WHITE PAPER

Enhanced Resin Removal for Stereolithography (SLA) Additive Manufactured Parts with an Innovative Chemistry Solution

POSTPROCESS
Automated. Intelligent. Comprehensive.

CONTENTS

I. SLA RESIN REMOVAL SOLUTION SUMMARY

This paper explores a new automated solution that improves on the cumbersome post-printing processes commonly associated with Stereolithography (SLA) resin removal. This comprehensive solution is anchored by a newly developed detergent chemistry, PG1.2, that provides users with quicker processing times and increased resin capacity while reducing the number of processing steps when compared to traditional industry methods. When combined with the software-driven DEMI powered by **Submersed Vortex Cavitation (SVC)** technology, the new solution provides lower operator attendance time with reduced environmental hazards, preservation of fine feature details, and overall improved resin removal from SLA printed parts.

SVC: Combining advanced pump flow, ultrasonics, and temperature control with software-driven agitation and process monitoring to optimize the chemical rate of removal of a submerged object.

II. STEREOLITHOGRAPHY (SLA) BACKGROUND & POST-PRINT CHALLENGES

3D printing is a process whereby a computer controlled device (e.g., a printer) creates an object through additive manufacturing. One such additive manufacturing process is Stereolithography (SLA), a process belonging to the “vat photopolymerization” family. SLA is famous for being the first 3D printing technology, with its inventor patenting the technology back in 1986. If parts of very high accuracy or smooth surface finish are needed, SLA is the most cost-effective 3D printing technology available.

Materials used in SLA are photosensitive thermoset polymers that start in a liquid form. The top surface of the vat is where a part is solidified by selectively curing the resin layer-by-layer using an ultraviolet (UV) laser beam. It is worth noting that SLA shares many characteristics with Digital Light Processing (DLP) and Continuous Liquid Interface Production (CLIP), two additional vat photopolymerization 3D printing technologies. For simplicity, the three technologies can be treated as equals, especially from a post-printing perspective. Best results are achieved when the designer takes advantage of the benefits and understands the limitations of the manufacturing process. Being that the SLA process involves only a single material at a time, with the final parts being submerged in a wet resin, there are some additional challenges when it comes to preparing the part for its final application.

The first challenge is the removal of uncured resin. This is a process that traditionally requires the use of repetitive harsh chemical baths. These baths are tedious, hazardous, and can be lengthy and inconsistent. In addition, a part manufactured using SLA technology often requires support structures to be printed to brace certain geometries during printing. Because the material is the same throughout the build, the unwanted support material cannot be isolated and removed through the means of chemistry alone. Thus, hand tools such as razor blades and sandpaper are traditionally used to separate the supports from the model and smooth the remnants, or nubs, of the support structures.

This paper will introduce a new solution to address the first stage of this process, uncured resin removal.

Up to this point, the industry has adapted a number of chemicals for resin removal and managed their inherent drawbacks. Some of these chemicals include acetone, IPA (isopropyl alcohol) and TPM (tripropylene glycol methyl ether). Acetone removes resin, can smooth part surfaces, and is very inexpensive. However, acetone has a low resin capacity and is highly flammable. Similarly, IPA removes resin and it is inexpensive, but IPA is dangerous to work with as it is very volatile. Two significant volatility measurements are vapor pressure and flash point. IPA has a high vapor pressure, which is a measure of a liquid's propensity to evaporate, and it has a low flash point, 53.1°F, which is the minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitable mixture with air. Conversely, TPM has a higher resin capacity as compared to IPA from a solvent performance standpoint, but it is expensive relative to IPA.

In addition, each of the aforementioned chemicals can take approximately 30 minutes to fully remove resin from an SLA build tray. A reduction in processing time can dramatically impact a user's throughput capabilities. Finally, each of these options requires disposal of the generated waste. It is expensive to dispose of this waste because the chemicals to be disposed of are considered to be hazardous due to their properties combined with the resin removed by the chemicals. In summary, each of these solutions suffers from safety hazards, inefficiencies, longevity issues, and throughput limitations.

III. TESTING & VALIDATION OF SLA RESIN REMOVAL SOLUTION

Lab testing for new SLA resin removal solution

The conclusions summarizing the PostProcess SLA resin removal solution in Section 1 were derived from a two-tiered testing approach. First, a controlled lab setting was used to develop initial chemical comparison data between IPA, TPM, and PG1.2. The part chosen to collect this lab data was a standard chess piece, the rook, printed using Accura® ClearVue™ resin. Immediately following printing, resin removal was performed on these parts in the specified chemistry, PG1.2, TPM, and IPA, at a specified weight and volume of chemistry. The time to clean each rook was recorded. To hasten the saturation process, resin by weight was added to the chemistry then the resin removal process was repeated. This was replicated until the part was observed to be tacky, indicating the inability to remove the excess resin. At this point, the solution was determined to be saturated.

