



Next-Level Finishing: Vapor Smoothing Voxeljet's HSS PA12 with AMT PostPro®

The Use of AMT PostPro® Vapor Smoothing for voxeljet's HSS PA12 Material

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. PostPro® achieves an injection molded surface quality, improved airtightness, and antimicrobial properties on parts printed using Laser Sintering, HP Multi Jet Fusion, High Speed Sintering, or Fused Deposition Modelling technology.

Extensive testing was done to characterize the effect of chemical vapor smoothing technology by AMT on material properties of PA12 parts printed via voxeljet HSS technology. The testing focused on surface quality, mechanical properties, and dimensional variation. The results demonstrated that AMT Postpro vapour smoothing can improve the surface quality of the parts without sacrificing dimensional tolerance or mechanical performance.

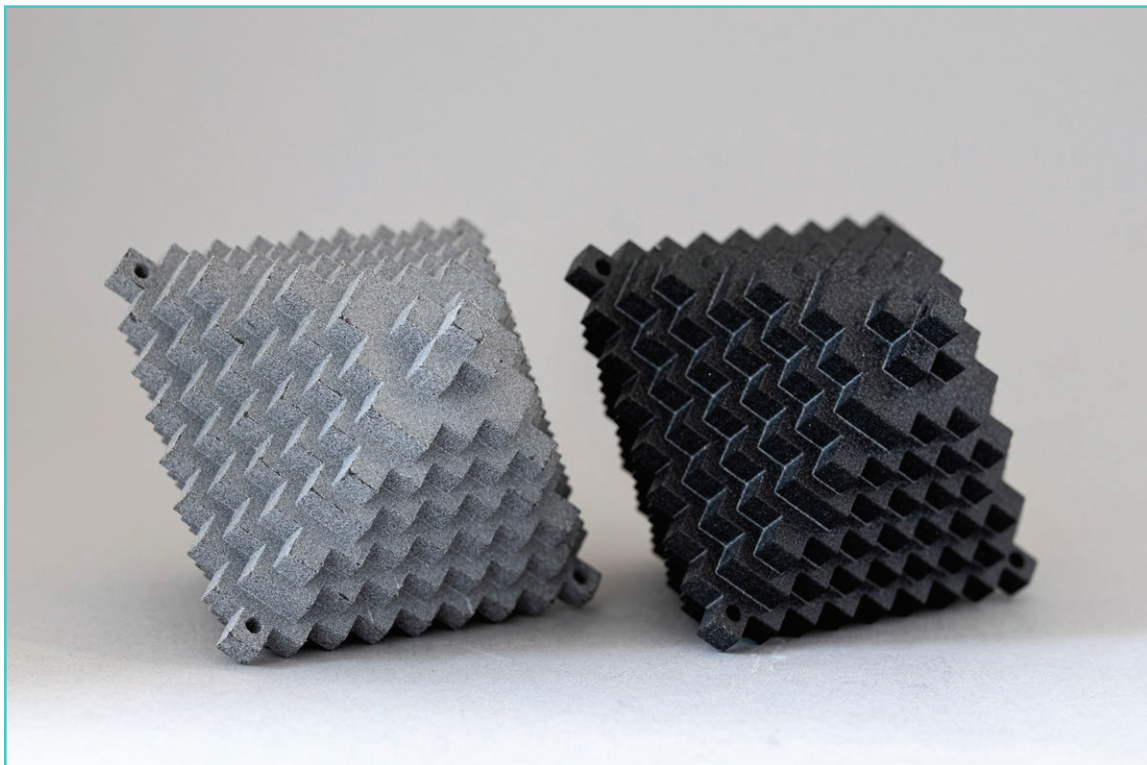


Figure 1. As-printed (a) and processed (b) HSS voxeljet parts

voxeljet HSS process

During the HSS process, a thin layer of polymer powder, such as PA12, is applied onto a heated building platform. Further printable materials include TPU, PP, PA11, PA6, PEBA, TPE a.o. Then an inkjet printhead rapidly moves over the powder layer, jetting an infrared-absorbing ink to selected areas of the powder bed. After that, the building platform is irradiated with infrared energy, resulting in the sintering of printed areas, while the unprinted areas remain un-sintered. The building platform then lowers by one layer thickness and the process is repeated until the 3D-part is finished. After printing, the whole jobbox is cooled down in a controlled manner outside the printer before the parts are removed and unpacked. Surrounding powder always remains below melting temperature and is therefore left un-sintered – it can be recycled and reused later. Due to voxeljet's patented energy application where the infrared light can be filtered and adjusted, no further cooling liquids are required.

