WHITE PAPER

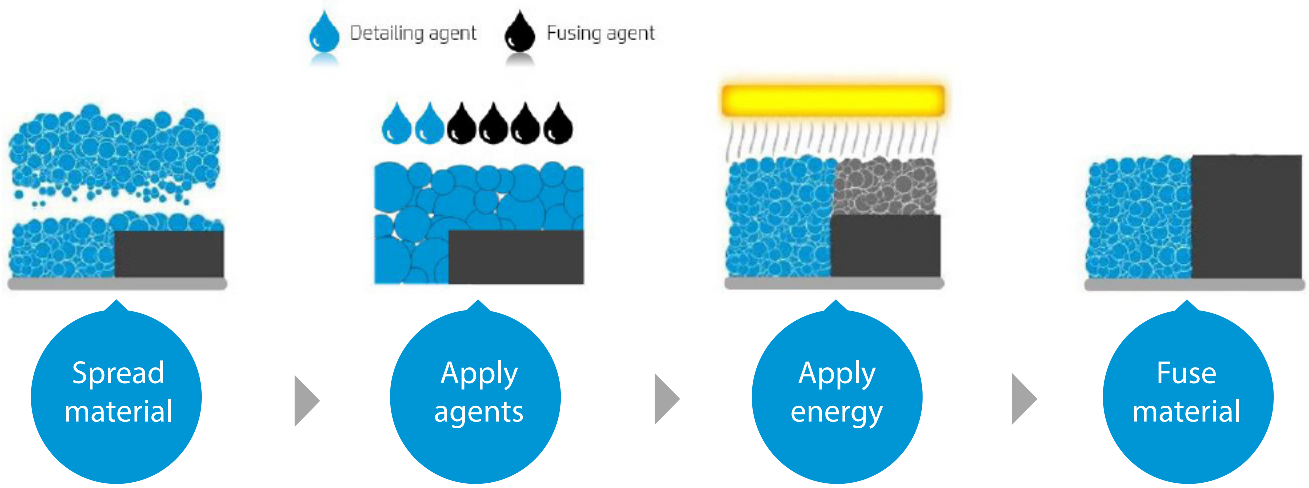
Eliminating Manual Surface Finishing For Multi Jet Fusion (MJF) 3D Printed Solutions

POSTPROCESS
Automated. Intelligent. Comprehensive.

This White Paper explores a new technology that automates surface finishing for Multi Jet Fusion (MJF) parts. This automated post-printing process enables higher quality parts with greater consistency, faster throughput with lower operator attendance time, and preservation of fine feature details, ultimately expanding the opportunity and application of MJF.

Multi Jet Fusion technology: How it Works

Basic Process



Today, the surface finish of MJF parts typically involves significant manual labor using sandpaper, sanding blocks, or even small dremel tools. The biggest limitation of this manual surface finish technique is the reliance on the availability and cost of manual labor. The current process requires an operator to manually sand one part at a time, estimating the required finish.

Another method used is a traditional vibratory system. With complex and fragile part geometries, handling parts in these systems not designed for additive can lead to wide inconsistencies and breakage. This uncontrolled approach, designed for subtractive manufacturing, runs a high risk of damaging parts, or at minimum, wearing down fine features before the desired surface finish is achieved. An automated approach designed specifically for additive manufacturing and capable of precision performance mitigates all of these challenges by freeing up labor, providing fast, repeatable results in batches, and preserving fine feature details.

EXECUTIVE SUMMARY

Utilizing the PostProcess MJF Surface Finish Solution, surface finish values of less than 2-microns were able to be realized across multiple MJF technology print platforms. To get to these R_a values, automated surface finish times ranged from 4 to 6 hours for the geometries tested. In addition, less than 5 minutes of technician time was needed to set up and remove the parts from the RADOR's *Suspended Rotational Force* (SRF) solution. With a software-enabled solution, post-processing is accomplished with significantly reduced touch time and increased consistency to a level required for production volumes.

