



Fast Cooling

Overview

The purpose of this guide is to provide a summary of all the actions that can be taken with, to know the capabilities of, and to garner optimal usage of your Multi Jet Fusion 4200/4210 System with the Fast Cooling functionality when using HP 3D High Reusability PA12, PA12GB or PA11. It includes a summary of recommendations on how to orient your parts, how to place them, and how to choose the right cooling profile to improve part quality and minimize the chances of defects.

Sometimes, depending on what you want to maximize, you should place or orientate the parts and/or choose a different cooling profile.

This guide is divided into the following sections:

- Fast Cooling Usage Recommendations
- The Fast Cooling Speed Knob
- How to Use Fast Cooling

Fast Cooling Usage Recommendations

When to Use Fast Cooling

In general, thermoplastic fabrication requires controlled timings, both during the high-temperature phase and the cooling phase, in order to obtain adequate part properties for their final applications.

Equipment design usually defaults to the standard timings required for optimal part quality for each specific printing profile.

Should we need to accelerate our parts' availability, there exists the possibility of accelerating the processes. In the case of printing, the Fast printing profiles reduce our printing times, but at the expense of lower mechanical properties, in general. The Cooling phase can also be reduced, but this also implies trade-offs with part quality. Typically, dimensional accuracy can be impacted (flat part warpage, etc.) when we accelerate these processes.

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Fast Cooling

The HP Jet Fusion 3D Fast Cooling feature reduces cooling time, resulting in faster time-to-part and more parts being ready on the same day.

The Fast Cooling Timer (a Build Unit parameter; not configurable) starts once the trolley leaves the printer. The timing is changed based on a cooling factor. This factor is used to calculate the Fast Cooling time for different job heights. Modifying this value may compromise part quality.

	Fast Cooling (Default times for PA12)	Natural Cooling (to reach 80°C)
Half bucket (190 mm)	7 h	18.5 h
Full bucket (380 mm)	10 h	36 h

Table 1. Cooling time table for standard fast cooling and minimum natural cooling

The usage of Fast Cooling may imply less uniformity in part cooling rates. Parts might finish at higher temperatures than with Natural Cooling (>50°C).

TIP: You can use the Fast Cooling Timer value for reference when printing similar jobs in the future.

NOTE: Part quality may be affected if the recommended cooling process is not completed.

NOTE: Once you have modified the cooling time, the Fast Cooling process needs to take place until completion with this input. Please, be sure the selected time is the right one before starting the process (the minimum time is 4 hours, the maximum time is 20 hours).

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A Quick Introduction to Cooling Effects

Here is a short description about two of the main cooling effects which could appear on specific printed parts:

Warpage → While cooling (after printing), this effect can appear on thin parts printed horizontally.



Figure 1. Warpage effect example

Bowing → Stemming from the cooling that takes place while printing, this effect is more common with thin parts printed vertically with PA11.

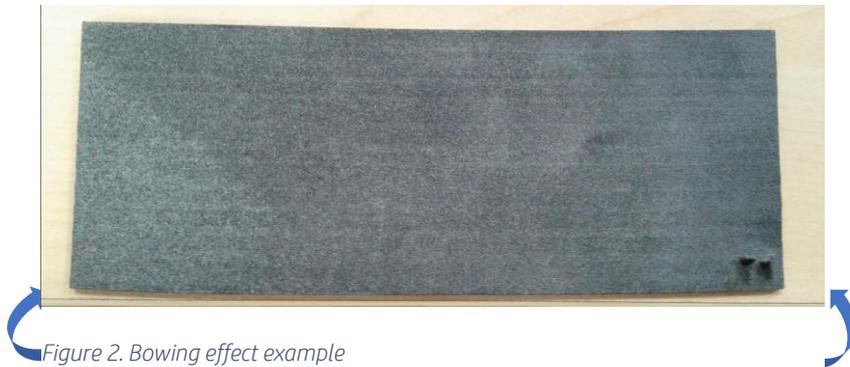


Figure 2. Bowing effect example

Here are some recommendations to prevent these cooling effects:

- **Warpage:**
 - Print shorter jobs
 - Increase the number of white layers to be printed last (adding a small amount at the end of the job)
 - Avoid Fast Cooling
 - Preferably, print at the bottom of the bucket
- **Bowing:**
 - Print in the center of the bed
 - Place parts horizontally
 - Use the Fast printing profile (with PA11), which minimizes this effect (similarly, when using PA12, it is almost non-noticeable)

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Part Classification

There are some parameters related to part dimension and shape that can be considered as the main factors for cooling classifications.

