Process for mechanical properties

Tuning your HP MJF technology to the design

Introduction

Selecting the proper printing and cooling profile, printing part material, or placing the part in a specific orientation in the build platform are a few ways to maximize the mechanical properties of a 3D-printed part.

Maximizing mechanical properties

There are several considerations that must be evaluated before printing a part in order to increase its mechanical performance:

Printing profiles and materials

- Mechanical and Balanced are the print profiles that yield the best mechanical properties for both HP 3D HR PA 11 ("HP PA 11") and HP 3D HR PA 12 ("HP PA 12") materials, with the former exhibiting better results.
- HP PA 11 provides higher elongation and impact resistance[1] than HP PA 12, while HP 3D HR PA 12 Glass Beads ("HP PA 12 GB") results in higher tensile moduli while reducing elongation and tensile strength.[2]
- Using Cosmetic (HP PA 12) or Fast (HP PA 11 and HP PA 12) print profiles is not recommended for applications with high mechanical requirements.

Build platform placement and printing process

- The recommended minimum distance between parts is 5 mm, and the ideal distance between parts and the build volume margins is 10 mm to 20 mm.
- It is recommended to leave enough space between dense parts, or those with wall thicknesses larger than 15 mm. Normally, this distance should be more than 10 mm.
- In cases where many parts with the same shape are tightly packed with parallel main surfaces, treat them as dense parts and increase the distance between them.

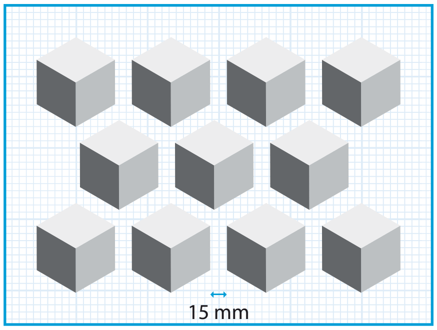

Figure 1. Recommended distance between dense parts

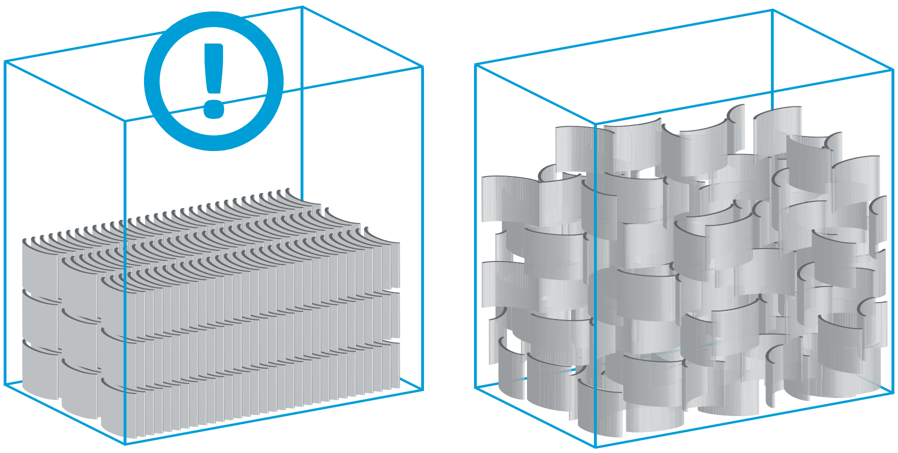

Figure 2. Left: Many parts arranged in a configuration that can result in excess heat. Right: Alternative configuration that increases heat homogeneity and facilitates dissipation, resulting in better results overall

- It is recommended to distribute the parts as homogeneously as possible on the XY-plane to facilitate similar energy absorption across the printing bed.

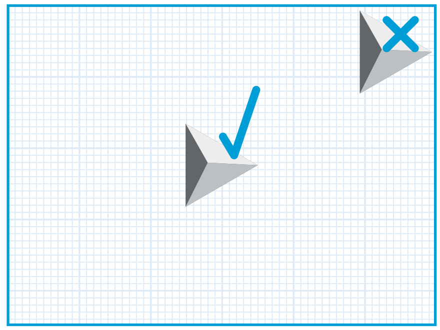

Figure 3. Recommended parts placement

- As well as in the XY-plane, it is recommended to place the parts in the bucket to prevent drastic changes in the printed areas per layer in the Z-direction.

