Multi Jet Fusion printing tips and tricks

August, 2017

The purpose of this guide is to provide a summary of all the actions that can be taken to improve part quality when printing with your Jet Fusion 3200/4200 printer. It includes a summary of best practices to keep your printer in optimal condition, and recommendations on how to orient parts, how to place them and choose the right printing or cooling profile to improve part quality and prevent defects.

Sometimes, depending on what you want to maximize, you should place, orient the parts and/or choose a printing or cooling profile differently. In this guide you will find a compilation of printing recommendations that you should consider when you are orienting parts in order to get good part quality with respect to your needs. This guide is divided into different chapters:

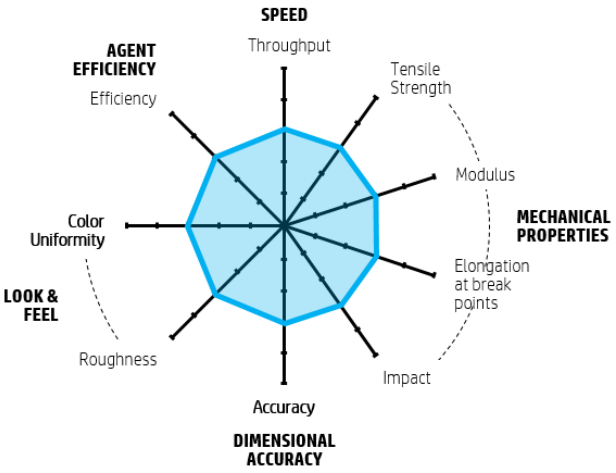
- General considerations
- Improving the look & feel of a part
- Optimizing mechanical properties
- Optimizing dimensional accuracy
- Examples
- Appendix

General considerations

1. The first step towards getting optimal part quality is preparing the site according to the requirements listed in the Site Preparation Guide:
    - The operating temperature of the equipment should be between 20-30 ºC, but more specifically, optimal performance can be achieved between 24-26 ºC
    - Operating humidity should be between 30-70%. The impact of humidity on this technology is lower than impact seen from temperature
    - Special attention should be paid to the Ventilation and Air conditioning chapters. If you install an active hot air extraction system, it will be easier to keep the printer in stable temperature conditions with less refrigeration needed
    - Power line quality is important. If you suspect that the power installation at the site could suffer from variability or alterations, we recommend installing an Uninterruptable Power System (UPS).
2. The second step towards ensuring part quality is to adhere strictly to the User's Guide cleaning, maintenance and calibration practices. For details on how to properly maintain the printer, please check chapter 12 - Maintenance in the User's Guide.
3. As a third step, there are different calibrations that should be performed that will help ensure that the printer's thermal control is correct. Please check chapter 12 - Maintenance in the User's Guide for more details on how to calibrate the printer.
    - Calibrating the Temperature camera: This calibration is used to compensate for small mispositionings of the Temperature camera sensor
    - Fusing lamp calibration: This calibration is used to correct irradiance deviations
4. Some problems might be caused by printhead issues. Make sure the printheads are correctly aligned, and follow the instructions in chapter 13 - Print quality optimization -> Printhead troubleshooting to learn how to troubleshoot printhead problems.
5. Even if your printer is perfectly clean and calibrated, it might still be necessary to fine-tune the energy provided for by the lamps. This is a process that can be done by customers and allows them to modify the irradiance of the lamps based on an assessment made after printing some control parts. Consult the newsletter "Part quality tuning - HP Jet Fusion 3D Printer" for details on how to do this fine-tuning. Remember that if you are going to use different print modes, lamps might need to be fine-tuned for every individual print mode.
6. Select the proper print mode according to what you want to optimize. Please see the diagrams below to understand differences between the currently available print modes.