- For parts with long and thin planar sections → The surfaces of interest are the thin planes.

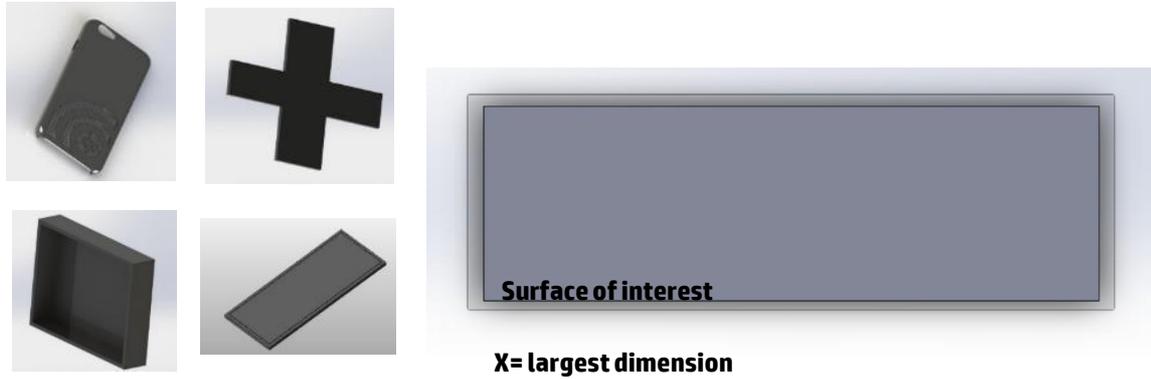


Figure 3. Surface of interest for long and thin planar sections

- For parts with slender planar sections next to thick areas → The surfaces of interest are the whole enclosed areas that need to be flat.

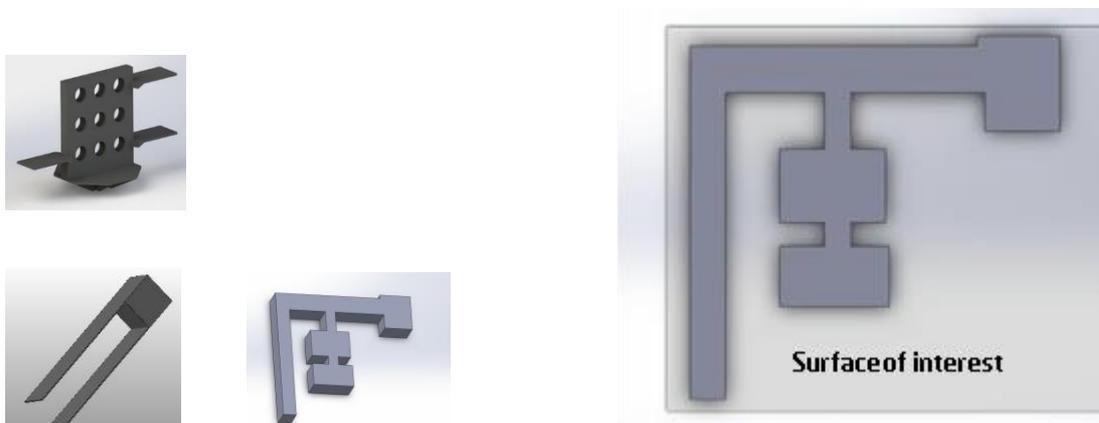


Figure 4. Surface of interest for parts with slender planar sections next to thick areas

- For parts with long, predominantly curved sections → The surfaces of interest are the outwards-projected areas of the long, curved sections.