PostPro[®] Vapor Smoothing Technology

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

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

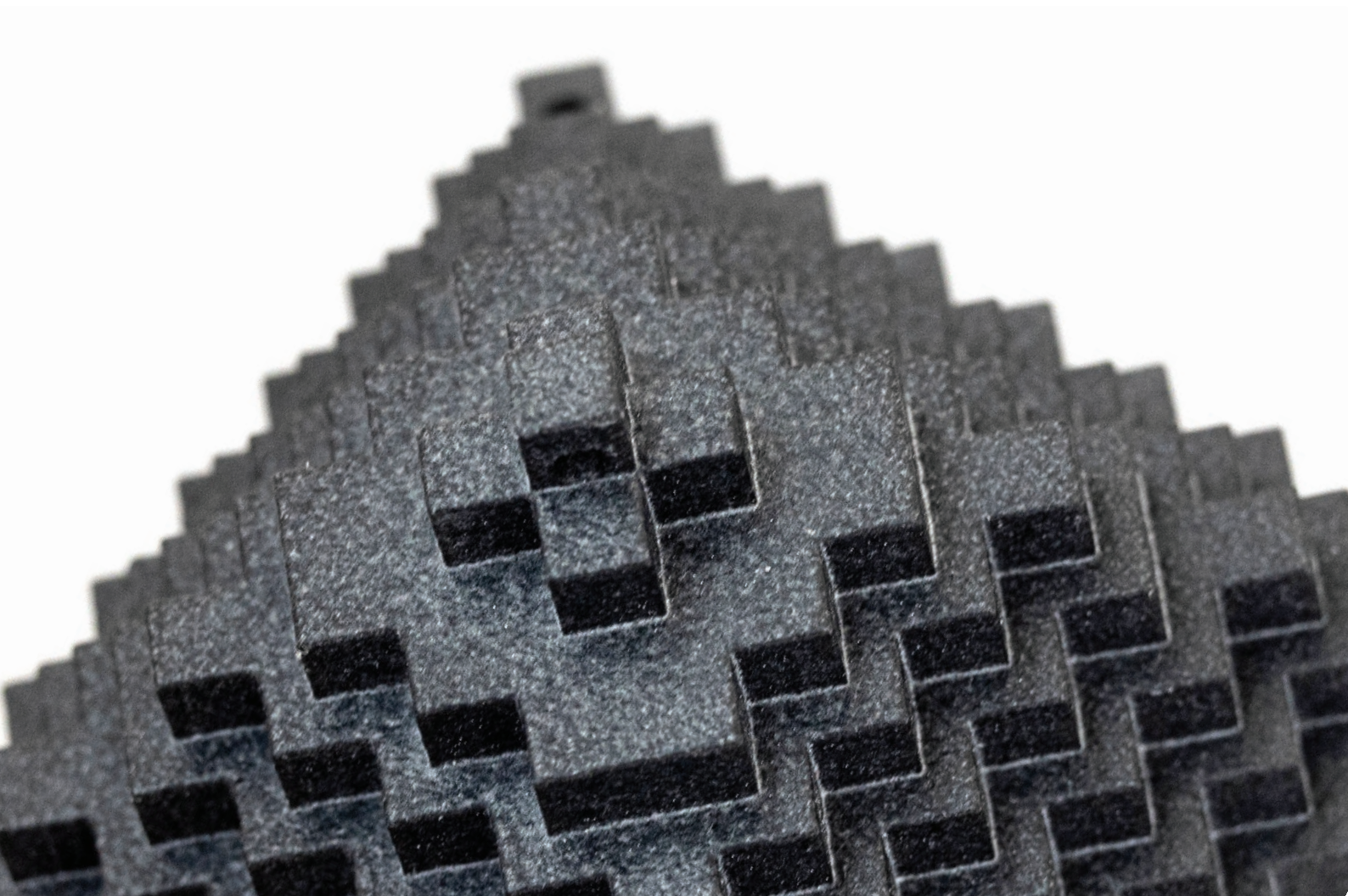
AMT's PostPro chemical vapor smoothing provides a sustainable post-processing solution to deliver repeatable and smooth parts with almost no dimensional variation and sealed surfaces avoiding liquid or gas uptake. Processed parts not only achieve high aesthetical standards but also are easier to dye and coat while their mechanical properties remain intact. 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

Parts used during this study have been printed on a voxeljet VX200 printer in XY and XZ directions. The parts have been de-powdered and cleaned of the loose powder before the smoothing. In total, 5 different tests were performed for both as-printed and post-processed parts summarized below in Table 1.

Table 1: Summary of conducted tests.

11XY + 9XZ	Sample type and test standard	Number of samples	Unprocessed	Processed
Tensile test	ASTM D638	22XY + 20XZ	11XY + 11XZ	11XY + 9XZ
Surface roughness	ASTM D638 Type I	30	10XY+10XZ+10plain	10XY+10XZ+10plain
Dimensional variation	Dimensional pyramids	4	2	2
Microscopy analysis	10mm2 square	2	1	1



Surface Roughness

The surface roughness (Ra) of the samples was measured using a Mitutoyo Surftest SJ-210 with a stylus tip radius of 2 μ m, tip angle 60° and measuring force 0.75kN. Five measurements at different areas of each surface were made before and after processing for 10 dogbones prepared in XY and XZ directions. The averages are given Figures 2 and 3.