Across all of the platforms, the average roughness after 2 hours was less than 4 microns. After 4 hours, it was less than 3 microns, and at 6 hours of processing time was nearing less than 2 microns. Overall, on average, 80% of the total surface roughness reduction occurred in the first 4 hours of processing.

OVERALL CONCLUSIONS

- The RADOR can consistently deliver less than 2-micron roughness average.

- For customers that want to perform additional processing requiring an even smoother finish (in cases, reaching even under 1 micron), the RADOR can deliver finishes that enable the most difficult post-printing processes like plating.

- The RADOR also has the ability to manage delicate parts, processing 1.5 mm diameter pins at 5 mm in length without breakage.

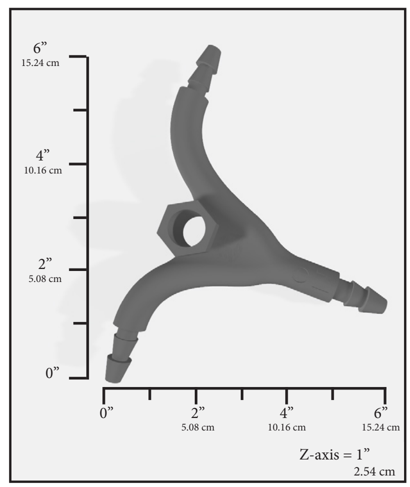
- The RADOR maintains the integrity of the edges and surfaces within 0.1 mm (minimal rounding) while delivering results in the less than 2-micron roughness average.

SURFACE FINISHING: ROI CALCULATIONS

Single Printer: 30 Parts per Day
5-Day per Week Operation

Current Method		PostProcess Method	
Hand Sanding		*RADOR Surface Finish Solution*	
Operator Time per Part	10 minutes	Operator Time per Cycle	5 minutes
		Parts per Cycle	5
		Automated Operating Time	2 hours
Labor $/Hr	$30.00	Labor $/Hr	$30.00
% Rejected Parts	1.00%	% Rejected Parts	0.10%
Daily Cost	$160.00	Daily Cost	$19.24
Total Cost per Part	**$5.33**	Total Cost per Part	**$0.64**
		Savings per Part	**$4.69**
		Savings per Day	**$140.76**
		Return on Investment	**35 Weeks**

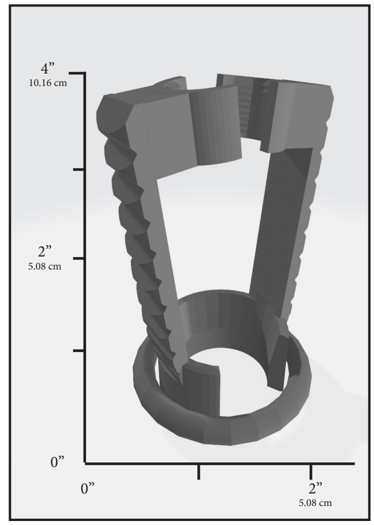
**Investment includes Surface Finish Solution and estimated daily consumables cost.*



Example MJF part 1

Multiple Printers: 500 Parts per Day
5-Day per Week Operation

Current Method		PostProcess Method	
Step 1: Traditional Vibratory		*NITOR Surface Finish Solution*	
Operator Time per Cycle	7 minutes	Operator Time per Cycle	7 minutes
Parts per cycle	50	Parts per cycle	250
Operating Time	10 hours	Automated Operating Time	2 hours
Labor $/Hr	$30.00	Labor $/Hr	$30.00
Step 2: Hand Sanding			
Daily Cost	$58.29		
Technician time per cycle	7 minutes		
% Rejected Parts	1%	% Rejected Parts	0.10%
Daily Cost	$250	Daily Cost	87.44
Total Daily Cost	$308.29		
Total Cost per part	**$0.62**	**Total Cost per Part**	**$0.17**
		Savings per Part	**$0.45**
		Savings per Day	**$225.00**
		Return on Investment	**57 Weeks**



Example MJF part 2

**Investment includes Surface Finish Solution and estimated daily consumables cost.*

**The NITOR is the largest PostProcess production-sized automated surface finish system, utilizing SRF technology, designed for small to large geometries.

