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Improving Ultrasint® TPU01 part properties by PostPro® vapour smoothing

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The patented novel PostPro® vapour smoothing technology is an automated post-processing solution to surface treat thermoplastic polymer 3D-printed parts. PostPro® is a patented and enabling technology, which reduces lead-time; and operational and maintenance costs providing the 'missing piece' in the digital manufacturing chain. PostPro® achieves an injection molded surface quality, improved airtightness as well as bacteria protection 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 novel post-processing technology BLAST by AMT on material properties of parts printed with BASF Ultrasint® TPU01 material. The testing focused on surface quality, mechanical properties and dimensional variation. The results revealed the compatibility of Ultrasint® TPU01 material with PostPro® 3D technology, produce high performance parts. The same quality of results can be expected by applying the PostPro® 3D technology to Ultrasint® TPU 88A.

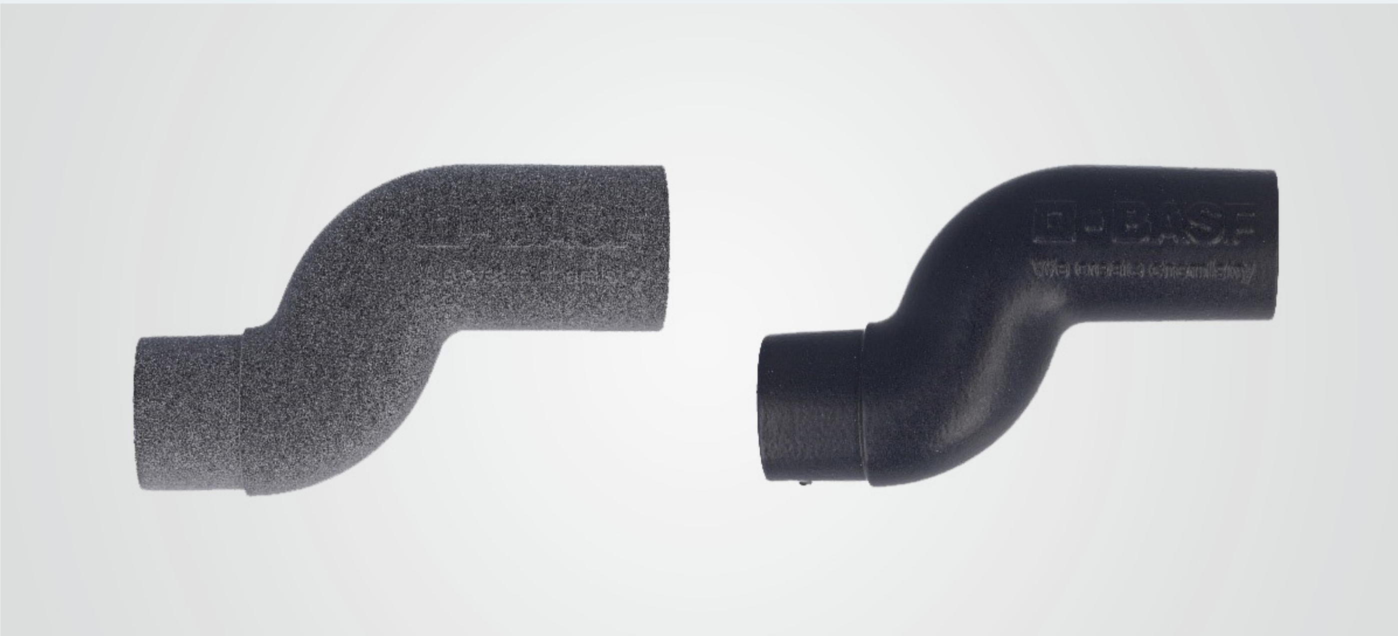

Figure 1: Piping duct printed with Ultrasint® TPU01 before and after chemical vapour smoothing.

Ultrasint® TPU01

Ultrasint® TPU01 is a multi-purpose thermoplastic polyurethane (TPU) powder, ideal to produce parts requiring shock absorption, energy return or flexibility. This highly processable multi-purpose material is explicitly designed for HP's 5200 series Multi Jet Fusion printers. Ultrasint® TPU01 offers strong, flexible and durable part performance, combined with an excellent surface quality and level of detail. Typical applications include sports protection equipment, footwear, orthopedic models, car interior components and various industrial tools like pipes and grippers.

