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PostPro Vapour Smoothing Ultrasint® PP Parts to Unlock New Potentials

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Abstract

Polypropylene (PP) is a common and versatile polymer used for a variety of applications in automotive, aerospace, medical, and consumer industries. It has excellent chemical resistance, robust mechanical properties, low cost and broad availability, resulting in wide variety of possible applications within the Additive Manufacturing industry. However, appropriate surface post-processing is required for many additively manufactured PP parts to be fully functional in many existing applications.

Extensive testing was done to characterize the effect of novel post-processing technology by AMT on the material properties of components printed with Forward AM's Ultrasint® PP nat 01. The testing focused on surface properties, mechanical properties, and dimensional variation. The results confirmed the excellent compatibility of Ultrasint® PP grades with PostPro® technology, producing high performance parts that can be used in a wide variety of applications

Figure 1: The vapour smoothed test specimen of Ultrasint® PP nat01 (Source: Forward AM).

The material – Ultrasint® PP nat 01

Ultrasint® PP nat 01 harnesses the properties of polyolefins for Powder Bed Fusion (PBF) technologies, making the rapid printing of individualized and functional serial production parts possible. Thanks to the well-known characteristics of polypropylene, this powder delivers excellent chemical resistance, ductility, and media tightness. Forward AM's enhanced formula goes one step beyond: In contrast to commonly used polyamides, Ultrasint® PP boasts excellent plasticity plus superior toughness, durability, and low moisture absorption. The high rigidity of Ultrasint® PP nat 01 makes the material especially well-suited for technical applications and durable 3D printed polypropylene parts, from prototyping through to functional light-weight parts. Moreover, this material is an economically attractive alternative to commonly used PA12, making it an interesting choice to expand the existing range of 3D printing applications and volumes.

PostPro® Chemical Vapor Smoothing Technology

Additive Manufacturing Technologies (AMT) has developed and introduced a new method to automatically smooth additively manufactured PP parts using a sustainable, green and industry-accepted solvent. This technology allows additively manufactured PP parts to compete with traditionally manufactured PP parts on quality and cost-per-part. The patented novel Vapor Smoothing Technology can be used on parts printed using Laser Sintering, HP Multi Jet Fusion, High Speed Sintering, and Fused Deposition Modelling technology.

During the process, the top layer surface material becomes mobile and is topologically rearranged, creating a sealed and smooth surface. The accuracy of the smoothing is rapidly controlled by instantly changing chamber conditions to achieve the required surface finish. The output of the machine results in smooth parts that show negligible dimensional or structural variation, while producing fully functional PP parts. Presented are the results from the prototype process replicating the commercial machine, which is due to be released.

Methodology

Parts used for this study were printed on an Prodways ProMaker P1000 X printer. The parts were thoroughly cleaned and de-powdered before the chemical smoothing process. In total, 13 different tests were performed on both as-printed and post-processed parts, summarized below in Table 1:

Table 1: Overview of tests performed

Test	Standard
Tensile strength	DIN EN ISO 527-2
Tensile elongation @ break	DIN EN ISO 527-2
Tensile modulus	DIN EN ISO 527-2
Flexural modulus	DIN EN ISO 178
Charpy impact unnotched	DIN EN ISO 179-1:2010
Charpy impact notched (smoothed & notched)	DIN EN ISO 179-1:2010
Charpy impact notched (un-smoothed & notched)	DIN EN ISO 179-1:2010
Dimensional variation	N/A
Haze and light transmission	ASTM D1003-13
Abrasion Resistance	DIN ISO 4649
Surface roughness	ISO4287
Optical microscopy	N/A

Surface Roughness

The surface roughness Ra of the samples was measured using a Mitutoyo Surftest SJ-210 with a stylus tip radius of 2µm, tip angle 60° and measuring force 0.75kN. Five measurements at different areas of each surface were taken before and after processing, and the average was then calculated. The average surface roughness for each sample is shown in Figure 2:

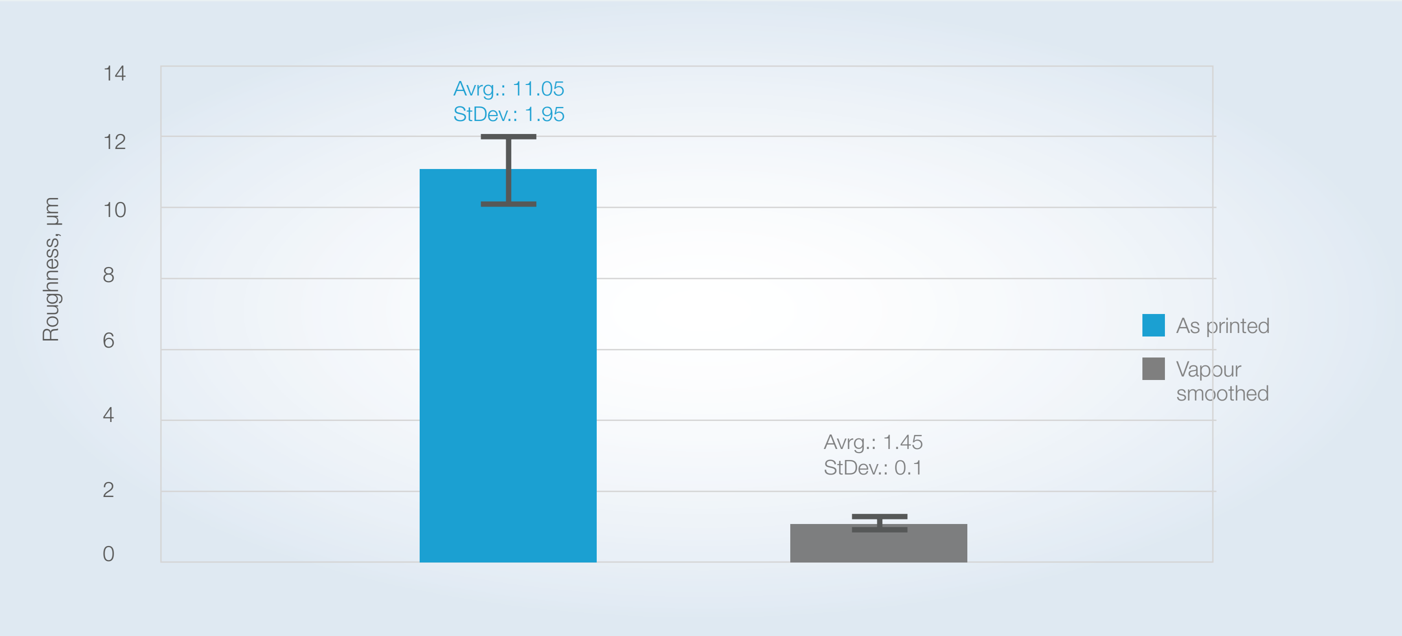

Figure 2: Surface roughness results

The average roughness Ra for unprocessed specimens was measured to be 11.04µm, with standard deviation reaching 1.95. The smoothing reduced average roughness to around 1.45 µm with standard deviation of just 0.1. Low standard deviation represents repeatability across the surface. A conventional injection-molded surface roughness Ra for polypropylene can be found to be within 0.1 – 0.5µm.

Microscopy

Surface microscopy of Ultrasint® PP surfaces smoothed with AMT technology was undertaken using a Hirox KH-8700 digital microscope with a MX(G)-2016Z lens. The polymer surfaces were analyzed at magnifications of 20x and 100x. The results are shown in Figures 3 and 4 below:

a) Semi-sintered material all across the surface

b) Surface pores

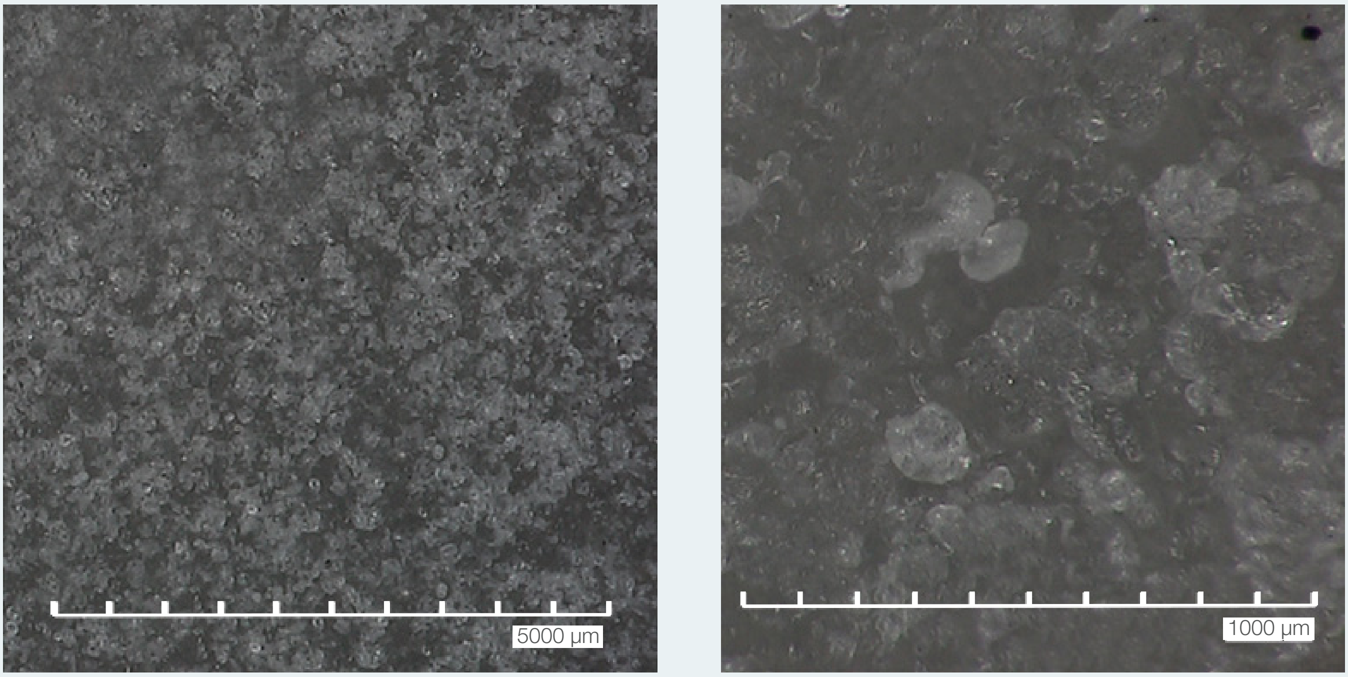

Figure 3: Microscopy image of unprocessed BASF Ultrasint® PP sample surface: a) Image at x20 magnification and b) x100 magnification.

