

Printed Composite Tooling for Lay-Up, Infusion and Cure: Surface, Permeability, Thermal Expansion and Tool Life

Juan Segurola

3Dresyns by Resyner Technologies S.L.

© 2026 Juan Segurola. All Rights Reserved.

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

ER-284 · Engineering Review · Version 0.3 · 23 September 2026

Abstract

Printed Composite Tooling for Lay-Up, Infusion and Cure is evaluated as the bounded decision of whether printed tooling preserves surface, vacuum/infusion integrity and dimensional fidelity through the declared composite cure history. The controlled state comprises tool material, reinforcement, print orientation, cure state, surface finish/coating, support, thermal cycle, pressure/vacuum load and number of uses. ER-284 uses its single direct source only for the bounded proposition described in section 3. ER-284 defines measurements, transfer logic, failure modes and release gates specific to this subject; no universal process window, product recipe or compliance conclusion is inferred.

Keywords: composite tooling; photopolymer; autoclave; thermal expansion; permeability; tool life; lay-up; infusion

1. Significance, scope and ownership

ER-284 owns whether printed tooling preserves surface, vacuum/infusion integrity and dimensional fidelity through the declared composite cure history. The review is organised around the decision-specific evidence chain and leaves neighbouring ownership intact.

1.1. Corpus boundary

This scope begins after the material has been selected for tooling and ends before sacrificial-core removal. ER-31 retains cure-shrinkage and warpage mechanisms, ER-170 accelerated ageing, and ER-285 sacrificial cores. ER-284 owns whether a reusable printed tool maintains surface, vacuum, geometry and load capability through its declared cure cycles.

2. Subject-specific state model and causal chain

For ER-284, causal interpretation begins by freezing tool material, reinforcement, print orientation, cure state, surface finish/coating, support, thermal cycle, pressure/vacuum load and number of uses. Thermal expansion, coating condition and loaded cycling can move together during cure, making room-temperature dimensions an incomplete description of tooling capability.

3. Direct evidence and point-of-use source map

Stiles, Kobler, Yeole and Vaidya developed photopolymer formulations toward autoclave/oven-capable tooling and demonstrated thermally cycled prototype tooling under bounded conditions. Their study shows that cure response, glass transition, hardness and dimensional change are coupled; it does not establish unlimited tool life. Reference [1] is used for direct autoclave-capable photopolymer tooling evidence.

4. Measurement architecture

The measurement architecture for ER-284 is built around tool-face metrology, roughness, vacuum leakage/permeability, CTE, Tg or transition state, stiffness, distortion under cure pressure and cycle-resolved dimensional drift. Tool-face metrology, vacuum integrity and hot-geometry measurements are repeated over representative loaded cycles to expose drift that an unloaded coupon would miss.

5. Qualification and transfer

Tooling transfer is tied to cure temperature, pressure or vacuum load, coating system and geometry. A bridge must reproduce the combination that maximises distortion or surface/vacuum demand rather than extrapolate from an unloaded room-temperature inspection.

6. Failure modes and interpretation traps

The central interpretation trap in ER-284 is that survival of a few cycles is called a service-life qualification; room-temperature geometry substitutes for hot loaded shape; a sealed coating masks substrate evolution without being included in the controlled configuration. Surface, vacuum, hot-geometry and loaded-cycle gates keep cosmetic success from masking drift that only appears under the cure history the tool must actually survive.

7. Non-compensatory release gates

Gate	Minimum evidence	Blocking failure
Tool state	Material/reinforcement/cure/coating frozen	Uncontrolled tool configuration
Surface	Tool-face roughness/fidelity tracked	Visual smoothness only
Vacuum/permeability	Leak integrity under use conditions	Bag seal masks tool evolution
Hot geometry	CTE/distortion under thermal load measured	Room-temperature shape substituted
Transition/mechanics	Tg/stiffness relevant to cure cycle	Nominal HDT substituted
Loaded cycling	Representative pressure/vacuum cycles run	Empty thermal cycling only
Coating system	Coating treated as controlled component	Coating hides substrate change
Tool life	Predeclared stop rule and drift trend	Few successful cycles called lifetime

8. Minimum verification experiment

Baseline the tool geometry and surface, perform a representative vacuum/pressure leak test, measure relevant thermal expansion and transition behaviour, run a predeclared series of cure cycles with representative lay-up or dummy load, and remeasure geometry, seal integrity and surface after selected cycles. Define a stop rule before testing.

9. Knowledge boundary

Prototype tooling studies do not establish universal autoclave life. Coupled coating degradation, substrate creep, moisture uptake, load-induced distortion and cumulative cycle-to-cycle drift remain material/configuration questions.

10. Conclusions

ER-284 makes reusable-tooling claims conditional on surface, vacuum, thermal geometry and loaded-cycle retention under the declared composite cure workflow.

References

1. Alex Stiles, Will Kobler, Pritesh Yeole, Uday Vaidya. Photopolymer formulation towards large scale additive manufacturing of autoclave capable tooling. Additive Manufacturing. 2022;50:102571. <https://doi.org/10.1016/j.addma.2021.102571>

Copyright

© 2026 Juan Seguro. All Rights Reserved.