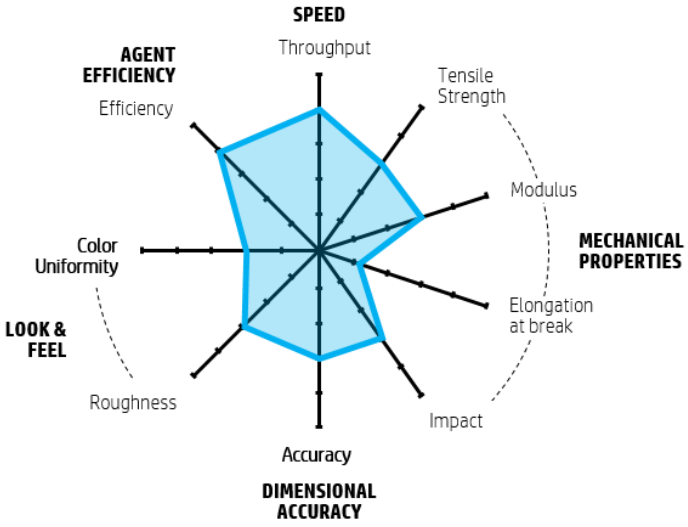
BALANCED PA12

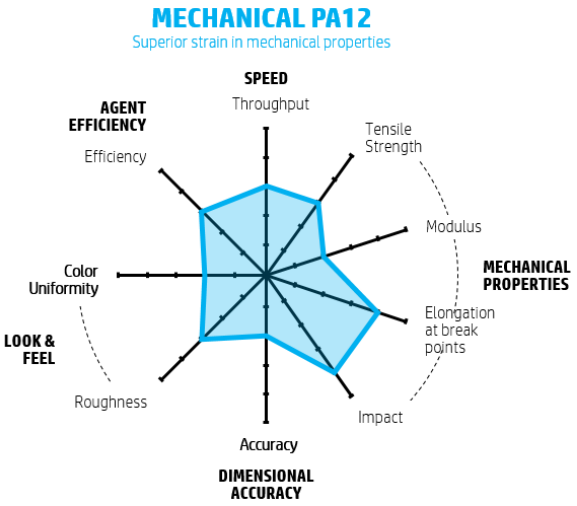
Default mode, delivering balanced properties



FAST PA12

Increased speed for any job





- Use the Balanced print mode to get a good compromise between look and feel, dimensional accuracy and mechanical properties.