a) Uniform surface

b) Uniform surface

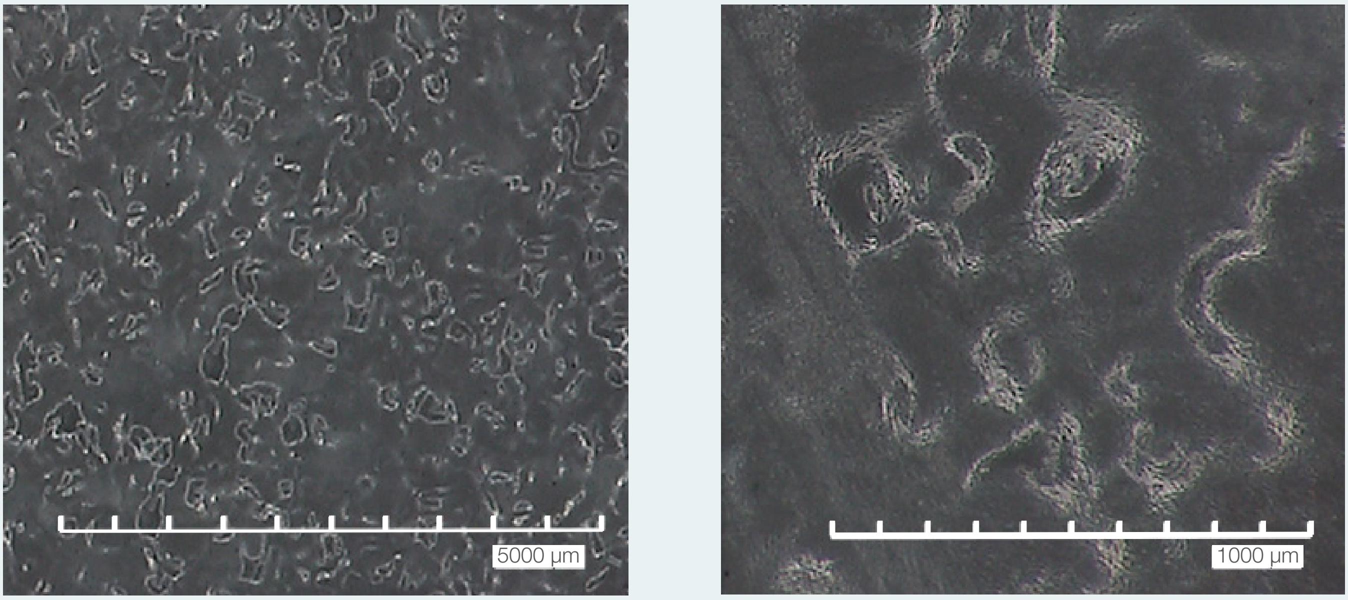

Figure 4: Microscopy image of processed BASF Ultrasint® PP sample surface: a) Image at x20 magnification and b) x100 magnification.

Microscopy images (µm scale) reveal the abundant presence of unsintered material and surface porosity on the as-printed surfaces (Figures a and b). Completely different surface morphology can be observed on the processed surface (Figures 3 a and b): No semi-sintered powder or surface porosity remains. This feature is especially relevant if a contamination-free, clean surface is needed, for example when the material is used to print fluid storage or flow parts for the automotive industry.

Light Transmittance

Two 49.5mm x 49.5mm square samples , as-printed and smoothed, were submitted to a third partylaboratory for evaluation of haze and light transmittance in accordance with ASTM D1003-13 Appendix X2. Specimens were stored in the laboratory at 23 ± 2°C and 50 ± 10% relative humidity for at least 40 hours prior to testing.

Haze and luminous transmittance were determined using a WGT-S haze meter, MSG/EQP/18/022, with CIE Illuminant C. The thickness of each specimen was measured in three areas, away from the test areas, using a calibrated micrometer, MSG/EQP/12/126. Three measurements were taken in different areas on each specimen. The results show vapour smoothed samples become more translucent (Figures 5 and 6). This translucency effect can be explained by ordered structure of the polymer outer layer after smoothing.

