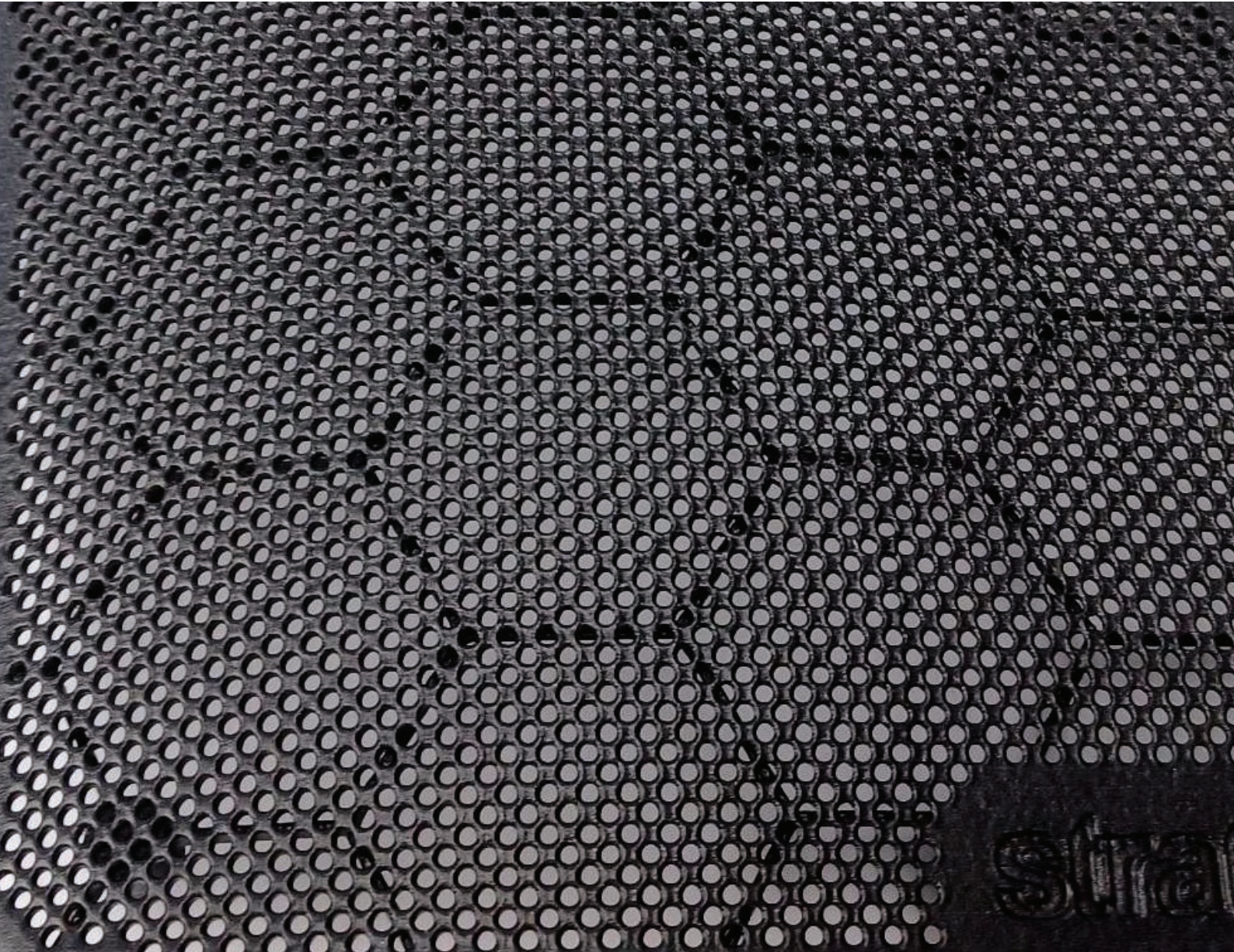




Vapor Smoothing of Stratasys SAF Parts via AMT's Sustainable PostPro Pure[®] Technology

The PostPro® vapor smoothing technology by AMT is an automated post-processing solution to surface treat thermoplastic polymer 3D-printed components. PostPro® is a patented and enabling technology, which reduces lead-time and operational/maintenance costs, providing the ‘missing piece’ in the digital manufacturing chain. The technology uses novel chemistry PostPro Pure, which is green, sustainable, non-hazardous and non-halogenated. As a result, PostPro® vapor smoothing can help achieve an injection molded surface quality, improved fluid-tightness, as well as bacteria protection on parts printed using Stratasys Selective Absorption Fusion (SAF), Laser Sintering, HP Multi Jet Fusion (MJF), High Speed Sintering (HSS), or Fused Deposition Modelling technology (FDM).