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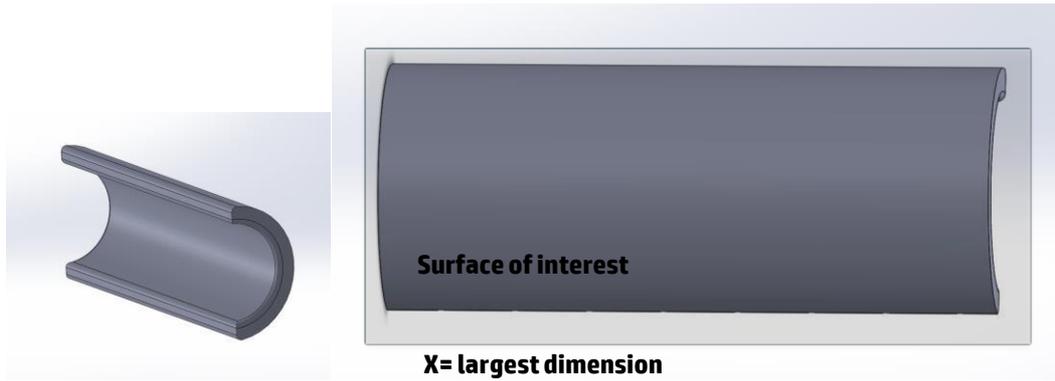


Figure 5. Surface of interest for long parts with predominantly curved sections

Depending on the **surface of interest**:

- A. $> 6500 \text{ mm}^2$ parts can be considered as large warpage-prone parts for which **Natural Cooling** is recommended.

For large, warpage-prone parts we additionally recommend minimizing the number of printed layers by using the bottom area of the build chamber (printing as close as possible to $Z=0$). Also, place these parts parallel to the XY-plane to prevent thermal differences along their height that could result from



Figure 6. Example of part $>6500 \text{ mm}^2$

tilting the parts.

- B. $< 6500 \text{ mm}^2$ parts can be considered as small warpage-prone parts:
 - If $< 1 \text{ mm}$ thick: **Natural Cooling** is recommended. This should be followed in cases where the thickest part of the part is at most 1 mm thick.
 - If $\geq 1 \text{ mm}$ thick:
 - If the XY dimension is $\geq 2 \text{ mm}$: **Natural Cooling** is recommended (where X is the largest dimension of the surface of interest)
 - If the XY dimension is $\leq 2 \text{ mm}$: check its cross-section:
 - For cross-section areas $\geq 1600 \text{ mm}^2$: **Natural Cooling** is recommended.

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- For cross-section areas $\leq 1600 \text{ mm}^2$: You can use **Fast Cooling** (recommended).

In general, for every part, we recommend checking its cross-section surface area in order to choose the right cooling process:

- For cross-sections $\geq 1600 \text{ mm}^2$: **Natural Cooling** is recommended.
- For cross-sections $\leq 1600 \text{ mm}^2$: You can use **Fast Cooling** (recommended).

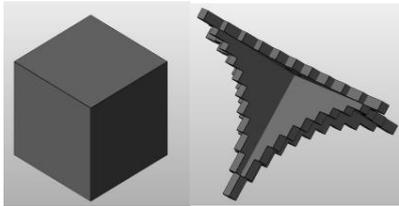


Figure 7. Example of parts $< 6500 \text{ mm}^2$

Tips for Reducing Deformation

Below are some recommendations for minimizing / eliminating deformations on small warpage-prone parts.

Part orientation:

- Print along the X-axis. As a reference, the X-axis is in the same direction as the movement of the carriage. One example is a 3D-printed phone case.
- Minimize the density that is printed per layer. This way, drastic thermal changes can be avoided. Packing density can be modified through build distribution, while layer density can be modified by orienting the part and modifying the design of its shape (hollowing, lattices, topology optimization).
- Place these parts at the bottom of the build. This recommendation can be followed if part shape and dimensions allow for it. At the bottom of a build there is more thermal stability than in other areas.

Part position inside the print bucket:

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- The optimal position for delicate or fragile parts is at the bottom of the print bucket.