The average roughness Ra improved from 12.81 μ m to 4.16 μ m for XY and from 16.83 μ m to 7.54 μ m for XZ directions. This roughness improvement is provided uniformly across the part independent of its geometry. This is demonstrated by the reduction in the standard deviation between Ra values across the surface from 1.60 and 1.41 to just 0.11 and 1.13 for XY and XZ respectively. The improvements come due to controlled re-flow of the surface, removal of imperfections, un-sintered material and micro-cracks.

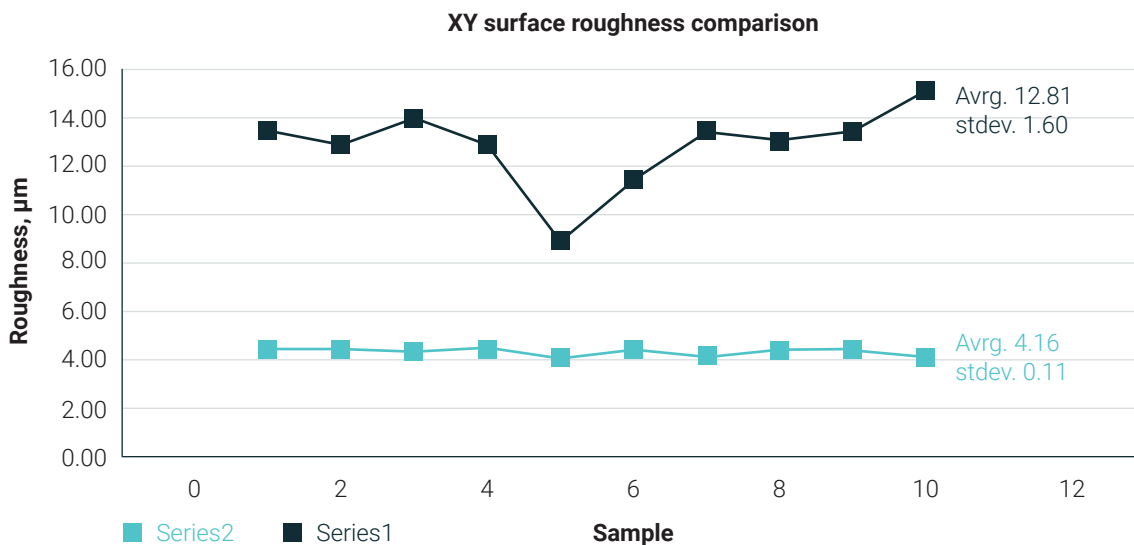


Figure 2. Surface roughness Ra results for the samples printed in XY direction

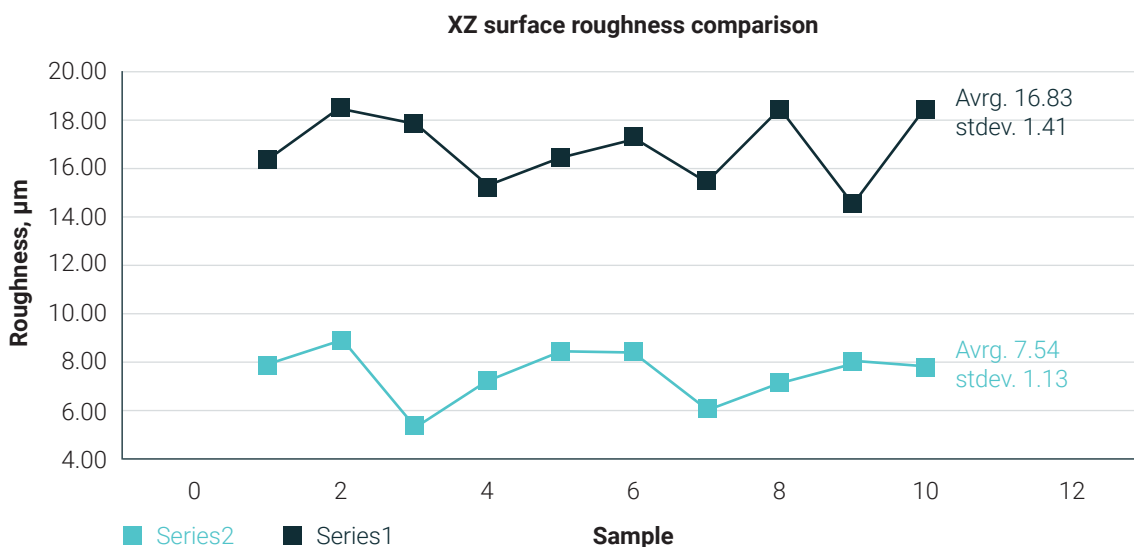


Figure 3. Surface roughness Ra results for the samples printed in XZ direction

Microscopy imaging

Surface microscopy of voxeljet HSS PA12 smoothed surfaces using the AMT PostPro chemical vapor smoothing was done using a Hirox KH-8700 digital microscope with MX(G)-2016Z lens. Analysis was done at magnifications of 20x, 60x and 100x. The results are shown in the Figures 3 (a, b, c, d, e, f).