Ultrasint® TPU01 opens unlimited design possibilities: it is extremely easy to print, has a very high process stability, and one of the highest throughputs for flexible materials in the 3D printing market. These unique characteristics make it a perfect fit for serial production with HP Multi Jet Fusion printers.

PostPro® Chemical Vapour Smoothing Technology

As-printed material surfaces exhibit rough, powdery and porous surfaces, limiting the use of such parts in various applications. AMT's PostPro3D machine with BLAST technology is able to solve these issues and produce smooth and sealed surfaces removing any loose adhered particles. This patented physico-chemical based process, can smooth a variety of thermoplastic polymers such as PA12, PA11, PA6, TPU, TPE, ABS and many other materials printed using Powder Bed Fusion (PBF) or Fused Filament Fabrication (FFF) methods.

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 rapidly controlled by instantly changing chamber conditions to achieve the required surface finish.

AMT's PostPro® provides a sustainable post-processing solution to deliver repeatable and reproducible results for high volume production. The output of the machine results in smooth parts that show negligible dimensional variation as well as sealed hydrophobic surfaces. Processed parts not only achieve high aesthetical standards but also are easier to dye and coat, while their mechanical properties improve. The system combines applied science and easy-to-use technology and can be integrated into automatic production lines to deliver enhanced polymer performance at scale [1, 2, 3].

Testing Methodology

Parts used during this study have been printed on a HP Jet Fusion 5210Pro MJF 3D printer. The parts have been thoroughly cleaned and de-powdered before the chemical smoothing process. In total, 13 different tests were performed for both as-printed and post-processed parts, summarized below in Table 1.

Table 1: Summary of conducted tests.

Test	Standard	Number of Parts
Surface Roughness	ISO4287	7
Dimensional Deviation	N/A	4
Microscopy	N/A	2
Hardness Shore A	DIN ISO 7619-1	1
Tensile Strength	DIN 53504, S2	5
Tensile Elongation @ break	DIN 53504, S2	5
Flexural Modulus	ISO 178	5
Tear Resistance (Trouser)	DIN ISO 34-1, A	3
Tear Resistance (Graves)	DIN ISO 34-1, B	2
Rebound Resilience	DIN 53512	3
Abrasion Resistance	DIN ISO 4649	2
Vicat Temperature	DIN EN ISO 306 10N, 120°C/h, A120	2
Charpy Impact Strength (notched)	DIN EN ISO 179-1 @ +23°C DIN EN ISO 179-1 @ -10°C DIN EN ISO 179-1 @ -40°C	9 9 9

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 made before and after processing and the average calculated. The average surface roughness for each sample is shown in Figure 2

