WHITE PAPER

How Smart Chemistry for 3D Printed Parts Optimizes Support Removal for PolyJet Technology

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I. INTRODUCTION

PolyJet™ printing is one of the most common Additive Manufacturing printing types used in industry and in labs. PolyJet printing layers are jetted liquid photopolymers that are instantly UV cured to create 3D models that can be handled immediately. Clean surface finishes, intricate geometries, and flexible materials are a few reasons PolyJet usage nearly doubled from 2016 to 2017 (1. Sculpteo, p 22). Regardless of material, in order to support pre-defined geometries, 3D parts are printed with a support material that needs to be removed to fully reveal the part and finish the product.

A number of existing methods have been adapted to address support removal, ranging from the mechanical use of water through a pressure washer to submersion baths with caustic agents chemically removing the support. Each of these solutions suffers from consistency and throughput limitations. What the Additive Manufacturing process has been lacking is a comprehensive post-print solution that intelligently leverages both chemical and mechanical energy simultaneously to efficiently address the increasing geometry complexity, material options, and productivity of PolyJet printers. Such an intelligent solution could offer significant advantages in throughput and end part consistency to drive efficiency for post-printing operations, especially as volume of PolyJet printing continues to grow in industrial use.

1. "The State of 3D Printing", Sculpteo, Edition 2017.

II. WHERE CONVENTIONAL TOOLS FALL SHORT

The two most common support materials printed with PolyJet technology are SUP705 and SUP706 - a softer, soluble version of the former allowing for more delicate and complex designs. It is common to remove these materials with high pressure water or a solution of sodium hydroxide (NaOH) and sodium metasilicate (Na_2SiO_3) in an immersion bath. Immersion baths sometimes include removal stimulant options such as ultrasonics or circulated heat. During a chemical soak, or Chemical Rate of Removal, cRoR, the polymer chains of the support material go through a series of stages as they are dissolved. The polymer at first swells, then becomes gelatinous, and then dissolves. These stages represent the increasing penetration of the solvents being used to dissolve the support polymer as the solvent surrounds the polymer chains and breaks them.

706 was developed to decrease the time and energy needed to clean PolyJet builds. It is more readily dissolved by chemicals than 705 which increases the rate of removal significantly. 705 and 706 both absorb water when left to soak without dissolution. 705 and 706 both dissolve in caustic solutions.

High Pressure

High pressure solutions focus on the Mechanical Rate of Removal, mRoR. In the event that there are only a few parts, and the parts are rather sturdy without small features or intricate geometries, high pressure water has been used to remove the support materials. This process is fairly efficient and quick for a single part, but the user needs to hold the part with one hand while jetting the water with a spray nozzle and directing it with their other hand. Skill is required and small features of parts can be easily damaged. This is a process that does not have consistent results that can be replicated efficiently in industry due to human error, as it relies on full concentration and time from the user. In addition, this method forgoes the benefits of the cRoR.

Submersion Bath

Submersion baths are generally large tanks with pumps for flow and heaters for elevated temperature treatment of parts. Other tanks offer an ultrasonic assist. While great at providing agitation, ultrasonics inherently create heat. Therefore, without the proper controls, if the user puts a part in the tank unattended there is a risk of overheating and warping the part.

Using a submersion bath, solution of 2% sodium hydroxide and 1% sodium metasilicate has been suggested to clean PolyJet models of their support. The caustic nature of the solution keeps the acrylate polymer ionized aiding in the dissolution of the support material. The sodium metasilicate, often called liquid glass, is also caustic, but has the additional benefit of being an abrasive in solutions, helping to physically break down the support. These two chemicals together effectively remove the polymer chains of the support material. Flow in the immersion bath as well as higher temperatures help speed the process. As with the more common solutions suggested by leading 3D printer manufacturers, mixtures are sourced as a solid powder and the solution is left to be mixed by the user.

