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BASF Ultrasint™ TPU01 for HP Jet Fusion 5200 Series 3D Printing Solutions

Mechanical Properties

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Rev 5.0

Introduction

Multi Jet Fusion (MJF) technology is a powder-bed fusion 3D printing technology that allows for the production of accurate, functional prototypes and final parts, including color parts. HP MJF technology does not require support structures, thus enabling the design of complex geometries without additional costs, which would be expensive or not even possible to produce with traditional manufacturing processes.

MJF printing process

The HP MJF 3D printing process begins with a thin layer of uniformly pre-heated powder particles that is spread across the build platform. Then, to achieve part quality at a high speed and produce truly functional parts, HP MJF technology uses the HP multi-agent printing process. HP's in-depth knowledge of 2D printing solutions and the capability of HP's proprietary architecture makes it possible to print millions of drops per second along each inch of the bed width, thus enabling extreme precision and dimensional accuracy.

HP Multi Jet Fusion's multi-agent printing process can control the exact amount of each agent that is deposited in each voxel of the intended part. This printing process involves two different types of agents that are applied across the build platform: fusing agents and detailing agents. A fusing agent is applied where the particles are meant to fuse together in the powder in order to create the corresponding part cross section, leaving the rest of the powder unaltered. A detailing agent is applied to the edges of the part in order to modify the fusing process and create fine detail and smooth surfaces.

Next, an energy source passes over the build platform, provoking a reaction between the agents and the material that causes the material to selectively melt. Once melted, the material entangles, consolidates, and eventually cools down until it is fully solidified. The internal crystal structure, and therefore, the mechanical properties that the parts have, depend on different factors such as the energy used to melt the material, the time during which the material exceeds the melt temperature, the cooling rates, etc.

Each material and print profile deliver different mechanical properties. Minor variations may also occur depending on the orientation of the parts, printer-to-printer variation, and small variances between different areas of the printer, for example, perimeter versus center.

Some of these variations can be minimized by efficiently managing materials and machine maintenance, ensuring tighter control over the energy, i.e. machine tuning, and by limiting other sources of variability that may affect mechanical properties such as variations in job size, cooling times, orientation and positioning of parts within the printable volume, environmental conditions, etc.

BASF Ultrasint™ TPU01

Ultrasint™ TPU01 is a multi-purpose thermoplastic polyurethane (TPU) powder, developed by BASF specially for use HP's Jet Fusion 5200 Series 3D Printing Solutions. Parts produced with this material offer a balanced property profile with good flexibility, shock absorption, and the possibility to print very fine structures with a high level of detail. In addition, the material is easy to print, and has good UV and hydrolysis resistance. Ultrasint™ TPU01 is only processable in HP Jet Fusion 3D printers.

BASF Ultrasint™ TPU01 mechanical properties

Test job

The baseline mechanical properties for parts in BASF Ultrasint™ TPU01 with the HP Jet Fusion 5200 Series 3D Printing Solution were characterized using two standard jobs, TPU_mechanicalprop_XY (Figure 1) and Elastomers_Forest_S1_S2_Tears_6mm (Figure 2), which contained 585 and 948 diagnostic parts, respectively, that were distributed throughout the printable volume.

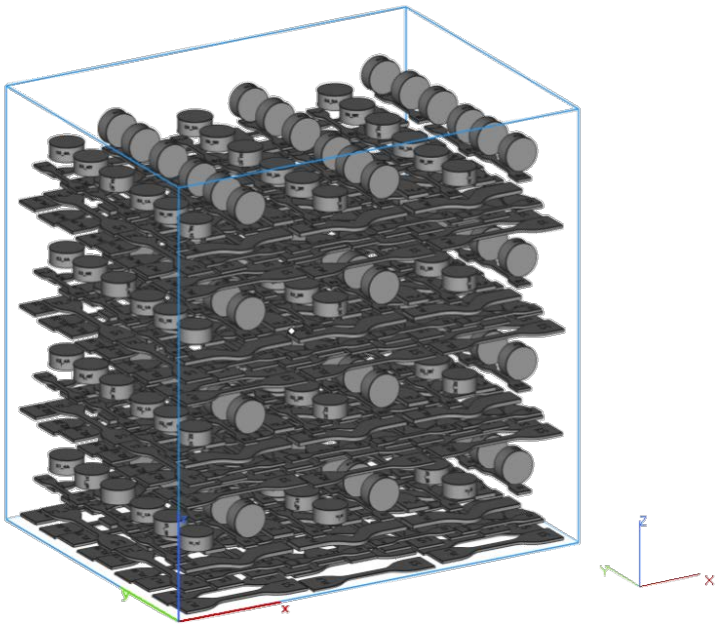

Figure 1. TPU_mechanicalprop_XY part property test job

Test job description	TPU_mechanicalprop_XY
Total parts	585
Packing density	6.87%

Table 1. General description of the test job

TPU_mechanicalprop_XY part property test job included three different types of standard tensile parts and three sets for compression, abrasion, and rebound that allowed different metrics in X Y and Z orientations to be measured and mapped.

Number of samples			
	X	Y	Z
S1 tensile sample	108	88	0
S2 tensile sample	80	72	0
Tear	48	40	0
Rebound	24		24
Compression	24		24
Abrasion	24		24

Table 2. Number of samples included in the TPU_mechanicalprop_XY test job

Elastomers_Forest_S1_S2_Tears_6mm part property test job included three different types of standard tensile parts that allowed different metrics in Z orientation to be measured and mapped.