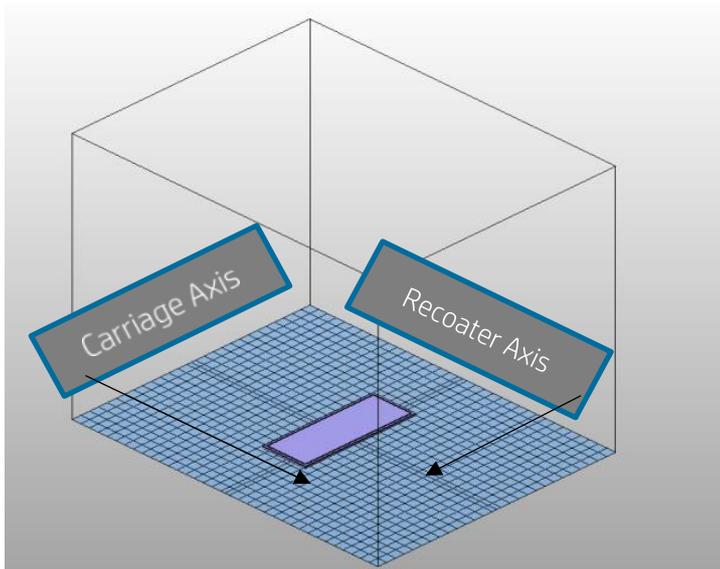


Figure 8. Fragile and delicate parts might be placed at the bottom

The following images show how to place and orient some parts:

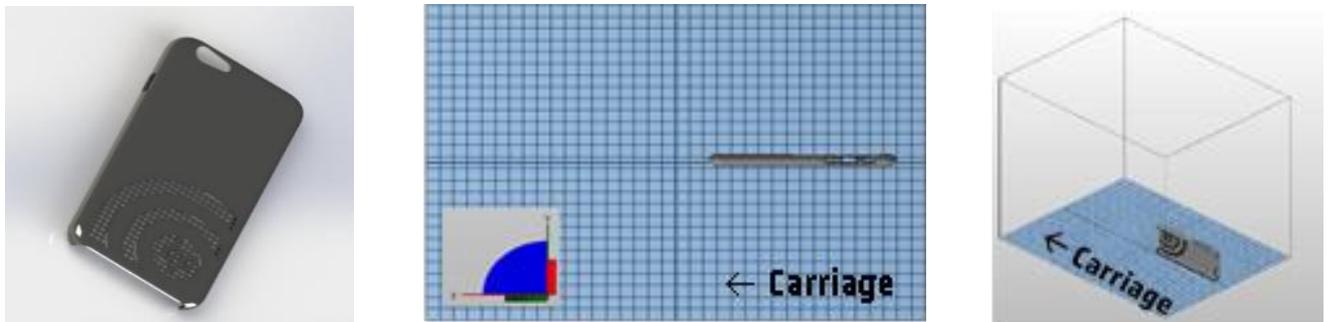


Figure 9. Placement example for phone cases

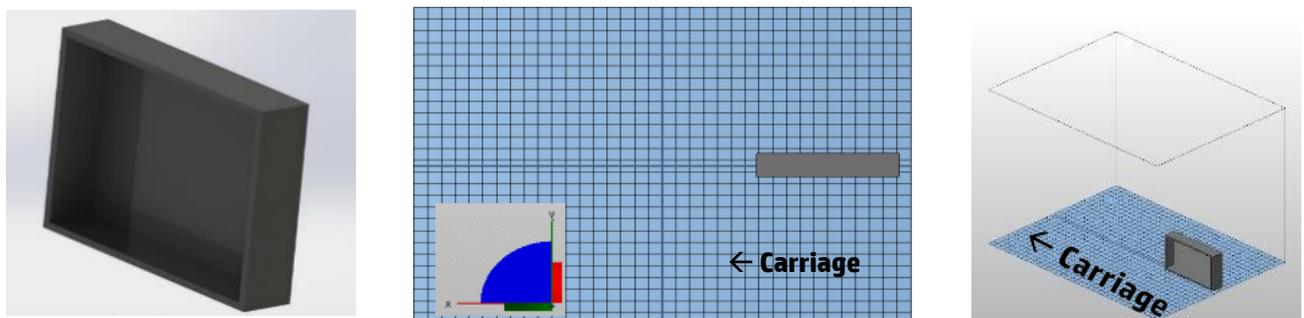


Figure 10. Placement example for housing and enclosure parts

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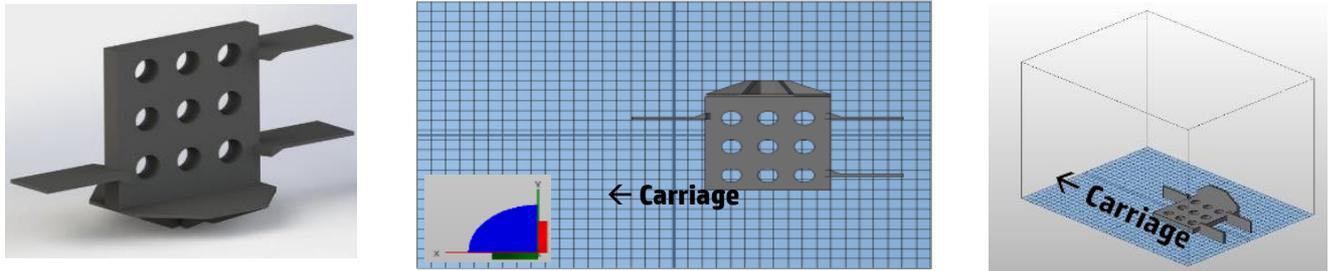


Figure 11. Placement example for parts with mass and section variations

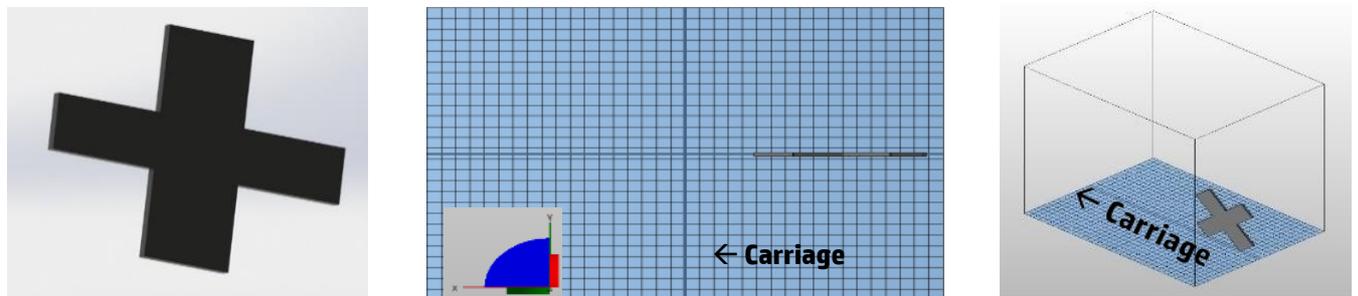


Figure 12. Placement example for long parts with planar sections

Here is a summary of the mentioned part orientations:

- Parts like phone cases should be oriented as shown in the picture, since temperature variations along the part are less pronounced with this orientation. This is applicable to parts with similar shape and volume.
- For rectangular covers and cases, you can follow the same advice.
- Parts with asymmetric protrusions should be placed parallel to the XY-plane to minimize warpage.
- Parts like crosses with long areas like wings or large, flat surfaces in different directions should be placed parallel to the X-axis. This is a recommendation for mitigating warping issues. In case other requirements are needed, please prioritize them (like critical dimensions along the XY-plane or desired mechanical properties in certain areas).

