

Auxetic Photopolymer Structures: Geometry, Manufacturing Defects, Strain Range and Failure

Qualifying negative-Poisson-ratio behaviour over finite strain while separating designed kinematics from print-induced imperfection and fracture

Juan Segurola

3Dresyns by Resyner Technologies S.L.

© 2026 Juan Segurola. All Rights Reserved.

Correspondence: info@3Dresyns.com · www.3Dresyns.com

ER-362 · Engineering Review · Version 0.2 · 1 October 2026

Abstract

Auxetic response is a geometric mechanism that can be lost through small changes in hinge thickness, re-entrant angle, node shape or material nonlinearity. ER-362 focuses on the conditions under which a negative Poisson response remains measurable, repeatable and structurally useful after photopolymer manufacture. Full-field strain measurements are coupled to as-built geometry and local damage inspection so that kinematic rotation can be distinguished from hinge bending, fracture or out-of-plane buckling. Strain-range, orientation and defect perturbations establish the usable auxetic window. Qualification therefore requires not only a negative Poisson ratio, but retention of the intended deformation mode and an explicit limit on damage accumulation and manufacturing sensitivity.

Keywords: auxetic; negative Poisson ratio; geometric defect; large strain; failure; vat photopolymerisation

1. Qualification problem: auxetic response

The central engineering task in auxetic response is to convert mechanism into an auditable decision boundary. The three boundaries considered are usable strain range before auxetic mechanism degrades, defect tolerance for critical ligaments, and whether recovery or one-time energy absorption is the design objective; their regime context is carried by re-entrant angle or chirality, ligament slenderness, and defect-to-feature-size ratio. [1,6]

1.1 Scope boundary.

ER-362 owns auxetic response and the defect-sensitive origin of negative Poisson response. ER-361 owns general metamaterial qualification, ER-363 grading, ER-364 snap-through stability, and ER-365 impact absorption; overlaps are limited to shared geometric defects and nonlinear failure.

2. Governing balances for auxetic response

Auxetic behaviour is interpreted through the geometric and defect relations listed below rather than by Poisson ratio alone.

negative Poisson response is a kinematic consequence of re-entrant, rotating, chiral or instability-based mechanisms

instantaneous Poisson ratio can vary strongly with strain and should not be represented by one small-strain scalar

hinge/ligament bending and rotation concentrate strain at topology-specific hotspots

The coordinates distinguish intended rotation mechanisms from ligament instability and defect-driven localisation.

3. Regime boundaries for auxetic response

For auxetic structures, the table indicates whether usable strain, ligament quality, or recovery objective sets the qualification boundary.

Table 1. Regime indicators for auxetic response.

Indicator	Engineering meaning	Use
re-entrant angle or chirality	kinematic geometry that sets the auxetic deformation mechanism	When 'usable strain range before auxetic mechanism degrades' is transferred, re-entrant angle or chirality provides the physical-similarity check and exposes departures in kinematic geometry that sets the auxetic deformation mechanism.
ligament slenderness	ligament geometry governing rotation versus bending failure	When 'defect tolerance for critical ligaments' is transferred, ligament slenderness provides the physical-similarity check and exposes departures in ligament geometry governing rotation versus bending failure.
defect-to-feature-size ratio	defect size relative to the feature carrying the auxetic mechanism	When 'whether recovery or one-time energy absorption is the design objective' is transferred, defect-to-feature-size ratio provides the physical-similarity check and exposes departures in defect size relative to the feature carrying the auxetic mechanism.

Auxetic qualification remains local to the demonstrated geometry, ligament, and defect state rather than to nominal topology alone.

4. Couplings that move the auxetic response

Overcure changes hinge thickness and can suppress auxetic rotation.

Resin brittleness limits usable strain even when geometry remains kinematically auxetic.

Build orientation and layer interfaces bias crack initiation.

5. Failure signatures and false diagnoses

A useful failure map keeps loss of auxetic response before nominal failure, hinge fracture at large strain and mode switching caused by asymmetric defects separate. Their observable counterparts—transverse and axial strain fields from DIC, local hinge rotation and curvature, CT of as-built re-entrant/chiral geometry—allow the suspected route to be tested before qualification is rejected or retained. Interpretation also tracks usable strain range and topology-dependent localisation, because a nominally negative transverse response can coexist with early ligament failure or defect-sensitive rotation.

