Geometry-informed surrogate modelling for architected metamaterial design under high-rate loading

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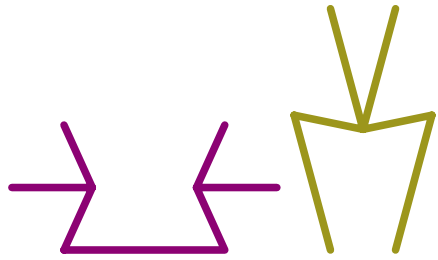
96th annual meeting GAMM
19 March 2026

Architected Materials Show New Properties

- negative Poisson's ratio



Gärtner et al. 2024

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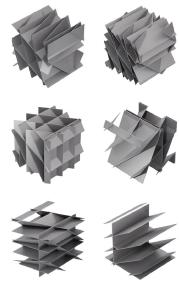

Meyer et al. 2024

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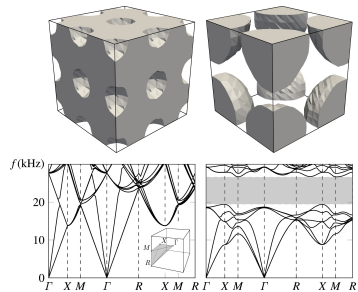
- acoustic bandgaps



van den Boom et al. 2023

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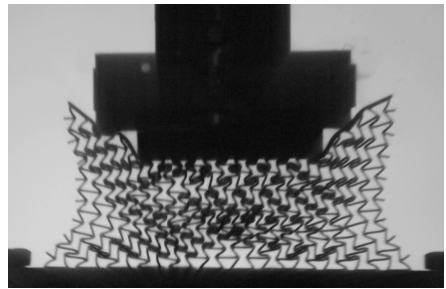

Gärtner et al. 2025a

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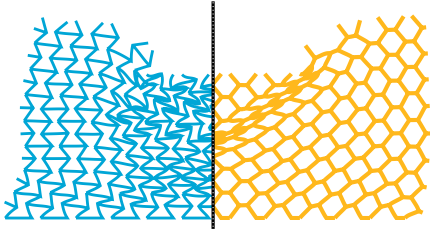
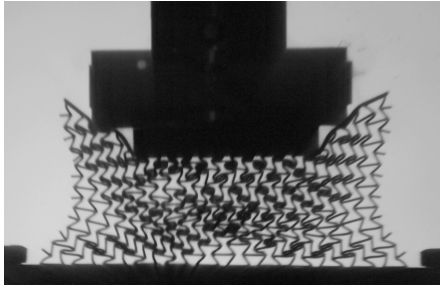
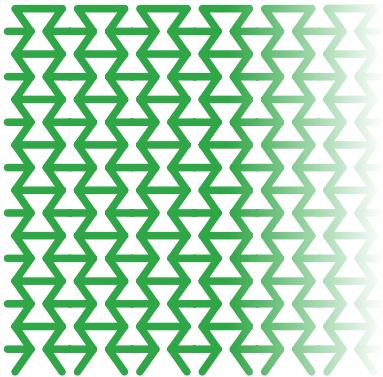




Gärtner et al. 2025a

Modelling of Lattices with Rods to Reduce Runtime

- Investigated materials are assemblies of rods



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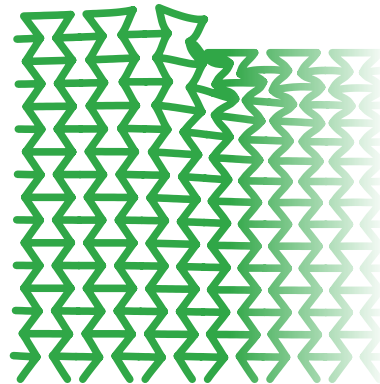
- Direct incorporation of elasto-plasticity into beam continuum[a]



[a] Gärtner et al. 2025b.