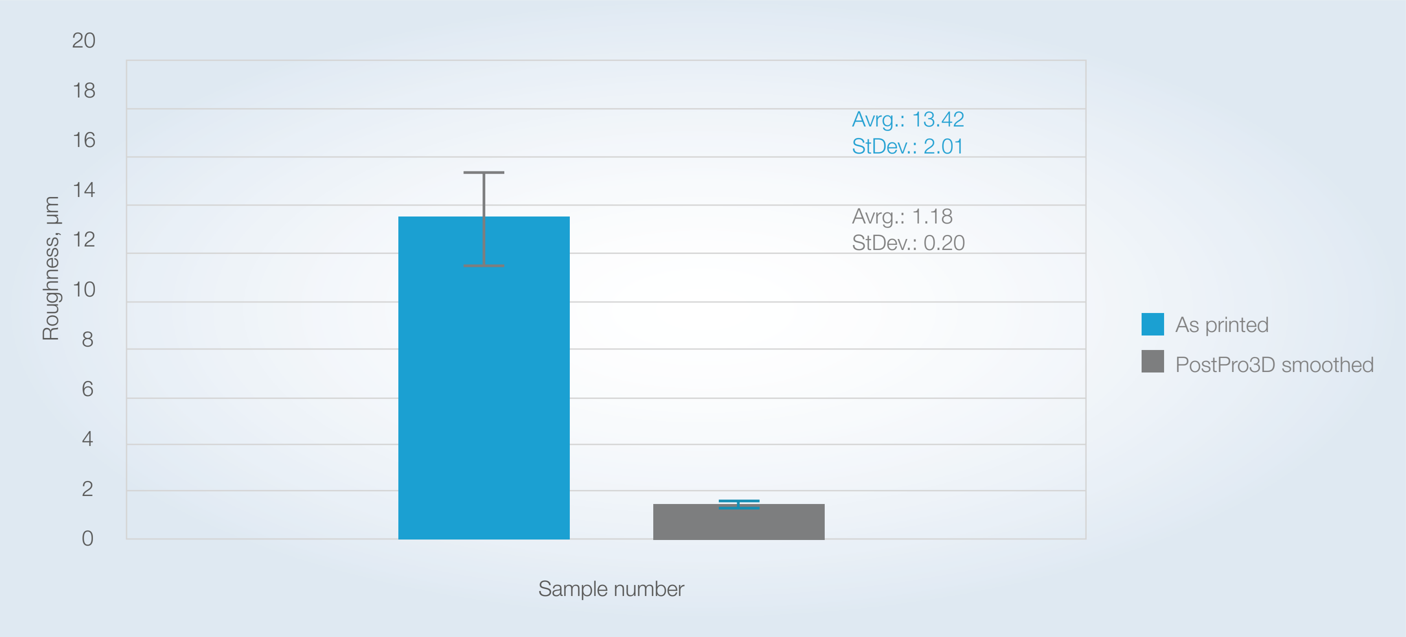

Figure 2: Surface roughness comparisons between as-printed and PostPro 3D® processed samples

The average roughness was significantly reduced from an as printed Ra value of 13.42 µm to 1.18 µm, this is a surface roughness reduction of over 1,000 percent. The roughness improvement is provided uniformly across the part surface, as demonstrated by the reduction in the standard deviation between Ra values across the surface from 2.01 to just 0.20. The improvements come due to controlled re-flow of the surface removing imperfections, adhered particles and micro-cracks.

Microscopy

Surface microscopy of Ultrasint® TPU01 surfaces smoothed with PostPro3D® was done using Hirox KH-8700 digital microscope with MX(G)-2016Z lens. The polymer surfaces were analysed at magnifications of 40x and 100x. The results are shown in Figure 3.