Table 2. Failure-mode discrimination for auxetic response.

Failure mode	Observable signature	Discriminating evidence
loss of auxetic response before nominal failure	transverse and axial strain fields from DIC	map Poisson ratio continuously versus strain
hinge fracture at large strain	local hinge rotation and curvature	introduce controlled geometric defects to determine robustness
mode switching caused by asymmetric defects	CT of as-built re-entrant/chiral geometry	test multiple cell counts and boundary conditions
permanent set that degrades repeat cycling	cyclic recovery and residual strain	compare monotonic and cyclic large-strain response

Table 2 provides four independent ways to reject the wrong mechanism; confidence increases only when the same explanation remains consistent across them.

6. Measuring auxetic response with traceable uncertainty

The three Table 2 measurement routes are carried through the uncertainty budget independently so that a weak channel remains visible at the decision stage. For the auxetic response problem, separate monitoring of defect localisation defines the independent cross-check rather than a tuning variable; during metrology of auxetic response, ligament bending is resolved against defect localisation. The main inference uses independent resolution of strain-dependent Poisson response and hinge rotation, whereas an uncertainty-controlled perturbation of ligament bending is reserved for the boundary test that can overturn the proposed interpretation; the uncertainty record for auxetic response keeps defect localisation separate from strain-dependent Poisson response.

7. Experiments that discriminate competing mechanisms

Mechanism selection uses the complete set of Table 2 interventions, including at least one test that should leave the proposed mechanism unchanged. Rather than reduce auxetic response to one surrogate, the analysis combines a replicate test of defect localisation with a causal contrast between strain-dependent Poisson response and ligament bending; during the causal challenge for auxetic response, defect localisation is tested against strain-dependent Poisson response. A separate a boundary challenge involving hinge rotation is used to challenge that interpretation, making disagreement between the two routes visible instead of averaging it away; the experiment for auxetic response separates strain-dependent Poisson response from hinge rotation.

8. Model identification and validation for auxetic response

The frozen model must reproduce two Table 2 branches that were excluded from fitting. Failure on either branch triggers model-form review rather than parameter retuning. [1,6] [2,4] [3,5] Each decision row receives a separate uncertainty interval, so a well-constrained limit does not conceal a poorly constrained one. An acceptable record for auxetic response must show an uncertainty-bounded check on defect localisation without inferring it from parameter estimation for strain-dependent Poisson response and hinge rotation; within model identification for auxetic response, strain-dependent Poisson response is not fitted through hinge rotation. In parallel, prediction against ligament bending probes the boundary condition most likely to change the interpretation, and the resulting uncertainty is carried forward explicitly; prediction for auxetic response keeps hinge rotation independent of ligament bending.

9. Qualification envelope and technology decisions

Table 3. Technology-decision matrix for auxetic response.

Decision	Minimum evidence	Acceptance logic
usable strain range before auxetic mechanism degrades	For usable strain range before auxetic mechanism degrades, require a replicated transverse and axial strain fields from DIC dataset that covers the proposed envelope and reports the uncertainty attached to the limiting state.	The decision remains valid only if 'map Poisson ratio continuously versus strain' gives a bounded, repeatable transverse and axial strain fields from DIC response and does not produce loss of auxetic response before nominal failure.
defect tolerance for critical ligaments	Demonstration of defect tolerance for critical ligaments needs traceable local hinge rotation and curvature measurements in the qualified state and at least two candidate states spanning the transfer interval.	The claim is accepted if 'introduce controlled geometric defects to determine robustness' reproduces the expected local hinge rotation and curvature behaviour at the limiting state and no hinge fracture at large strain signature is present.
whether recovery or one-time energy absorption is the design objective	Build the case for whether recovery or one-time energy absorption is the design objective from CT of as-built re-entrant/chiral geometry measured at the baseline, an intermediate state and the proposed limit, with independent replication.	Acceptance follows when 'test multiple cell counts and boundary conditions' leaves the measured CT of as-built re-entrant/chiral geometry relationship intact and no transition toward mode switching caused by asymmetric defects is detected.

