

Rheology, Recoating and Dispersion Control of Highly Filled VPP Suspensions

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Statement of Significance

A viscosity value at one shear rate cannot predict recoating, refill or stability in a highly filled suspension. Qualification must connect flow history, recovery, temperature, particle state and production timing to layer formation and printed performance.

Keywords: rheology; recoating; refill; yield stress; thixotropy; dispersion; high solids; ceramic and metal suspensions.

Abstract

This note consolidates the former ER-35 dispersion-stability manuscript into ER-36. Five verified topical sources address rheology of filled slurries, rheology-linked cure measurement, ultra-high-viscosity VPP, conductive-filler dispersion and optical cure control with photoabsorbing fillers. None directly quantifies sedimentation in an operating photopolymer vat. Sedimentation, stratification and depth-dependent sampling are therefore treated as qualification controls and evidence gaps, not as established quantitative findings. ISO 3219-1:2021 and ISO 3219-2:2021 provide current terminology and general principles for rotational and oscillatory rheometry. RP-02 defines the shared evidence-to-decision method.

1. Evidence boundary

The evidence covers rheology improvement in silicon-nitride/resin slurries [1], rheological cure-depth measurement in filled and unfilled photopolymers [2], processing of ultra-high-viscosity resin [3], rheological and electrical percolation in carbon-filled systems [4], and cure-depth control with photoabsorbing fillers [5]. These studies support formulation-specific relationships between particle state, flow, light transport and printing. They do not supply a universal yield stress, settling rate or recoating limit.

2. Topic-specific findings

- High solids loading increases hydrodynamic and particle-contact contributions to flow resistance; the usable response depends on particle, matrix and dispersion state [1,4].
- Flow state and optical cure cannot be separated in filled formulations because particle and filler distributions affect both rheological response and light transport [2,4,5].
- Ultra-high-viscosity materials can be processed using a purpose-designed vat-photopolymerisation architecture, but that result does not establish compatibility with a conventional printer or recoating motion [3].
- Temperature changes the flow state and therefore defines a different process condition; any heated-processing window requires renewed cure, recoating and stability checks [3].

3. Dispersion stability and sampling controls

The former ER-35 asserted sedimentation mechanisms without a primary sedimentation study. The merged note retains the necessary controls while making the evidence gap explicit:

- A sampling plan must fix depth, lateral position, elapsed time, temperature and mixing/shear history. Surface and vat-bottom samples are not assumed equivalent.
- Particle-size or microscopy results must state whether the preparation can disrupt agglomerates and whether the sampled fraction represents the production vat.
- Any sedimentation or creaming claim requires a time-resolved height or concentration profile under the relevant temperature and rest/shear sequence.
- Mixing may restore bulk uniformity without demonstrating reversal of irreversible agglomeration, adsorption or chemical change.

No study in the five-source set quantifies stratification during an operating VPP build. These statements are qualification requirements rather than reviewed quantitative findings.

4. Minimum reporting set

Measurand/control	Minimum method record	Required report
Flow curve	Rotational rheometry using ISO 3219-1:2021 terminology and ISO 3219-2:2021 principles	Geometry, gap, temperature, preshear, rest time, rate/stress sequence and hysteresis
Yield/recovery	Creep, oscillatory amplitude sweep or three-interval thixotropy	Full protocol; for 3iTT, shear rate and duration of every interval; report yield as method-defined
Recoating/refill	Film-thickness and levelling observation at production gap and motion	Time to uniform layer, defects, temperature, cycle time and acceptance criterion
Dispersion profile	Time-resolved concentration, height, imaging or validated proxy with fixed sampling plan	Depth, position, elapsed time, mixing history and process temperature
Particle/optical state	Particle/agglomerate distribution plus spectral attenuation and working curve	Preparation method, sampling basis and optical result after the defined shear history
Printed function	Position- and time-resolved coupons or representative articles	Link vat state and layer history to the accepted-part criterion

5. Failure interpretation

- Incomplete refill or levelling may reflect excessive resistance, insufficient recovery time, geometry, trapped gas or an unsuitable recoating motion.
- A stable bulk viscosity does not exclude local concentration or agglomerate changes.
- A working curve measured immediately after mixing is not automatically valid after rest, repeated shear or temperature change.
- Successful coupons taken from one vat location do not establish through-vat or through-build uniformity.

6. 3Dresyns implementation examples

The following are manufacturer-controlled implementation candidates, not independent evidence:

- 3Dresyns ceramic/metal LMM binders and high-viscosity formulation routes are made-to-order solutions; each candidate should be qualified for the intended powder, solids loading, printer, temperature and recoating motion.
- 3Dresyns conductive, nano/micron and reactive-composite additives are formulation routes, not evidence that an arbitrary loading remains dispersed or printable.
- Heated processing can widen a flow window but creates a different material/process state requiring renewed cure and stability checks.

A controlled mixing and sampling instruction must accompany each filled-system qualification. Any product-specific implementation must identify and verify the current exact product name, TDS/IFU revision and public link at the time of use.

7. Limitations and priorities

The evidence is formulation- and equipment-specific and does not establish a universal rheological window. No source in the reviewed set measures operating-vat sedimentation directly. Priorities are printer-relevant rheological protocols, in-vat concentration monitoring, recoating imaging in opaque suspensions, accelerated stability methods tied to real build histories, and joint rheology–optics–cure process maps.

8. Conclusions

- Rheology, recoating, dispersion and optical cure must be qualified as one bounded material–process system.
- Yield stress and recovery values are method-defined and require the complete protocol.
- ER-35 is retired as a standalone publication; its valid sampling and stability controls are incorporated here without presenting unsupported sedimentation claims as evidence.
- Made-to-order LMM routes require powder-, solids-loading-, printer-, temperature- and recoating-specific qualification.

Declarations

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