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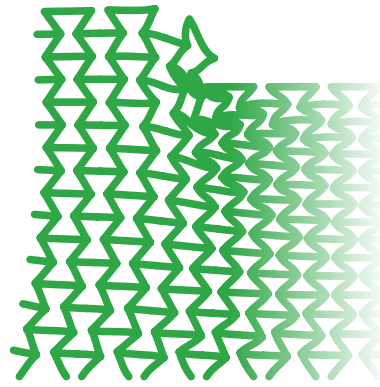

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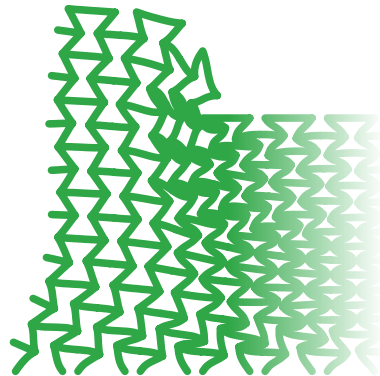
- Adaptive time stepping using an explicit predictor-corrector scheme



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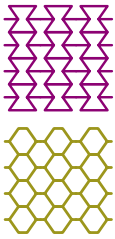
Single Parameter Changes Response Significantly



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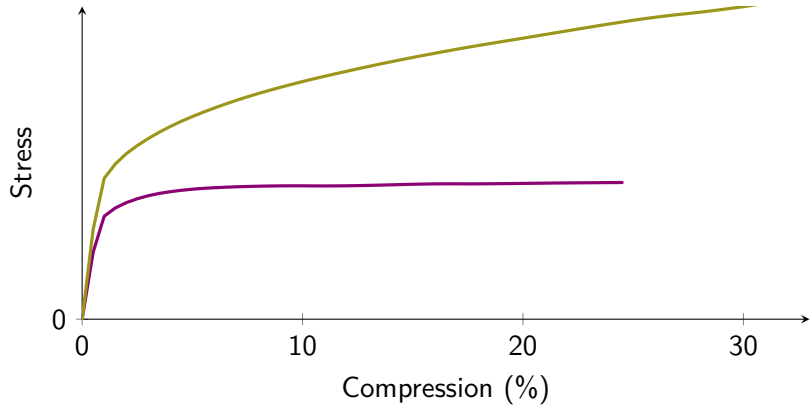

cf. Gärtner et al. 2025c

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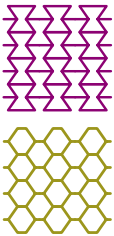
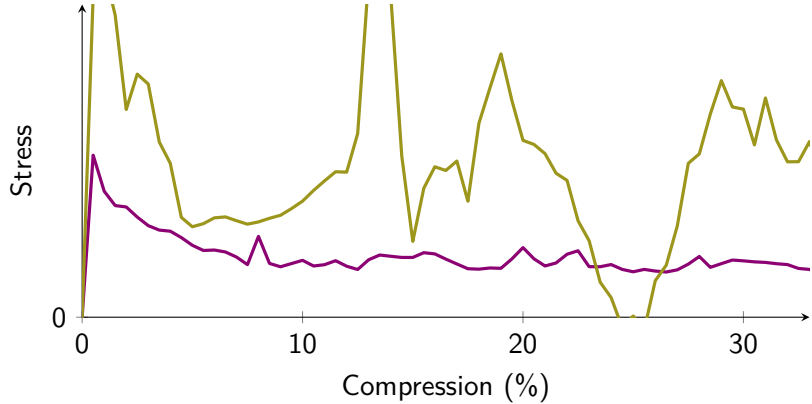


$1000\,\mathrm{s}^{-1}$



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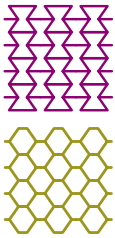
Transmitted Forces Limited by Static Yield



