3D-MODEL

Vapor Smoothing of HP Parts Printed Using HP Multi Jet Fusion (MJF) Technology With AMT's Green and Sustainable PostPro Pure® Consumable

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The PostPro® vapor smoothing technology by AMT is an automated post-processing solution that surface treats thermoplastic polymer 3D-printed components. PostPro® is a patented and enabling technology, which reduces lead-times and operational costs, providing the 'missing piece' in the digital manufacturing chain. The technology uses the innovative consumable 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 Laser Sintering (SLS), HP Multi Jet Fusion technology (MJF), High Speed Sintering (HSS), or Fused Deposition Modelling technologies (FDM).

Extensive testing was conducted to characterize the impact of vapor smoothing using PostPro® Pure, on the material properties of parts printed using HP 3D High Reusability (HR) PA 12 material, enabled by Evonik. The tests focused on the surface quality, mechanical properties, and biological toxicity. Both HP's traditional gray HP 3D HR PA 12, enabled by Evonik (printed via HP 5200) and white HP 3D HR PA 12 W (printed via HP Jet Fusion 5400W Series 3D Printing Solution) materials were tested. The results demonstrated that AMT PostPro® vapor smoothing improved the surface quality of the parts without sacrificing mechanical performance and confirmed that the processed parts exhibited no cytotoxic effects.

HP MJF Technology Process

HP's Multi Jet Fusion (MJF) technology is a powder-based additive manufacturing platform which utilizes precise inkjet print heads to apply a fusing agent and detailing agent, selectively onto a fine layer of plastic powder. During the fusing step, the powder bed is exposed to an energy source which induces a complete melt of powder particles where the fusing agent was applied. This dual-agent approach enables tight control over print bed temperatures, and fine features, to deliver engineering-grade parts.

HP MJF technology is uniquely designed for production purposes. Engineered for high throughput and low part cost, MJF's area-wide fusing process enables the printing of an entire print layer in a single pass, significantly reducing manufacturing times compared to other additive manufacturing technologies. The technology delivers excellent mechanical properties and dimensional accuracy, making it ideal for large-scale manufacturing of functional, end-use parts.

PostPro® Vapor Smoothing Technology

Printed material surfaces exhibit rough, powdery and porous characteristics, limiting the use of such parts in various applications. AMT's PostPro® vapor smoothing process solves these issues and produces smooth, sealed surfaces which are completely free of loose un-sintered powder. The patented vapor smoothing process can smooth a variety of thermoplastic polymers including PA12, PA11, PA6, TPU, ULTEM 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 adjustable parameters within the process chamber to achieve the required surface finish.

PostPro® Pure sets the benchmark for sustainability in post-processing. From the way it is manufactured, to its raw materials, and its application, all contribute to an environmentally responsible solution. It is non-hazardous, non-halogenated, non-benzene derivative and is FDA-approved. Additionally, PostPro® machines are designed with this green consumable in mind, ensuring high-performance results while consuming less energy. PostPro® Pure is food compatible per FDA's 21 C.F.R. regulations for 3D-printed food-contact articles and also meets the relevant requirements of EU regulations for materials and articles used for food contact as described in Regulations (EC) 1935/2004, (EC) 2023/2006 and (EC) 10/2011.

AMT's PostPro® Pure consumable provides a green and sustainable post-processing solution to deliver repeatable and smooth parts with sealed surfaces to avoid liquid or gas uptake. Processed parts have an improved aesthetic whilst also having an 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

Two different materials were evaluated: HP HR PA 12 W (white material printed using HP Jet Fusion 5420W Series 3D Printing Solution with balanced mode) and HP HR PA 12, enabled by Evonik (gray material printed using the HP Jet Fusion 5200 3D Series Printing Solution with balanced mode) in both XY and XZ directions (see Figure 1). Before smoothing, the parts underwent depowdering and cleaning to remove loose powder. Six tests were conducted for both as-printed and post-processed parts, these are shown in Table 1.

Table 1: Summary of tests and type of samples used in the study

Test Description	Sample Type, Size or Test standard.	HP HR PA 12 W (White)	HP HR PA 12 (Gray)	Total samples
Tensile test: strength, elongation at break, elongation at yield, modulus	ASTM D638 Type I	10XY + 10XZ	10XY + 10XZ	20XY+ 20XZ
Surface roughness	N/A	5XY	5XY	10XY
Microscopy analysis	10mm^2 square	1	1	2
Cytotoxicity	50mm x 10mm samples	3	3	6

