

Mechanical and Interfacial Design for Disassembly in Photopolymer Products: Reversible Joints, Access and Component Recovery

Designing printed products for non-destructive separation, service and material recovery rather than irreversible assembly

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ER-451 · Engineering Review · Version 0.1 · 8 October 2026

Abstract

Circularity in photopolymer products depends not only on resin chemistry but also on whether parts, inserts, electronics and high-value components can be separated without destroying them. Photopolymerisation readily creates integral geometries and bonded interfaces, but those same features can obstruct repair, remanufacture and material recovery. This review defines a qualification framework for design-for-disassembly in photopolymer products. It focuses on reversible joints, tool access, damage-free separation, interface ageing, disassembly sequence, retained component value and evidence that a nominally reversible connection remains reversible after service.

Keywords: design for disassembly; photopolymer; reversible joint; interface; remanufacturing; component recovery; circular design; repairability

1. Significance and scope

Design for disassembly is a product-architecture problem rather than an end-of-life instruction added after manufacture. Reviews of circular product design consistently identify fasteners, access, sequence and component value as determinants of whether non-destructive separation is feasible [1].

This review owns mechanical and interfacial design for disassembly in photopolymer products. ER-452 and ER-453 own chemical network breakdown; here the desired outcome is recovery of intact components before chemistry is invoked.

2. Product architecture determines recoverability

Photopolymerisation can consolidate housings, channels, ribs and interfaces into a single part. That reduces assembly steps but can eliminate the separation planes required for repair or recovery. A circular design should therefore identify target components before geometry is frozen.

Disassembly-system reviews show that product architecture, connector choice and sequencing affect both labour and recovery quality [1]. For printed products, these variables should be translated into measurable access paths, number of operations, required tools and damage states.

Qualification should distinguish designed separation interfaces from incidental fracture paths. The product definition should mark which boundaries are intended to open, which are permanent, and which components may be sacrificed during recovery.

Architecture-level disassembly planning should include tool access and extraction trajectories, not only connector reversibility. A joint can be nominally removable yet practically inaccessible once neighbouring printed walls, cable paths or encapsulated components are present.

3. Reversible joints require mechanical qualification

A joint is not reversible merely because it can be opened once in a prototype. Threaded inserts, snap features, wedges, clips and compliant latches must retain function after cure shrinkage, post-cure, environmental exposure and repeated use.

Design-for-disassembly criteria developed for product policy emphasise non-destructive removal, connector simplicity and accessibility [2]. The same logic applies to photopolymer products but requires additional attention to brittle fracture, creep and notch sensitivity near printed features.

4. Access and sequence are engineering variables

A detachable metal insert may be recoverable while the surrounding printed boss is sacrificed. Qualification should state whether the target is recovery of the insert, reuse of the printed body, repair of the assembly or clean separation of material classes; these are different success criteria.

Access should be measured in the assembled state. A fastener that is visible in CAD may be blocked by wiring, seals, adjacent modules or service contamination. Tool approach angle and extraction path should therefore be included in the design definition.

Sequence also matters because removing one element can unload or expose another. Modern disassembly mapping links sequence to circular value and remanufacturing targets, providing a useful model for photopolymer assemblies [3].

Connection geometry should be tolerance-qualified after printing and post-cure. Clearance, thread engagement, latch deflection and insert position can shift enough to change disassembly force even when the assembled product initially functions.

5. Interfaces age during service

Interfaces can age through thermal cycling, moisture, solvents, radiation, friction or static load. A snap fit that works immediately after printing may become brittle, permanently set or fused by contamination during service.

Adhesives and overmould-like printed interfaces are especially consequential. If an adhesive is necessary, its debonding trigger and compatibility with the substrate should be defined; otherwise the interface should be classified as destructive rather than reversible.

Identification and documentation are part of mechanical recoverability. Hidden inserts, embedded conductors and mixed-material regions should be located in product data so that disassembly does not rely on destructive exploration.

Axis	Measurement	Failure mode
Architecture	target component and separation plane	integral geometry blocks recovery
Joint	type, cycle count, failure mode	single opening treated as reversibility
Access	tool path and sequence	CAD visibility treated as accessibility
Ageing	service exposure before disassembly	fresh joint treated as lifetime state
Recovery	damage and retained function	separation treated as reuse

Table 1. Domain-specific qualification matrix for disassembly-oriented photopolymer product design.

6. Device-level verification of disassembly

Device-level verification should use the complete assembly, representative service ageing and the intended tools. Measure time, operation count, extraction force where meaningful, damage to recovered components and whether reassembly restores function.

Failure analysis should distinguish connector failure, printed-body fracture, inaccessible sequence, seized interface and damage introduced by the disassembly tool itself. A single “success/fail” result conceals the design mechanism that needs correction.

Qualification should also test foreseeable misuse: wrong tool, off-axis extraction, repeated cycles and contaminated interfaces. Robust disassembly requires tolerance to realistic variability, not only a trained operator on a clean first article.

Device-level testing should record both successful recovery and damage distribution. A low average disassembly force is not sufficient if the process frequently fractures a high-value insert, tears a reusable housing or leaves bonded fragments that prevent material sorting.

7. Minimum qualification framework

Report target recovery object, joint type, printed material state, insert or mating material, geometry, tool, access path, disassembly sequence, ageing history, cycle count and acceptance criteria.

Record whether the recovered component is reusable, remanufacturable, recyclable or merely separable, and preserve evidence of damage and residual contamination after separation.

8. Engineering conclusions

Photopolymer circularity improves when recoverability is designed into architecture rather than delegated to end-of-life processing.

Reversible joints, access and sequence must remain functional after service if component recovery is to be an engineering property rather than an intention.

References

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Competing interest

Juan Segurola is founder, CEO and CTO of 3Dresyns by Resynr Technologies S.L., which develops and commercialises photopolymer materials and related additive-manufacturing technologies. This review is an engineering analysis and does not constitute a product-performance claim or a device qualification.