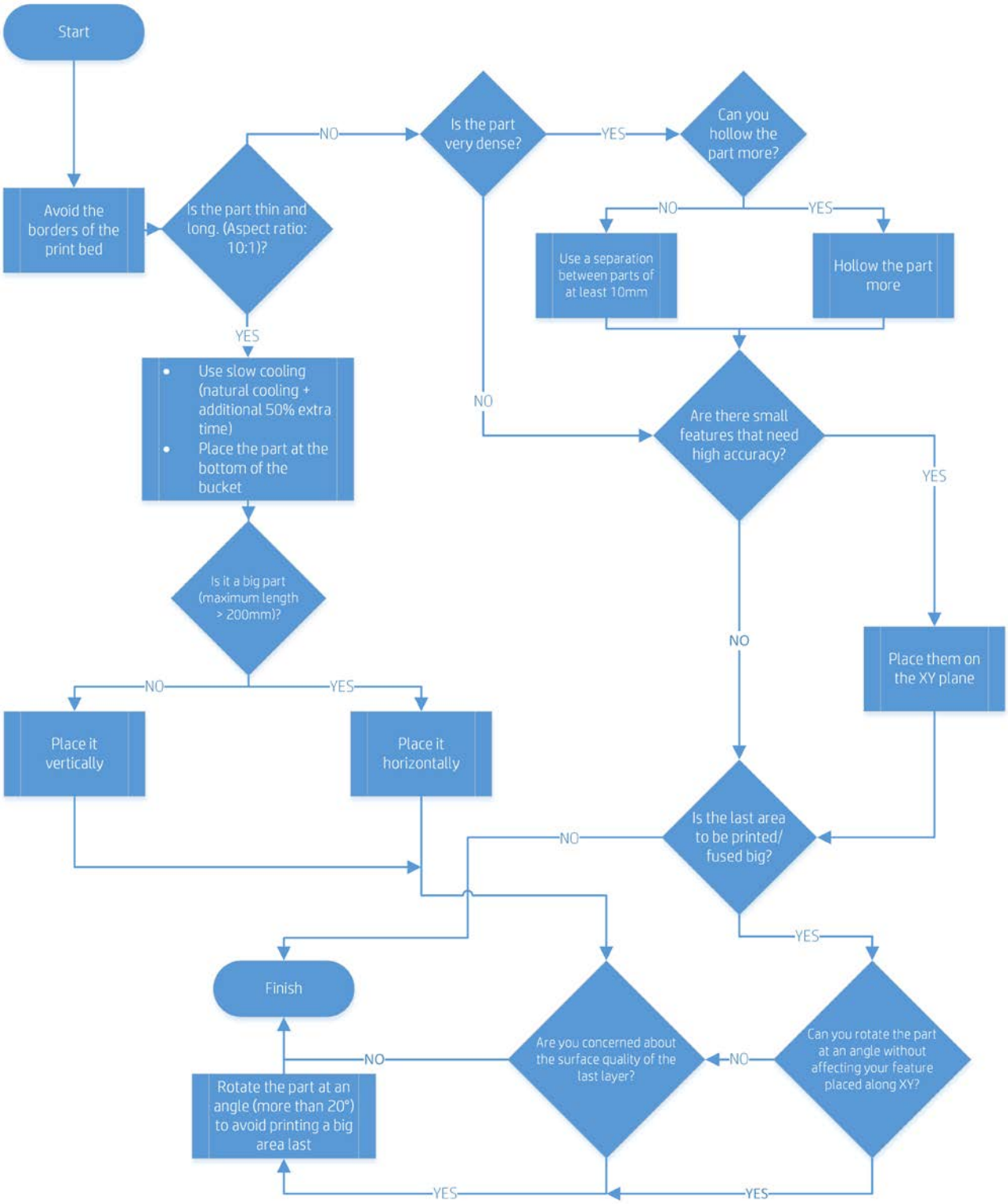
- Use the Mechanical print mode to get the best elongation-at-break-point results for your printed parts. Even with a lower Young's modulus, they will be the strongest parts.

  Please note, however, that the Mechanical print mode will not increase ultimate strength and as the build temperature will be higher, it is not recommended for parts that need to be very accurate.

- The Fast print mode is recommended to reduce the time to print and cost but it may reduce elongation at break points, even though tensile strength will be the same.

7. Orient and position your part, or apply some design changes to it in order to improve part quality in some specific areas. Follow the next chapters in this guide when making your final decisions based on what needs to be optimized (look and feel, mechanical properties or accuracy). Notice that some of these recommendations will be useful to solve problems that we are still investigating and working on. Check for updates to the guide to have the most up to date set of recommendations on hand.

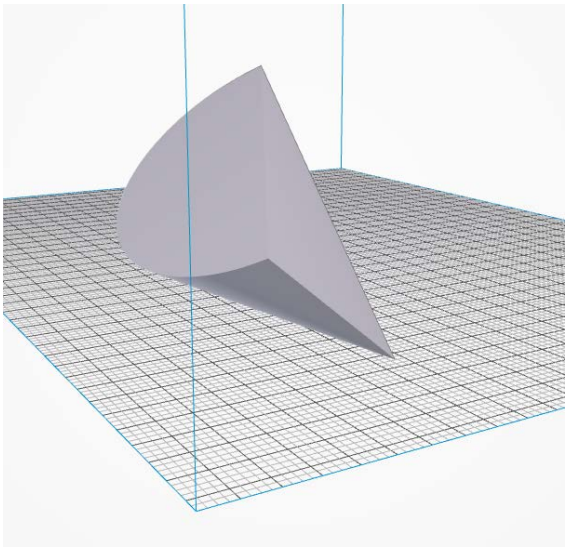
As general best practices on how to orient and position your part, please follow this flowchart:



Improving the look and feel of a part

General considerations

Smoothness is best achieved with surfaces that are upside down in the build chamber. If a part needs a particularly smooth surface, it should be positioned upside down.