Extensive testing was conducted to characterize the impact of chemical vapor smoothing using AMT’s new green sustainable chemistry, PostPro Pure, on the material properties of Stratasys SAF PA12 parts. The testing focused on surface quality, mechanical properties, and dimensional variation. The results demonstrated that AMT PostPro® vapor smoothing can improve the surface quality of the parts without sacrificing dimensional tolerance or mechanical performance.

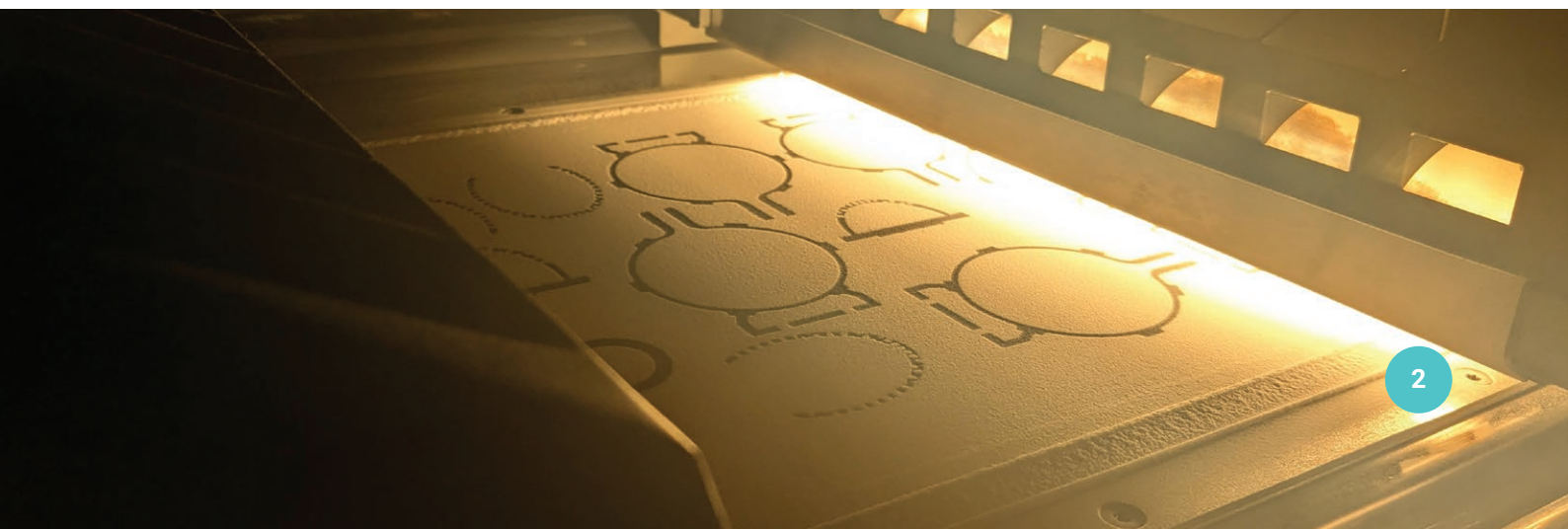
Stratasys SAF Process

What is SAF 3D printing?

Stratasys SAF technology transforms 3D printing with its innovation, making it easy to create high-quality, durable plastic parts in any quantity. It uses smart powder management and targeted heating for better strength, catering to businesses large and small. Suited to a wide range of industries and applications, SAF offers the scalability, flexibility and responsiveness needed to meet today’s – and tomorrow’s – manufacturing challenges.

How does SAF 3D printing work?

SAF technology revolutionizes 3D printing by deploying industrial-grade print heads to precisely apply a fusing fluid on a powder bed. Using an infrared lamp to selectively fuse particles layer by layer, the fluid enhances heat absorption of the powder particles to form solid objects. This method supports high-volume production of complex shapes, rendering an efficient and cost-effective way to manufacture end-use parts, without the constraints of traditional manufacturing processes.