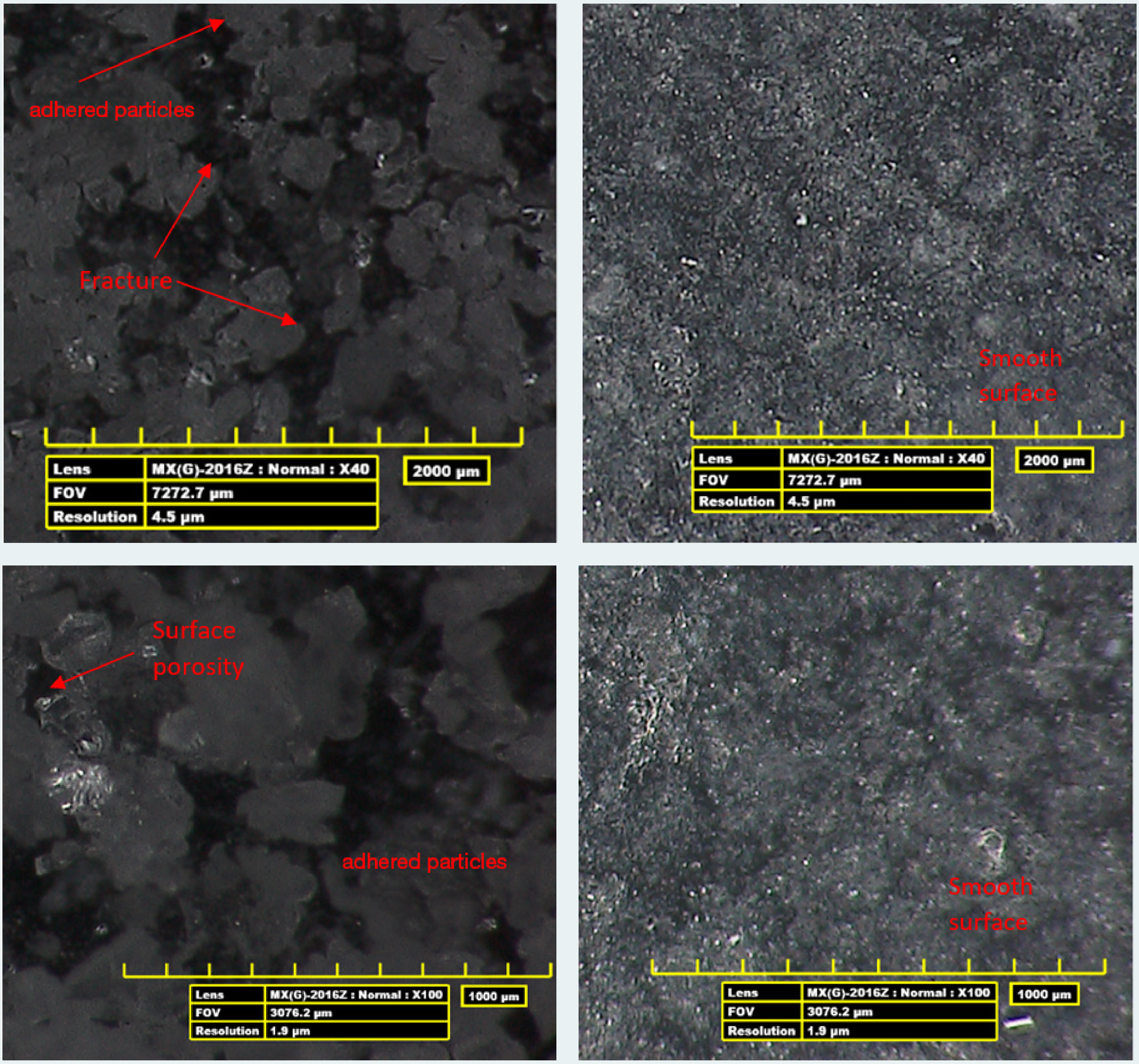

Figure 3: Surface microscopy of as-printed (left side) and vapour smoothed (right side) parts

Microscopy images (µm scale) reveal the abundant presence of un-sintered material, microfractures and surface porosity on the as-printed Ultrasint® TPU01 surfaces (Figure 3 left side). These artefacts were completely removed by the PostPro3D® process, leaving the surface smooth and uniform.

Dimensional Variation

Four samples shown in Figure 4 were printed to compare the effect of chemical vapour smoothing as post-processing on part dimensions. Both parts were scanned before and after chemical vapour smoothing.