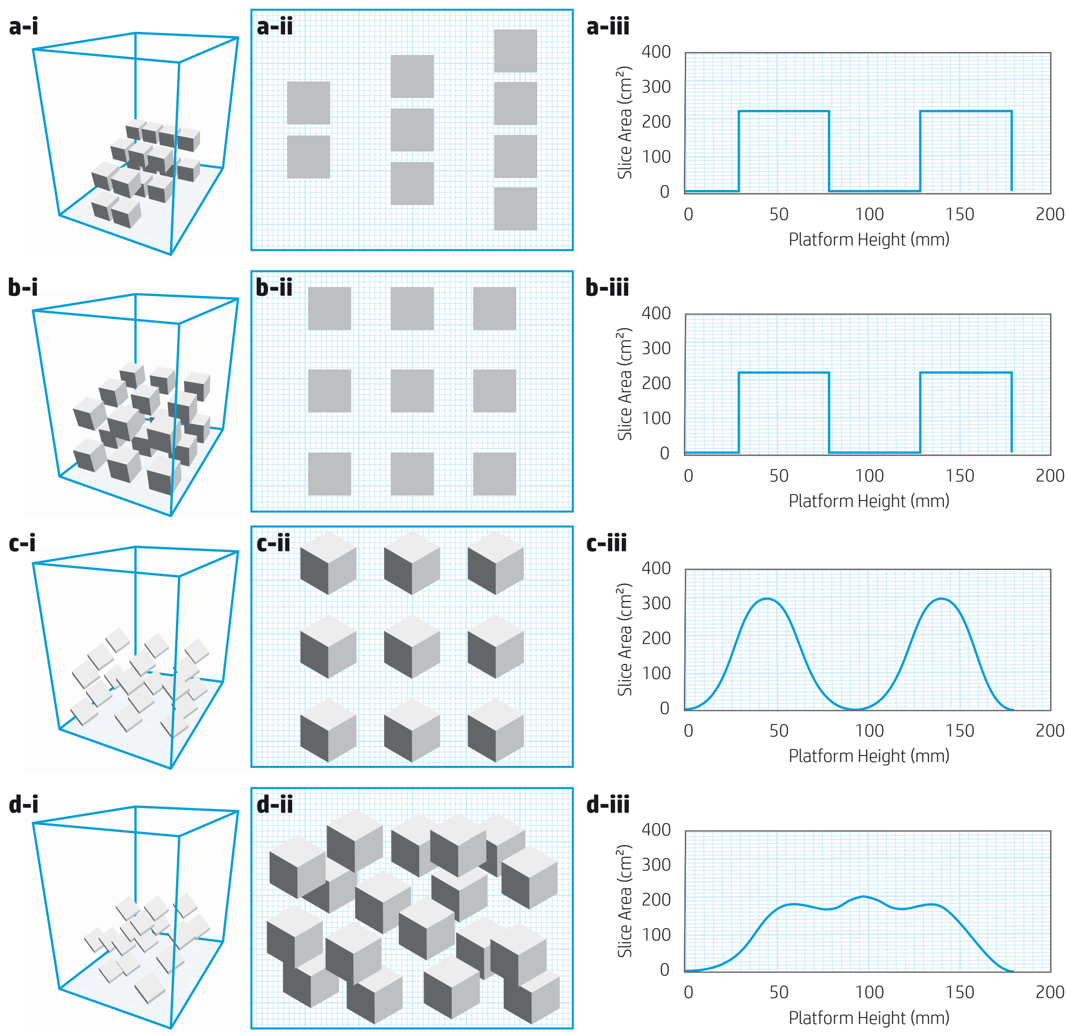

Figure 4. The printed area per layer distribution (right column) is used as an indicator of homogeneity in the Z-direction to prevent major differences in the energy absorption of parts
a) An example of a non-recommended job configuration displaying non-homogeneity in the three dimensions
b) A job that is homogeneous on the XY-plane but with a distinct and potentially problematic gap along the Z-axis
c) The gap along the Z-axis is smoother after rotating the cubes in order to avoid exposing large areas to the last layers to be printed
d) Using automatic packing, the printed area distribution is smoothed even further, minimizing adverse thermal effects. This is a recommended configuration

Information about the printed area distribution is available from professional suites like Materialise Magics.