Evidence for auxetic response is not accepted from a single nominal condition; inside the auxetic response envelope, hinge rotation and ligament bending define different transfer limits. The analysis requires tested ranges in strain-dependent Poisson response and hinge

rotation, follows it with an explicit transfer limit on defect localisation, and uses a separate boundary for ligament bending as a targeted challenge wherever the two indicate different mechanism or margin; qualification of auxetic response bounds ligament bending separately from defect localisation.

10. Design consequences for auxetic response

The technology decision is decomposed into three Table 3 rows, with a separate acceptance record and uncertainty statement for each. During implementation, an implementation check on ligament bending is challenged deliberately while defect tolerance for critical ligaments is controlled independently, leaving a design change governed by strain-dependent Poisson response as the design variable rather than a hidden compensator; during design implementation for auxetic response, ligament bending is constrained by defect localisation. The resulting design record therefore distinguishes intended control from incidental compensation in auxetic response; the auxetic response design record separates defect localisation from strain-dependent Poisson response.

11. Evidence gaps for auxetic response

Qualification of auxetic response treats scale transfer of strain-dependent Poisson response as one axis and independent replication of defect localisation as another; for unresolved auxetic response transfer, defect localisation is studied separately from strain-dependent Poisson response. Between them, uncertainty in hinge rotation versus ligament bending supplies the deliberate challenge that determines whether the apparent transfer is mechanistic or merely coincidental; the evidence gap in auxetic response distinguishes strain-dependent Poisson response from hinge rotation.

12. Qualification outcome for auxetic response

The supported claim is restricted to states satisfying every Table 3 boundary. Crossing one boundary invalidates the transfer assumption for that decision. The auxetic response workflow deliberately separates causal evidence that separates hinge rotation from ligament bending from agreement between measurement and prediction for strain-dependent Poisson response; this avoids fitting the challenge into the quantity being qualified; at final qualification of auxetic response, strain-dependent Poisson response is reconciled with hinge rotation. A renewed-evidence trigger when defect localisation changes is then examined on its own terms before any transfer statement is retained; the closing auxetic response claim keeps hinge rotation distinct from ligament bending.

References

1. Egan GC, Angilella AJ, Corrado CR, Skelton WV Jr. The impact of additive manufacturing induced geometric defects on auxetic lattices. *Composite Structures*. 2025;358:118968. doi:10.1016/j.compstruct.2025.118968.
2. Iantaffi C, Bele E, McArthur D, Lee PD, Leung CLA. Auxetic response of additive manufactured cubic chiral lattices at large plastic strains. *Materials & Design*. 2023;233:112207. doi:10.1016/j.matdes.2023.112207.
3. Khosravani MR, Anders D, Ayatollahi MR, Reinicke T. Fabrication of mechanical metamaterials by 3D printing: recent advancements and current challenges. *Archives of Civil and Mechanical Engineering*. 2025;25:244. doi:10.1007/s43452-025-01290-8.
4. Meng Z, Xu Y, Xie J, Zhou W, Bol RJM, Liu QF, Šavija B. Unraveling the reinforcing mechanisms for cementitious composites with 3D printed multidirectional auxetic lattices using X-ray computed tomography. *Materials & Design*. 2024;246:113331. doi:10.1016/j.matdes.2024.113331.
5. Lu C, Hsieh M, Huang Z, Zhang C, Lin Y, Shen Q, Chen F, Zhang L. Architectural Design and Additive Manufacturing of Mechanical Metamaterials: A Review. *Engineering*. 2022;17:44-63. doi:10.1016/j.eng.2021.12.023.
6. Naik DL, Kiran R. On anisotropy, strain rate and size effects in vat photopolymerization based specimens. *Additive Manufacturing*. 2018;23:181-196. doi:10.1016/j.addma.2018.08.021.

Competing interests

The author is Founder, CEO and CTO of 3Dresyns by Resyner Technologies S.L. No comparative product recommendation is made.

Data availability

No new experimental dataset was generated for this review.