PostPro[®] Vapor Smoothing Technology

Printed material surfaces exhibit rather rough, powdery and porous characteristics, limiting the use of such parts in various applications. AMT's PostPro vapor smoothing process is able to solve these issues and produce smooth and sealed surfaces, removing any loose un-sintered powder. The patented vapor smoothing process can smooth a variety of thermoplastic polymers including PA12, PA11, PA6, TPU, TPE, TPA, ABS and many other materials printed using Powder Bed Fusion (PBF) or Fused Filament Fabrication (FFF) methods.

The process works by creating favorable thermodynamic conditions for the parts to process. During the process, the top layer surface material becomes mobile and is rearranged creating a sealed and smooth surface. The accuracy of the smoothing is controlled using tailored conditions within the process chamber to achieve the required surface finish.

AMT's PostPro Pure chemistry provides a green and sustainable post-processing solution to deliver repeatable and smooth parts with almost no dimensional variation and sealed surfaces avoiding liquid or gas uptake. Processed parts not only achieve high aesthetical standards but also show improved mechanical performance, dyeing uniformity, and ease of painting. The system combines applied science and easy-to-use technology that can be integrated into automatic production lines to deliver enhanced polymer performance at scale [1, 2, 3, 4, 5, 6, 7].



Testing Methodology

The study compared the vapor smoothing impact on SAF PA12 parts before and after smoothing via AMT's eco-friendly PostPro Pure® solvent. Six tests were conducted for both as-printed and post-processed parts as shown in the Table 1. Samples were printed and tested in both XY and XZ directions (see Figure 1). Before smoothing, the parts underwent de-powdering and cleaning to remove loose powder.

Table 1. Summary of conducted tests

Test	Sample type and test standard	Samples (SAF PA12 unprocessed)	Samples (SAF PA12 processed)
Ultimate Tensile Strength (MPa)	ASTM D638-14	10XY+ 10XZ	10XY+ 10XZ
Elongation at break	ASTM D638-14	10XY+ 10XZ	10XY+ 10XZ
Flexural Strength	ASTM D790-17	10XY+ 10XZ	10XY+ 10XZ
Flexural Modulus	ASTM D790-17	10XY+ 10XZ	10XY+ 10XZ
Impact Strength	ASTM D256 Unnotched	10XY + 10ZX	10XY + 10ZX
Surface roughness	ASTM D638 Type I	18XY + 18XZ	18XY + 18XZ
Microscopy analysis	10mm2 square	1XY + 1XZ	1XY + 1XZ
Accuracy		15XY + 15XZ	15XY) + 15XZ

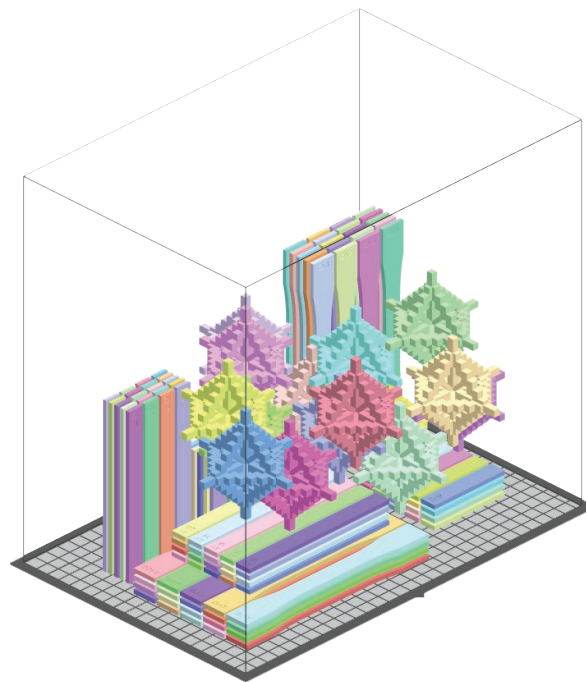


Figure 1. Build job of test samples

Surface Roughness

The surface roughness (Ra) of the samples was measured using a Taylor Hobson Surtronic S128 contact profilometer. Measurements were done on the three areas of the samples: upper, lower (printed in XY direction) and the side (printed in ZX direction). The results are given Figure 2.