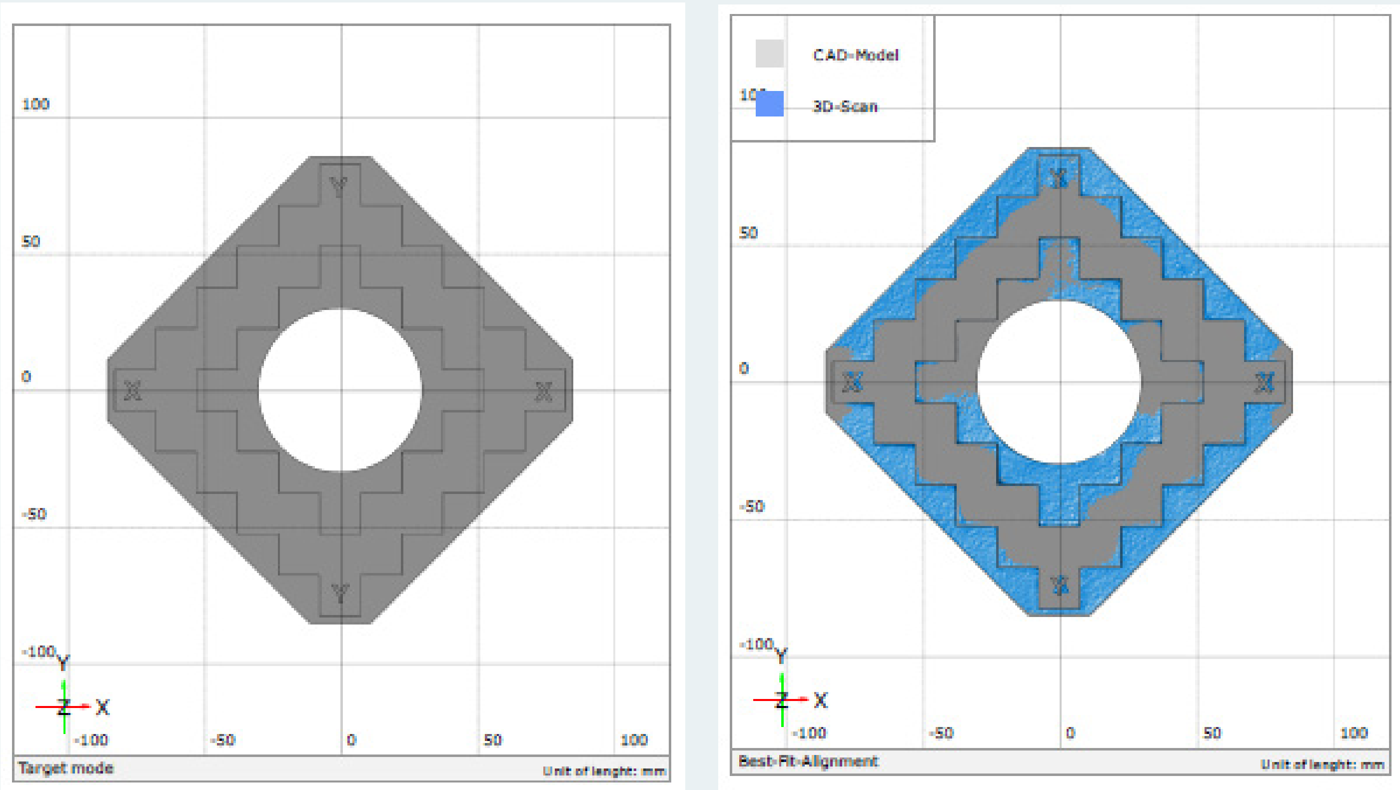

Figure 4: Best-Fit-Alignment of CAD and STL out of 3D-Scan.

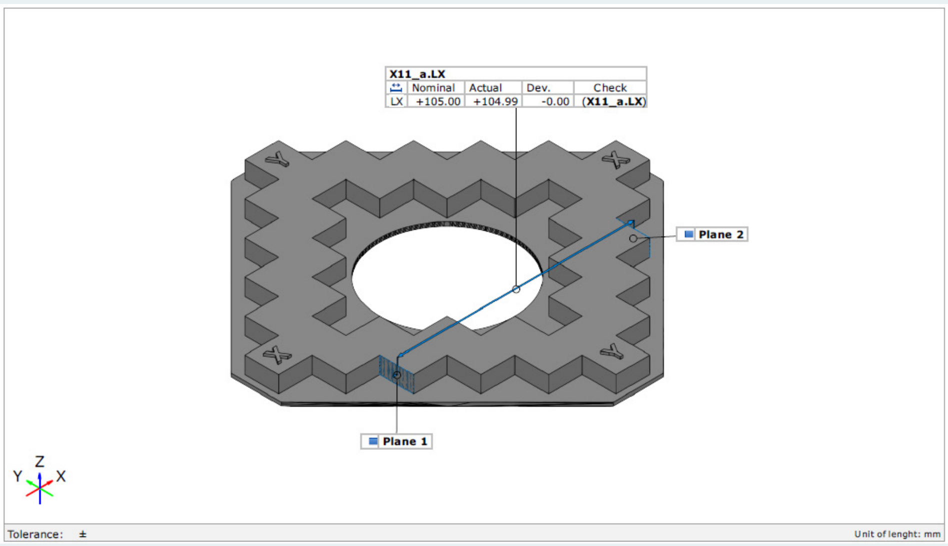

Figure 5: Exemplary distance measurement.

The optical 3D scanner ATOS Core 200 with the associated software ATOS Professional from GOM was used for the measurement and subsequent evaluation of the linear dimensions. The STL file generated by the 3D scan is aligned to its original CAD design by means of best-fit alignment (see Figure 4 to the right). Subsequently, auxiliary planes are constructed on the inner and outer surfaces, which are checked for their distance as shown in Figure 5. Since each sample is scanned after printing as well as after vapour smoothing, two „ACTUAL values“ for the same plane distance are obtained for each component state. These values are set in relation to each other to determine the influence of vapour smoothing on the part dimensions without including the influence of the manufacturing process.

The distance measurement was done on the opposite surfaces both inside and outside in x- and y-direction for the distances 15mm, 45mm, 75mm, 105mm, 135mm and 165mm. Figure 5 shows the methodical approach of one exemplary distance measurement of 105mm of the outer surfaces (Plane 1 and Plane 2) in x-direction. Figure 6 shows the dimensional deviations of vapour smoothed samples in x- (left) and y-direction (right) in mm for the distances of 15mm, 45mm, 75mm, 105mm, 135mm and 165mm.