Microscopy images reveal abundant presence of un-sintered material, crevices and surface porosity on the as-printed HSS surfaces (Figures 3 a, c and e). These artefacts are completely removed by the PostPro chemical vapor smoothing process (Figures 3 b, d and f), leaving the surface smooth, sealed and uniform. As a result the processed surface opens new applications for HSS printed parts, e.g. fluid contact parts.

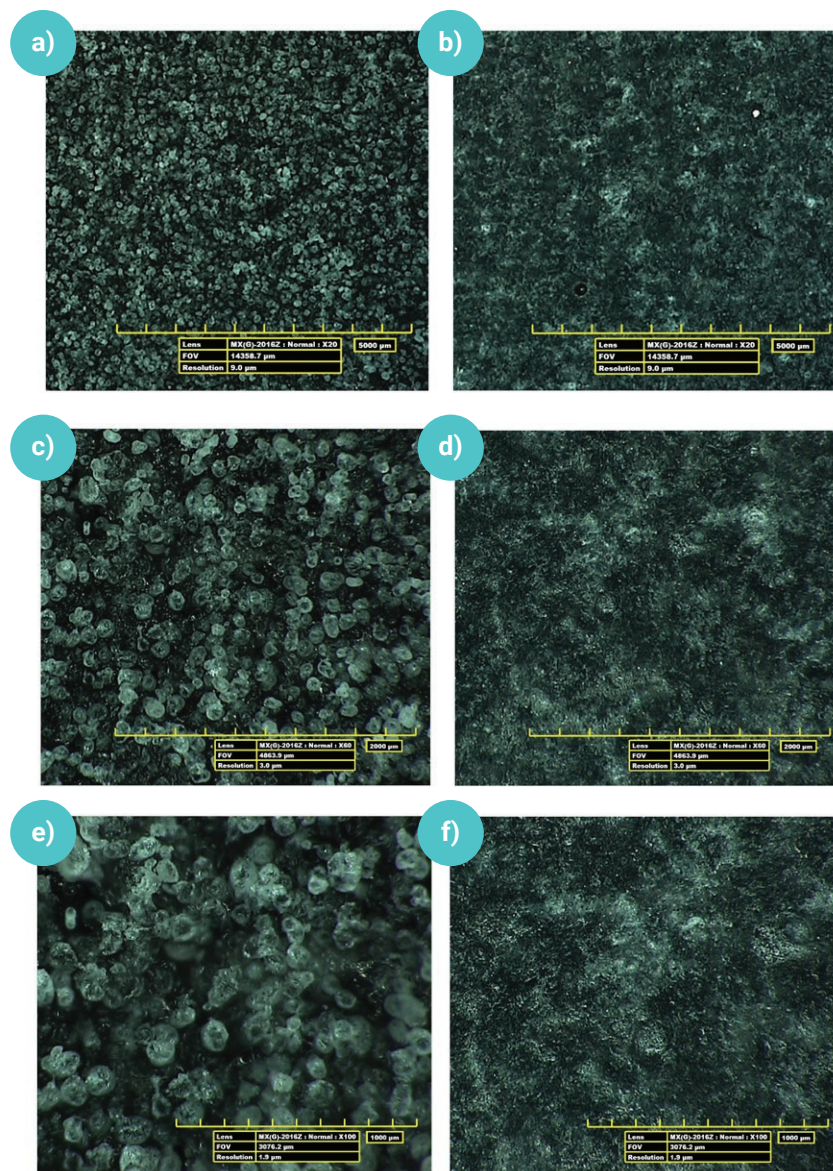


Figure 4. Surface microscopy of as-printed (a, c and e) and processed (b, d and f) parts at 20x; 60x and 100x magnifications

Dimensional Variation

4 dimensional pyramids were printed to compare the effect of chemical smoothing as post-processing on part dimensions (Figures 5 to 8). The parts were scanned both after printing and chemical smoothing. The optical 3D scanner ATOS with the associated software ATOS Professional was used for the measurements. The distance measurement was done on the opposite surfaces both inside and outside in x- and y-direction. On average the results reveal a slight shrinkage after processing compared to the as-printed parts of no more than 0.22mm (0.25%) after printing and no more than 0.39mm (0.4%) after vapour smoothing compared to the original STL model (Figures 7 and 8).