The average Ra roughness of all samples improved from 7.5 μm to 1.4 μm . The roughness improvement was provided uniformly across the part independent of its print side, which was showed by the reduction in the standard deviation between Ra values across the surfaces for both printers in all directions from around 1 μm for Raw to 0.34 μm for Smoothed. The improvements come due to controlled re-flow of the surface, removing imperfections, un-sintered material and micro-cracks.

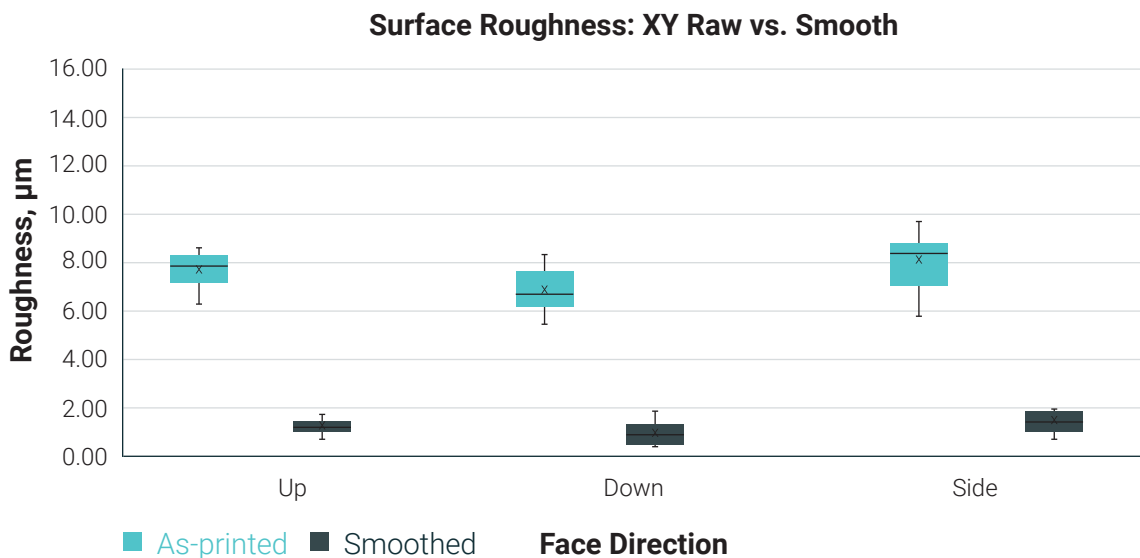


Figure 2. Surface roughness results.



Microscopy Imaging

Surface microscopy of SAF PA12 smoothed surfaces using the AMT PostPro vapor smoothing was done using a Hirox KH-8700 digital microscope with MX(G)-2016Z lens. Analysis of samples was done at magnification of 100x. The results are shown in the Figures 3-6.

Microscopy images reveal abundant presence of un-sintered material, crevices and surface porosity on the as-printed SAF surfaces (Figures 3 and 4 for as-printed and 5-6 for smoothed). These artefacts are completely removed by the vapor smoothing, leaving the surface smooth, sealed and uniform. As a result the processed surface opens new applications for SAF printed parts, e.g. fluid contact parts.