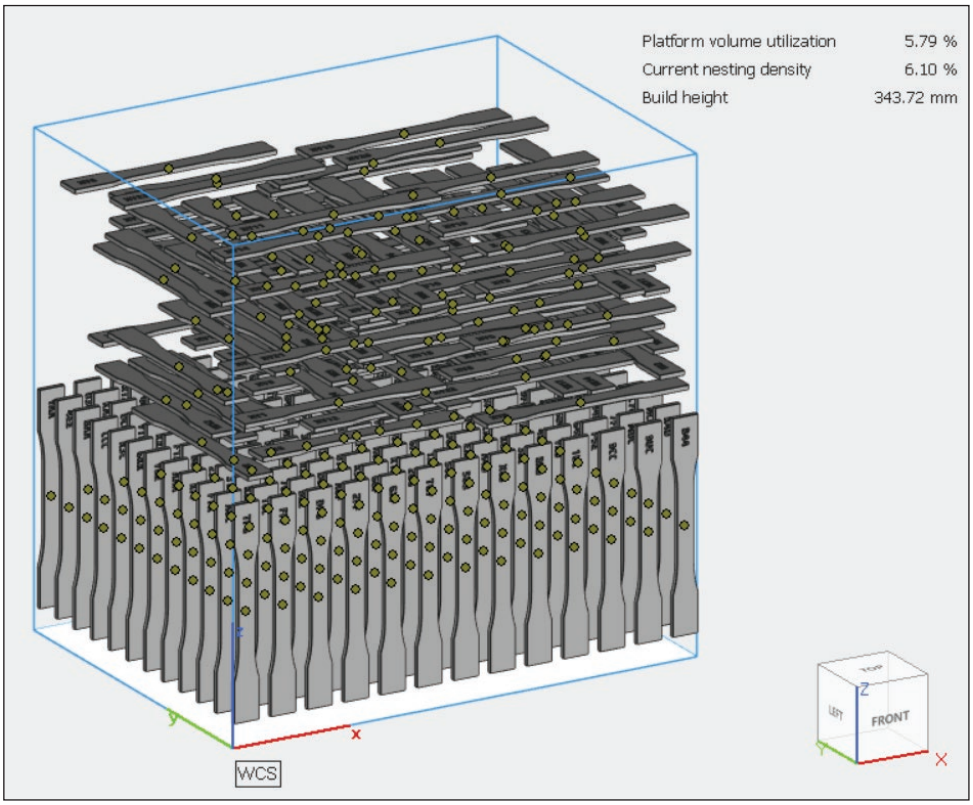


Figure 1: Test samples printing orientation

Surface Roughness

The surface roughness (Ra) of the samples was measured on the bottom-print surfaces using a Mitutoyo Surftest SJ-210 with a stylus tip radius of 2µm, a tip angle of 60° and a measuring force of 0.75kN. Five measurements at different areas of each surface were made before and after processing for 5 dogbones printed in XY direction. The results are given in Figures 2 and 3.

For the white samples, the average roughness Ra improved from 6.10µm to 1.55µm and from 5.99µm to 1.2µm for the gray samples.

Vapor smoothing improvements were comparable for both materials and the roughness improvement was applied uniformly across the part independent of its geometry. This is demonstrated by the reduction in the standard deviation between Ra values across the surfaces for both materials. These improvements were possible thanks to the controlled re-flow of the surface, removal of imperfections, un-sintered material and micro-cracks.

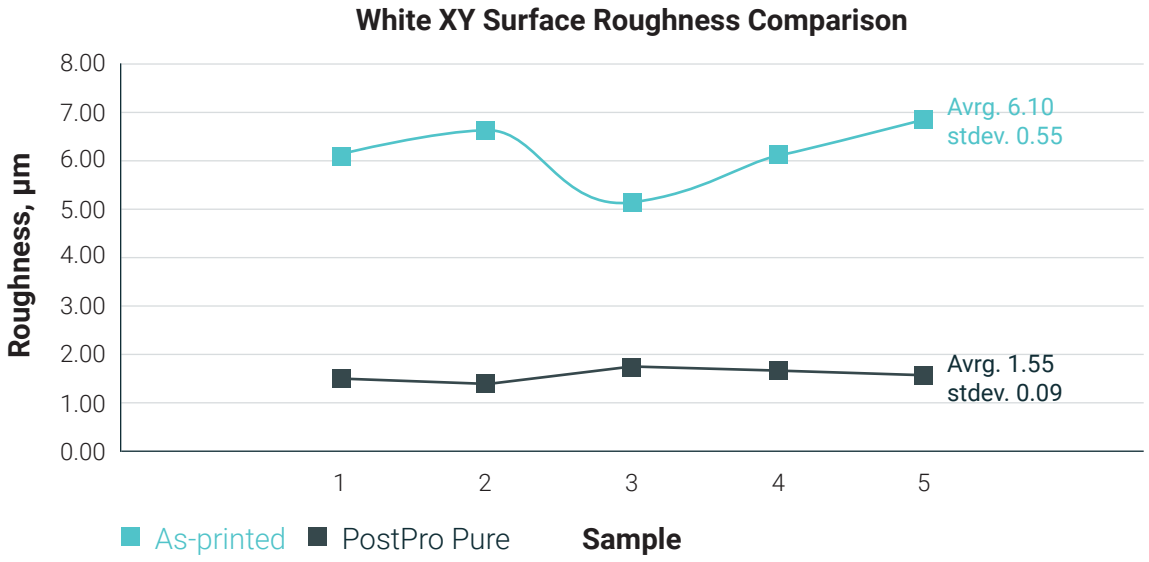


Figure 2: Surface roughness (Ra) results for the samples printed in XY direction (HP HR PA12 W)