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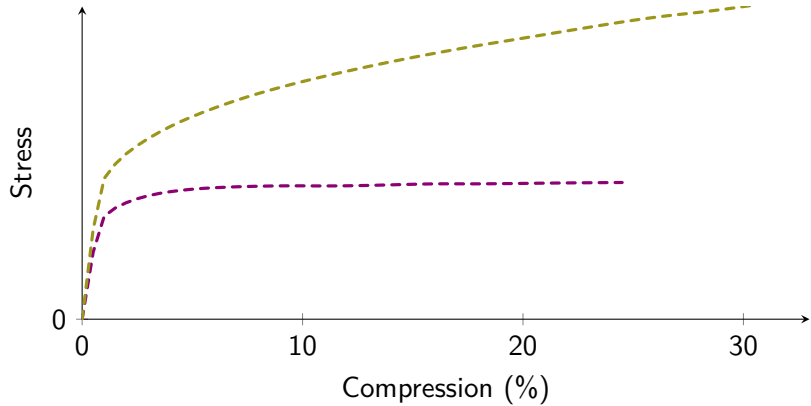

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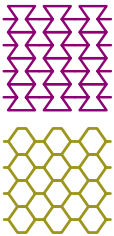

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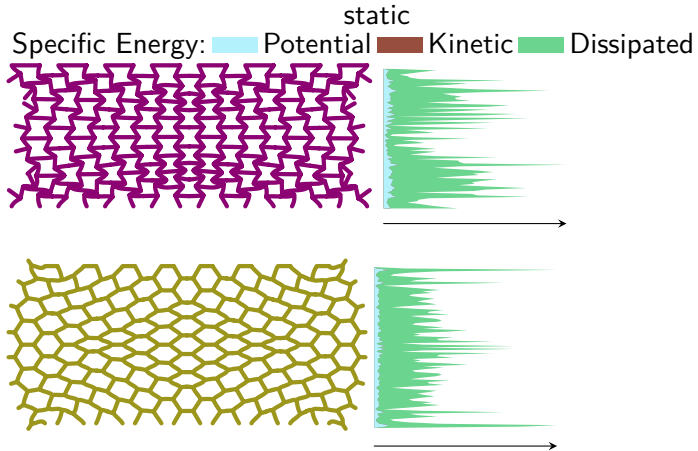

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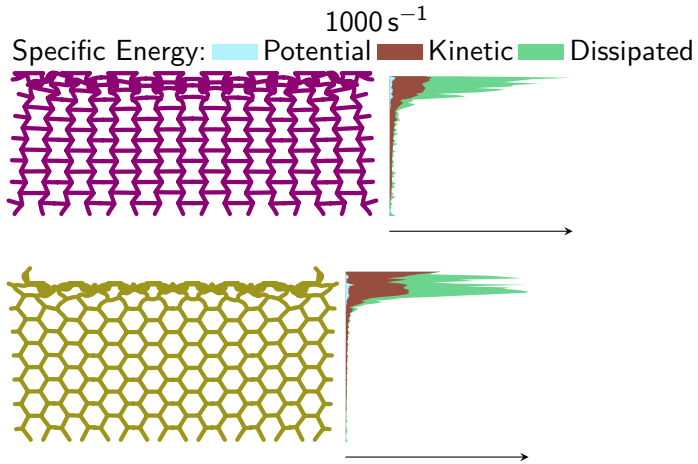

Vast Plethora of Design Options

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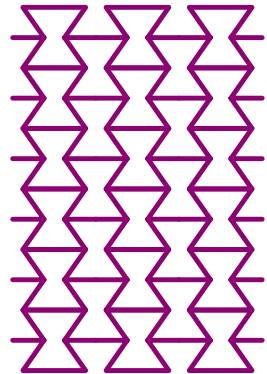

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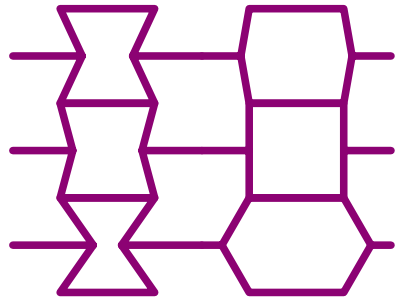