FIGURE 1 below shows the degradation of processing time as the solutions became saturated with resin. For context, 50% resin in solution, represented on the x-axis in FIGURE 1, would mean that there are equal parts resin and chemical solution in the container. The data collection concluded once the solution was no longer effective at removing resin. As depicted, the PG1.2 detergent held near a 10 minute cycle time even at 25% resin in the solution. This represents a dramatic improvement over the alternatives IPA and TPM as their processing times were inconsistent, increasing more than 5 times their initial cycle times, and neither was effective beyond 20% resin in the solution.

FIGURE 1 - % Resin in Solution vs Cycle Time (to Point of Saturation)

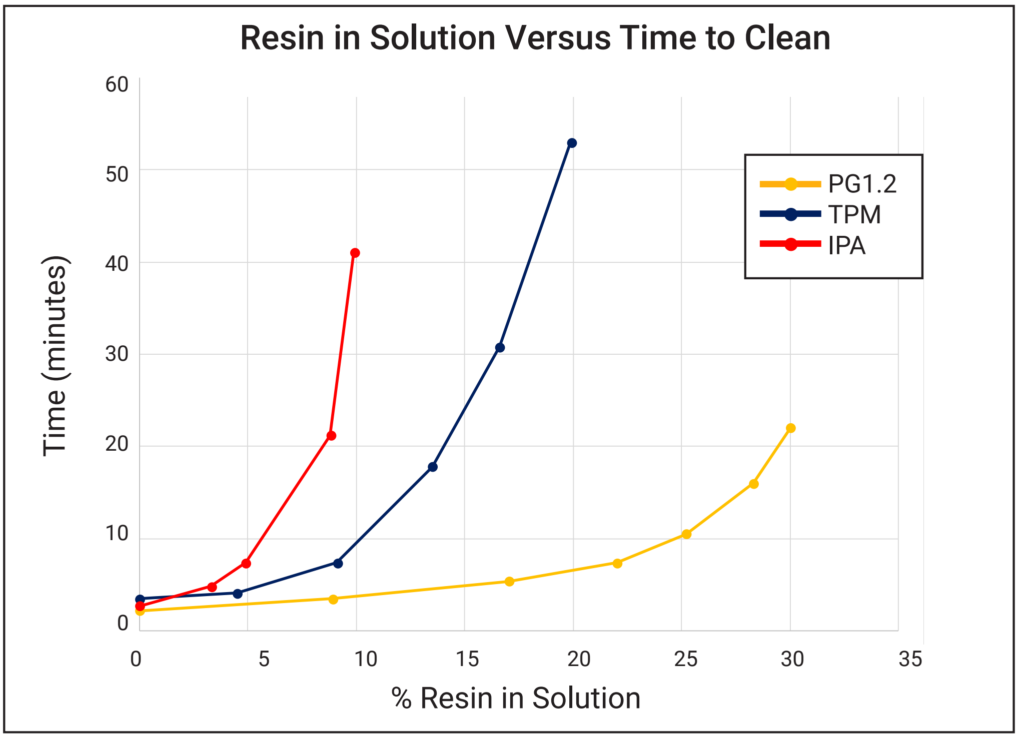
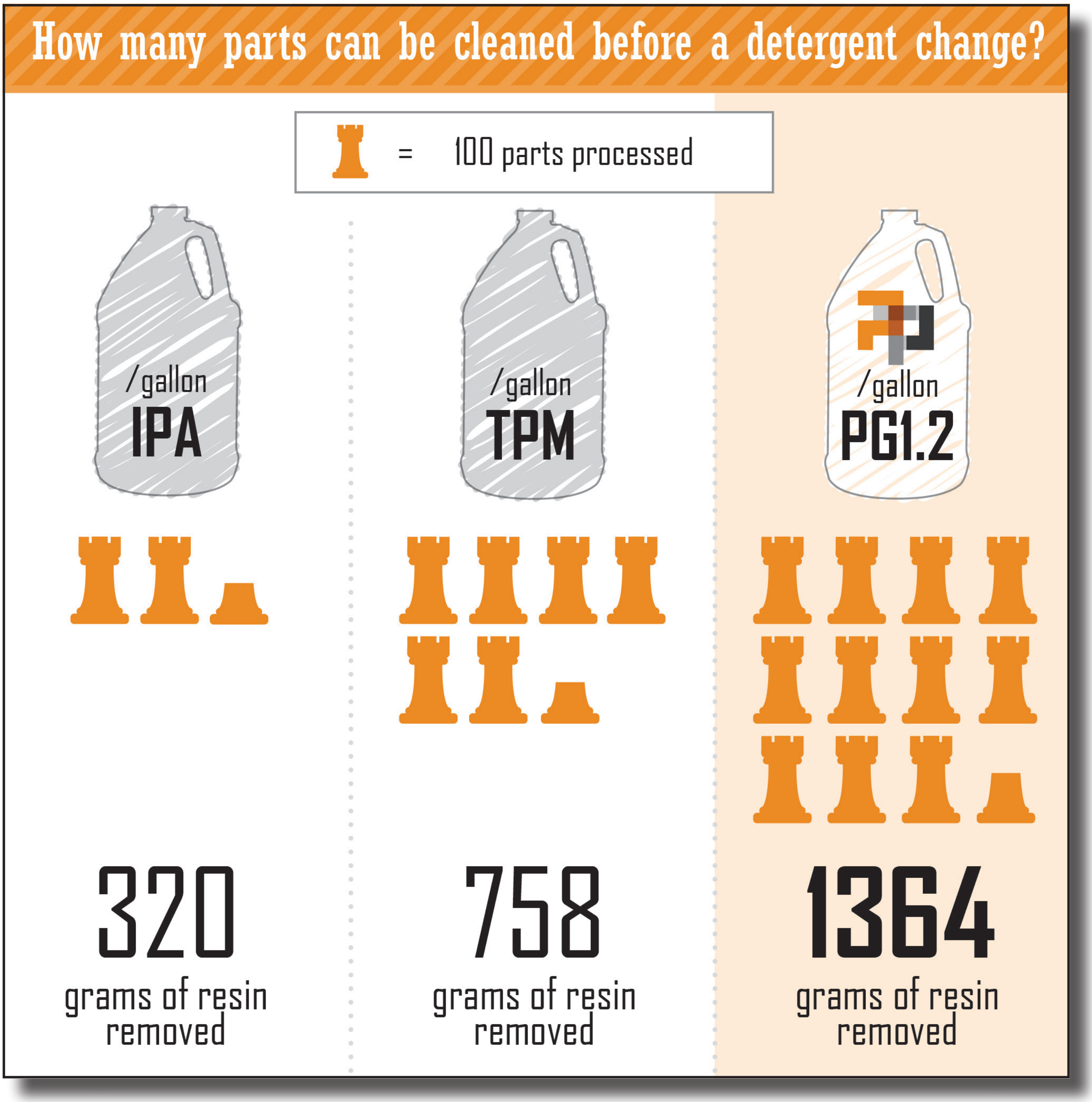


