI: 10.1002/admt.202201441.

Category

Bio / Mechanical Engineering

Keywords

- Strain-stiffening
- Cell inspired materials
- Monolithic elastomer structure

Development stage

Prototype

Seeking

Licensee

IP status

Patented (DE) / EU application pending

Background

Many technical and especially medical applications require components that combine flexibility at low loads with high stiffness at higher loads. Examples include orthoses, prostheses, and vascular implants, where materials must allow natural movement or physiological deformation initially, but prevent excessive strain or structural failure under increased loading.

Conventional elastic elements typically exhibit either linear or continuously nonlinear (often exponential) force–displacement behavior. Linear systems lack adaptability, while existing progressive systems generally do not provide a clearly defined transition between soft and stiff regimes. In contrast, many biological tissues display a distinct “strain-stiffening” behavior: they are compliant at low strain and become significantly stiffer beyond a certain threshold. Existing technical solutions are often limited by complex geometries, multi-material designs, or restricted scalability.

Therefore, there is a need for a simple, scalable structure that provides a well-defined transition between two linear stiffness regimes while being adaptable to different applications and size scales.

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Technology

The presented technology introduces a structurally engineered progressive deflection element with a tunable dual-stage mechanical response. It consists of at least two supporting backbone structures and multiple slender pillar-like elements arranged between them, all made from an elastomeric material and preferably fabricated as a monolithic structure.

The characteristic behavior results from the interaction of these components. At low loads, deformation is dominated by bending of the pillars, leading to a soft, approximately linear response. As deformation increases, the pillars come into contact, causing a stiffness increase (strain-stiffening). At higher loads, the stiffer backbones carry the load, resulting in a second linear regime with significantly higher stiffness. This enables a clearly defined transition between a compliant and a stiff behavior.

The mechanical properties can be precisely tuned by adjusting geometric parameters such as the number, size, and spacing of the pillars, as well as the dimensions of the backbones. The structure can be manufactured from a single elastomer using established methods such as molding, 3D printing, or micromachining, and can be adapted to a wide range of applications and scales.

Benefits

- Dual-stage linear stiffness behavior
- Biomimetic strain-stiffening
- High tunability and scalability
- Versatile manufacturing

Applications

- Medical Technology (Vascular grafts, Orthoses, Prosthetic)
- Mechanical Engineering (Damping / Suspension Elements, Adaptive Springs)
- Micro- and Precision Engineering (Microscale Actuators, Functional Material)

Publications

- Taale, M., Schmidt, M., Taheri, F., Timmermann, M. and Selhuber-Unkel, C. (2023), A Minimalistic, Synthetic Cell-Inspired Metamaterial for Enabling Reversible Strain-Stiffening. Adv. Mater. Technol., 8: 2201441. https://doi.org/10.1002/admt.202201441

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