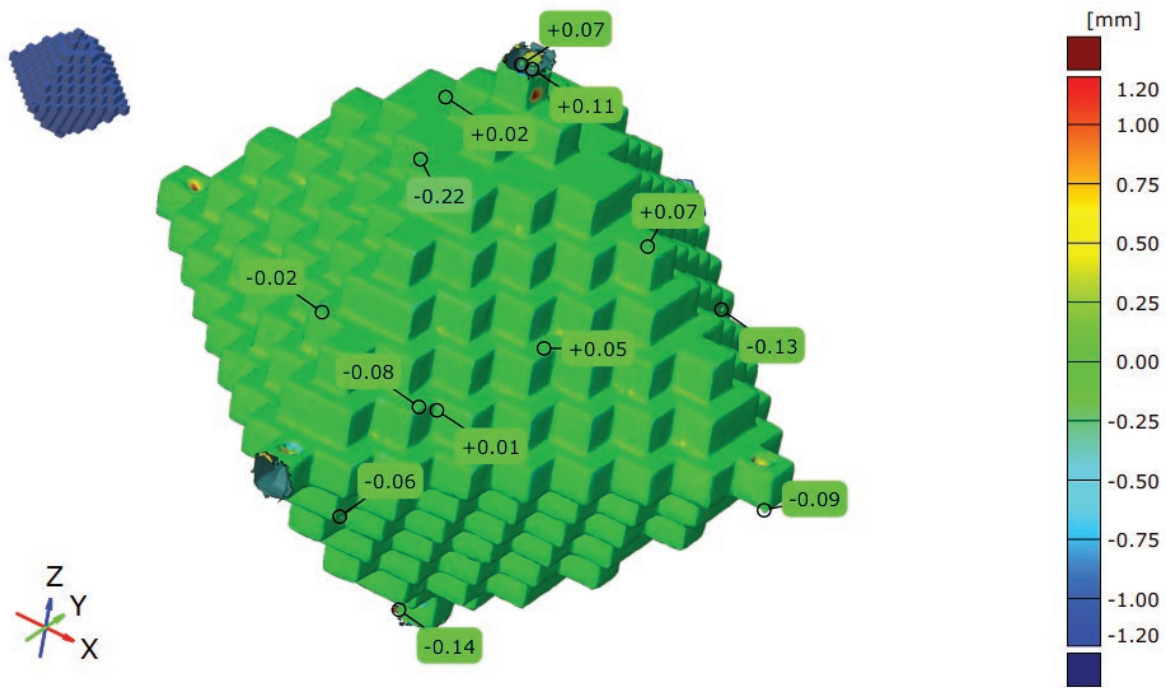


Figure 5. Variations on as-printed sample no.1 compared to the original STL model

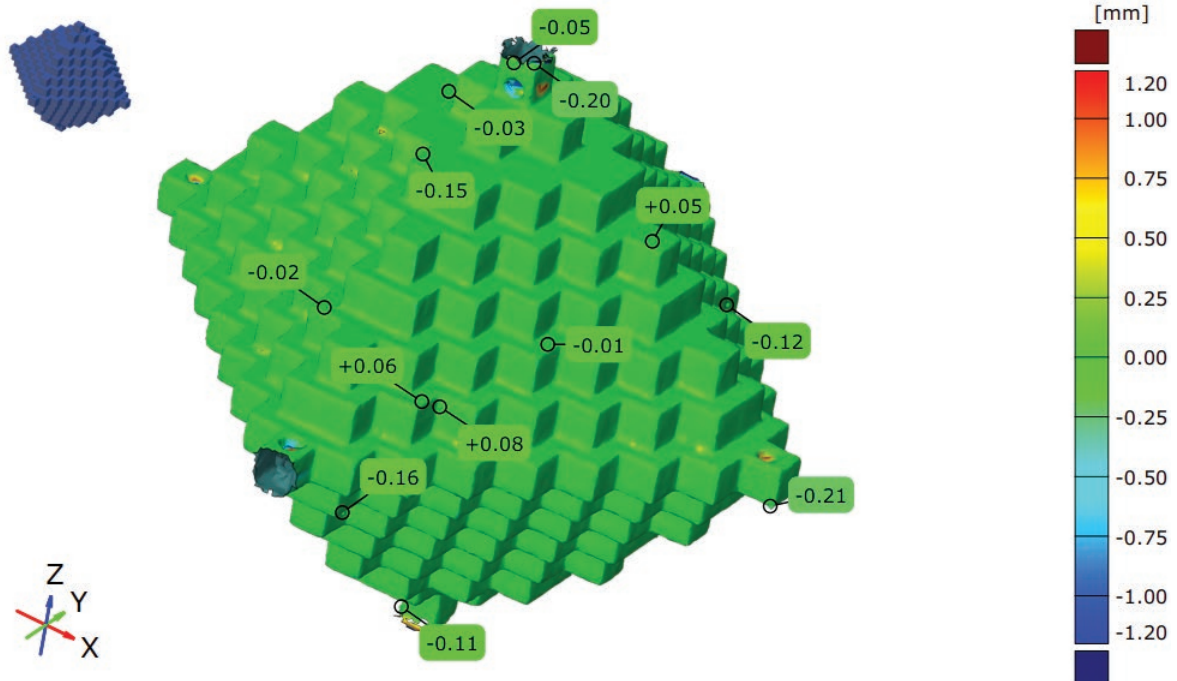


Figure 6. Variations on as-printed sample no.2 compared to the original STL model