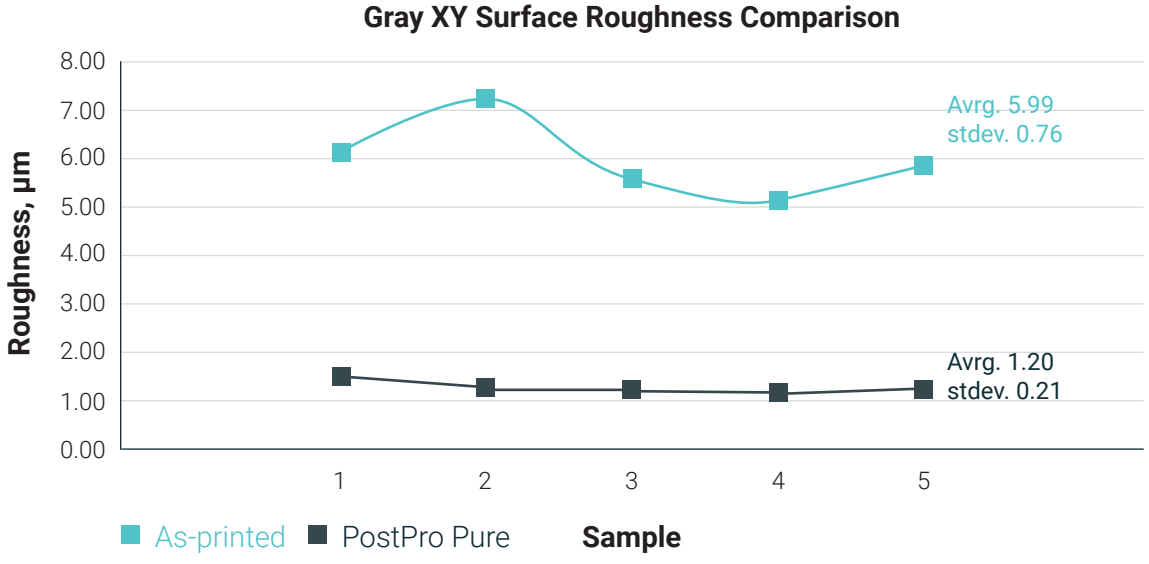
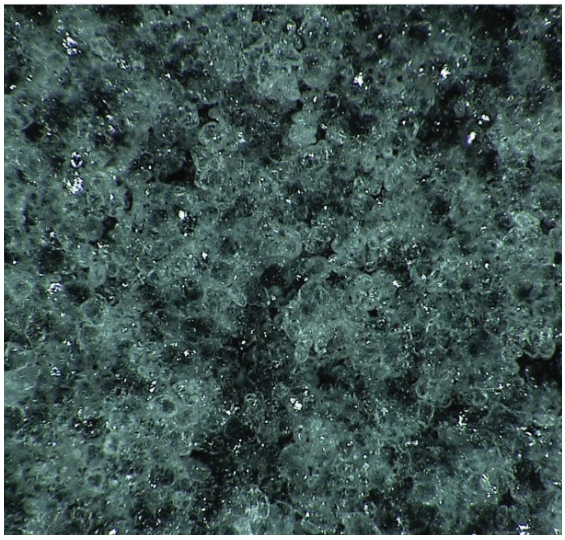


Figure 3. Surface roughness (Ra) results for the samples printed in XY direction (HP HR PA12)

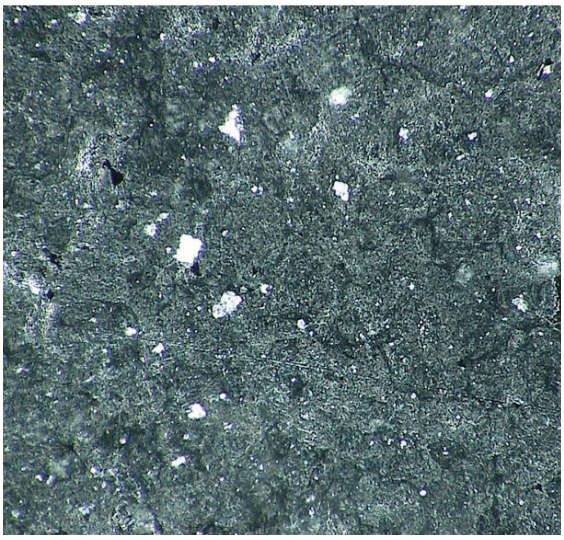
Microscopy Imaging

Surface microscopy of the smoothed surfaces was done using a Hirox KH-8700 digital microscope with MX(G)-2016Z lens. Analysis of the raw and smoothed samples was done at magnification of 100x, the results of which are shown in Figure 4.