Most 3D print facilities do not have dedicated chemistry personnel or labs. While the risks associated with mixing may seem limited, they are not without hazard to process or person. Errors in achieving the correct concentrations can lead to solutions higher in pH than intended. These oversights can lead to variations in cycle time or even damaged parts. For personal safety, one thing is unavoidable: these solutions require the user to handle and mix caustic powders. Additional time and equipment is necessary to safely mix the solutions without putting users in a hazardous situation.

III. SYNCHRONIZING CHEMISTRY AND HARDWARE FOR OPERATIONAL EFFICENCY

It is clear that isolated mechanical and chemical energy are limited, and attempts at combining the two have required untimely operator intervention with unstable results. To combat this issue, PostProcess Technologies provides families of production-ready solutions for today's demanding post-printing requirements of Additive Manufacturing (AM). These products put a brain behind the chemistry for an enhanced Rate of Removal: RoR = cRoR + mRoR. Intelligent, flexible, patent-pending hardware paired with safe, aqueous, detergents are filling this post-processing void.

PostProcess™ has mastered the support removal of PolyJet Support SUP705 and SUP706 produced by Stratasys. Patent-pending detergents used in PostProcess equipment efficiently and safely removes these support materials in a scalable system. PostProcess immersion baths, which are specifically designed for Additive Manufacturing, are extremely effective. This is due to the detergents power being amplified using a strong mixing flow with heat and ultrasonics resulting in precise agitation. Using the correct combination of these tools leads to quick support softening and removal aiding in the post-processing of many parts simultaneously. It is this holistic approach that provides real value in the post-printing of PolyJet parts.

Submersion Units Comparison

An ultrasonic bath is a common industry practice for removing PolyJet support material. While an ultrasonics bath is efficient at producing a high watt density, it lacks in the following areas:

- Fluid flow: In addition to balancing temperature, circulation will allow for improved agitation and support the 'peeling' away of support material as it weakens.
- Temperature control: Ultrasonics generate heat, and without controls in place, or constant user intervention, this will lead to thermostatic runout and overheating.
- Maintaining part buoyancy: If the part is unable to float and rotate throughout the cycle, surfaces opposite the ultrasonics source are limited to chemical energy only.
- Uniform support removal: If the part is in a static position throughout the cycle and heat is not distributed, the ultrasonics bath will not address the support material evenly.
- Lights-out operation: With the above limitations, an ultrasonics bath will require regular operator intervention, such as letting the tank cool down and rotating the part, to avoid the risk of damaging parts.

Figure 1

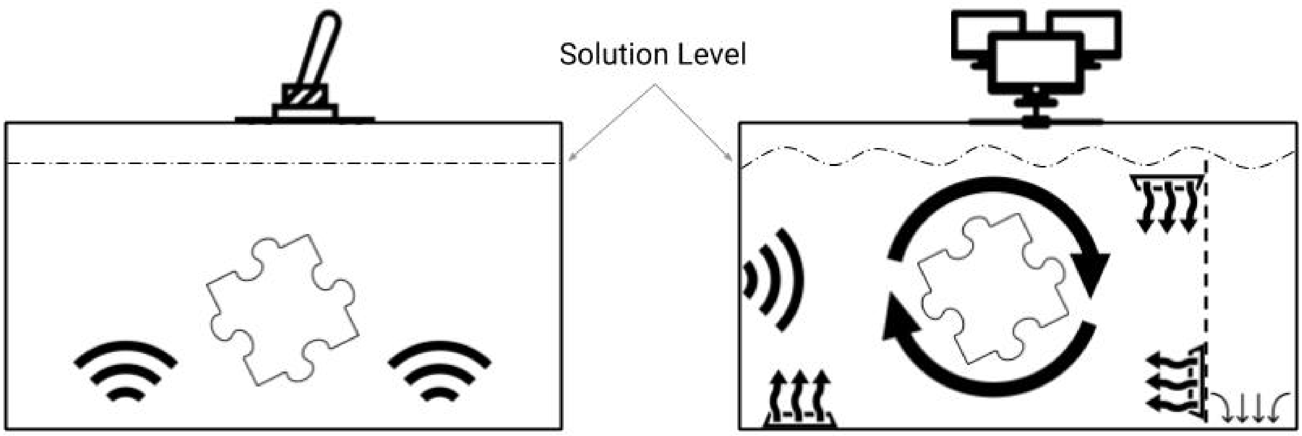

Figure 1: Comparing representations of submersible PolyJet support removal systems.
On the left: a traditional ultrasonic cleaning bath.
On the right: a PostProcess support removal system driven by AUTOMAT3D™ software.