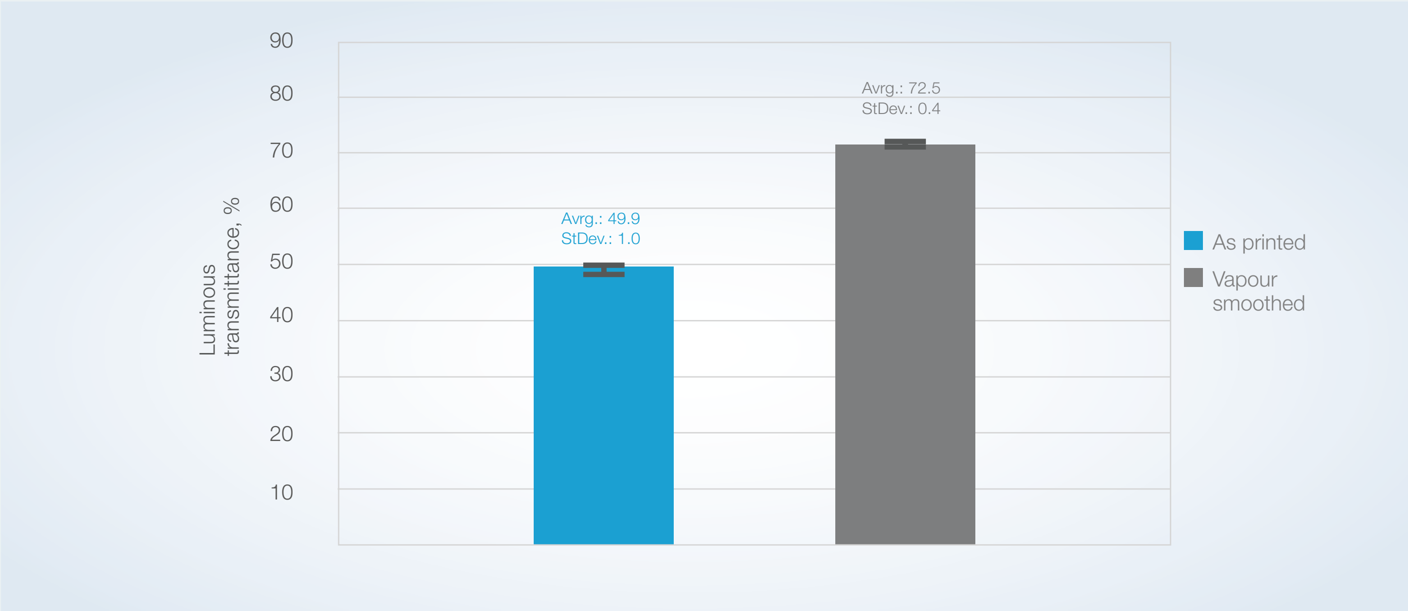

Figure 5: Luminous transmittance results

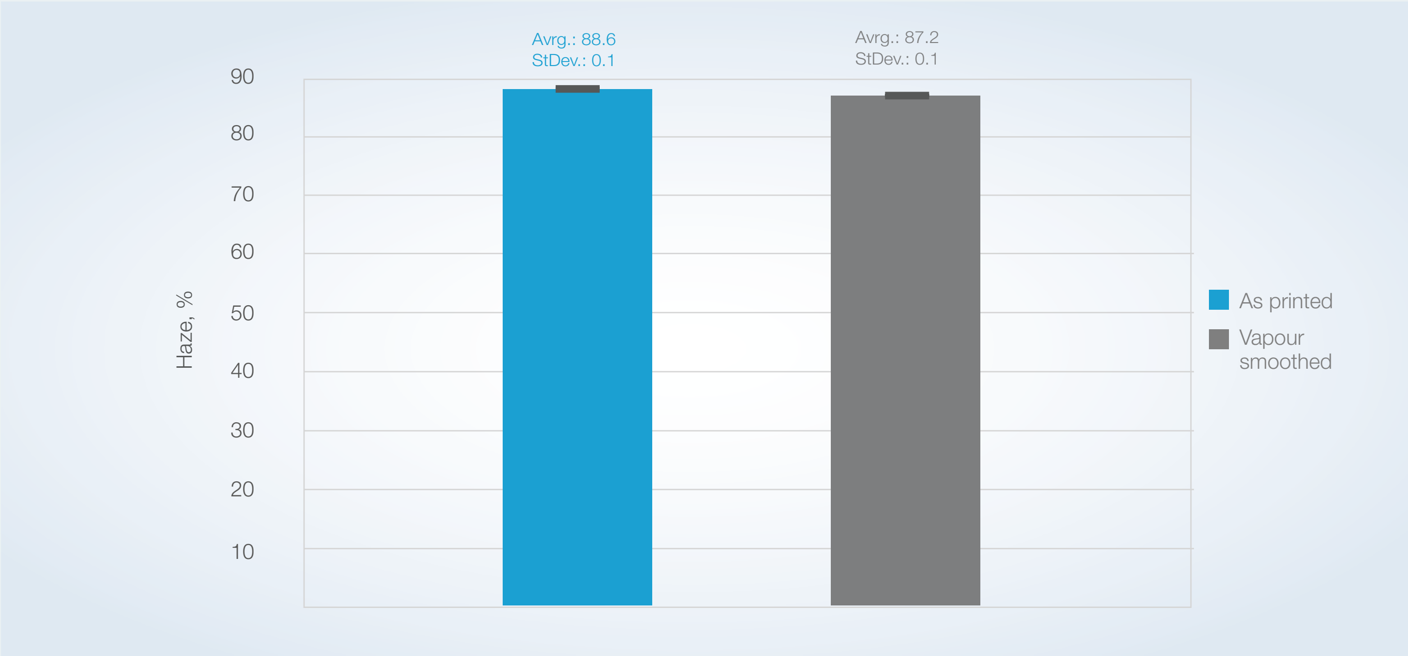

Figure 6: Haze results

Dimensional Variation

Five dimension test cubes were analyzed for dimensional change on the X, Y and Z axes before and after processing. The dimensions of each test cube are 50x50x50mm with a stair steps geometry of an edge length of 5mm. Each sample was scanned before and after chemical vapour smoothing with optical 3D scanner ATOS Core 200. The STL file generated by the 3D scan is aligned to its original CAD design by means of best-fit alignment (see Figure 9 & 10).