GENERAL OVERVIEW OF PROBLEM, CHALLENGE, OPPORTUNITY

The Powder Bed Fusion family of printing technologies inherently has the same characteristic of a non-uniform, often rough surface. This is a common output of any solution in the powder bed fusion family, and the main contributing factors are particle size and distribution. PostProcess’ aim is to use our *Suspended Rotational Force* (SRF) technology in the RADOR (or NITOR) to produce a smoother, more consistent surface finish for all powder bed fusion parts. Along with producing more consistent, better overall final end-use parts, our solution allows for greater success with secondary processes such as coating and dyeing and is designed specifically to address the challenges of additive.

Consistency:

In an industry that is driving to increase output and quality, current methods such as hand sanding are unscalable. Being a manual process with a variable performance from individual “sanders,” consistency in part finish is the exception, not the rule. It also does not fulfill the throughput needs of many MJF customers. An automated solution not only provides a consistent, repeatable result but allows resources to shift from low value, repetitive tasks, to other higher-value operations.

Secondary processes:

Production parts printed via MJF often undergo additional processing (following surface roughness improvement) to fulfill additional application requirements or achieve a desired cosmetic result. Processes like plating, coating, and dyeing come with a unique set of prerequisite surface finish requirements that need to be met for their processes to be effective. Automated surface finishing in the RADOR helps meet those requirements to ensure a positive result of further post-processing.

Flexibility for AM:

The RADOR was designed specifically for the additive manufacturing market. Higher frequency, lower amplitude operation results in a gentler process, conducive to processing delicate, complex additive parts. The hands-off operation allows the user to focus more on higher value add operations and less on manual post-processing operations. Printers are designed to provide flexibility. Every part of a batch can be unique, so surface finishing needs to be adaptable too. If each part requires new training, lengthy setup and cannot leverage data throughout the workflow, the process is not scalable. The following solution overview and test results show how PostProcess' SRF technology in the RADOR provides a distinct advantage for MJF customers for surface roughness reductions while reducing part breakage, limiting material removal, radiusing, or geometry alterations as a result of our proprietary process.

CURRENT SOLUTION / PROCESS / METHOD USED

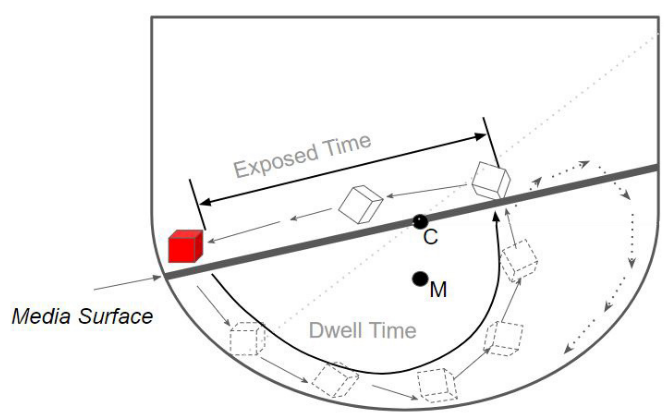
Today, MJF surface finish is accomplished through a combination of vibratory finishing and hand sanding. Traditional vibratory systems use a solid abrasive media to wear down the outermost edges of parts to a smoother surface. This is generally a very aggressive process, with little regard for fine feature details or critical dimensions, and no intelligent software control. Based on existing testing, Roughness Average is typically limited to less than 2.5-4 micron within a 10 hour cycle time, and due to the aggressive process, rejected parts will be more numerous than with SRF solutions.

To meet customers' final target surface finish requirements, many users will perform an additional hand sanding step, creating an additional potential workflow bottleneck. After printing multiple parts in one build, finishing a single part at a time is not a scalable operation. This manual process introduces surface finish inconsistencies and other human errors, such as an increased scrap rate due to damaged or uneven parts. Some customers choose to perform this final step with a traditional subtractive vibratory tub, which improves surface roughness but sacrifices part integrity and dimensional accuracy.