- When optimizing mechanical properties, a good compromise between throughput and part quality is a packing density range between 8% and 10%.
- Using a low packing density improves the heat management between parts, which increases positive results through homogeneity.
- It is recommended to print short jobs in order to minimize the Z-height—number of layers—which allows for faster printing and cooling stages, and to increase the elongation at breakpoints and impact resistance of parts.
- Fast Cooling has a similar beneficial effect on elongation at breakpoints and impact resistance, but it should not be used for parts prone to warpage. This is especially critical for HP PA 11, which is more prone to warpage.

Mechanical examples

Below is an example of a part orientation for a part that requires increased elongation and impact resistance in its thinner features:

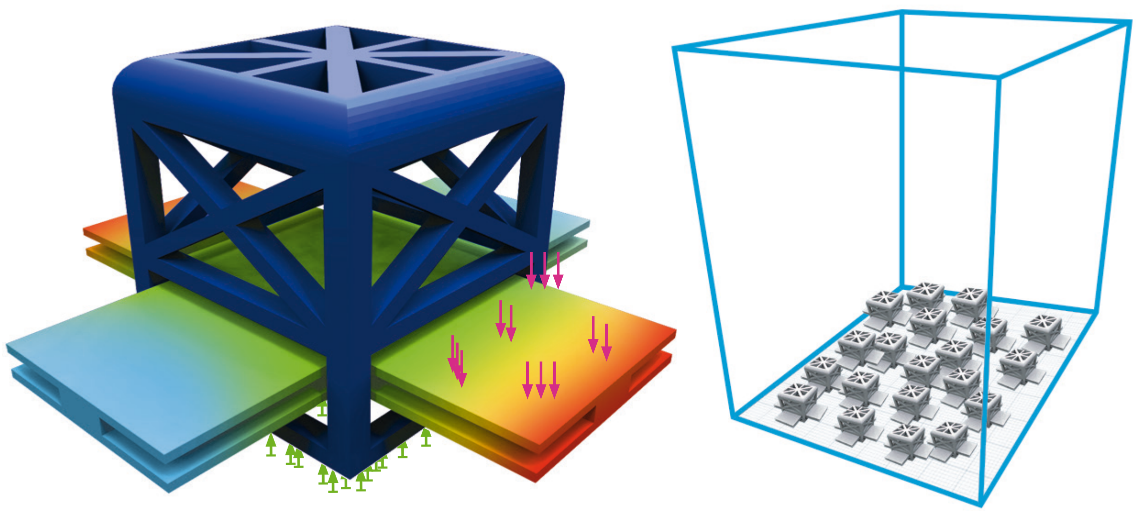

Figure 5. Left: A mechanical part with high elongation requirements on its thinner features
Right: A short bucket containing 20 iterations of the same part

As mentioned previously, process factors such as print profiles, cooling profiles, and job heights are key factors in achieving better mechanical properties.

Thus, to obtain high elongation and impact resistance values, it is recommended to use a Mechanical print profile, to cool the parts as fast as possible, and to print shorter jobs (minimizing Z-height) with low packing densities.

The choice of Mechanical print profiles for both HP PA 11 and in HP PA 12 entails a trade-off in dimensional accuracy. However, this is not an issue for the present application. Similarly, Fast Cooling would most likely induce warpage on thinner features, but their flatness in this case is not as relevant as their elongation, which would be boosted with faster cooling.

In terms of materials, the Mechanical print profile for HP PA 11 would result in higher elongation than its HP PA 12 counterpart, even without using Fast Cooling. HP PA 12 GB would not be a good choice of material for this application since it typically results in stiffer parts that tend to snap rather than bend.

1. Based on internal testing and public data for solutions on market as of April, 2016. Cost analysis based on: standard solution configuration price, supplies price, and maintenance costs recommended by manufacturer. Common cost criteria: using HP 3D High Reusability PA 11 material, and the powder reusability ratio recommended by manufacturer. HP Jet Fusion 3D 4200 Printing Solution average printing cost per part is lower than the average cost of selective laser sintering (SLS) printer solutions from \$100,000 to \$300,000 USD. Cost criteria: printing 1 build chamber per day/5 days per week over 1 year of 30 cm^3 parts at 10% packing density.

2. Testing according to ASTM D638, ASTM D256, and ASTM D648 using HDT at different loads with a 3D scanner for dimensional stability. Testing monitored using statistical process controls.

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