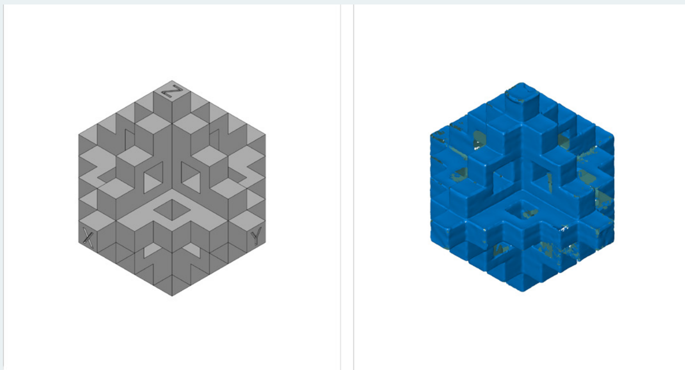

Figure 9: Graphical representation of target and actual geometry;

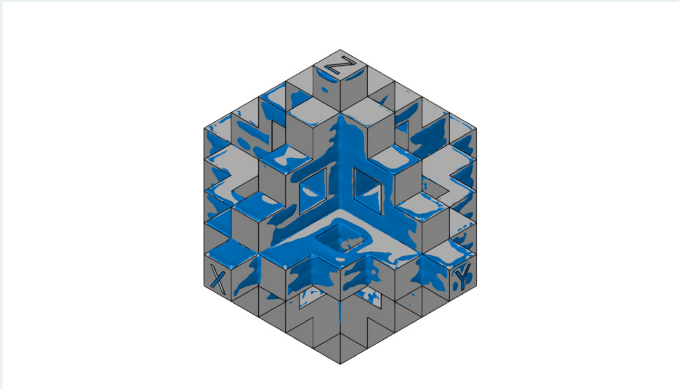

Figure 10: Best-fit alignment with subsequent geometric alignment

Subsequently, auxiliary planes are constructed on the outer surfaces of the stair steps geometry and its distance measured in X, Y and Z axes (see Figure 11).