Figure 3. Un-processed SAF PA12 surface.
x20 magnification

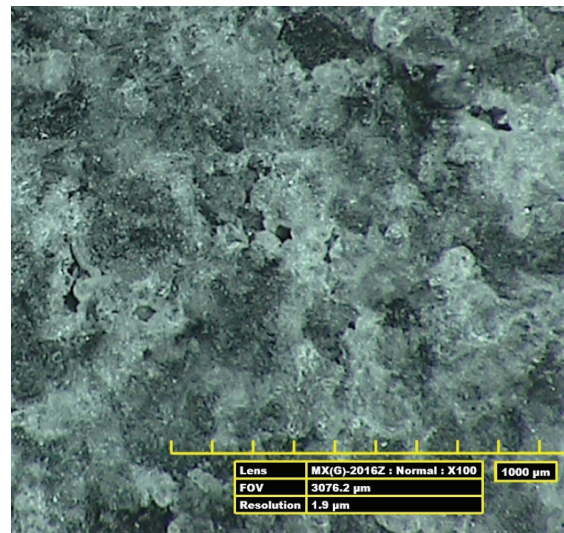


Figure 4. Un-processed SAF PA12 surface.
x100 magnification

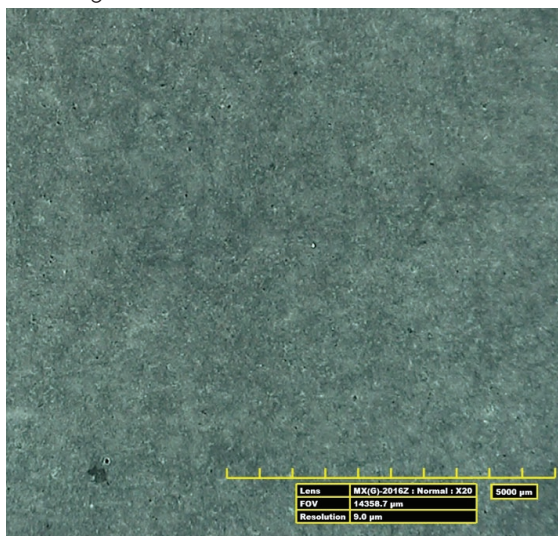


Figure 5. Processed SAF PA12 surface.
X20 magnification

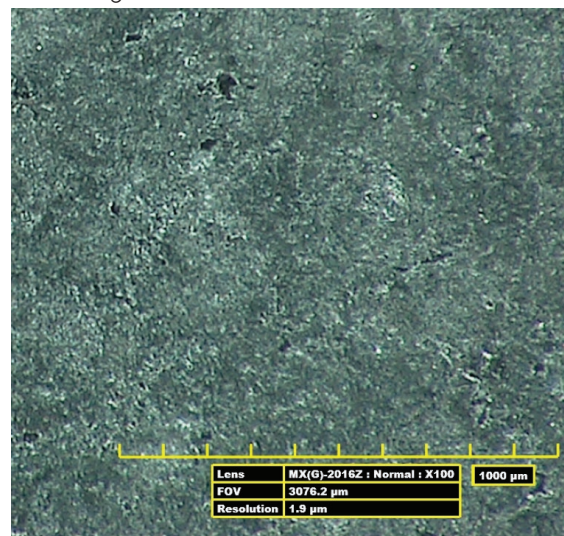


Figure 6. Processed SAF PA12 surface.
X100 magnification

Mechanical Properties

Mechanical test results for raw and smoothed samples printed in both XY and XZ directions are provided in the Tables 2, 3, 4 and 5. Smoothing slightly reduced the ultimate tensile strength in both orientations, with a decrease of approximately 3% in XY and 9% in ZX. However, it improved ductility, as indicated by the elongation at break, which increased by 34% in XY and 103% in ZX. Flexural strength decreased with smoothing, showing reductions of about 19% in XY and 11% in ZX. Similarly, the flexural modulus dropped by 20% in XY and 14% in ZX after smoothing. Overall, the increase in elongation at break with smoothing suggests enhanced ductility of the material, which results in the corresponding reduction in flexural strength and stiffness is not unexpected by as much as 26%.

The impact strength results for as-printed and smoothed unnotched samples (Tables 5 and 6) reveal a significant influence of the smoothing process on material performance. In the ZX orientation, the unfinished samples exhibited an average impact strength of 7.2 kJ/m², while the smoothed samples demonstrated a notable increase by 62% to 11.7 kJ/m², indicating that the smoothing process enhances the impact resistance in this direction. In the XY orientation, the average impact strength increased by 33% from 7.8 kJ/m² to 10.4 kJ/m². The data suggest that smoothing improves impact resistance in both orientations, with a more pronounced effect in the ZX direction.

