

Cure Shrinkage, Residual Stress and Warpage in VPP: A Qualification and Minimum-Reporting Note

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Statement of Significance

Polymerisation shrinkage is a local material response; residual stress and warpage are structural outcomes of nonuniform conversion, evolving stiffness and constraint. A single shrinkage percentage cannot describe all three.

Keywords: polymerisation shrinkage; residual stress; warpage; dimensional metrology; post-cure; VPP.

Abstract

This note distinguishes chemical shrinkage from residual stress and geometry-dependent warpage. Three topical sources support curing-dependent thermoviscoelastic behaviour, grayscale dose-gradient modelling and digital warpage compensation. ISO 291:2008 is identified for conditioning atmosphere, while the exact dimensional, thermal and mechanical methods must be selected for the intended claim. The document is not a quantitative meta-analysis and does not pool values across formulations, machines or geometries. RP-02 defines the shared qualification method.

1. Evidence boundary

The topical evidence covers curing-dependent shrinkage and thermoviscoelasticity [1], warpage correction [2] and reaction–diffusion behaviour under grayscale exposure [3]. General photopolymer reviews [4,5] are background sources and do not support digital compensation or a specific thermomechanical result.

2. Topic-specific findings

- Network formation changes specific volume while stiffness evolves, so chemical shrinkage can become constrained and stored as residual stress [1].
- Spatial dose gradients produce spatial conversion gradients; their dimensional consequence depends on geometry and constraint rather than dose alone [3].
- Thermal and curing-dependent response must be interpreted with a stated temperature history and material state [1].
- Digital compensation can reduce error for a calibrated geometry but does not remove the underlying material/process state [2].

3. Minimum reporting set

Measurand/control	Minimum method record	Required report
Shrinkage	State whether volumetric, linear, pre-gel or post-gel; identify the validated method	Conversion, temperature, time and constraint state
Residual stress	Curvature, layer-removal or validated inverse method	Boundary conditions, model assumptions and uncertainty
Warpage	3D scan against CAD after a stated atmosphere and dwell	Registration method, datums, local/global error and uncertainty
Conditioning	ISO 291:2008 where applicable, or a justified application-specific atmosphere	Temperature, humidity, dwell and measurement timing
Thermomechanics	DSC, DMA and/or TMA with method fully identified	State the Tg definition; DSC midpoint, DMA E' onset and tan δ peak are not interchangeable

4. Failure interpretation

- Curl after support removal indicates released structural constraint, not simply a bulk shrinkage value.
- Post-cure drift must be separated from print-stage distortion by measurements at defined time points.
- A compensation field calibrated on one geometry is not automatically transferable to another.
- Registration choices can hide or exaggerate local form error and must be reported.

5. 3Dresyns implementation examples

Anti-warping additives, kinetic modifiers and CRT-guided exposure changes are manufacturer-controlled process candidates, not universal corrections. Their effects must be measured on representative geometries after the complete wash, dry, release, post-cure and conditioning sequence. Any product-specific implementation must verify the current exact product and controlled-document revisions.

6. Limitations and priorities

The three topical sources do not establish universal shrinkage or warpage values. Priorities are coupled conversion–stress validation on representative parts, transparent registration conventions, and conditioning-time studies that separate reversible thermal/moisture response from irreversible cure and stress release.

7. Conclusions

- Shrinkage, residual stress and warpage require distinct measurands.
- Digital compensation is geometry- and calibration-specific [2].

- Dimensional claims require a stated conditioning atmosphere, dwell, registration and uncertainty.

Declarations

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References

- [1] Kubra Sekmen, Thomas Rehbein, Michael Johlitz, Alexander Lion, Andrei Constantinescu. Curing-dependent thermo-viscoelastic and shrinkage behaviour of photopolymers. *Mechanics of Materials*. 2023;179:104566. <https://doi.org/10.1016/j.mechmat.2023.104566>
- [2] Taehyub Lee, Chin Siang Ng, Pei-Chen Su. Warpage correction for vat photopolymerization 3D printing. *Additive Manufacturing*. 2025;102:104740. <https://doi.org/10.1016/j.addma.2025.104740>
- [3] S. Macrae Montgomery, Craig M. Hamel, Jacob Skovran, H. Jerry Qi. A reaction–diffusion model for grayscale digital light processing 3D printing. *Extreme Mechanics Letters*. 2022;53:101714. <https://doi.org/10.1016/j.eml.2022.101714>
- [4] Ali Bagheri, Jianyong Jin. Photopolymerization in 3D Printing. *ACS Applied Polymer Materials*. 2019;1(4):593–611. <https://doi.org/10.1021/acsapm.8b00165>
- [5] Jeffrey W. Stansbury, Mike J. Idacavage. 3D printing with polymers: Challenges among expanding options and opportunities. *Dental Materials*. 2016;32(1):54–64. <https://doi.org/10.1016/j.dental.2015.09.018>

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