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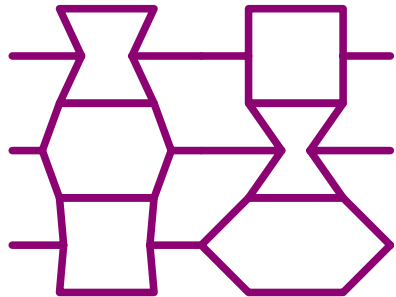

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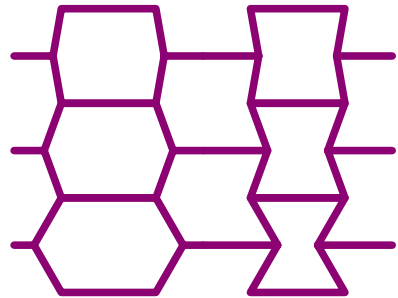

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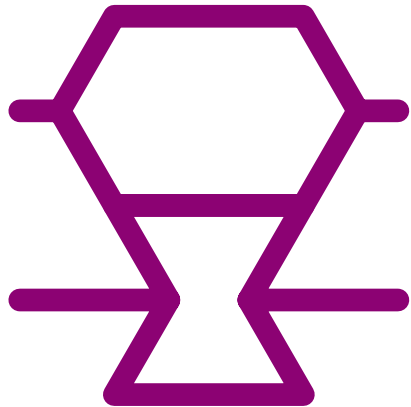
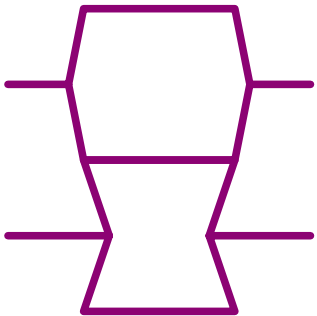
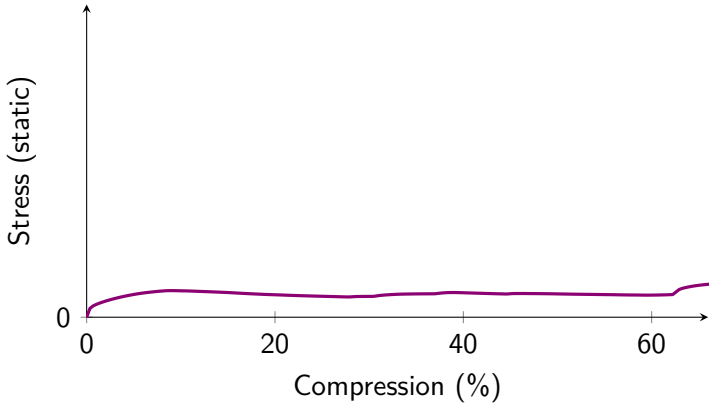
- First proxy for large lattice: single column



Response as Two Stage Process





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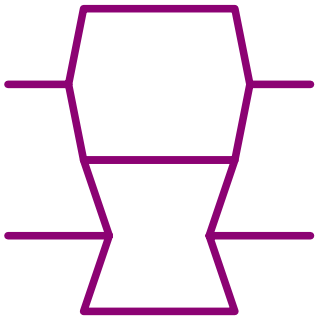

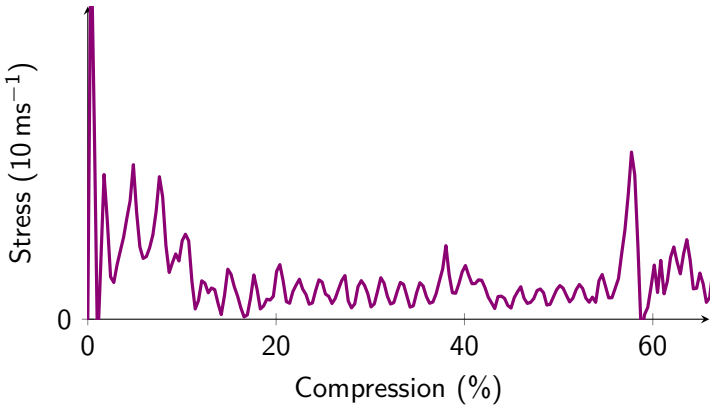

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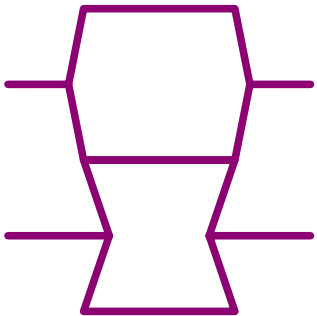