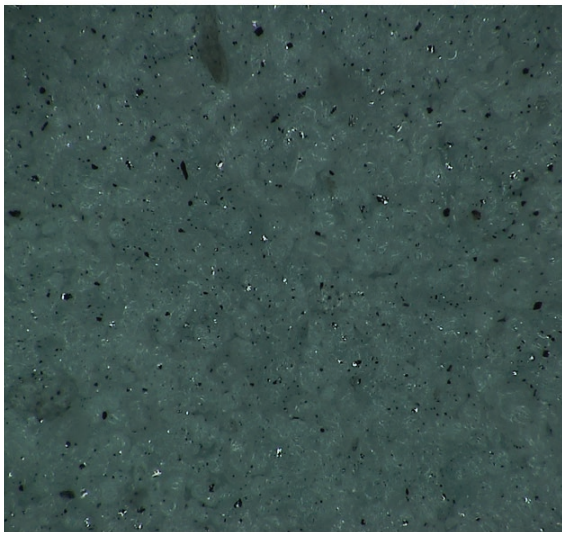
The microscopy images reveal an abundance of unsintered material, crevices and surface porosity on the as-printed HP MJF technology samples (Figure 4 A and C). These artefacts are completely removed by vapor smoothing, leaving the surface smooth, sealed and uniform (Figure 4 B and D). As a result, the processed surface opens new applications for parts printed using HP MJF technology, e.g. fluid, medical and food contact.



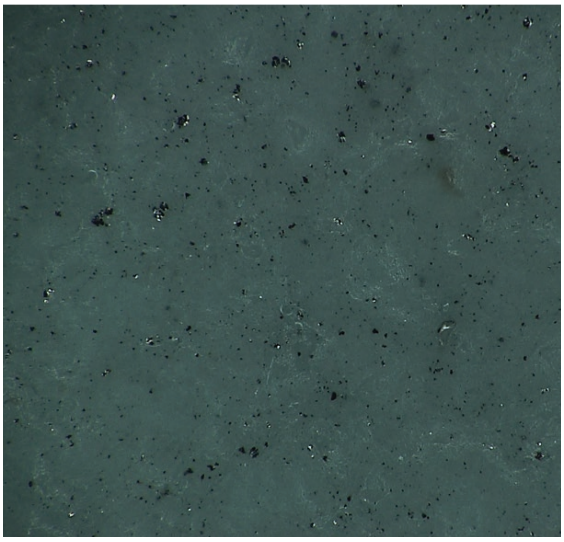
a.) As-Printed HP HR PA 12, enabled by Evonik (Gray)



b.) PostPro Pure HP HR PA 12, enabled by Evonik (Gray)



c.) As-Printed HP HR PA 12 W (White)



d.) PostPro Pure HP HR PA 12 W (White)

Figure 4. Surface microscopy of as-printed (a,c) and vapor smoothed (b,d) parts at 100x magnification

Mechanical Properties

The mechanical tests were conducted using an Instron AVE2 extensometer equipped with a 16 mm lens for non-contact strain measurement. Type 1 ASTM D638 samples with a 50 mm gage length were tested at a crosshead speed of 50 mm/min. Results based on job described in Testing Methodology, Figure 1, may vary with other jobs and geometries.

Mechanical test results for PA 12 white and gray samples are summarized in Table 2 and the Figures 5 to 8. Samples printed in both XY and Z directions were tested. PostPro® Pure treatment had a significant effect on elongation properties, with Elongation at Break increasing by 55.7% and 38.7% in PA12 White Z and XY respectively. HP 3D HR PA 12 (enabled by Evonik) Gray also showed improvements, with increases by 74.1% in Z and 21.4% in XY.

Elongation at Yield followed a similar trend, with HP 3D HR PA 12 W samples increasing by 37.8% in Z and 17.5% in XY, while HP 3D HR PA 12 Gray increased by 27.3% in Z and 10.0% in XY.

Tensile strength remained relatively stable after the treatment, with an average decrease of ~3% observed in all materials and print directions. Young's Modulus consistently decreased, with the largest reduction observed in HP 3D HR PA 12 W White Z samples (-12.1%). The decrease in Young's Modulus is normal and expected as vapor smoothing softens the material reducing its stiffness. Vapor smoothing also showed a more pronounced effect on elongation properties.