FIGURE 2 below depicts the quantity of parts processed in each of the chemical solutions at point of saturation.

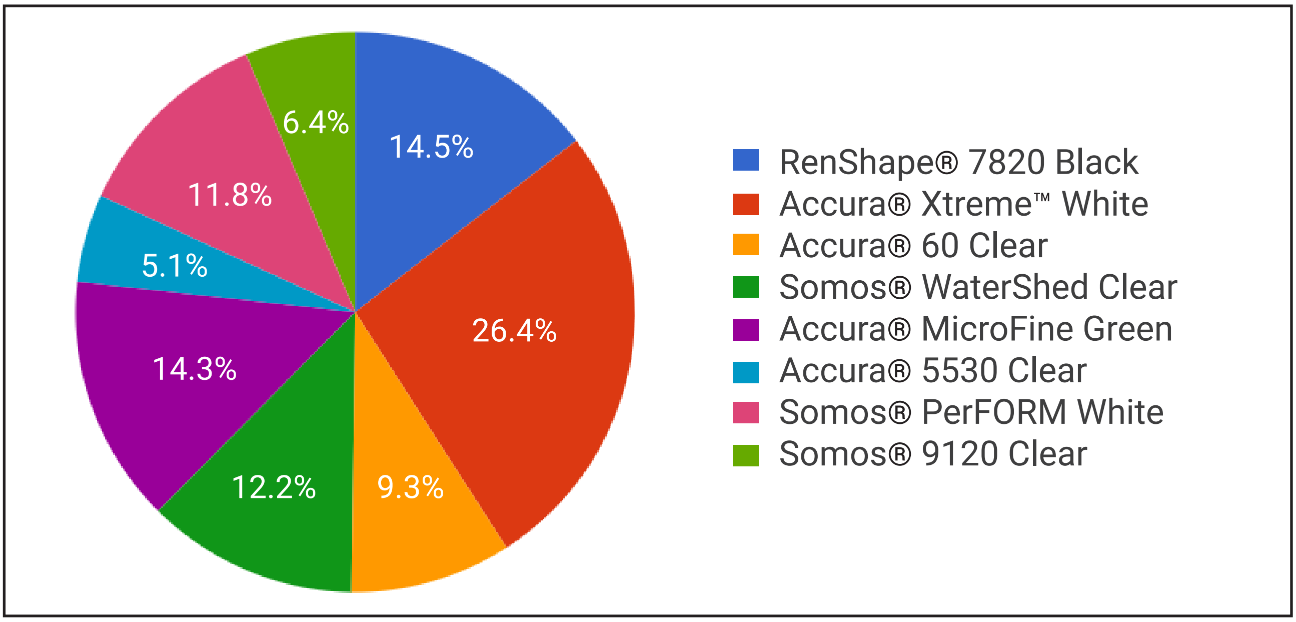
FIGURE 2 - Cleaning Rooks to Point of Saturation (End of Useful Life)