Table 2. Ultimate Tensile Strength Results

Ultimate Tensile Strength (MPa)				
	XY		ZX	
	As-printed	Smoothed	As-printed	Smoothed
	44.6	43.3	48.4	44.8
	44.1	43.0	48.1	43.7
	44.8	44.0	46.9	45.0
	45.4	43.3	49.3	43.5
	45.6	44.3	49.4	46.2
	45.6	44.4	49.7	44.8
	45.6	44.5	50.8	46.8
	45.5	43.4	50.0	44.7
	45.3	44.0	48.2	45.2
	45.0	43.8	49.1	43.8
Average	45.2	43.8	49.0	44.9
Change %	-3%		-9%	

Table 3. Elongation at Break Results

Elongation at Break (%)				
	XY		ZX	
	As-printed	Smoothed	As-printed	Smoothed
	14.3	14.9	7.3	14.3
	15.1	17.9	5.6	17.0
	14.6	15.3	-	11.5
	14.1	21.0	7.0	10.4
	11.9	21.1	8.3	14.2
	15.0	20.5	7.1	11.6
	13.7	19.7	8.0	16.3
	14.4	20.3	6.2	11.8
	12.5	15.4	5.2	18.5
	14.1	21.6	9.0	18.6
Average	14.0	18.8	7.1	14.4
Change %	34%		103%	

Table 4. Flexural Strength Results

Flexural Strength (MPa)				
	XY		ZX	
	As-printed	Smoothed	As-printed	Smoothed
	58.0	45.3	56.0	49.8
	58.1	45.9	56.3	50.5
	-	46.4	56.3	49.3
	57.2	47.1	56.1	51.9
	58.2	47.4	55.4	49.2
	57.2	47.2	54.9	49.8
	57.3	47.8	57.5	51.5
	56.1	46.0	56.9	51.1
	55.9	45.7	57.3	51.4
	56.6	44.8	56.8	51.6
Average	57.2	46.4	56.4	50.6
Change %	-19%		-11%	

Table 5. Flexural Modulus Results

Flexural Modulus (MPa)				
	XY		ZX	
	As-printed	Smoothed	As-printed	Smoothed
	1,527	1,182	1,563	1,317
	1,540	1,204	1,555	1,335
	-	1,161	1,566	1,338
	1,501	1,234	1,545	1,352
	1,534	1,197	1,534	1,329
	1,489	1,184	1,479	1,325
	1,458	1,215	1,623	1,354
	1,441	1,140	1,552	1,329
	1,470	1,209	1,599	1,339
	1,486	1,168	1,552	1,321
Average	1,494	1,189	1,557	1,334
Change %	-20%		-14%	

Table 6. Impact strength results for XZ samples

ZX (kJ/m²)		
	XY	
Sample	As-printed	Smoothed
1	6.6	15.6
2	5.9	9.4
3	6.1	10.6
4	8.7	10.8
5	7.2	12.3
6	9.0	10.9
7	6.4	15.6
8	8.6	10.6
9	6.3	11.7
10	7.1	9.1
Average	7.2	11.7
Change %		62%

Table 7. Impact strength results for XY samples

Table 6. Impact strength results for XY samples		
	XY (kJ/m ²)	
Sample	As-printed	Smoothed
1	8.6	11.2
2	7.3	6.7
3	8.0	10.9
4	8.6	7.6
5	4.7	9.4
6	6.5	11.3
7	7.7	10.5
8	8.2	11.6
9	8.3	12.0
10	10.2	12.4
Average	7.8	10.4
Change %		33 %

Dimensional Accuracy

Accuracy test was done on the pyramid samples shown in the Figure 7 and the results are shown in the Table 8. In the as printed raw condition, the sample accuracy was measured at 100% for both the x and y axes and 94% for the z-axis, resulting in an overall accuracy of 98%. After smoothing, accuracy remained consistent at 100% for the x and y axes but decreased slightly to 91% for the z-axis, bringing the overall accuracy to 97%. Given the slight trade-off in the z-axis accuracy, the overall reduction is minimal and likely acceptable in most applications.

Table 8. Accuracy test results

	Tolerance +/- 0.2mm			
	x	y	z	Overall
As-printed	100%	100%	94%	98%
Smoothed	100%	100%	91%	97%