In the figure above you can see that the part is also placed in order to prevent stair-stepping (avoiding angles less than 20 degrees to the horizontal plane) by placing the curves upside down.

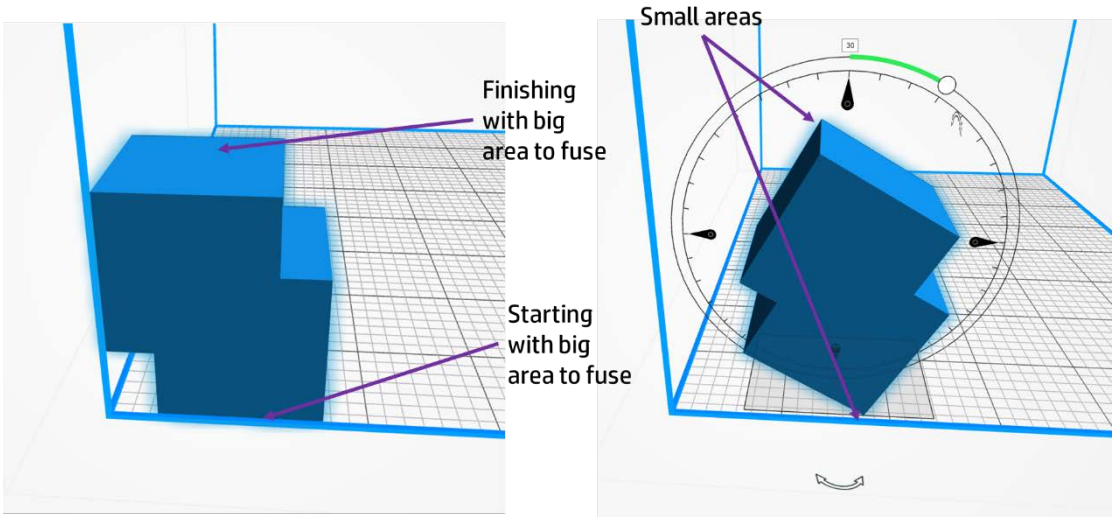
Also, finishing the print job with a small area to fuse is a key to improving the quality of the last layer.

High-density parts

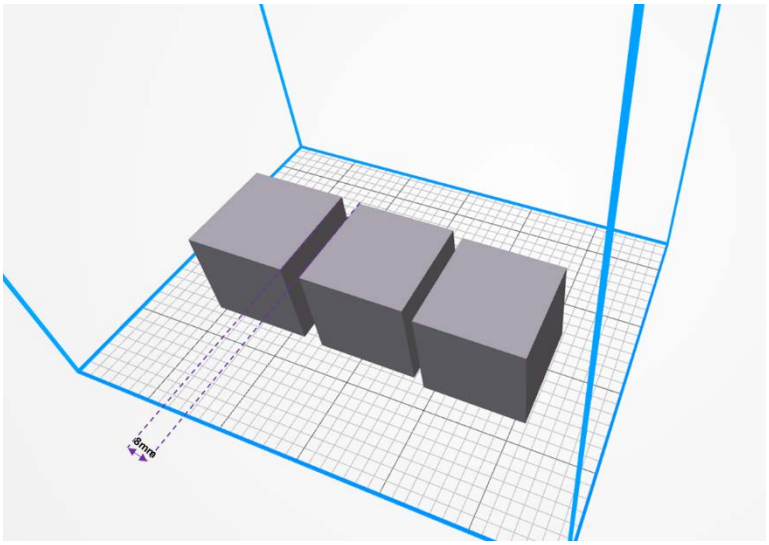
Very dense parts require more energy to be fused; therefore to get the best results it is recommended to consider the following:

Orientation and positioning recommendations

- Start with a small area to fuse and also finish with a small area to print/fuse in the case that you are faced with abraded tops or sinks (see Appendix for a more detailed explanation). This can easily be achieved by rotating the part at a certain angle: It is recommended to rotate the part more than 20 degrees to minimize stair-stepping (see Appendix). For example:



