T. Gärtner[a,b]
S.J. van den Boom[a,b]
J. Weerheijm[a]
L.J. Sluys[a]

[a] TU Delft
[b] TNO

On the Behaviour of Architected Metamaterials under High-Rate Loading Conditions

Are Auxetics Better for Protection?

Motivation

Superiority of auxetic materials for impact mitigation is a widespread claim in literature. The aim of this project is to scrutinize this claim.

Approach

Auxeticity is only achieved in carefully architected metamaterials. Due to the high cost of ballistic experiments the majority of this study is conducted using numerical experiments.

How can lattice structures be efficiently and accurately modelled using numerical tools?

Architected materials are modelled as a collection of non-linear, shear-deformable beams (Fig. 1). A consistent scaling approach (Fig. 2) for the elastoplastic modeling of beams is developed and implemented using an explicit return mapping scheme. The dynamics of the system is simulated using an explicit predictor-corrector with adaptive stepping.

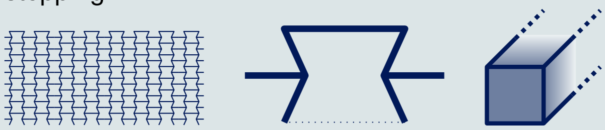


Figure 1: Abstraction levels of architected metamaterials.

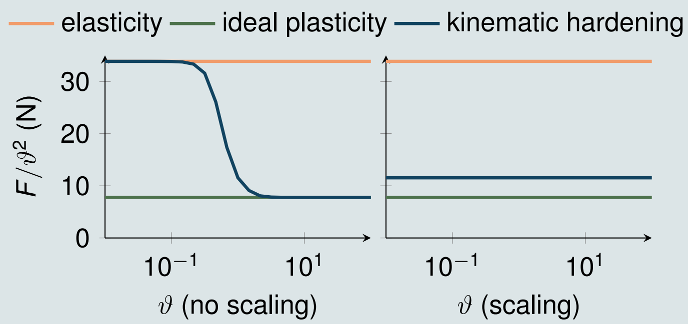


Figure 2: Effect of the proposed scaling strategy.

How does the microstructure influence force transmission in architected materials?

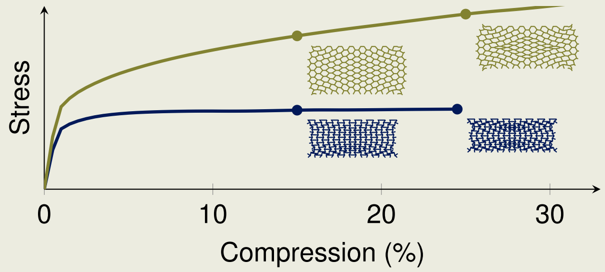


Figure 3: Static response of different architectures.

Auxetic structures promote localization throughout static deformation, leading to a weaker overall response (Fig. 3). The dynamic reponse is dictated by the distribution of inertia within the microstructure (Fig. 4).

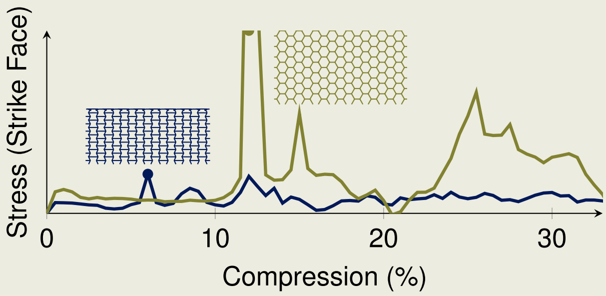


Figure 4: Dynamic ($4 \times 10^3\ s^{-1}$) response.

How does the strain rate influence force transmission in architected materials?

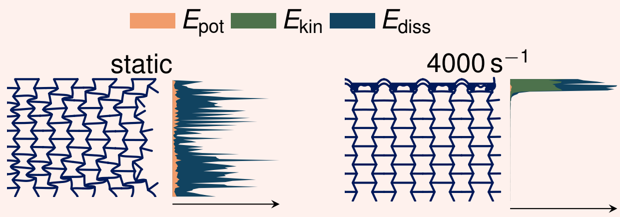


Figure 5: Energy concentration at localized deformation.

The energy dissipation limits the forces transmitted due to yielding of the material and localization of deformation (Fig. 5). The forces observed on the backside approach in a first approximation the static limit (Fig. 6).

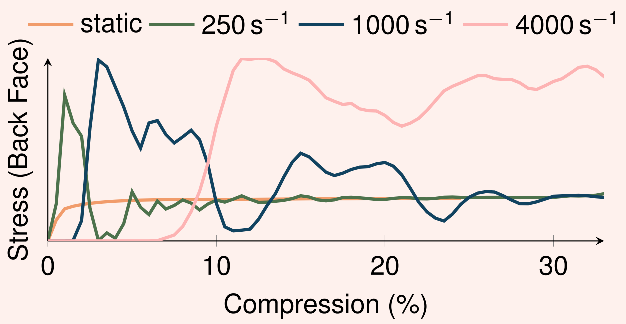


Figure 6: Stress on the back face of re-entrant patches.

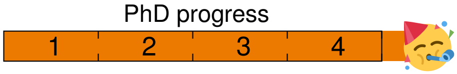
Conclusion

All results in this investigation lead to the assessment that

Auxetics are *not* Better for Protection.

TUDelft

PhD progress



TNO