WHITE PAPER

Guide to Post-Printing Advanced Thermoplastics: Support Removal Challenges & Technology Opportunities

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ABOUT THE AUTHOR

Michael Frauens, Principal Process Development Engineer, has decades of industrial engineering experience, including with 3D printer manufacturer Stratasys and Eastman Kodak, where he was awarded several patents. Frauens' material science background and system implementation expertise have allowed him to advance the company's FINISH3D™ lab, where over 500,000 parts have been benchmarked. Michael leads the company's initiative to develop a platform to transform material data into useful information for development engineering, as well as a recommendation model that enables customers to scale their additive manufacturing operation into high volume production. Frauens earned a master's degree from Massachusetts Institute of Technology (MIT) in System Engineering and Management.

I. INTRODUCTION

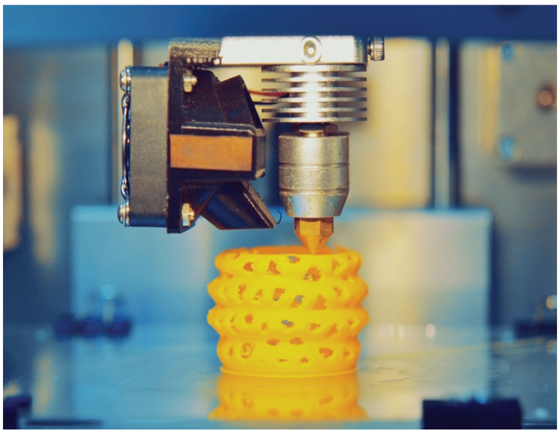
Advanced thermoplastic geometries produced by various additive manufacturing means for both prototype and production purposes are often created with a sacrificial build-in-place fixture, commonly called a support structure, that must be removed from the as-manufactured geometry. While this support material is necessary to build the geometry, the part is unusable until the support removal is completed. Historically, conventional degrease or washing spray systems have been applied without a complete understanding of the infinite geometries and materials used in additive manufacturing processes. Therefore, these wash systems rely only on pressure to mechanically break the supports free, but at substantial harm to the expensive part. This paper will review the current state of post-processing techniques for 3D printed advanced thermoplastics and discuss innovations for optimizing the support removal step.

II. CURRENT STATE OF POST-PRINT SUPPORT REMOVAL TECHNIQUIES

Fused Deposition Modeling (FDM) uses two dissimilar materials during the build. The first is for the model itself and the second is the necessary support material. Both materials are placed as a filament extruded by the FDM printing head. After the part is finished, the support material is then dissolved by using specialized chemistry leaving the model behind. This dissolution is one form of support removal.

Polyjet jets layers of a liquid photopolymer into place. The photopolymer is placed using a high-resolution ink jet system and cured simultaneously with a UV light source. The support material is placed at the same time as the model material. Removal of the supporting material after the part is built is a second form of support removal.

Stereolithography Apparatus (SLA) is a resin-based system. The part is drawn out of a bath of UV curable material. SLA uses a directed UV emitting laser that exposes the material into the shape the model is intended to be as the part is pulled out of the bath. The supporting structure of the emerging model is made of the same material as the model itself. When the part is removed, it is covered with residual resin that must be removed. This is sometimes referred to the part being "green". Removal of this resin is one part of support removal. However, when the resin is removed, support structures may still be in place that aided building of the model. These support structures must be broken away as a second part of the support removal process.



Existing solutions for support removal include manual handling of parts with brushes or other mechanical means to break the part free. Using these kinds of mechanical means can often result in part breakage. Furthermore, in cases where the mechanical action is from human intervention, there is typically a corresponding decrease in throughput due to the extra handling. Human intervention also typically results in increased part variability. The additional manual processing steps result in higher labor costs, reduced part quality consistency, and part breakage for costly advanced thermoplastics.

Alternatively, heated submersion baths may be used to remove the support. However, in these cases, the cycle times can be quite poor, the process may be labor intensive and may use pump-driven baths of chemistry not designed for the application. Another weakness of submersion baths is associated with parts made with a porous structure. In these cases, the liquid used in the bath often ends up in the interior of the part. Therefore, it is often recommended to use a vacuum and dryer to fully remove the chemistry from the part. This increases handling of the part and consequently results in higher cycle times with decreased throughput.

Wash systems may result in faster cycle times compared to parts processed in a bath. However, they rely on high pressure, low volume action from the nozzles and have little to no intelligent software control. Therefore, they cannot be viewed as support material systems but instead are wash systems. They also often operate with chemistry not optimized for advanced thermoplastics. These alternate systems remove the support material one part at a time, slowing throughput. Furthermore, the high pressure in some of these systems often risk breaking features of the part. Conventional systems are washers with no control and often run with chemistry not optimized for additive manufacturing.

III. EMERGING TECHNOLOGIES FOR OPTIMIZED SUPPORT REMOVAL

As opposed to the legacy techniques previously discussed, there are emerging technologies that are designed and built specifically for post-printing of additive manufactured parts now available. These newer spray systems have been conceptualized for efficient and effective support removal on advanced thermoplastics, offering improvements in reduced part breakage, improved cycle times and throughput, and reduction in touch time per part. An integrated system of hardware, software, and chemistry, this technology that is tailored for a 3D printed parts offers advancements in multiple areas.