Step	Traditional Process	PostProcess
Roughness Improvement	Vibratory tubs	RADOR
Final Target R_a	Hand sanding, Vibratory tubs	RADOR

POSTPROCESS SOLUTION

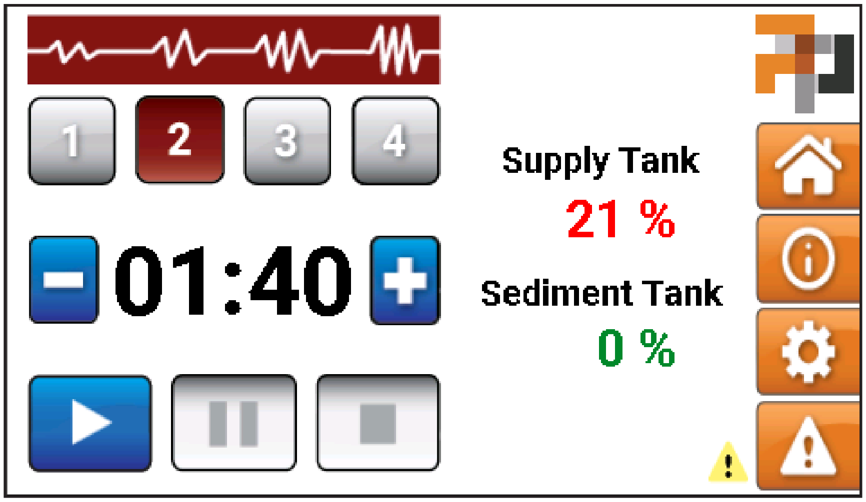
To overcome these challenges and deliver the consistent quality needed for customer-ready parts, there is a surface finishing solution specifically designed for additive that meets these requirements. PostProcess Technologies has developed a technology called *Suspended Rotational Force* (SRF). At a high level, it can be described as digitally tuned oscillations creating a horizontal or vertical circular motion in a chamber consisting of a composite or single material, abrasive, and fluid mixture. Identifying the optimal amplitude to maximize dwell time and balance G-force with part safety is essential. The result is an even, controlled mechanical force applied to each part at the surface level. This simplified schematic provides visualization for the description. The SRF technology is demonstrated in the RADOR surface finishing solution combining hardware, software, and chemistry designed to function together to finish additive parts consistently.



C = Center of Mass
RPM = Exposed Time + Dwell Time

In looking at the hardware design, the part chamber allows for multiple geometries to be processed simultaneously, which provides a throughput advantage over manual processes that are limited to handling a single part at a time. The chamber design, combined with a proven vibrational frequency, provides a balanced and gentle mechanical force to external surfaces.

To further ensure process consistency, the AUTOMAT3D™ software allows for easy control over key parameters. The primary processing parameters include Agitation Level and Cycle Time. Selecting from four customizable Agitation Levels, the user can select a fluid dosing sequence that aligns with their application. With the ability to monitor the supply tank, the software will calculate the maximum cycle time, ensuring that there are no interrupted cycles, allowing for repeatable, hands-free processing.



Screenshot above shows the AUTOMAT3D™ processing screen where the user can control the Agitation Level and Cycle Time with visibility into tank levels and any active alarms or warnings

These software configurations also allow for great flexibility. Easily adjusting Agitation Levels to align with PostProcess' various media options provide the RADOR with a flexible platform, an aforementioned necessity in the additive industry. In addition to the part processing flexibility, the RADOR also provides two different waste removal options. Depending on process preference and facility capabilities, the user has the option to continuously drain their sediment tank without interruption, or manually trigger the drain pump when notified. This option can be toggled as needed as the workflow scales.

The detergent, PG3, is strategically dosed into the part chamber to aid in cleaning the media and adds a microscopic layer of fluid to modify the level of friction between the abrasive and geometries being processed. This detergent also keeps the parts clean and ensures that any material removed is directed to the sediment tank to eliminate any contaminants that could hinder continuous, consistent part processing.

