

HP 3D High Reusability PA 12 W for the HP Jet Fusion 5400W Series 3D Printing Solution

Mechanical properties



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 HP 3D High Reusability (HR) PA 12 W that can be achieved with the HP Jet Fusion 5400W Series 3D Printing solution.

In this white paper, you will find

- Key mechanical properties for HP 3D High Reusability (HR)¹ PA 12 W.
- A detailed explanation of the test conditions under which these values were obtained.
- Additional information on the mechanical properties of thermoplastic materials, and a glossary of key terms used.



Data Courtesy of Invent Medical

Material properties for HP 3D HR PA 12 W

Test job for material characterization

The baseline mechanical properties of each print profile and material of the HP Jet Fusion 5400W Series 3D Printing Solution were characterized using a standard job “Half_Commercial_Datasheet_Job”. The job contained 349 diagnostic parts that were distributed throughout the printable volume.

The configuration of the job is shown in Figure 1.

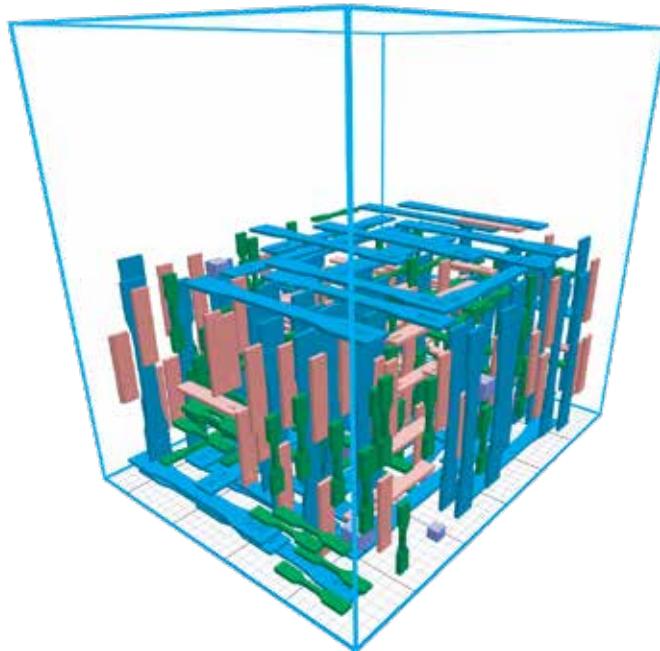


Figure 1. “Half_Commercial_Datasheet_Job” part property test job

Test job description	Half_Commercial_Datasheet_Job
Total parts	349
Packing density	6%

Table 1. General description of the test job

1. HP Jet Fusion 3D Printing Solutions using HP 3D High Reusability PA 12 W provide up to 75% powder reusability ratio, producing functional parts batch after batch. For testing, material is aged in real printing conditions and powder is tracked by generations (worst case for reusability). Parts are then made from each generation and tested for mechanical properties and accuracy.

The 'Half_Commercial_Datasheet_Job' part property test job included three different types of standard tensile specimens that allowed different metrics in X, Y, and Z orientations to be measured, where the X axis is the printheads direction, the Y axis is the recoating direction, and the Z axis is the vertical printer direction.

	Number of samples		
	XY	YX	ZX
Tensile sample I	22	20	42
Tensile sample V	30	30	70
Impact Izod 3.2 mm	30	30	60
Density and color cubes	15 (2 sizes)		

Table 2. Number of samples included in the "Half_Commercial_Datasheet_Job" test job

Test results for HP 3D HR PA 12 W (Balanced print mode)

Table 3 shows the values that were obtained for HP 3D HR PA 12 W in the HP Jet Fusion 5400W Series 3D Printing solution with the Balanced print profile and Type I tensile specimens.

	Axis	Value	Test Method
Tensile strength (Mpa)	XY	49	ASTM D638
	Z	45	
Tensile modulus (Mpa)	XY	1900	ASTM D638
	Z	1850	
Elongation at yield (%)	XY	11	ASTM D638
	Z	8	
Elongation at break (%)	XY	17	ASTM D638
	Z	9	
Impact strength (KJ/m ²)	XY	4.8	ASTM D638
	Z	4.1	
Density (g/cm ³)	XY	1.01	ASTM D792
	Z	1.01	

*Data from 4 jobs on 2 printers using 3 HP 3D HR PA 12 W powder lots (job: Half_Commercial_Datasheet_v5 OCR, firmware: HO_18_23_101, IDs: MR_231_1088, MR_231_1090, MR_294_728, MR_294_726)

1. Based on internal testing and measured using the "HP Half_Commercial_Datasheet_Job". Results may vary with other jobs and geometries.
2. HP Jet Fusion 3D Printing Solutions using HP 3D High Reusability PA 12 W provide up to 75% powder reusability ratio, producing functional parts batch after batch. For testing, material is aged in real printing conditions and powder is tracked by generations (worst case for reusability). Parts are then made from each generation and tested for mechanical properties and accuracy.
3. Following all HP-recommended printer setup and adjustment processes and printheads aligned using semi-automatic procedure.
4. Tensile strength typical variation (95% of parts) falls within the 45-55 MPa range, while tensile modulus values remain within the 1650 to 2200 MPa range.
5. Using the Izod test method A with notched @ 3.2 mm specimen according to the ASTM D256 standard.

Table 4 displays the results of color variability obtained through ΔE (CIE 2000)

	ΔE	Test Method
Printed new part color consistency*	2.4	Ci64 X-Rite, 14mm, aperture F2, 10o
Printed part color after weathering test**	3.5	ASTM G154/ASTM D4329

Table 4 above presents the color variability results for both new and aged printed parts

The ΔE between part CIELAB coordinates and HP white reference: $L^=86.769$, $a^*=-1.74$, $b^*=-3.19$. The parts were printed with different powder lots and different powder generations.

