White paper

BASF Ultrasint® TPU01 for the HP Jet Fusion 5200 Series 3D Printing Solution

Mechanical Properties

Data courtesy of Kupol

Introduction

At HP, we are committed to providing part designers and part manufacturers with the technical information and resources needed to enable them to unlock the full potential of 3D printing and prepare them for the future era of digital manufacturing.

The aim of this white paper is to illustrate the mechanical properties of BASF Ultrasint® TPU01[1] that can be achieved with the HP Jet Fusion 5200 Series 3D Printing Solution.

In this white paper, you will find:

- Key mechanical properties for BASF Ultrasint® TPU01 material,
- A detailed explanation of the test conditions under which these values were obtained, and
- Additional information on the mechanical properties of thermoplastic materials, and a glossary of key terms used.

Material properties for BASF Ultrasint® TPU01

Test job

The baseline mechanical properties for parts produced with 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.

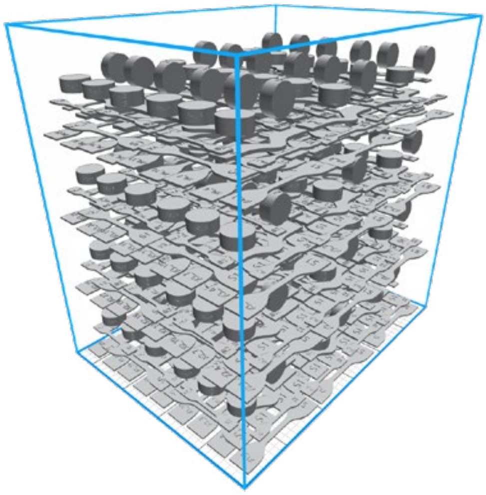

Figure 1. TPU_mechanicalprop_XY part property test job

Test job description	TPU_mechanicalprop_XY
Total parts	585
Packing density	6.87%

Table 1. General description of the test job

1. Available for the HP Jet Fusion 5200 Series 3D Printing Solution.

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.

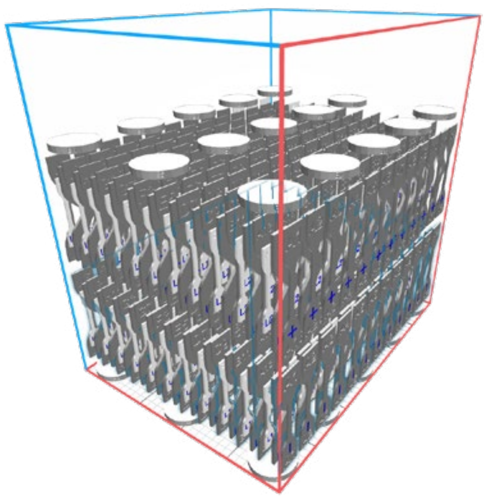

Figure 2. Elastomers_Forest_S1_S2_Tears_6mm part property test job

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 aforementioned part property test jobs. 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 Series 3D Printing Solution.

HP 3D HR CB PA 12[i ii iii]	Average (XY)	Average (Z)	Test Method
Tensile strength (MPa)[iv]	9	7	DIN53504
Tensile modulus (MPa)	56	61	DIN53504
Elongation at break (%)	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

i. Based on internal testing and measured using "Elastomers_Forest_S1_S2_Tears_6mm" and "TPU_mechanicalprop_XY". Results may vary with other jobs and geometries.

ii. 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.

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

iv. Reporting S2 tensile values.

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

Appendix 1: Choosing the right material for mechanical requirements

One of the most critical aspects to understand before choosing a material is the stresses the part will experience in its regular operation mode. The chosen material must meet the application's requirements in terms of behavior under stress and provide a suitable yield point in order not to impact the part's functionality. Loads, boundary conditions, and design space for the part are usually given parameters, which cannot be modified. In some other cases where the loads may vary due to a dynamic situation, other factors and calculations should be considered to ensure, for instance, that the part withstand fatigue.

Ideally, designers should choose the material based on the application's specific requirements. However, performing the final selection is not easy, as often not all of the requirements for the application are known and, even if they are, there may not be a clear correlation between these final application requirements and the generic material properties (characterized by the standard procedures) or the variations the materials may have depending on the environment and conditions in which they operate. To simplify this choice, the commonly used process for material selection involves three steps:

STEP 1: Select a material with generic properties according to key attributes. In thermoplastics, the most commonly used properties are tensile strength, tensile modulus, and elongation, (but others may also be considered).

- Tensile strength measures the resistance of the material to breaking under tension.
- Tensile modulus measures the rigidity or resistance to elastic deformation.
- Elongation measures the deformation (elastic or plastic) that a part undergoes given a certain strain.