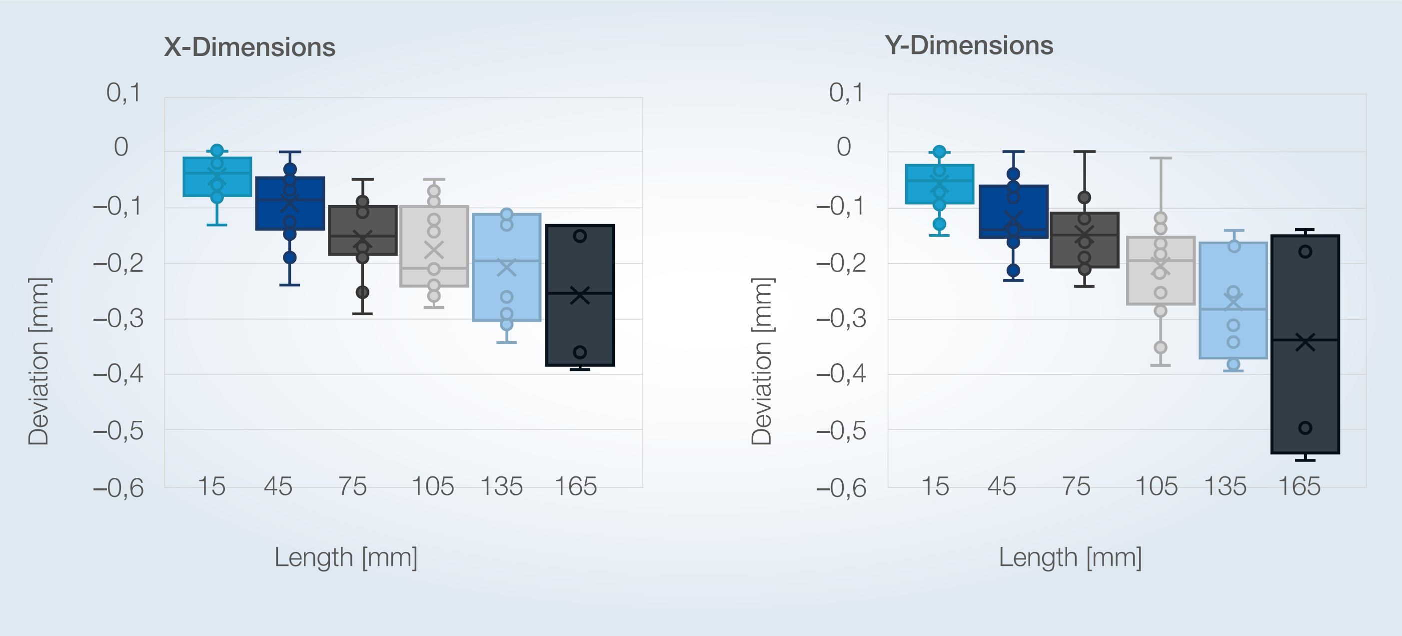

Figure 6: Dimensional variation in x- and y-direction

The results reveal a slight shrinkage of the parts, but no expansion in any direction after processing. The shrinkage reaches a maximum of 1 percent for both directions. The dimensional effect on the parts can be grouped into 3 categories depending on the feature size: small features (up to 45mm) varying up to 1 percent, medium (45 – 105mm) varying up to 0.39 percent and large (105-165mm) varying up to 0.33 percent. This average variation holds within the typical printing tolerance of +/- 0.30mm for well-designed Ultrasint® TPU01 parts as shown in Figure 7.