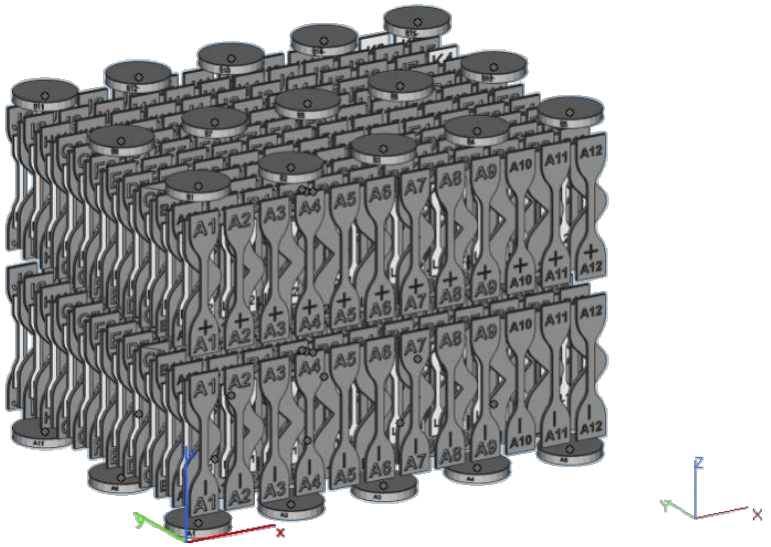

Figure 2. Elastomers_Forest_S1_S2_Tears_6mm part property test job

Test job description	Elastomers_Forest_S1_S2_ Tears_6mm
Total parts	948
Packing density	10.63%

Table 3. General description of the test job

	Number of samples		
	X	Y	Z
S1 tensile sample	0	0	288
S2 tensile sample	0	0	440
Tear	0	0	220

Table 4. Number of samples used in Elastomers_Forest_S1_S2_Tears_6mm test job

Test results

A characterization of mechanical part properties for BASF Ultrasint™ TPU01 was obtained based on the part property test jobs described previously. Testing was performed with a 20% refresh ratio using the Balanced print profile, warm unpack, and measured after sandblasting with glass beads 300-400 µm at 5-6 bars.

Table 3 contains the values that have been obtained for BASF Ultrasint™ TPU01 with the HP Jet Fusion 5200 3D Printing Solution, firmware version BD2[1][2][3][4].

	Average (XY)	Average (Z)	Test method
Tensile strength (MPa)[5]	9	7	DIN53504
Modulus (MPa)[5]	56	61	DIN53504
Elongation at break (%)[5]	213	137	DIN53504
Tear resistance (KN/m)	33	45	ASTM D624
Rebound (%)	63	63	ASTM D7121
Compression set (%)	20	20	ASTM D395
Abrasion loss (mm^3)	158	120	ASTM D4060

Table 5. Mechanical property test results for BASF Ultrasint™ TPU01

[1] Based on internal testing and measured using the "HP Elastomers Forest S1 S2 Tears" and "HP TPU_mechanicalprop_XY" . Results may vary with other jobs and geometries.

[2] Using BASF Ultrasint™ TPU01 material, 20% refresh ratio, Balanced print profile, warm unpack and measured after sandblasting with glass beads 300-400 µm at 5-6 bars.

[3] Using HP Jet Fusion 5200 Series 3D Printing Solution firmware version CRAITCRAIT_08_19_26.35.

[4] Following all HP recommended printer setup and adjustment processes and print heads aligned using semi-automatic procedure.

[5] Reporting S2 tensile values

Glossary

- **Tensile strength** or Ultimate Tensile Strength (UTS) is typically measured in MPa or N/mm^2. It is the capacity of a material to withstand tension loads. Tensile strength is measured by the maximum stress that a material can withstand while being pulled before breaking.

- **Tensile modulus** or Modulus of Elasticity or Young Modulus or E is typically measured in MPa or N/mm^2. It is a mechanical property that measures the stiffness of a solid material. It defines the relationship between stress and strain in a material in the linear elasticity regime. Since thermoplastics have a very short linear elasticity zone, it is calculated as the slope of the stress-strain curve very close to zero. Tensile modulus is required as an input for mechanical FEA simulations.
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- **Elongation** measures the deformation that a part undergoes given a certain stress, for thermoplastics it is typically expressed as a percentage (%) of the deformed amount versus the original part length.

    - **Elongation at yield** in thermoplastics is the deformation corresponding to the tensile strength point, so where the stress-strain curve has its maximum.
    - **Elongation at break** is the deformation corresponding to the fracture point of the part.

- **Abrasion volume loss** measures the ability of a material to resist abrasive wear. The abrasion loss is given as the volume loss in cubic millimeters.

- **Tear resistance** or tear strength is defined as the **resistance force** which a material sample, modified by cutting or slitting, offers to the propagation of the tear.

- **Rebound** or resilience indicates the material's ability to return the energy it absorbs after it is deformed by a single impact.

- **Compression set** of a material is the permanent deformation remaining after removal of a force that was applied to it. The term is normally applied to soft materials such as elastomers.