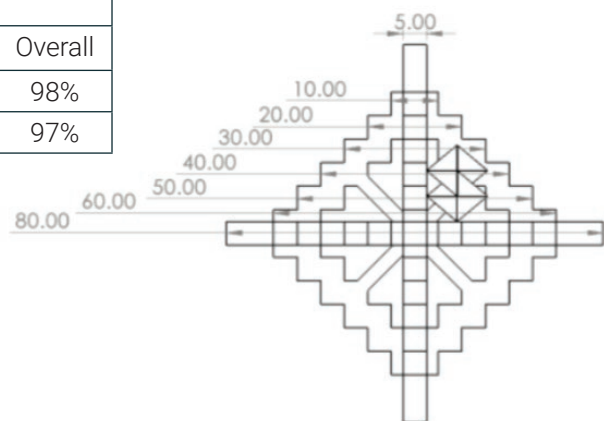
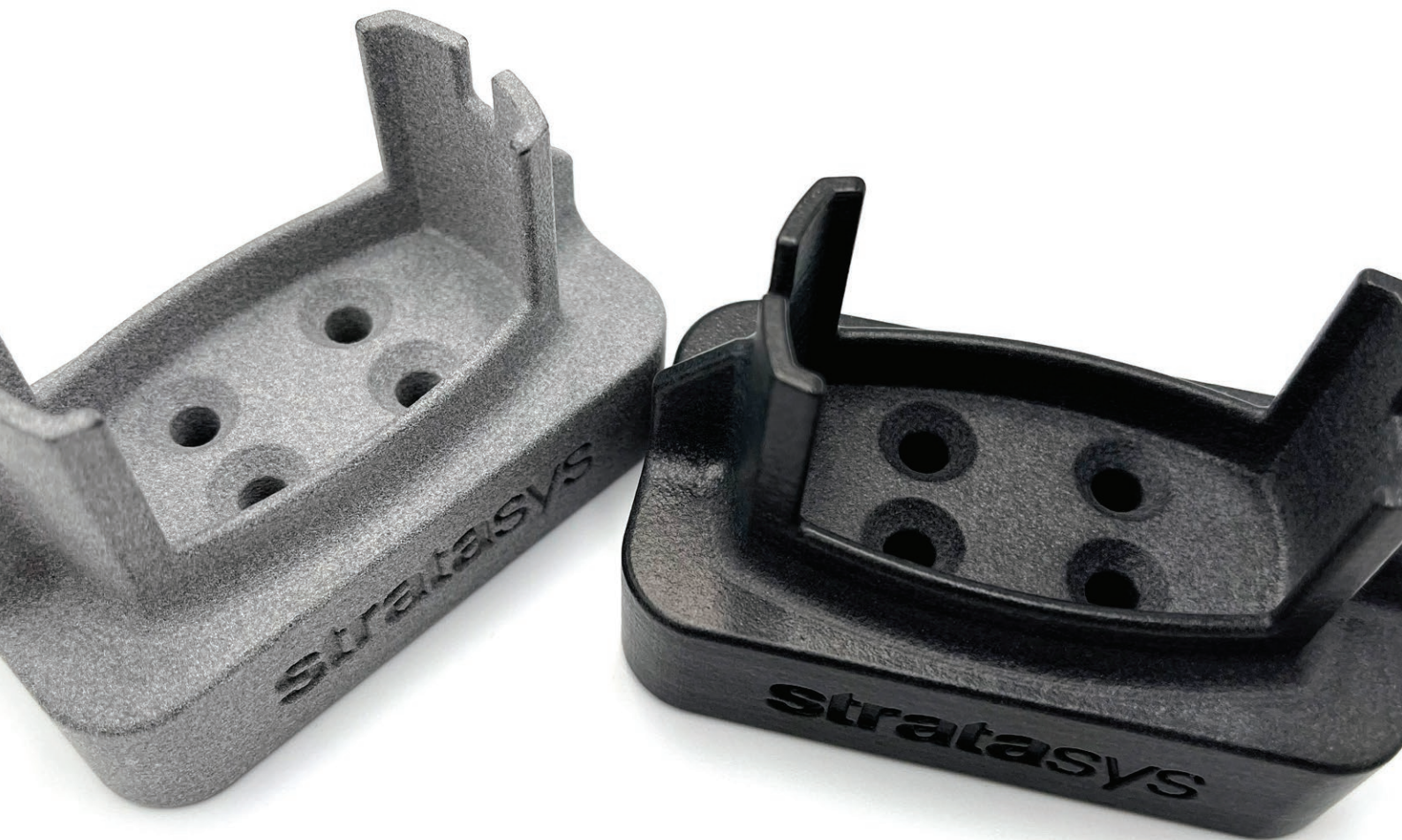