Field testing for new SLA resin removal solution

The next step in testing the SLA resin removal solution was to put it into a high-volume, high-mix, production environment and test against additional geometries and common resin types. During field testing, the following resins were processed in the PostProcess DEMI™ system either simultaneously or in succession:

GRAPH 1: Field Testing, 40 Gallons Polygone PG1.2 Detergent (DEMI):



Below, TABLE 1 provides a summary of the results from the field testing done with the DEMI. Resin removal took 10 minutes or less for 94% of 1,030 trays processed. The maximum cycle time was 15 minutes, attributed to more complex geometries.

TABLE 1 - Field Test Results of POLYGONE PG1.2

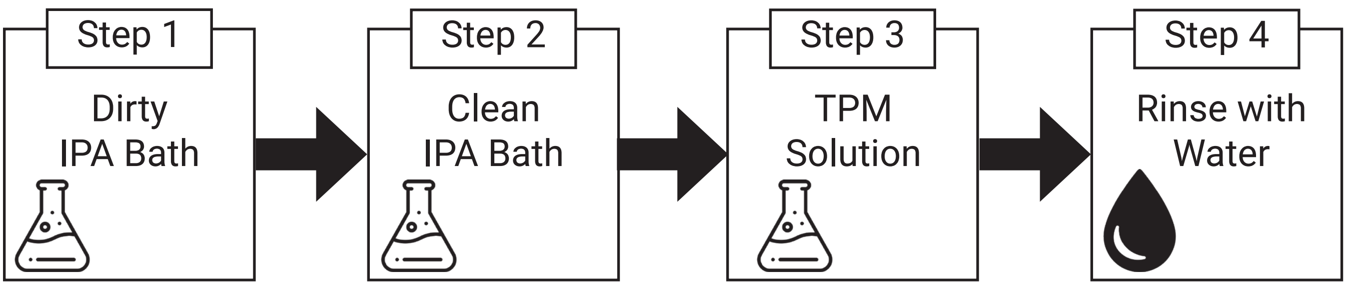
Average Resin per Tray	**55.1 grams**
Number of Trays Processed	**1030**
Volume of PG1.2 (gallons)	**40 gal**
Total Resin into PG1.2 Solution	**56,799 grams**
% Resin into PG1.2 Solution to Saturation (by weight, grams/grams)	**42.20%**
Final Measurement at Saturation, (grams of resin/gallons of PG1.2)	**1420 grams/gal**

A notable advantage of the increased longevity of PG1.2 is the reduction in waste generation compared to other solvents. Each of the detergents and chemicals used will also contain the resins they removed. These resins do not become less hazardous when removed and are all considered hazardous materials in the chemicals used to remove them. The frequency and volume of waste disposal will be a factor in the total cost to dispose of the exhausted chemicals. Since PG1.2 has significantly greater useful life and resin capacity, there will be less waste generated compared to IPA and TPM when removing comparable amounts of resin.

"Resin removal took 10 minutes or less for 94% of 1,030 trays processed."