The PostProcess MJF Surface Finish solution also brings a number of other benefits to MJF customers. The RADOR provides an environmentally friendly solution, not requiring additional ventilation and having a "library quiet" sound profile. For waste handling, waste can be automatically transferred outside the machine where it can be separated into liquid and solid elements through a sedimentation process, allowing the liquid to be sent directly to drain and the non-hazardous solid waste to be disposed of accordingly.

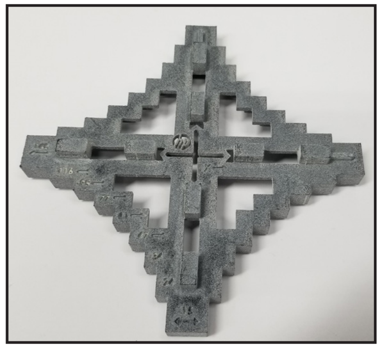
In summary, the RADOR with SRF technology is designed to meet the demands of additive manufacturing Throughput, consistency, efficiency, and flexibility are all key considerations for any surface finishing application. The RADOR meets these requirements, having been designed specifically for additive and tested for MJF.

TEST OVERVIEW

Three different part geometries were utilized, each one designed to test a different parameter of the process.

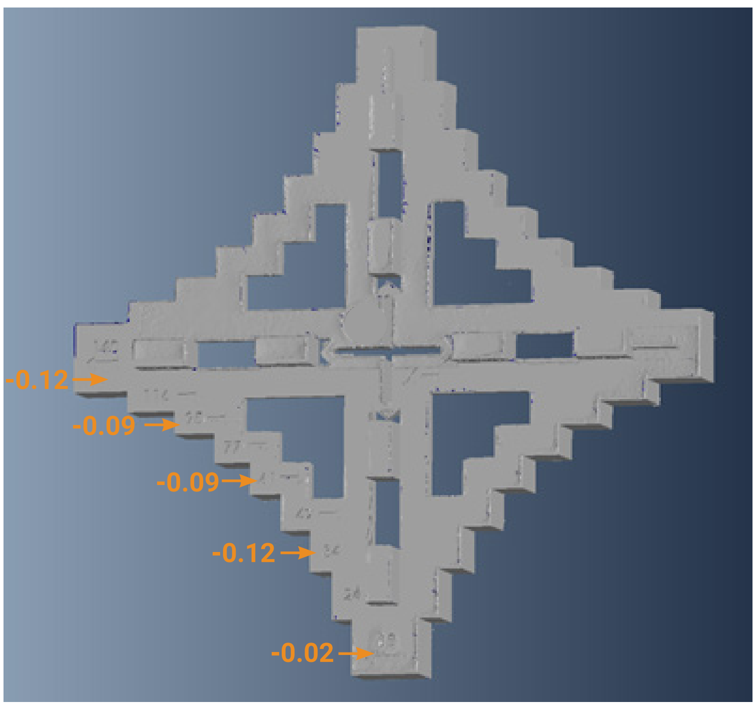
1. Pyramids

Used to measure dimensional change as a function of time using two different medias.



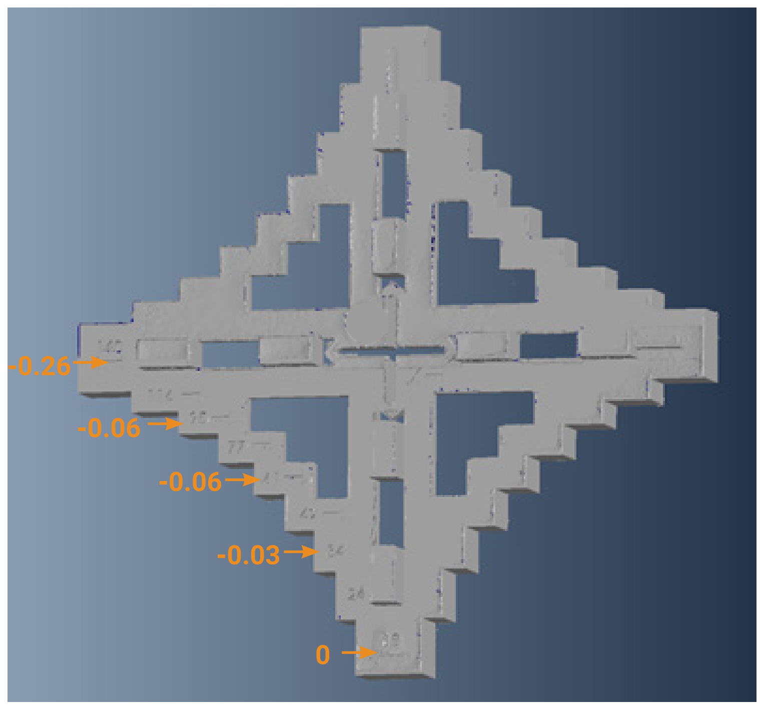
Material Loss Over 6 Hours:
(in mm)