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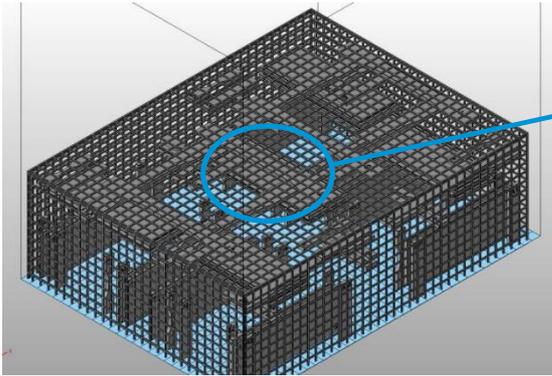
Cages

To prevent the random uncovering of hot parts, we recommend using enclosed meshes.

With the usage of Fast Cooling, cold powder from the borders and top areas of parts tends to be vacuumed before the powder at their centers. This can lead to cooling differences over exposed parts. Enclosed mesh cages help to remove the powder from the borders while covering the areas that need to be cooled in a controlled way.

These cages are generated automatically by some 3D build-preparation and part-fixing software. The spacing and thickness of a cage's walls will depend on your part's shape and its dimensions.

This coverage is recommended only for parts which fulfill part classification requirements for Fast Cooling and for those which could be exposed to the environment with areas still covered by powder, implying a thermal gradient impact along their lengths.



Try to create a solid circle in this area which fills the mesh cells in order to prevent top layer powder from being vacuumed. The Processing Station's hose will be placed over it.



Figure 13. Recommendation while using 3D-printed cages with the Fast Cooling functionality

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Airflow

If cages are not used and there is enough space, try to minimize the presence of parts in the center of the print job to allow better airflow through the center of the job. This will help the hottest parts, which are in the center of the print bucket, to cool down at a faster speed.



Figure 14. Recommendation for part placement while using the Fast Cooling functionality

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Margin

If possible, try to leave margins between the printed volume and print bucket's walls on the top layers. This should help the Fast Cooling process to be more effective at removing the unprocessed and less compact powder. We recommend creating a margin of approximately 25 mm for parts that tend to warp.

This recommendation does not mean this area cannot be used; the printable area remains the same. However, this is a way to minimize warping issues in this area for certain part shapes and dimensions.