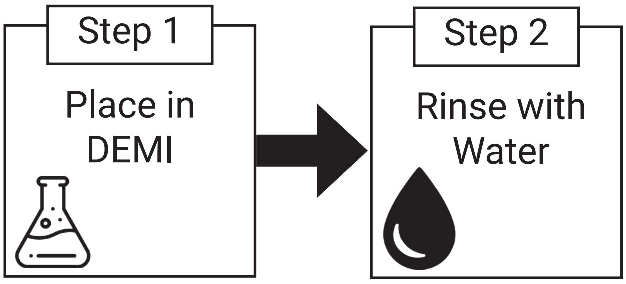
In addition to the dramatic increase in capacity and reduction in cycle times, the DEMI proved to be more efficient by also reducing processing steps. Traditional chemical resin removal processes for 3D printed SLA parts using IPA and/or TPM are typically 4 or 5 steps. For example, printed parts first go into a "dirty" IPA bath to remove the initial bulk of the uncured resin, followed by an immersion bath into a second cleaner IPA bath to remove the majority of the uncured resin. After this second process step, parts go into a 3rd immersion bath of TPM or IPA bath followed by a fourth final rinse step in water to remove trace solvent(s). This multi-step process, depicted below, is less efficient and requires more operator time transferring parts from bath to bath.

Traditional Resin Removal



During testing, it was determined that the new PostProcess SLA solution, when used in combination with the DEMI's SVC technology, is a two-step process. Multiple trays of parts were run through the DEMI filled with the standard 40 gallons of PG1.2. After processing in this new detergent, parts only need to be rinsed and dried. There is no need for a secondary and tertiary organic rinse solution to process the parts in as the processing is accomplished all in one tank in one chemical solution. This two-step process (depicted below) is more efficient and requires less operator time transferring parts from bath to bath.

PostProcess SLA Resin Removal



Safety Considerations

Inhalation and combustion risks during the resin removal process are a concern for SLA users. Table 2 below shows vapor pressure for PG1.2 along with the aforementioned liquids commonly used for SLA resin removal, as well as a commonly known liquid, gasoline, for context.

TABLE 2 - Vapor Pressure Comparison

Flammable/ Combustible Liquids	Vapor Pressure @ 20 °C (mm Hg)
Gasoline	360-525
Acetone	186
IPA	33.1
PG1.2	0.23
TPM	0.01

Vapor pressure is a measure of a liquid's propensity to evaporate, forming vapors above the liquid. The higher the vapor pressure, the more volatile the liquid is and, therefore, the more hazardous it is. The lower the vapor pressure the lower the degree of the hazard. Below further describes the hazards associated with vapor pressure:

» Vapors from combustible liquids with low vapor pressure will not travel as far because they tend to condense as they are cooled by ambient air and therefore not a hazard (NFPA 497 2017, 4.2.7.1).

» A combustible liquid has a flash point at or above 100°F (37.8°C) and low vapor pressure. It will only form a hazardous ignitable vapor mixture when heated above its flash point (NFPA 497 2017 4.2.7).

» A flammable liquid has a flashpoint below l00°F (37.8°C) (NFPA 497 2017, 3.3.6). Flammable liquids have higher vapor pressures which lead to hazardous environments. Additional safety precautions must be implemented for fire and explosion prevention for flammable liquids.

Gasoline, acetone, and IPA have high vapor pressures and are flammable liquids that require specific safety precautions. PG1.2 and TPM are combustible liquids with low vapor pressure that do not require the safety standards associated with acetone and IPA.

IV. CONCLUSION

In conclusion, PostProcess Technologies' new SLA resin removal solution is a definitive improvement over current mechanical and chemical technologies used to remove excess resin. Utilizing the PostProcess comprehensive SLA resin removal solution, a combination of a new PG1.2 detergent, and the SVC technology, uncured resin removal can be accomplished in 10 minutes or less for simultaneous trays of SLA printed parts. The new detergent has a much higher resin capacity yielding a longer useful life compared to other chemical methods. With intuitive software controls and process monitoring, the speed and ease of use of the solution results in increased consistency at levels required for production volumes. Finally, the attended operator time is greatly reduced and the new PG1.2 detergent is inherently safer to use.

SLA Resin Removal from PostProcess

Improved Efficiency √ Quicker cycle times √ Less process steps
Increased Longevity √ Higher resin capacity √ Less downtime
Reduced Waste Generation √ Less chemical handling and disposal frequency
Mitigates Traditional Safety Hazards √ Low inhalation and explosion risks

Can you benefit from optimizing your SLA resin removal process?
Request a benchmark here.

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