M-CTS media



Average Dimensional Change: **-0.106 mm**

M-SPC media



Average Dimensional Change: **-0.085 mm**

A total of four parts were 3D scanned and evaluated against each other for material loss. Two samples were processed in M-SPC media, one for 1 hour and one for 6 hours. These two parts were compared against each other in the first two figures to show material loss between the two cycle times. The same approach was taken with M-CTS media, and as shown, more material loss is observed when utilizing the M-CTS (ceramic) as opposed to the M-SPC (plastic).

2. Pins Part

Used to gauge the proclivity to breakage, various pin diameters and lengths on both faces of the part used with different medias.

M-SPC																		
	3 mm Pin Length									5 mm Pin Length								
Hours	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
1	6	6	3	1	0	0	0	0	0	6	5	0	0	0	0	0	0	0
2	6	6	4	0	0	0	0	0	0	5	2	0	0	0	0	0	0	0
3	6	6	5	1	0	0	0	0	0	5	5	0	0	0	0	0	0	0
4	5	6	3	0	0	0	0	0	0	6	6	5	1	0	0	0	0	0
5	6	6	0	0	0	0	0	0	0	6	6	4	0	0	0	0	0	0
6	6	6	4	2	0	0	0	0	0	5	4	0	0	0	0	0	0	0
7	6	6	2	1	0	0	0	0	0	6	6	4	1	0	0	0	0	0
8	6	6	6	1	0	0	0	0	0	6	6	4	0	0	0	0	0	0
9	6	6	3	0	0	0	0	0	0	6	5	3	0	0	0	0	0	0
10	6	6	5	2	0	0	0	0	0	6	6	1	1	0	0	0	0	0

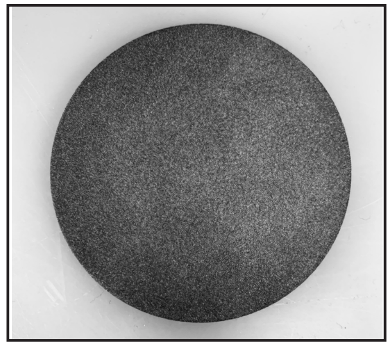
Figure 1: Breakage mapping of pins parts processed in M-SPC media

M-CTS																		
	3 mm Pin Length									5 mm Pin Length								
Hours	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
1	6	6	2	0	0	0	0	0	0	6	3	4	0	0	0	0	0	0
2	6	6	5	6	2	0	0	0	0	6	6	2	1	0	0	0	0	0
3	6	6	6	3	1	0	0	0	0	6	5	0	0	0	0	0	0	0
4	6	6	5	5	1	1	0	0	0	6	6	4	0	0	0	0	0	0
5	6	6	6	6	2	0	0	0	0	6	5	3	0	0	1	0	0	0
6	6	6	6	3	1	0	0	0	0	6	6	2	0	0	0	0	0	0
7	6	6	6	6	4	1	0	0	0	6	6	6	2	2	3	0	1	0
8	6	6	6	6	3	0	0	0	0	6	6	6	2	1	0	0	0	0
9	6	6	6	4	0	0	0	0	0	6	6	2	1	0	1	0	0	0
10	6	6	6	6	1	0	0	0	0	6	6	4	0	0	1	0	0	0

Figure 2: Breakage mapping of pins parts processed in M-CTS

3. Poker Chip

Used to measure surface roughness as a function of time, including the delta between top facing and bottom facing surfaces, using two different medias.