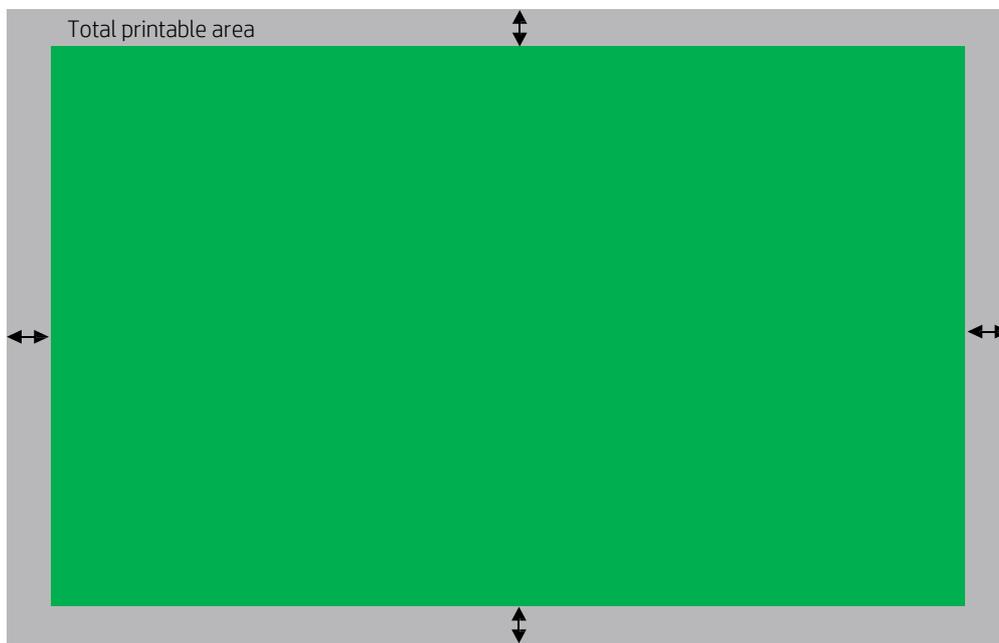


Figure 15. Safe margins while using Fast Cooling to avoid cooling effects

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The Fast Cooling Speed Knob

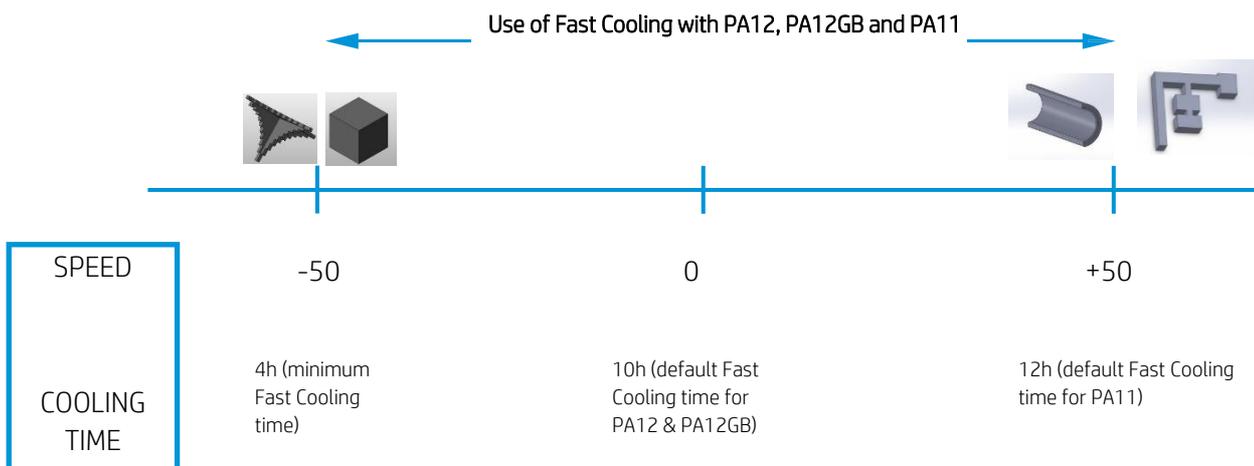
The Fast Cooling process will include a speed knob in future releases.

The operator can change the **Fast Cooling** time with the knob, increasing or decreasing it.

- For parts that are classified for **Natural Cooling**, it will be possible to use longer **Fast Cooling**. The operator will be able to increase **Fast Cooling** to up to 20 hours (compared with the 36 hours of **Natural Cooling** time for a full bucket).
- For parts that are classified for **Fast Cooling**, the operator will be able to decrease the default time down to 4 hours, depending on the part (compared with the 10 standard hours of **Fast Cooling** time required for a full bucket of PA12).
- The same cooling times and speed knob capabilities of **PA12** are recommended for **PA12GB**.
- **PA11** differs from PA12 and PA12GB in the following ways:
 - The default cooling time is about 12 hours instead of 10.
 - A minimum cooling time is not recommended for PA11, since its thermal characteristics and melting temperature are higher than PA12's and PA12GB's.
 - The same recommendations for part classifications and Fast Cooling usage can be followed for PA11. However, due to the same reasons given before, warpage / shrinkage issues could be aggravated when using this material.
 - With PA11 there may be other effects, like bowing, which is related to the cooling that occurs during the printing of parts printed vertically.

This effect is not related to Fast Cooling or the post-printing cooling process.

Check the "Part Quality - Tips & Tricks (2018) MJF" document to understand how to prevent this effect.



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How to Use Fast Cooling

Some things to consider when using Fast Cooling are:

Unpacking

- SAFETY FIRST: Use suitable gloves (high-temperature-resistant gloves)
- In case parts are large or the powder around them seems very hot, put them to aside for a while to allow them to further cool down.
- If vacuum speed slows down (due to excess powder temperature), the cooler powder (or the parts in cooler locations in the build) need to be unpacked.

TIP: The sides and corners of the print bucket are cooler than the center of the print bucket. Try to alternate powder extraction from between the center and the sides.



Figure 16. Example of high-temperature-resistant gloves

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