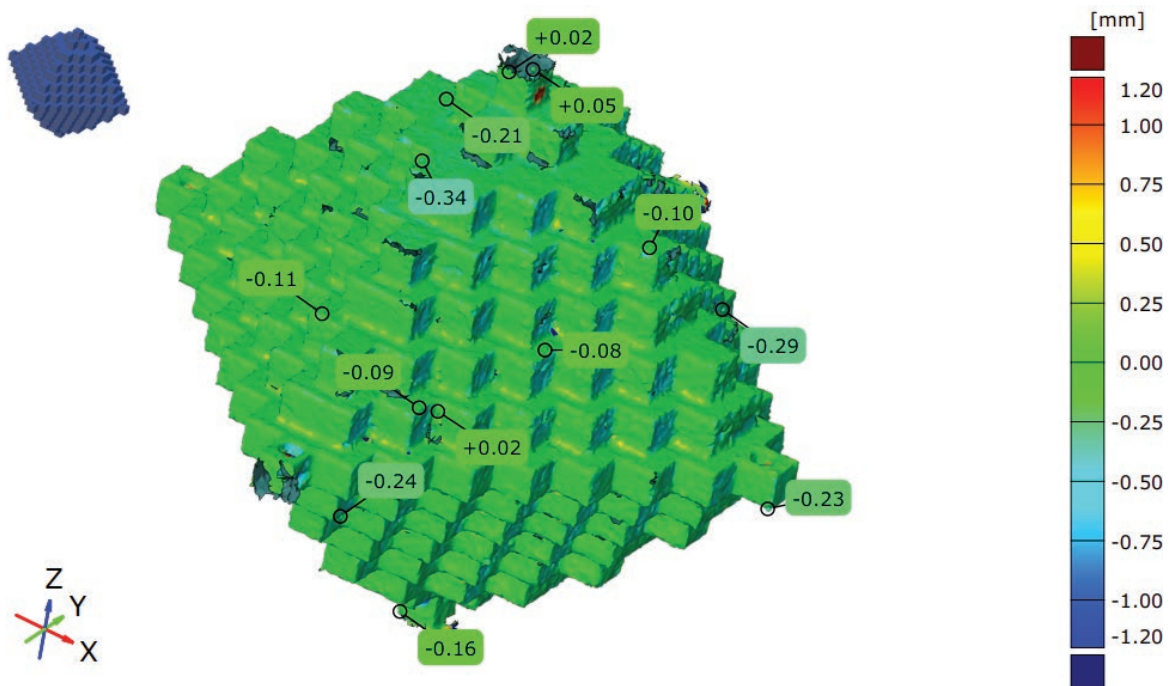


Figure 7. Variations on vapour smoothed sample no.3 compared to the original STL model

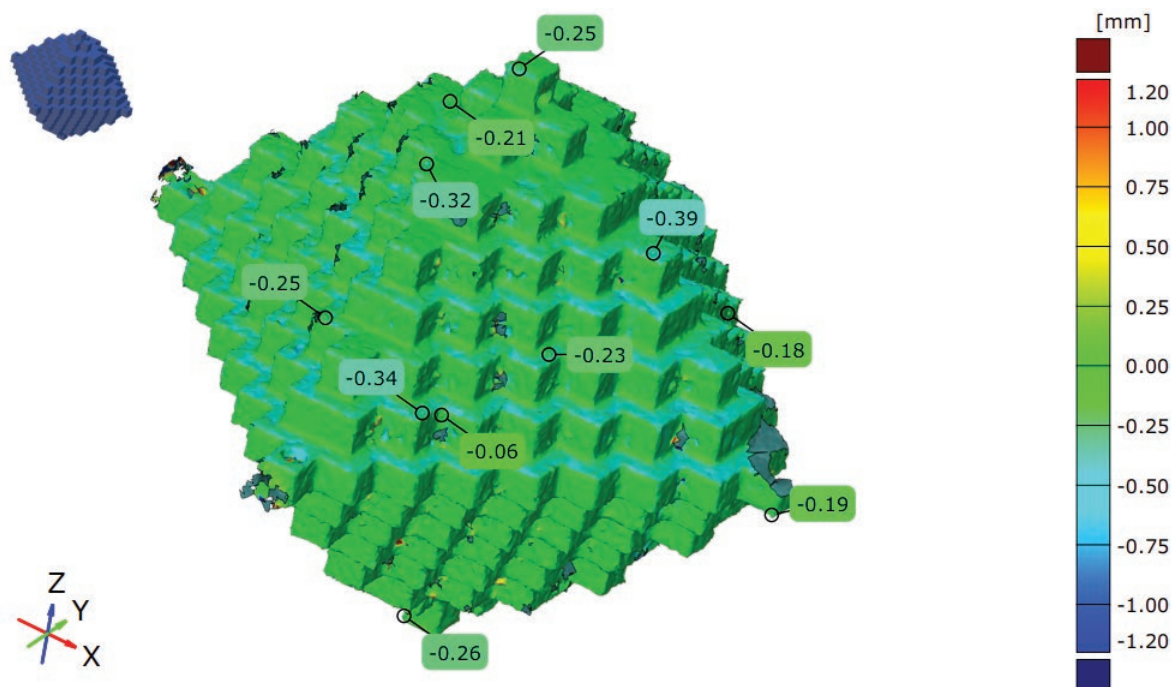


Figure 8. Variations on vapour smoothed sample no.4 compared to the original STL model