Table 2. Mechanical testing results after vapor smoothening compared to as-printed

Material	Print direction	Tensile Strength (MPa)	Elongation at Yield (%)	Elongation at Break (%)	Young's Modulus (MPa)
Vapor Smoothed HP 3D HR PA 12 W White	XY	42.21 (-4.4%)	14.79 (+17.5%)	31.28 (+38.7%)	1492 (-11.4%)
	Z	40.68 (-2.4%)	11.44 (+37.8%)	13.56 (+55.7%)	1479 (-12.1%)
Vapor Smoothed HP 3D HR PA 12 Gray	XY	49.28 (-3.8%)	13.70 (+10.0%)	25.37 (+21.4%)	1673 (-8.7%)
	Z	49.34 (-2.5%)	12.64 (+27.3%)	18.46 (+74.1%)	1749 (-8.5%)

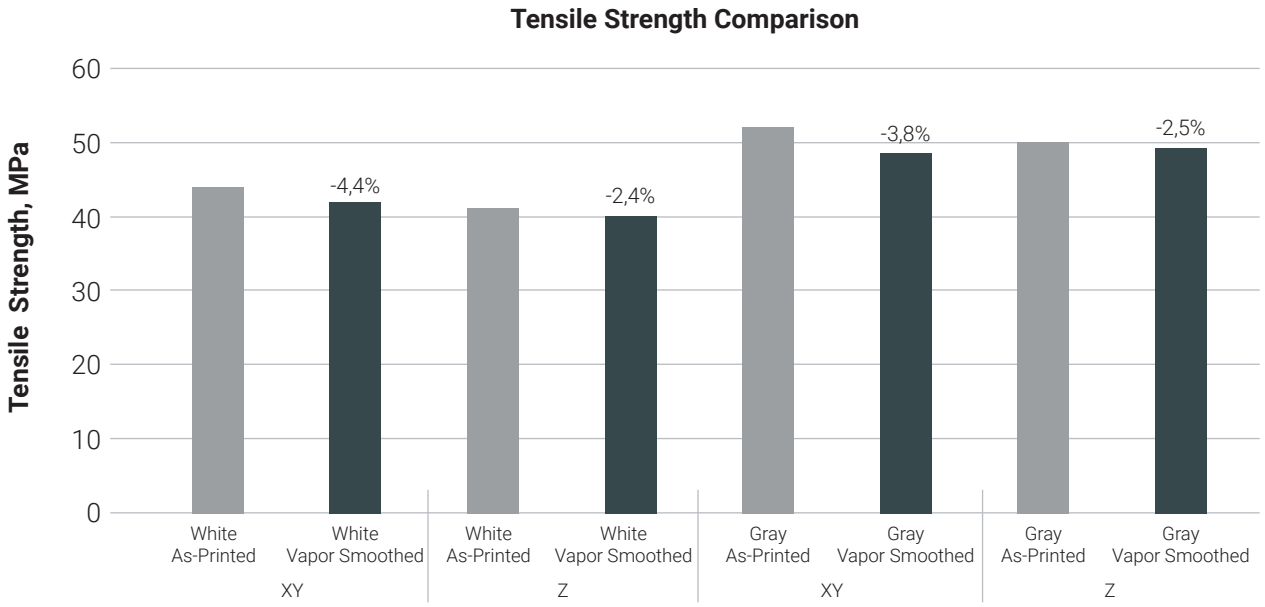


Figure 5: Tensile Strength Comparison

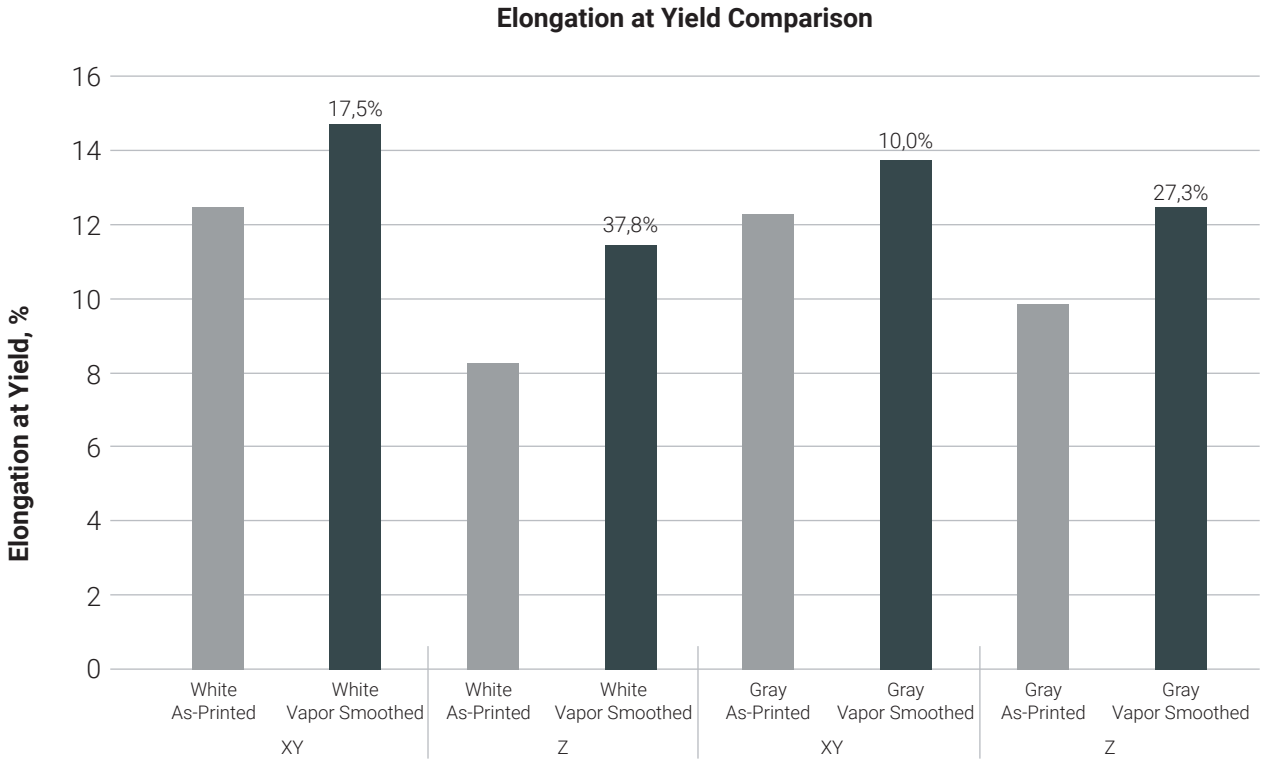


Figure 6: Elongation at Yield Comparison

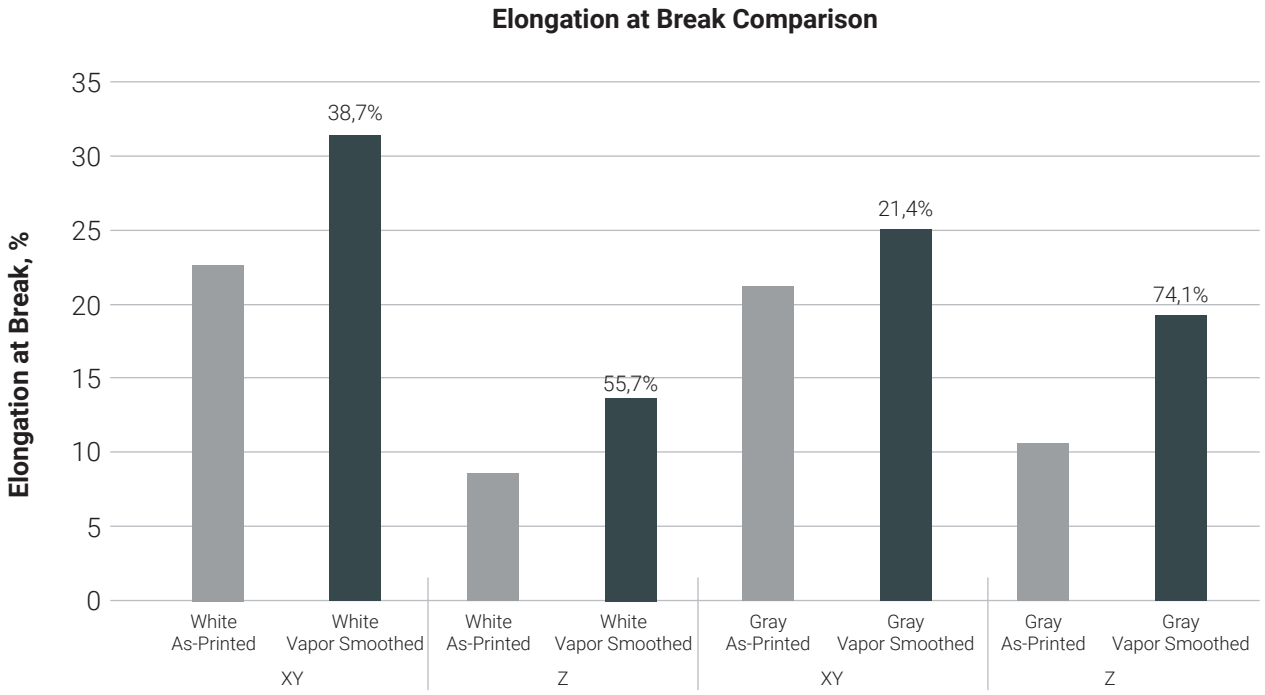


Figure 7: Elongation at Break Comparison

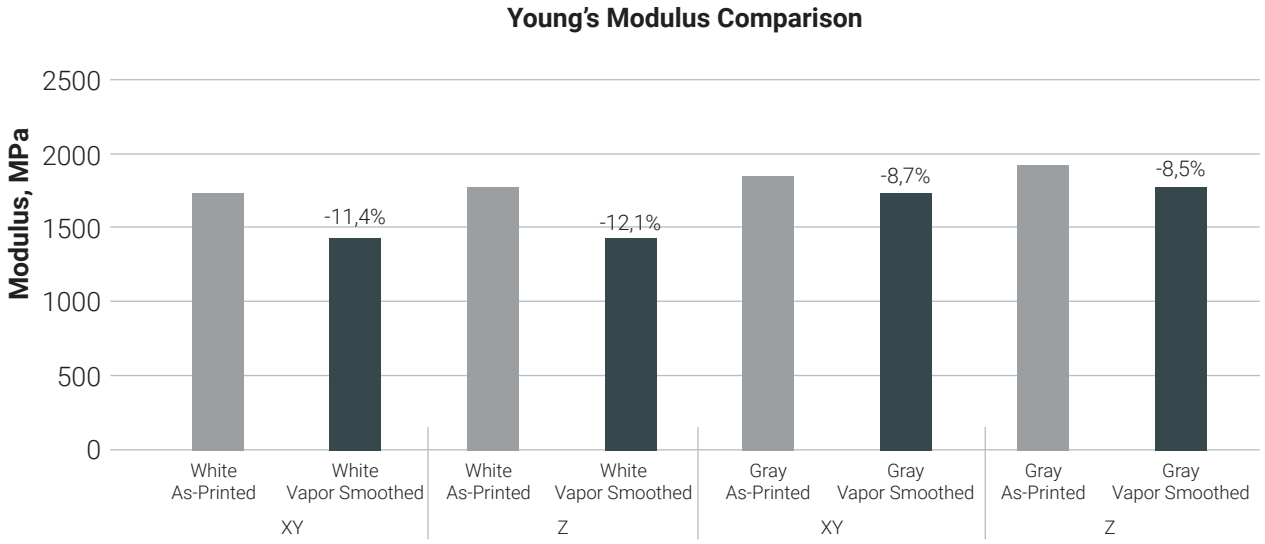