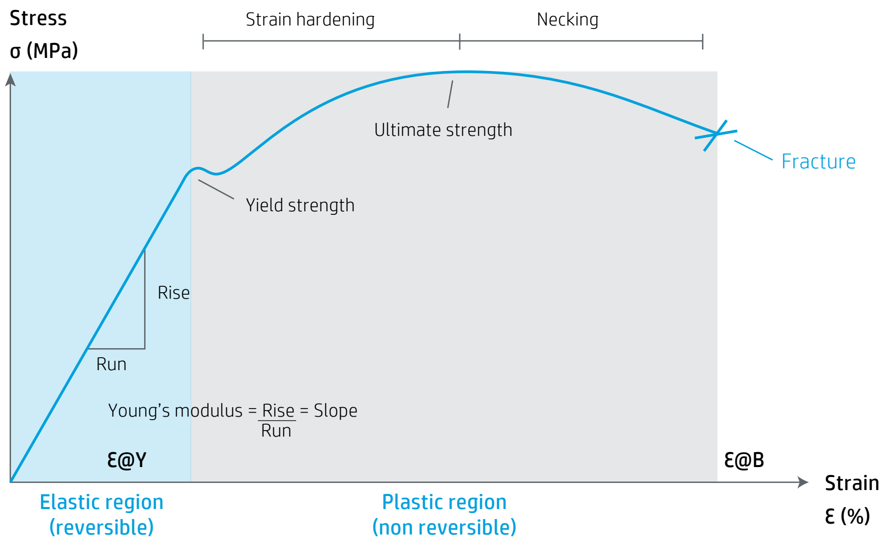

Figure 3. A typical stress-strain curve for a ductile material

These properties and the relative behavior of polymers compared to other materials are shown in Figure 4.

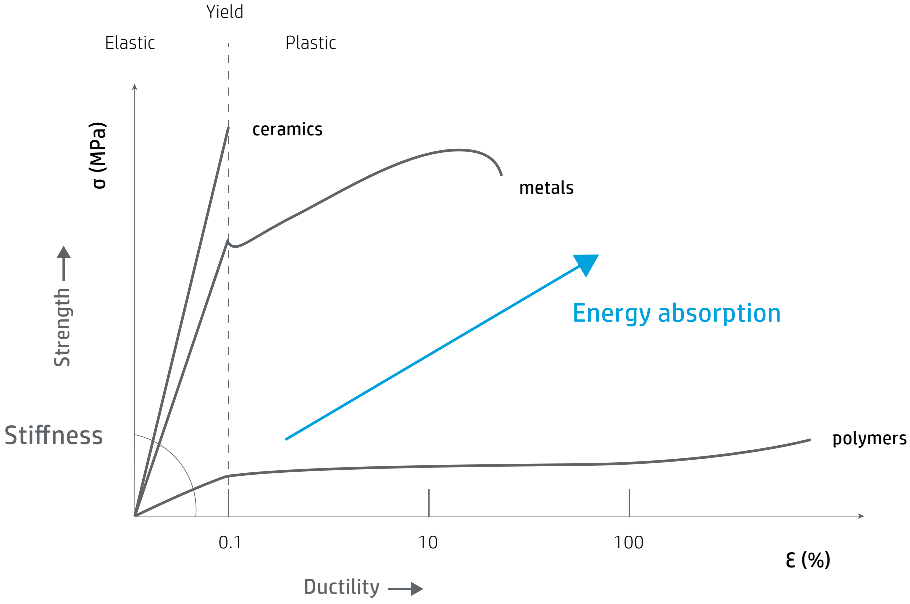

Figure 4. Comparison of polymer, metal, and ceramic materials

STEP 2: Once a material has been selected, the design of the part needs to be performed in line with HP Multi Jet Fusion design guidelines, allowing enough of a design margin (two or three times, depending on the property) to accommodate for all possible variations in the part itself or in the application-specific conditions.

STEP 3: Even after the design has been performed according to these principles, it is highly advisable to conduct a full application-specific qualification to ensure the precision of the design, obtain validation data that represent the application's end-to-end performance, and characterize its variation over time or according to other production and application variation factors.

Appendix 2: Key terms

- **Tensile strength** or Ultimate Tensile Strength (UTS) is typically measured in MPa or N/mm². 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** (also Young's Modulus or E) is typically measured in MPa or N/mm². 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.
- **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 reaches 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.
- **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.
- **Impact strengt**h measures the impact resistance of a material or the amount of energy absorbed by a material during fracture associated with its toughness. The units are typically kJ/m2 (energy per unit area). There are two standard methods to measure impact strength: the Izod and the Charpy. Notched and unnotched specimens are used on the specific pendulum testers to determine the impact strength and the notch sensitivity.
- **Tear resistance** or tear strength is defined as the resistance force that a material sample, modified by cutting or slitting, offers to the propagation of the tear.
- **Stress** is the force density (quotient of internal force and effective area) prevailing in every area element. There are two types of stresses depending on their direction to the cross-sectional plane studied: normal stress and shear stress.
- **Deformation** refers to any stress on a solid body that generates strain. A distinction is made between elastic and plastic deformation. Elastic deformations disappear once the imposed external load has been removed. Plastic deformations occur when the inner stresses exceed a certain limit that is intrinsic to the material. In this case deformations will remain after removal of the external load. Hence, plastic deformation is permanent and non-reversible.

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