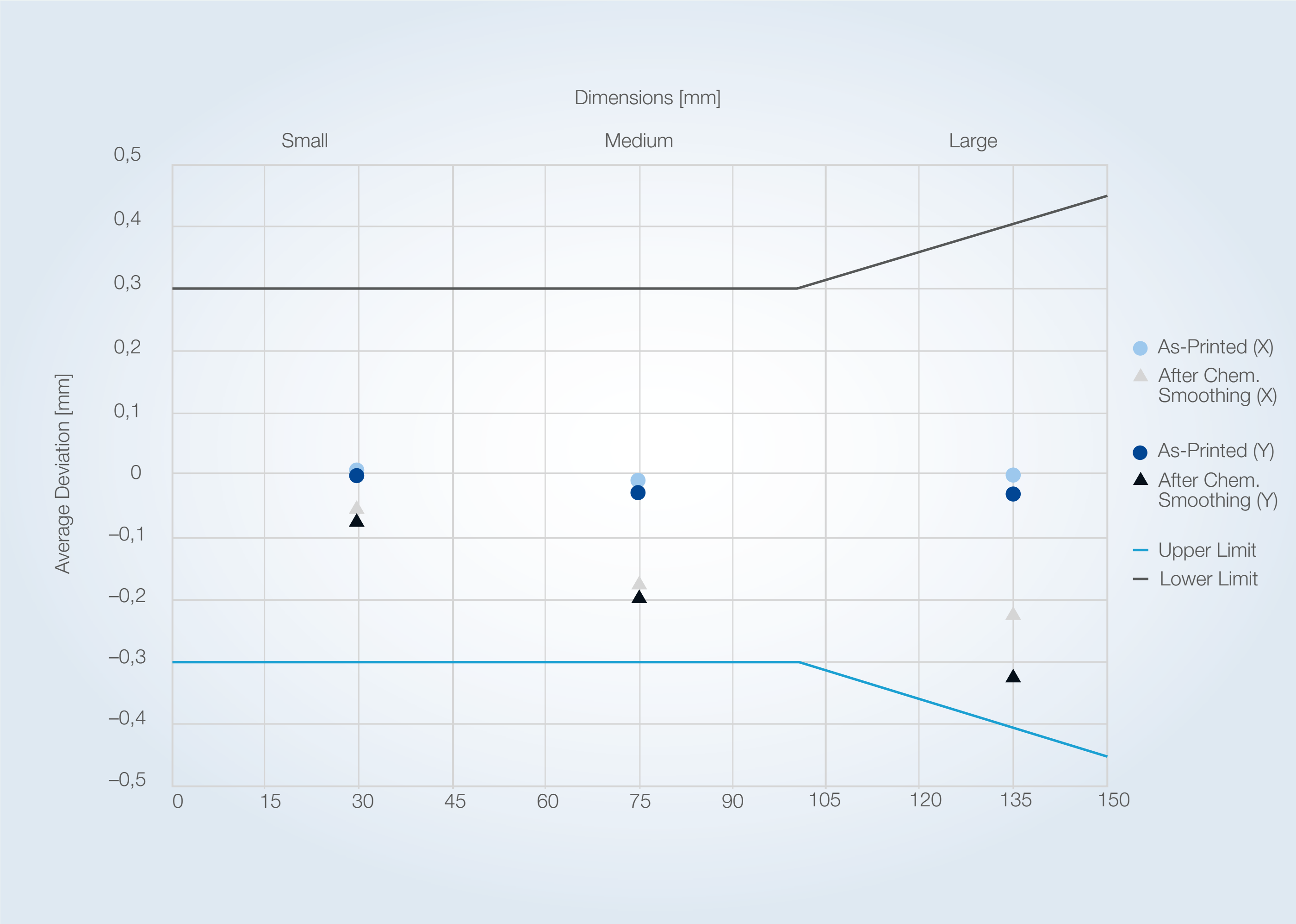

Figure 7: Average deviation for printed and smoothed parts

Mechanical Properties

Ten different mechanical tests were performed on the as-printed and the vapour smoothed parts, summarised below in Table 2. All properties were measured after conditioning the parts for 3 days at 23°C and 50 percent RH. Figure 8 and Figure 9 provide visual representations of the results summarized in Table 2.

Table 2: Mechanical test results before and after chemical vapour smoothing.

	Test method	Sandblasting XY-direction	Sandblasting Z-direction	Chemical Smoothing XY-direction	Chemical Smoothing Z-direction
Hardness Shore A	DIN ISO 7619-1	88–90	88–90	92	92
Tensile Strength/MPa	DIN 53504, S2	8.4	6.8	9.1	7.5
Tensile Elongation @ break / %	DIN 53504, S2	291	128	301	131
Flexural Modulus /MPa	ISO 178	74	71	70	76
Tear resistance (Trouser) / kN7m	DIN ISO 34-1 A	20	17	21	19
Tear resistance (Graves) / kN7m	DIN ISO 34-1 B	38	31	40	33
Rebound resilience / %	DIN 53512	63	63	62	63
Abrasion resistance / mm³	DIN ISO 4649	96	103	108	102
Vicat temperature / °C	DIN EN ISO 306 10N 120°C/h A120	97	98	96	
Charpy Impact Strength (notched) kJ/m²	DIN EN ISO 179-1 23°C	No break	No break		
	DIN EN ISO 179-1 –10°C	46	44	54	44
	DIN EN ISO 179-1 –40°C	4.5	3.7	4.1	3.4