Figure 8: Young's Modulus Comparison

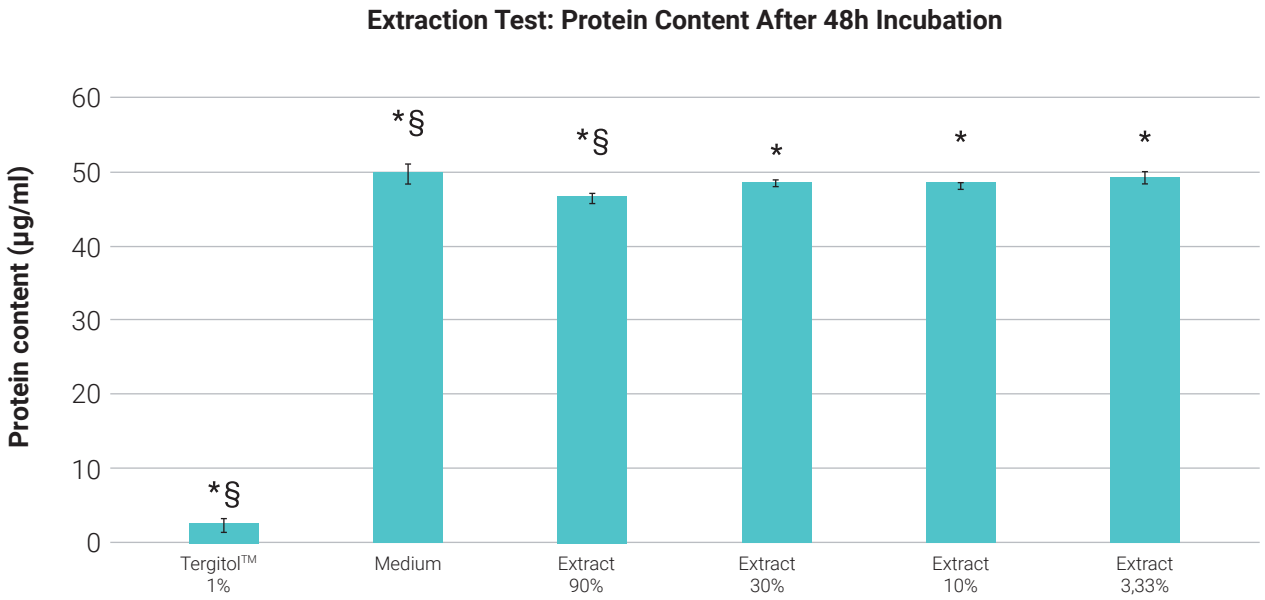
Cytotoxicity

The cytotoxicity test is a biological evaluation and screening test that uses tissue cells in vitro to observe the cell growth, reproduction and morphological effects by medical devices. Cytotoxicity is an important indicator for toxicity evaluation of medical devices as it is simple, fast and has a high sensitivity. Cytotoxicity tests were performed on both White and Gray samples smoothed with PostPro® Pure at an external European laboratory to Normative References: ISO 10993-5 (2009); ISO 10993-1 (2021); ISO 10993-12 (2021).

The material was extracted for 24 h at 37°C and a partial pressure of 5% carbon dioxide in extraction medium (DMEM medium with antibiotics, without fetal calf serum [FCS]). The material surface/ extraction volume ratio was 3 cm^2 material per ml extraction medium. After extraction, the extraction medium was sterile filtered and supplemented with sterile FCS (concentration of FCS in extraction medium: 10%). The FCS-supplemented extraction medium was pipetted under sterile conditions on pre-cultivated cells of the mouse fibroblastic cell line L929 and incubated for 48 h at 37°C and a partial pressure of 5% carbon dioxide. The extract was tested in four dilutions (90%, 30%, 10% and 3,3%). Each dilution was tested in four parallel experiments. Tergitol™ was used as a toxic control substance (concentration in the experiment: 1% v/v). Cell culture medium was used as a non-toxic control. After the 48 h incubation period the protein content of the cell culture was determined by the method according to Bradford.