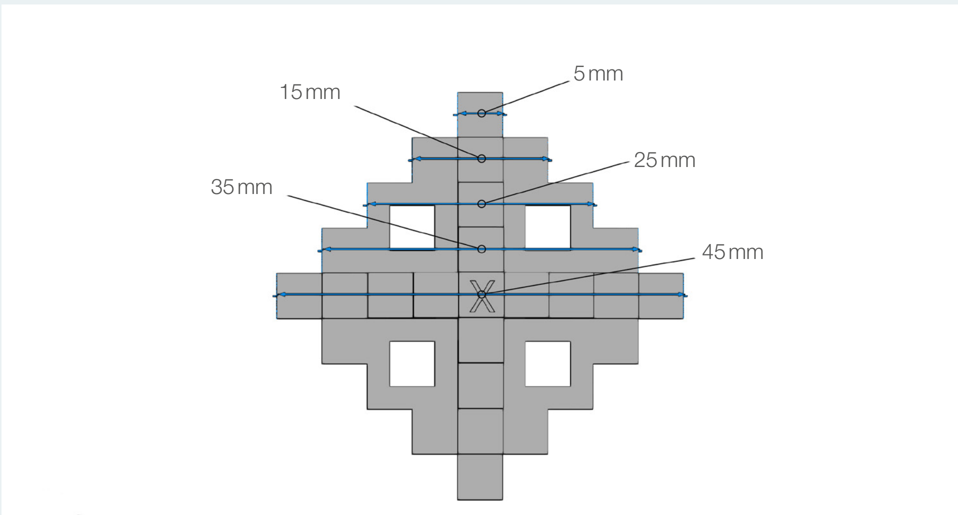

Figure 11: Geometric comparison

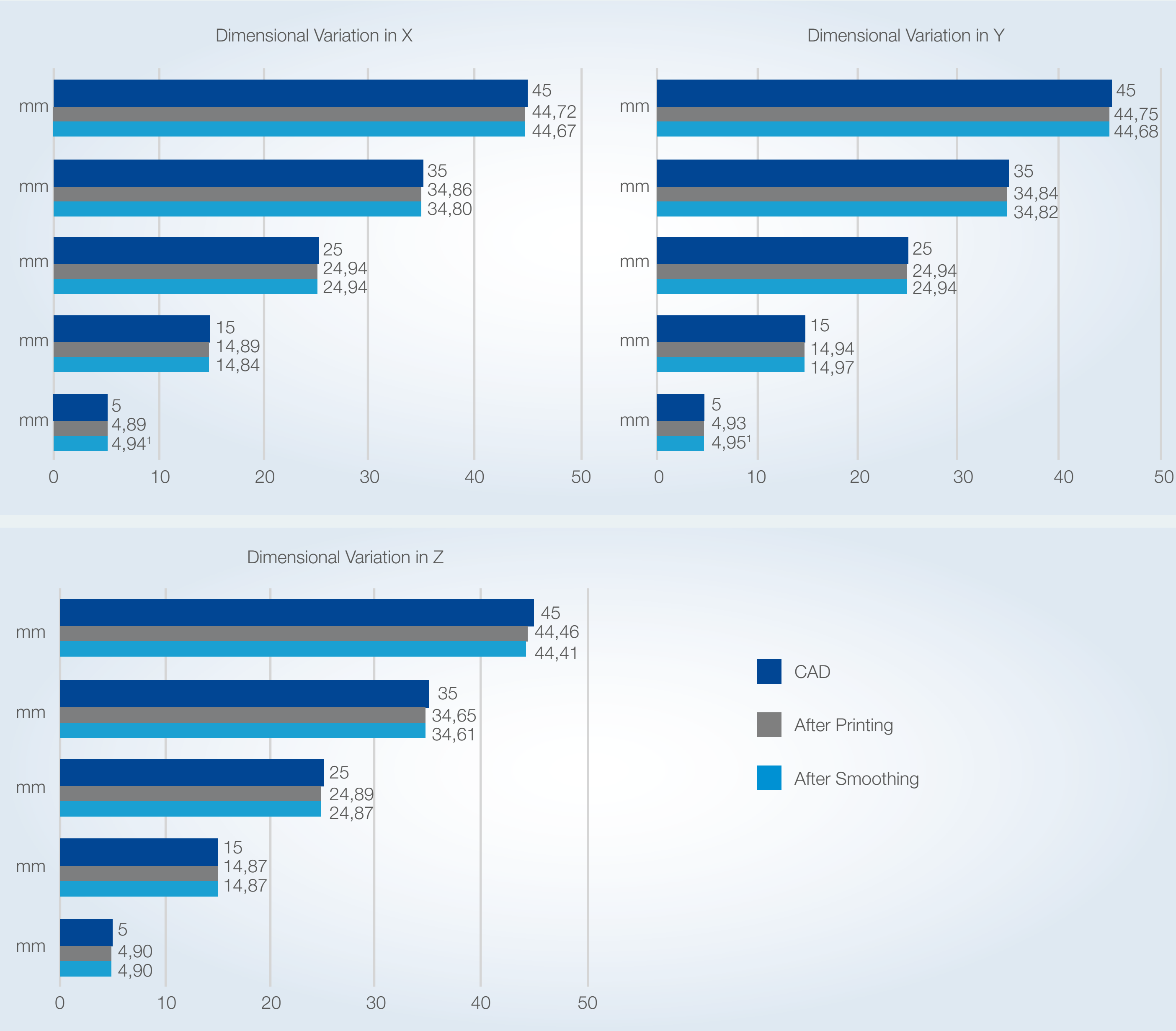

Figure 12: Distance measurement values between the CAD model, as-printed and vapor smoothed part

Figure 12 shows a comparison of the distance measurement values between the CAD model, as-printed and vapor smoothed part in X, Y and Z directions . A slight shrinkage can be observed for vapor smoothed parts at measurements longer than 20mm. The dimensional variation after smoothing becomes insignificant and falls within printing and measurement inaccuracies at smaller measurements below 15mm.