PostProcess has mitigated these concerns with automated solutions that integrate and balance fluid flow, temperature control, ultrasonic agitation, and part rotation. The pumping scheme utilizes suction and strategic outlet locations to ensure uniform heat distribution while creating a tumbling effect to maximize part exposure and support removal. In addition, ultrasonics are pulsed to create a cross-directional agitation to improve efficacy. The hardware is controlled by automated sequencing that will vary throughout the cycle to maintain parameters. This ensures that the system synchronizes with the detergent.

Since its conception in 2014, POLYGone1 (PG1) detergent was specifically formulated for submersion units. It is a ready made solution that effectively dissolve the PolyJet support materials using caustic as well as organic solvents specifically chosen to be effective in solving the acrylic polymers in the support material. The potassium hydroxide has better solubility with organics than sodium hydroxide and this helps create a homogeneous solution that chisels away at support. PG1 also has surfactants in the solution that aid in the quick dissolution of the support creating an interface that molecularly cleans the part.

SUP705 and SUP706 can be dissolved away from the parts polymer without aggressive mechanical force leaving the part as printed. This is a gentle process that can clean most internal features with ease. A technician can place a part in a PostProcess submersion unit and walk away taking care of other tasks. This detergent is also premixed so there is never any question as to whether a powder was fully dissolved into water.

In a lab study comparing a conventional 500W, 6 gallon aqueous ultrasonics bath consisting of 2% NaOH and 1% Na2SiO3 (System A), with one of PostProcess' AUTOMAT3D units (the DECI 4 combined with PG1 detergent - System B), it was evident that without automation, specialized and frequent operator intervention is required to maintain constant chemistry and temperature for a repeatable and reproducible process. As a result, skilled-labor is performing hazardous and non-value-added tasks leading to efficiency losses. See the results below:

	System A	System B
Constant Temperature	105°F	
Chemistry	$NaOH + Na_2SiO_3$	PostProcess PG1 chemistry
Total Cool Down (% of total cycle time)	45%	0 minutes
Cycle Efficiency % (value-add/cycle time)	55%	100%
Operator Attendance Time (startup, temp control, removal)	30 minutes	1 minute
Labor Cost/Part ($35/hr)	$17.50	$0.58

The total cycle time is reduced by over 20% with the DECI 4, with the added benefit of being uninterrupted. By freeing up labor with PostProcess' AUTOMAT3D software, labor cost was reduced by over 96%. The ultrasonic bath also put the part in jeopardy as the temperature climbed nearly 5°F every 15 minutes. Without an operator nearby to remove the part to allow cool down, there is a risk of the ultrasonics overheating the bath and damaging the part. In addition, frequently removing the part means the operator is inherently rotating the part. This tumbling effect is designed into PostProcess' fluid flow allowing for an unattended operation, yet another way PostProcess is producing smart chemistry.

IV. CONCLUSION

It is clear that chemistry plays a critical role in the support removal process. When paired with mechanical energies, a more efficient RoR is achieved. However, the addition of mechanical energy without automation leads to extensive operator intervention to avoid damaged parts, while still risking inconsistent results. PostProcess Technologies employs both immersion and high flow atomized spray instruments to clean away PolyJet support in an intelligent manner that is paired with the novel detergents and software-driven agitation programs. These state of the art systems digitize tribal knowledge to decrease technician time and safety risk, and improve cycle time, leading to industry-ready, reproducible results. That's smart.

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POSTPROCESS TECHNOLOGIES INC.
2495 Main Street, Suite 615, Buffalo NY 14214
1.866.430.5354
info@postprocess.com
www.postprocess.com