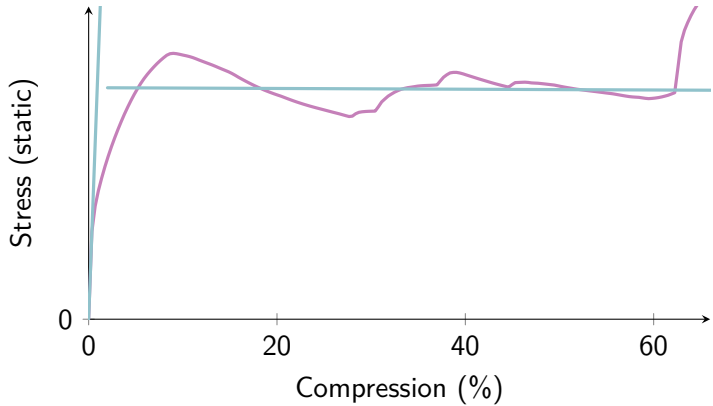

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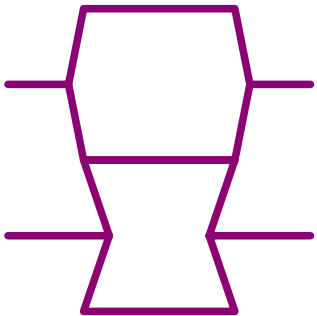

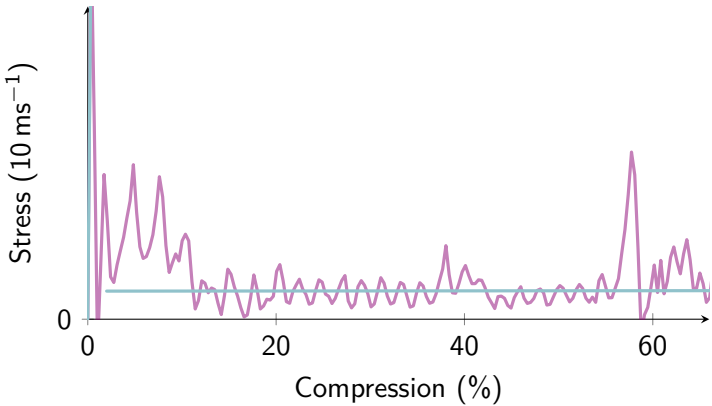

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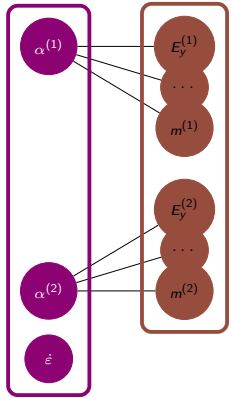

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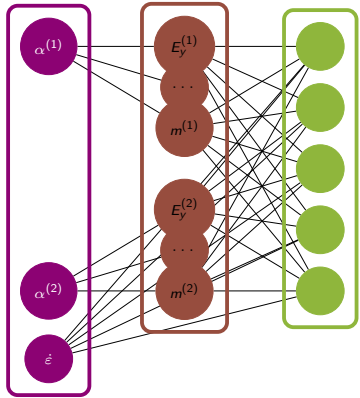