The overall average dimensional variation of the test cubes was measured to be 0,02mm in X axis with a standard deviation of ± 0,04mm. For Y and Z axis it was measured an average of 0,01mm and 0,02mm with standard deviations of ± 0,03mm and ± 0,02mm respectively.

Overall, dimensional results confimed that no significant dimensional variation of the parts occurrs after vapor smoothing. This confirms that the smoothing process prevents structural deformation of the processed parts while retaining the part tolerances and fine feature details.

[1] Note that the graphs show an increase in the length dimensions in the X direction at 5mm and in the Y direction at 5mm and 15mm. This effect can be attributed to the generation method of the surfaces to be measured. An averaged plane is created based on the scanned surface. Depending on the surface roughness and condition of the marked area, the position of the generated plane is influenced, which is reflected in the evaluation of the length dimensions.

Mechanical Properties

Three different mechanical tests were performed on the as-printed and the vapor-smoothed parts, both in XY- and Z-direction. The results are summarized below in Table 2.

Table 2: Mechanical test results before and after vapor-smoothing of Ultrasint PP nat 01

Properties	Unit	Test method	XY-direction		Z-direction	
			as-printed	Vapour Smoothed	as-printed	Vapour Smoothed
Tensile Strength	MPa	DIN EN ISO 527-2	27.9 ± 0.92[1] (n=8)	32.9 ± 0.83[1] (n=11)	25 ± 1.17[1] (n=8)	31.1 ± 1.63[1] (n=13)
Tensile elongation @ break	%	DIN EN ISO 527-2	7.6 ± 0.9[1] (n=8)	10.4 ± 1.3[1] (n=11)	6.0 ± 0.7[1] (n=8)	7.5 ± 0.7[1] (n=13)
Tensile modulus	MPa	DIN EN ISO 527-2	1.550 ± 55[1] (n=8)	1.450 ± 0.47[1] (n=11)	1.510 ± 79[1] (n=8)	1.370 ± 74[1] (n=13)
Flexural modulus	MPa	DIN EN ISO 178	1274 ± 62 (n=8)	1340 ± 76 (n=10)	1214 ± 2 (n=2)	1410.2 ± 62 (n=10)
Charpy impact unnotched	kJ/m²	DIN EN ISO 179-1:2010	25 ± 2 (n=10)	29.2 ± 1.8 (n=10)	14.9 ± 1.9 (n=10)	20.7 ± 1.7 (n=10)
Charpy impact notched (smoothed notched)	kJ/m²	DIN EN ISO 179-1:2010	3.05 ± 0.32 (n=10)	2.38 ± 0.46 (n=6)	2.34 ± 0.60 (n=10)	2.75 ± 0.37 (n=6)
Charpy impact notched (un-smoothed notched)	kJ/m²	DIN EN ISO 179-1:2010	3.05 ± 0.32 (n=10)	2.33 ± 0.46 (n=10)	2.34 ± 0.60 (n=10)	2.16 ± 0.64 (n=10)

Overall, processing Ultrasint® PP does not degrade any of the key mechanical properties. In fact, the smoother part surface leads to a significant increase in tensile strength and elongation at break.

Two different notched charpy impact tests were conducted: with smoothed and without smoothed notch. The results after processing stay unchanged within scatter width and reveal no significant change. The unnotched charpy impact test shows an increase after vapour smoothing the Ultrasint® PP. A positive impact can also be observed for the flexural modulus which can be explained due to an improved outer fiber strain enabled by surface sealing.

[1] Mechanical tests were carried out using 1BA tensile bars as the vapour smoothing was conducted by AMT in a smaller R&D chamber and not a commercia machine .Results may vary from official TDS where 1A tensile bars were used.

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Conclusion

Ultrasint® PP material can be post-processed efficiently and is compatible with AMT PP smoothing technology. The processing delivers significant improvements in surface roughness and translucency while maintaining the full integrity of key mechanical properties, dimensional variations within widely accepted tolerance limits, and without degrading the material. BASF Ultrasint® PP's unique properties in combination with AMT's innovative smoothing technology delivers superior 3D printed components with Additive Manufacturing materials, enabling high performance parts for a comprehensive range of applications.

Find out more about Forward AM on our website here.

More information about AMT Post Pro3D® here.

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