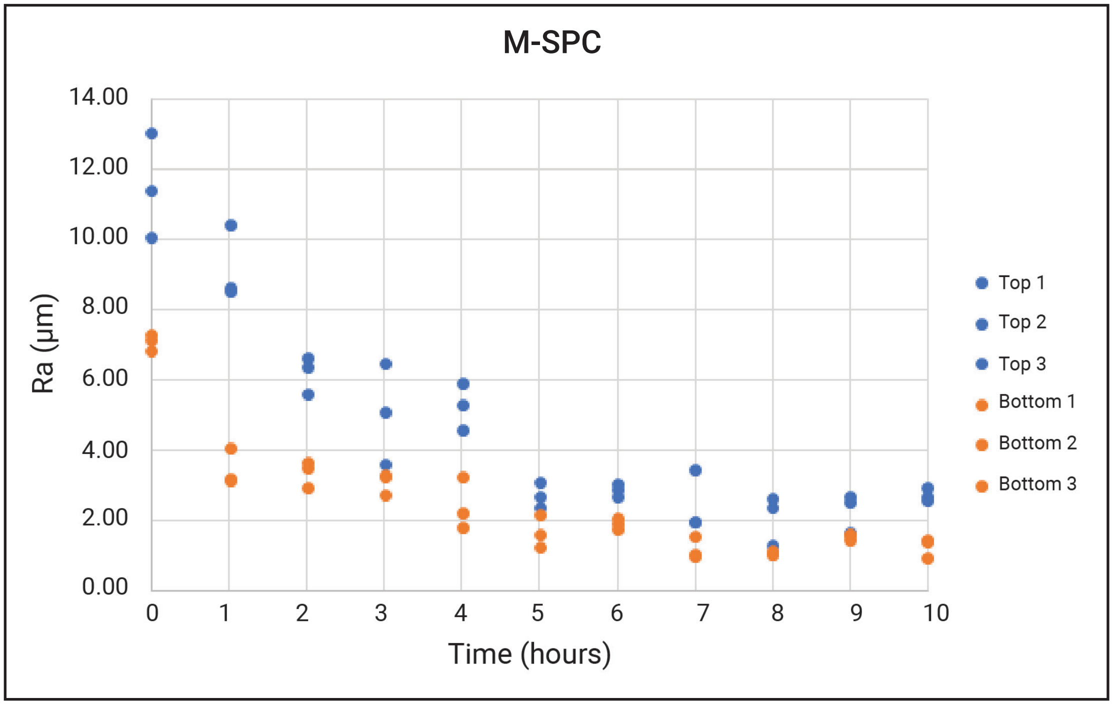


Figure 3: Roughness reduction over time of poker chip parts in M-SPC media

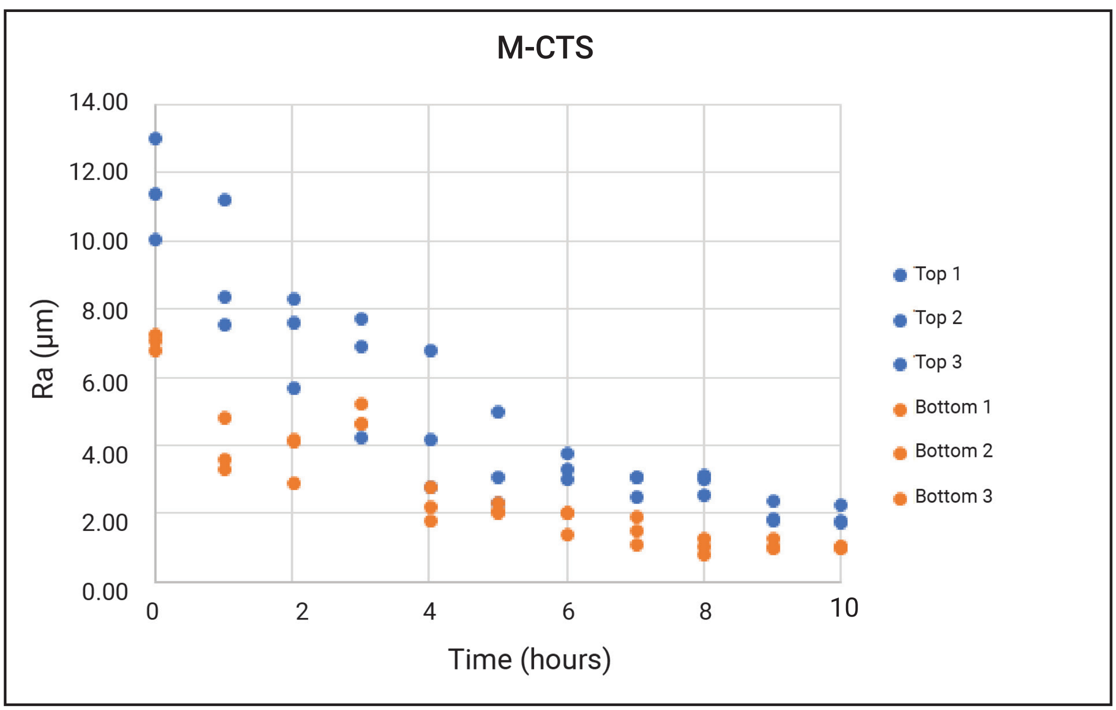


Figure 4: Roughness reduction over time of poker chip parts in M-CTS

MEDIA SUMMARY

Based on the testing, we can observe a few differences between the two media used. The M-SPC, a synthetic, lighter weight media, and M-CTS a heavier ceramic media were both able to achieve surfaces R_a’s of < 1 micron. The main difference between the media is the breakage results shown in figures 1 and 3. It is clear that M-CTS is a good option for robust parts lacking geometries smaller than 2.0 mm in diameter, while the M-SPC is able to keep geometries down to 1.5 mm in diameter intact.

SECONDARY PROCESSING

Below is a 20X close-up of a part following both 6 hours of surface finishing in the M-SPC test media and an additional 2 hours in a polishing media, UPM1.

Raw Part

After Processing

Based on these results, further post-processing steps were performed. Plating was evaluated, with the end goal being a smooth Nickel finish. The entire process consists of both Copper and Nickel layers.

PA-12

The consistent improvements in the results show that each variable, print, post-print, and secondary processing (plating), is essential to achieving the desired end product. All three processes need to be optimized to provide a quality end-user part.

CONCLUSIONS