Surrogate for the Two Stage Process

- fixed geometric information ($\alpha \rightarrow E_y, ...$)
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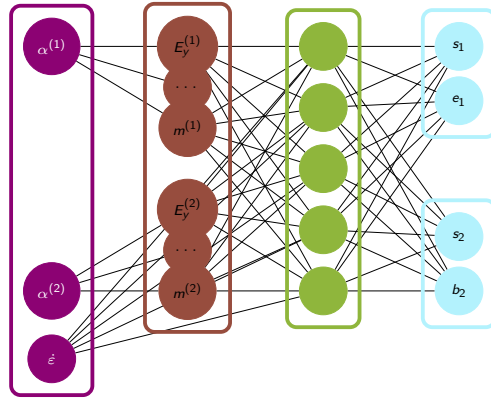
- Additional loss terms for physical behaviour:
  - $\bar{E}_y \Leftrightarrow s_1$ (static)
  - $(\alpha^{(1)}, \alpha^{(2)}) \Leftrightarrow (\alpha^{(2)}, \alpha^{(1)})$ (static)
  - $\dot{\varepsilon} \uparrow \Rightarrow s_1 \uparrow$
  - $\dot{\varepsilon} \uparrow \Rightarrow b_2 \uparrow$



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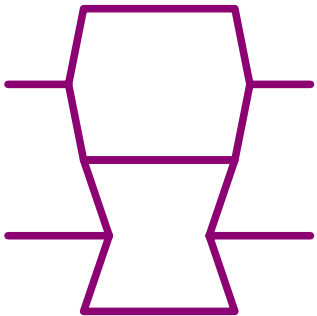

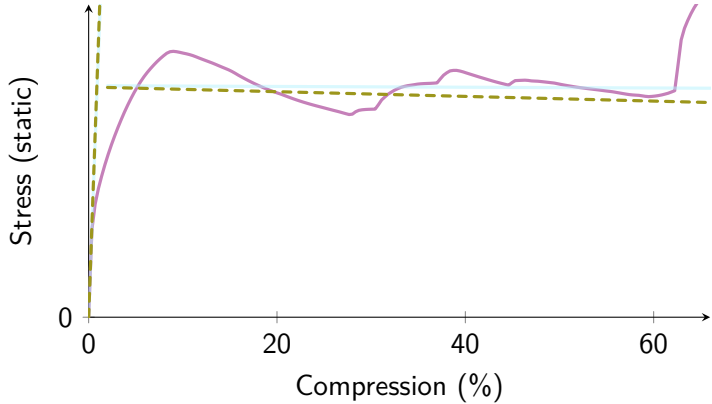

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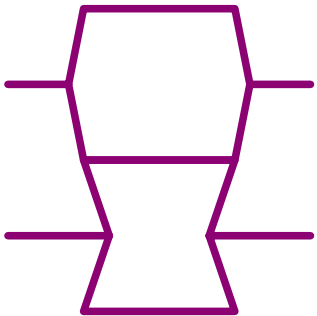
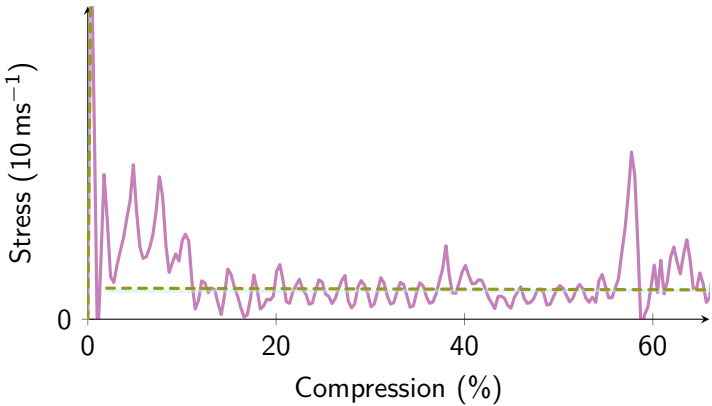
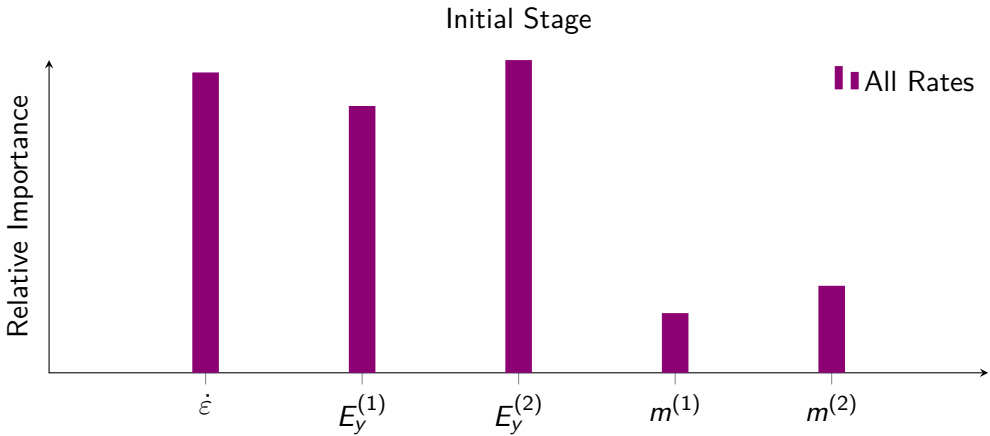