Mechanical Properties

Mechanical test results are provided in the Tables 2 and 3. Samples printed in both XY and XZ directions were measured. In voxeljet's official PA12 data sheet, the UTS values are 52 (+/- 1) MPa for XY and 46 (+/- 2) MPa for Z. The reason for the discrepancy is that the data given in the material data sheet refers to prints with process parameters optimized for mechanical data. By contrast, the dogbones printed for this study were printed with parameters optimized for precision and detail. Customers can therefore choose to have parts printed with specs optimized for their own applications, tying into the open-source strategy offered by voxeljet. Among the biggest changes are increases in Elongation at break by 38.10% and 25.00% for XY and Z respectively. Tensile strength showed an improvement by 2.90% for XY samples and 4.62% for the Z printed samples. The improvements can be explained by changed crystallinity structure of the material, closed microcracks and surface pores. Young's modulus did not show significant variations from the reference as-printed samples.

Table 2. Mechanical test results of samples printed in XY direction

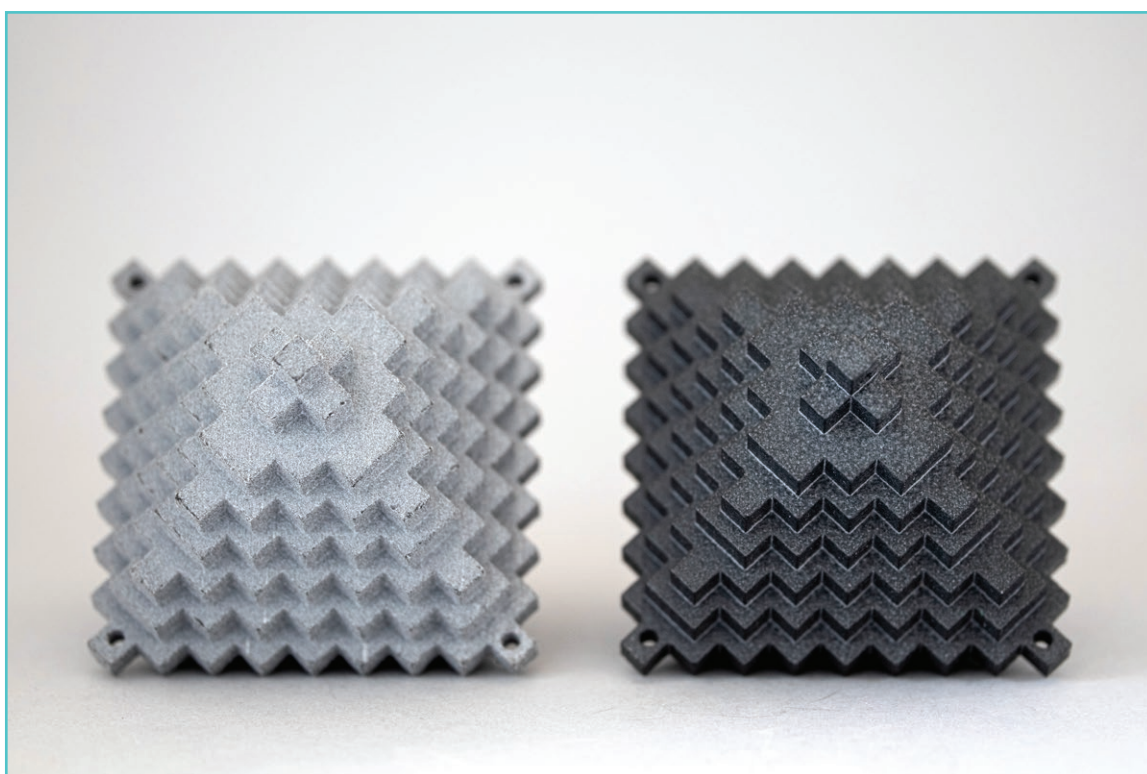
Samples printed in XY						
Specimen	Raw			Chemically Smooth		
	Young's modulus (Mpa)	Tensile strength (Mpa)	Elongation at break (%)	Young's modulus (Mpa)	Tensile strength (Mpa)	Elongation at break (%)
1	1550	46.8	6	1480	44.5	7.9
2	1510	47.5	6.6	1490	45.7	8.6
3	1490	46.5	7.1	1440	45.6	10
4	1410	39.2	5.3	1480	48.1	11
5	1571	46.6	6.9	1490	46.1	8.6
6	1490	43.8	6.6	1530	48.4	8.1
7	1590	45.8	5.3	1530	47.3	7.2
8	1550	45.2	6.7	1490	44.7	8.9
9	1370	37.6	5.3	1460	45.8	11
10	1570	47.8	7.2	1540	45.7	7.6
11	1590	46.6	6	1510	46.4	7.5
Mean	1520	44.9	6.3	1490	46.2	8.7
Std. dev	72.9	3.39	0.72	30.4	1.26	1.3
% change				-1.97%	2.90%	38.10%