** The ΔE between a new part and the part after accelerated weathering test performed under standard ASTM G154/ASTM D4329 (8h under UV @60oC+4h Condensation @50oC, repeated up to 1000h).

As a reference for color ΔE , the HP Jet Fusion 5400W Series 3D Printing Solution is on par to the industry benchmark set by:

- Injection molding
 - Molded plastic typically requires $\Delta E=3.5-5$ between new and aged parts. Weathering test on MJF printed parts resulted in a maximum color $\Delta E=3.5$
 - Injection molding raw material specification is $\Delta E=1$, and HP HR 3D PA12W fresh powder lots show comparable color variability to injection pellets.
- The paper industry will typically require a color stability specification between lots of $\Delta E=2$ for standard quality paper, and $\Delta E=1$ for higher quality.

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.

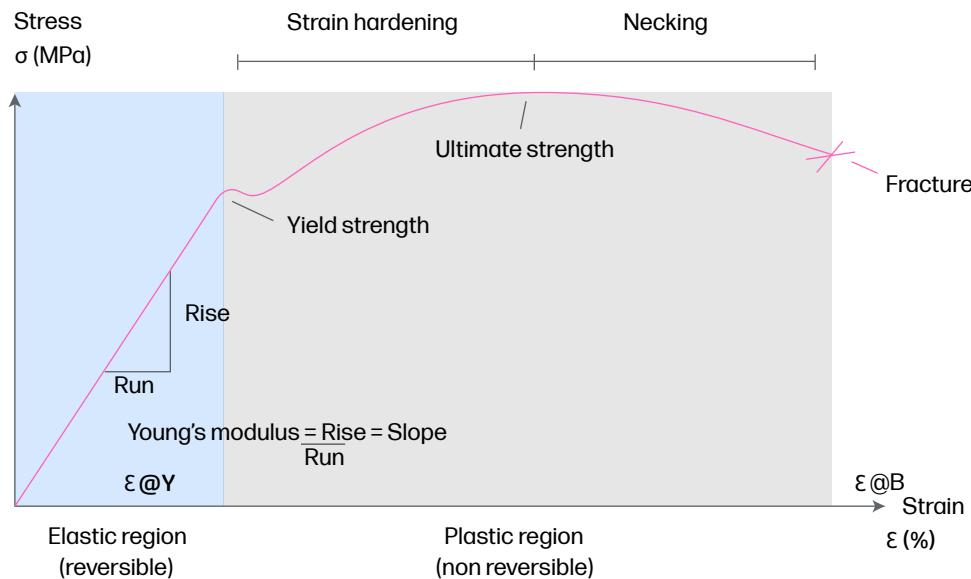


Figure 2. A typical stress-strain curve for a ductile material

These properties and the relative behavior of polymers compared to other materials are shown in Figure 3.

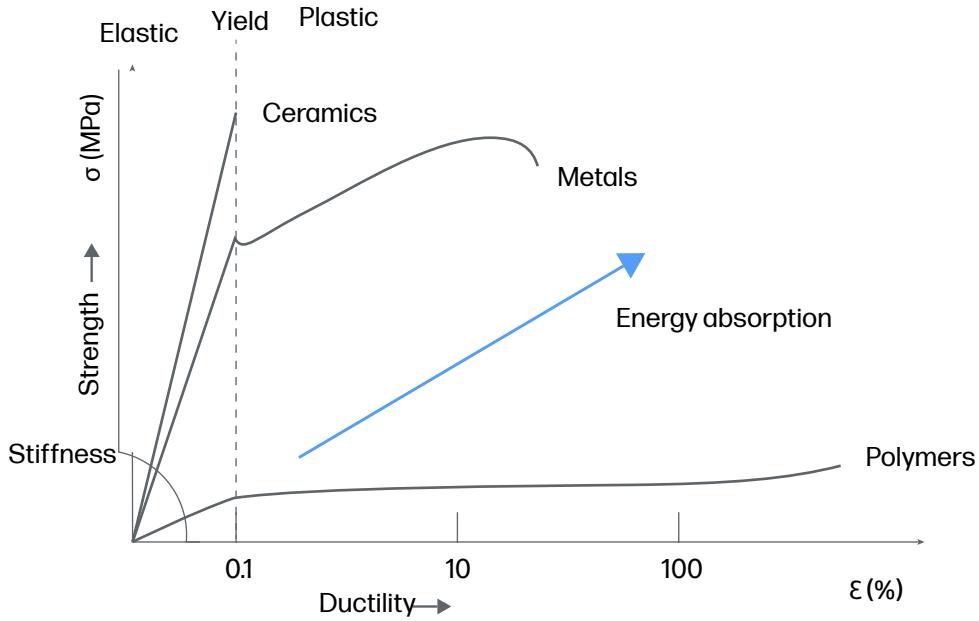


Figure 3. Comparison of polymer, metal, and ceramic materials

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.
- Impact strength 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.
- 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 nonreversible.
- Heat deflection temperature is defined as the temperature at which a standard test bar deflects a specified distance under a load. It is used to determine short-term heat resistance. It is determined at different loads, for example, 1.8 MPa (264 psi), which helps to determine maximum service temperature of parts, and 0.46 MPa, which provides an estimate of the service temperature a given polymer can withstand. Other settings like speed of the temperature increase or even part design will significantly influence the final thermal performance of an application.

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