The PostProcess MJF Surface Finish solution allows parts to be finished for end-use, or to be prepared for an additional post-printing process. This solution has proven to provide excellent surface finishing, even in the difficult situation of reaching a desired plated surface. The roughness reduction from all platforms and materials shows an average improvement of ~6-10 μm depending on the surface build orientation. The first 4 hours of processing time produced over ~80% of the total reduction in surface roughness, with the final 6 hours typically reducing the surface roughness by about another 1 μm.

Breakage testing indicates high confidence in maintaining geometries >1.75 mm in diameter and less than 5 mm in length. M-SPC better protected the most delicate geometries.

Finally, the dimensional change results show that media selection has an effect on geometry during the process. The heavier ceramic media leaves more rounded edges and removes more material in the same amount of time as plastic media.

Overall, the test results confirm our assumptions about the effectiveness of the PostProcess MJF Surface Finish solution:

1) Consistency is high, especially when compared to current traditional finishing methods.

2) The surface finish results allow for secondary processes such as plating to be achieved.

3) The solution has the flexibility to be used on a variety of geometries printed on all MJF products.

POSTPROCESS
Automated. Intelligent. Comprehensive.

PostProcess Technologies
2495 Main Street, Suite 615
Buffalo, NY 14214
+1.866.430.5354
info@postprocess.com

PostProcess Technologies International
Les Aqueducs B3
535 Route des Lucioles
06560 Sophia Antipolis, France
+33 (0)4 22 32 68 13