A. Advancements in Hardware Design

Conventional remain-in-place or tunnel "wash" systems require a large amount of manufacturing space and typically cannot be run unattended. Advancements in support removal spray systems provide an integrated solution requiring much less manufacturing space. Furthermore, when integrated with an intelligent software solution, these systems allow for continuous lights out, first in / first out, unattended usage of the machine, minimizing the direct labor costs. This, coupled with features such as an optional pass-through door, is another step in the drive to the automated factory of the future.

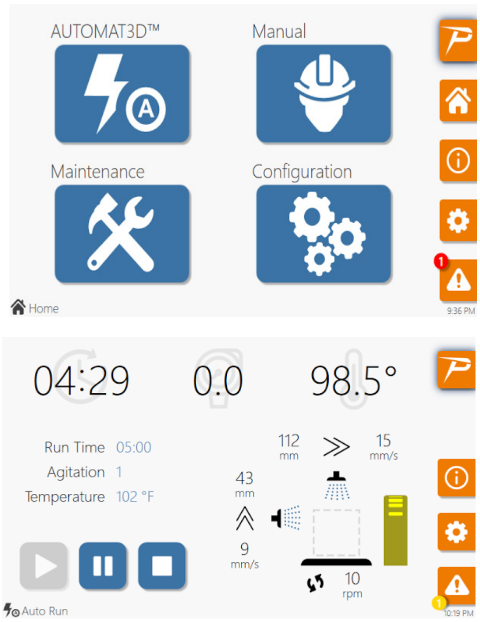
In consideration of post-printing additive manufactured parts, the intelligent PostProcess spray system design includes nozzles that are both below and above the part. The nozzles above the part, associated with the system, have programmable movement of their location and speed as they traverse the part envelope. This reliance on a high-volume pump and spray nozzle system allows for improved cycle times and improved part cleanliness during support removal without subjecting the advanced thermoplastic part to undue stress and risk of breaking or cracking.

Robustly constructed, the user of these systems is no longer required to wear extensive personal protective equipment (PPE). Learning to use the system can be achieved in less than a day. Stainless steel construction and use of sanitary clamps and precision spray nozzles allow for easy cleaning of the system and provides superior reliability.

B. Advancements in Software

Designed specifically with industrial 3D printing in mind, PostProcess spray systems will operate system parameters such as speed, distance, direction, temperature, pressure, and pH all under software control. Driven by an intuitive software program, AUTOMAT3D™, the unit purposefully varies the levels of key parameters such as changes in spray pressure, duration of pause, and speed of travel to clean the most complex of advanced thermoplastic geometries. Different sets of key parameters, called Agitation Algorithms, allow the user to tune the action of the nozzles and mass flow rate for optimized support removal.

Default values are provided with the machine, but the user has the flexibility to build and define custom agitation behavior. One example of how these algorithms work is that the system can pause the nozzles and turn them off allowing the part to temporarily "soak" in the chemistry for better effectiveness. Even the ratio of detergent in the water is managed through a dosimeter whereby two dissimilar components of the chemistry are introduced at a precise ratio when the system is filled.



AUTOMAT3D™ software screens; PostProcess Technologies

With the rapid rate that industries are adopting additive manufacturing into production environments, more and more of the related manufacturing data will be in digital form. This "digital thread" is the set of data used to create a given part and will be required in future manufacturing environments. The PostProcess systems will be capable of providing run-time and archival of post-print data that will be required as part of the digital thread.

C. Advancements in Chemistry

PostProcess spray system solutions run at lower pressure, but high mass flow rates within a chamber holding multiple parts. Using a unique blend of eco-friendly detergents (aqueous in nature) at low concentrations in water, generally less than 10%, and a comparatively low pressure, this is a faster, easier to use, and more production-oriented solution. This spray system that performs support removal relies less on spraying chemicals at high pressure and low mass flow rates in favor of high mass flow rates of proprietary detergents under more modest pressures.

IV. CONCLUSION

When traditional wash finishing systems are applied to 3D printed parts, there is little to no adjustability. Any given part is washed as any other part that goes through the system. The PostProcess support removal solution of software, hardware, and chemistry is interdependent, working together to control the temperature, force, location, and application of detergent to the part. Purpose-driven to the needs of the specific part, the parameters can be varied to match the specific parts' needs. There is no "one size fits all".

PostProcess support removal spray systems routinely achieve a 75% reduction in part support removal cycle times when compared to submersion systems, all without exposing the advanced thermoplastic parts to the high pressures of legacy wash systems. Furthermore, because support removal is usually complete, there is no hand finishing of the part after it is processed as with conventional bath systems. This saves labor cost and improves part consistency. Lastly, when compared to other spray systems, multiple parts can be done at once in PostProcess hardware resulting in minimum cycle times with low part breakage rates.

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