Figure 7. Sample measurement locations for the accuracy test

Summary

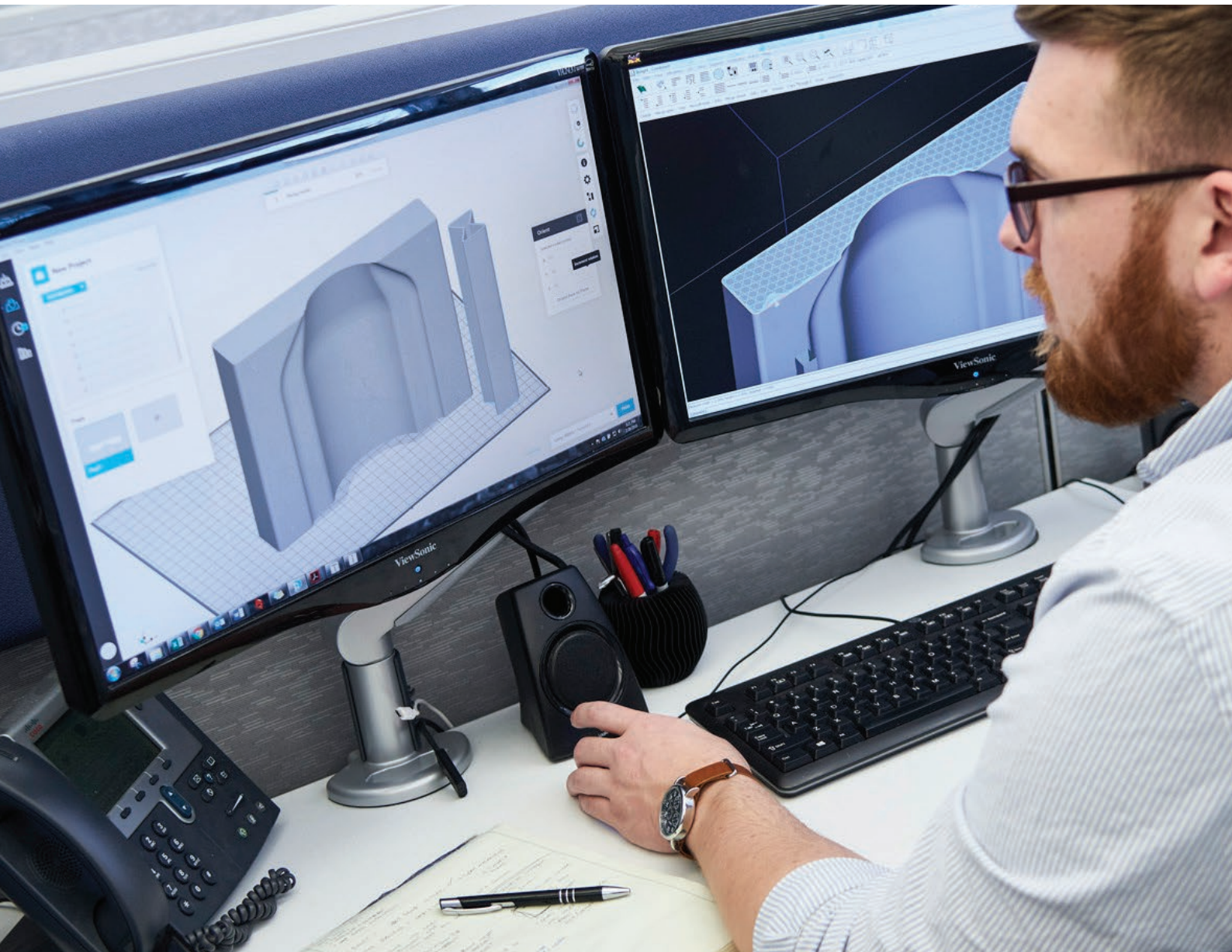
AMT's PostPro® vapor smoothing technology using the sustainable PostPro Pure® chemistry, enhances the surface quality of 3D-printed SAF PA12 parts while maintaining dimensional accuracy and mechanical properties. Testing demonstrated that vapor smoothing significantly enhances impact strength, increases ductility, and achieves injection-molded surface quality without compromising precision. Microscopy analysis revealed that smoothing also eliminates surface porosity and micro-cracks, making the parts suitable for a variety of fluid-contact applications.



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