Shapely Confirm Geometric Information



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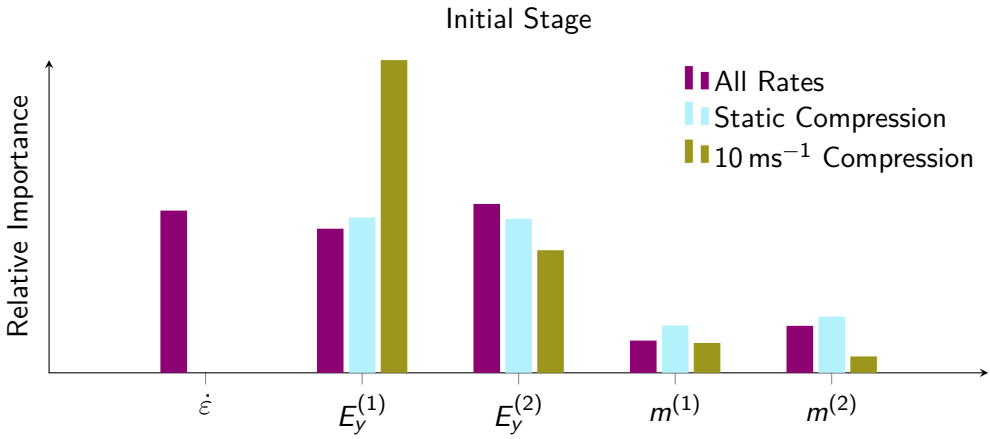

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TODO: Expansion of the model

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96th annual meeting GAMM

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Thank you!

Questions?

http://go.lu-h.de/data-27

References I

[1] T. Gärtner et al. “Geometric Effects on Impact Mitigation in Architected Auxetic Metamaterials”. In: *Mechanics of Materials* 191, 104952 (May 2024), p. 104952.

[2] Paul P. Meyer, Thomas Tancogne-Dejean, and Dirk Mohr. “Non-Symmetric Plate-Lattices: Recurrent Neural Network-Based Design of Optimal Metamaterials”. In: *Acta Materialia* 278 (2024).

[3] Sanne J. van den Boom et al. “A Level Set-Based Interface-Enriched Topology Optimization for the Design of Phononic Crystals with Smooth Boundaries”. In: *Computer Methods in Applied Mechanics and Engineering* 408 (Apr. 1, 2023), p. 115888.

References II

[4] T. Gärtner et al. "(In)Efficacy of Architected Auxetic Materials for Impact Mitigation". In: *International Journal of Impact Engineering* 206, 105402 (Dec. 2025).

[5] T. Gärtner et al. "A Strategy for Scaling the Hardening Behavior in Finite Element Modelling of Geometrically Exact Beams". In: *Computational Mechanics* 75.5 (May 2025), pp. 1471–1482.

[6] T. Gärtner et al. "Force Transmission and Dissipation in Dynamic Compression of Architected Metamaterials". In: *Materials Today Advances* 28, 100656 (Dec. 2025).