Table 3. Mechanical test results of samples printed in XZ direction

Samples printed in XZ						
Specimen	Raw			Chemically Smooth		
	Young's modulus (Mpa)	Tensile strength (Mpa)	Elongation at break (%)	Young's modulus (Mpa)	Tensile strength (Mpa)	Elongation at break (%)
1	1610	41.4	3.7	1530	39.9	3.5
2	1610	42	4.2	1520	42.5	4.9
3	1580	41.8	3.9	1540	44.6	5.7
4	1540	25.1	1.8	1560	43.5	5.3
5	1570	39.8	3.3	1410	33	3.2
6	1610	34.4	2.6	1530	36.1	2.8
7	1620	27.6	1.9	1420	22.1	1.6
8	1590	42.4	4.1	1640	45.2	5
9	1600	26.1	1.7	1520	28.5	2
Mean	1592	36.0	3	1519	35.6	3.5
Std. dev	25.39	7.44	1.03	65.8	8.03	1.5
% change				-1.29%	4.62%	25.00%

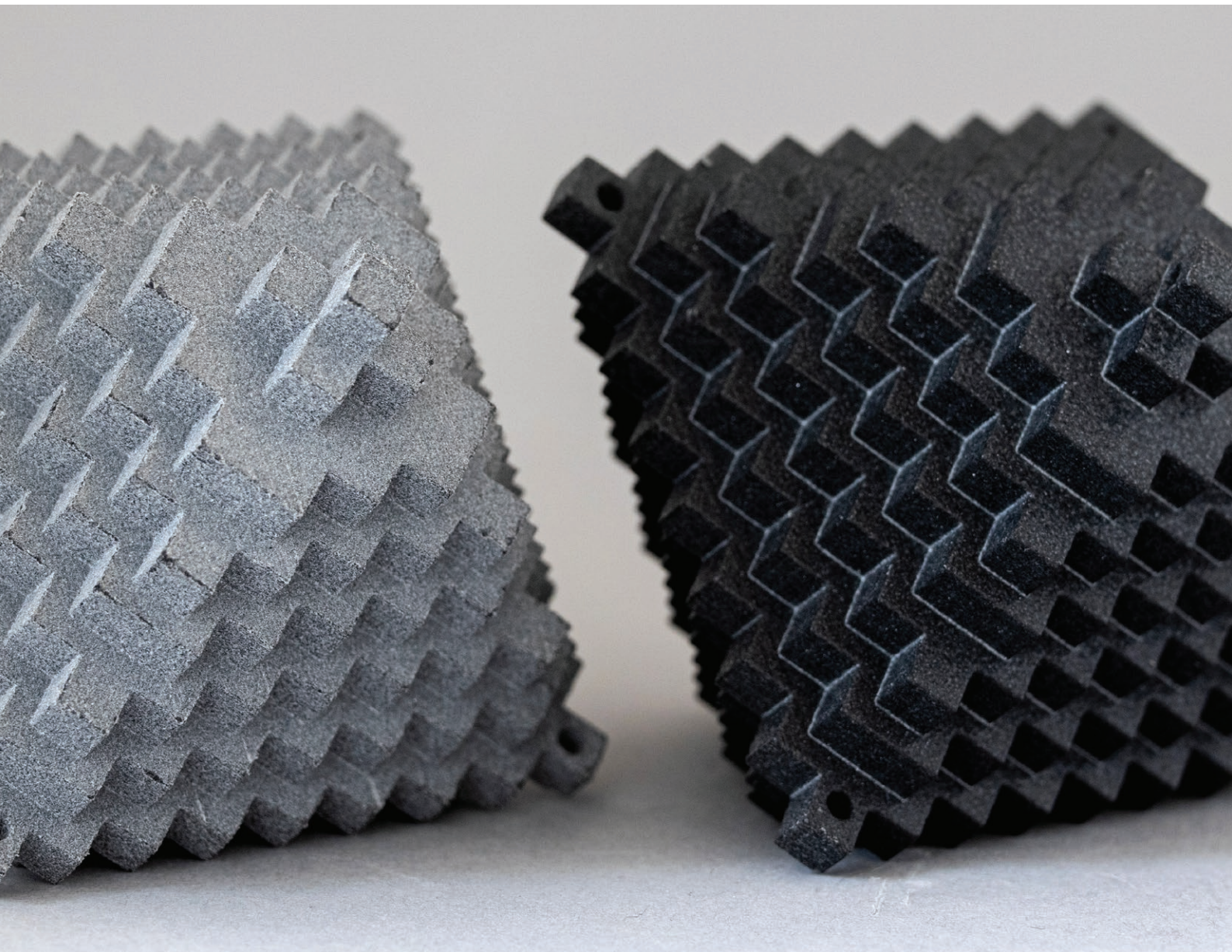
Conclusions

Samples printed via voxeljet HSS method can be post-processed and are compatible with AMT PostPro chemical vapor smoothing technology. The process delivers significant improvements in surface smoothness, elongation at break and general surface morphology without damaging or degrading the materials whilst providing uniform results. PA12 powder has unique functional, flexible properties suited for production, and in combination with PostPro chemical vapor smoothing technology delivers superior performing 3D printed components, enabling high performing parts for a comprehensive range of applications.



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