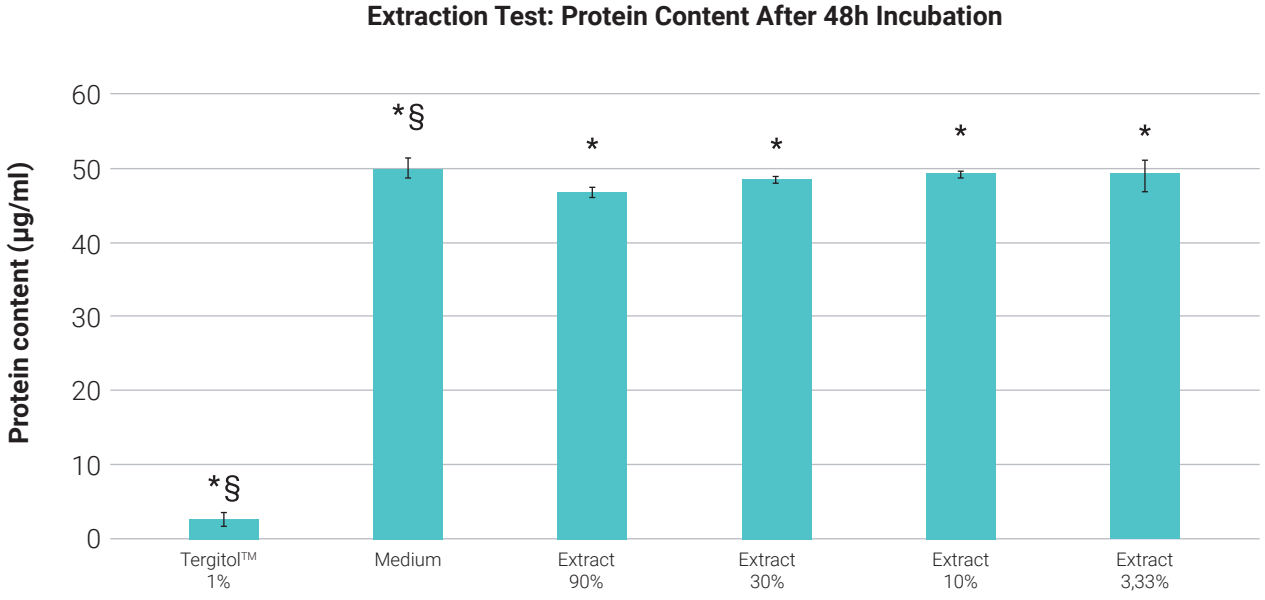
The results in Figures 9 and 10 show that in the presence of Triton X 100 in the cell culture medium, 6.0% of the protein content compared to the negative control was reached. This value is within the valid range of 15% protein content or less compared to the negative control. Materials are considered cytotoxic if the material extract leads to a protein content of the test cells of less than 70% compared to the negative control. This was not the case in these tests.

The material extracts, therefore, do not show cytotoxic effects for both HP 3D HR PA 12 W (white) and HP 3D HR PA 12, enabled by Evonik (Gray) vapor smoothed via PostPro® Pure .



Result data µg/ml	Protein content=4					
	Tergitol™ 1%	Culture medium	Extract 90%	Extract 30%	Extract 10%	Extract 3,33%
Mean	2,87	50,43	47,39	49,03	49,36	49,12
Standarddev.	0,84	1,39	0,57	0,51	0,50	0,67

Figure 9. Cytotoxicity results of HP Jet Fusion 5420W 3D Printing Solution (White) samples smoothed via PostPro Pure



Result data µg/ml	Protein content=4					
	Tergitol™ 1%	Culture medium	Extract 90%	Extract 30%	Extract 10%	Extract 3,33%
Mean	2,34	48,89	48,23	48,35	49,49	49,24
Standarddev.	0,47	1,34	0,64	0,55	0,82	1,18

Figure 10. Cytotoxicity results of HP Jet Fusion 5200 3D Series Printing Solution (Gray) samples smoothed via PostPro Pure

Conclusions

Samples printed using HP MJF technology method can be post-processed and are compatible with AMT's PostPro® Pure consumable for vapor smoothing. The process delivers significant improvements in surface smoothness, elongation and general surface morphology without damaging or degrading the materials whilst providing uniform results. The results are comparable to or better than AMT's standard consumable FA326. HP HR PA 12 W (White) and HP HR PA 12, enabled by Evonik (Gray) materials also have unique functional and flexible properties suited for production. When combined with PostPro® Pure, they deliver superior performing 3D printed components, enabling high performing parts for a comprehensive range of applications.

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