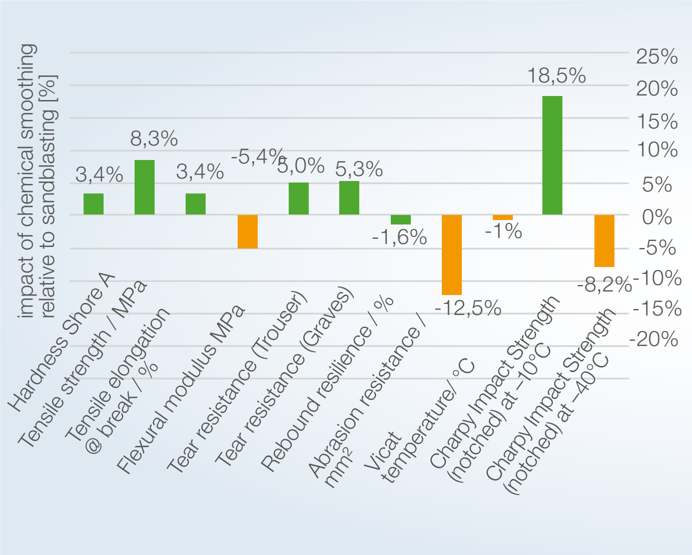

Figure 8: Mechanical properties before and after chemical vapour smoothing: x/y-direction

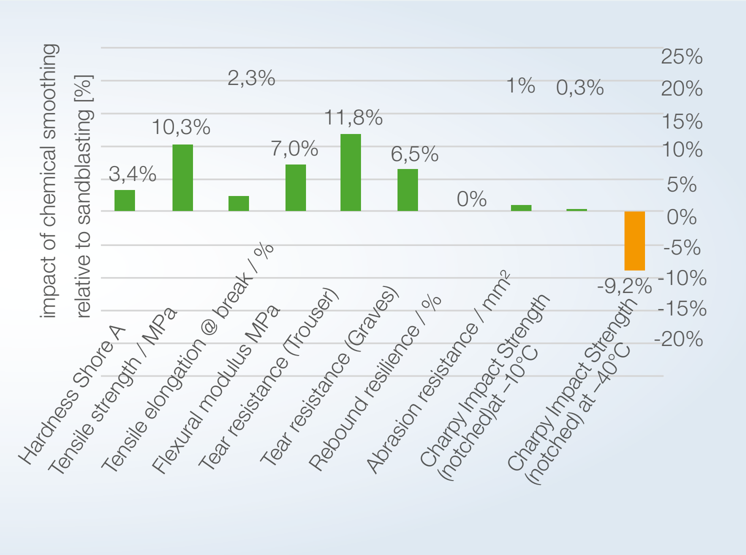

Figure 9: Mechanical properties before and after chemical vapour smoothing: z-direction

In general, the measured differences in all mechanical properties are limited, showing that the PostPro® 3D process keeps the mechanical properties intact and does not degrade the material. In fact, vapor smoothing provides parts with improved Hardness Shore (x/y: +3,4%; z: +3,4%), Elongation at break (x/y: +3,4%; z: +2,3%) and Tear Resistance (Trouser: x/y: +5%; z: +11,8%; Graves: x/y: +5,3%; z+6,5%). Improvements in Tensile properties can be explained by re-flown and re-crystallised surface of the parts, eliminating crack-initiation sites, whereas Hardness Shore and Tear Resistance is influenced by the removal of loose adhered particles powder and better surface uniformity (see Figure 3).

Conclusion

Ultrasint® TPU01 material can be post-processed and is compatible with PostPro3D® smoothing technology. The processing delivers significant improvements in surface smoothness and uniformity while keeping key mechanical properties intact and dimensional variations within widely accepted tolerance limits. BASF Ultrasint® TPU01's unique properties in combination with AMT's innovative PostPro 3D® 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 Ultrasint® TPU01 on our website here.

More information about AMT Post Pro3D® here.

References

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