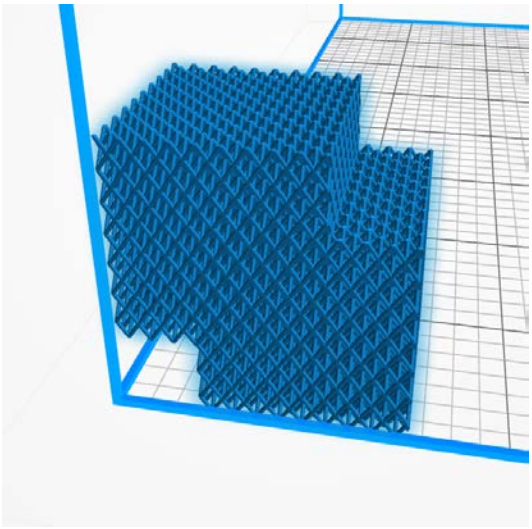
- Place the parts with a distance between them of at least 10 mm in case elephant skin is observed (see Appendix for details):



- Use the Fast print mode to prevent top surface sinks (see Appendix for details).

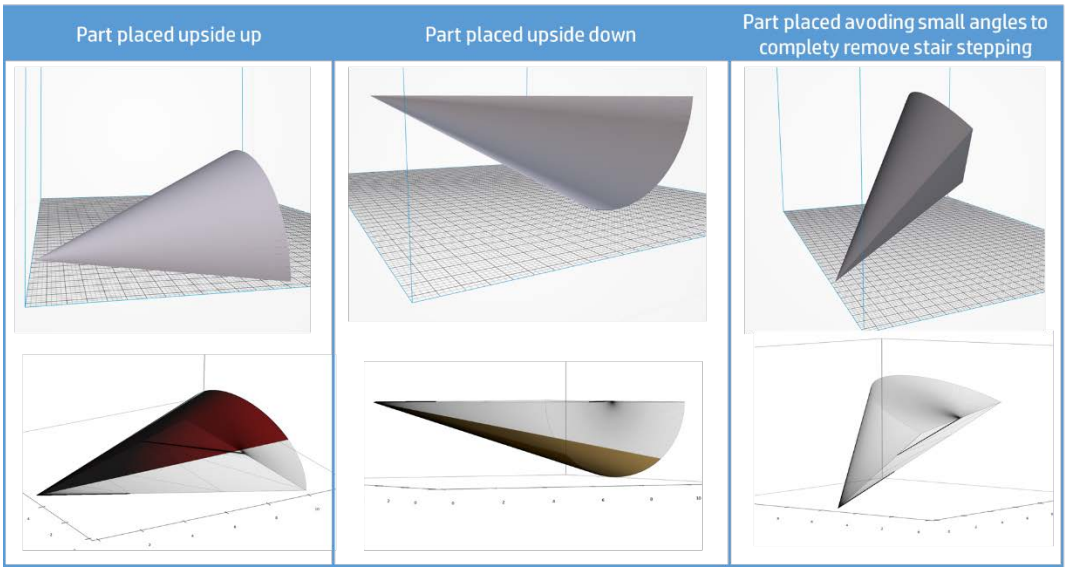
Design modification recommendations

- HP Multi Jet Fusion Technology allows you to create complex structures, such as lattice structures, that will help you to hollow your part, achieving the best look and feel and accuracy results, without compromising mechanical properties:



Parts with curves

As was explained in the “General considerations” subsection of the “Improving the look and feel…” section, visible areas of your parts should be placed upside down. Also, it is recommended, in order to prevent stair-stepping (see Appendix), to avoid placing curved surfaces upside up at an angle lower than 20 degrees. In other words, if you want to place a surface at an angle (not flat), the angle needs to be at least 20 degrees:



Optimizing mechanical properties

Improving elongation and impact resistance

Use Fast Cooling

Using Fast Cooling will increase part elongation at break and impact points.

For parts that are likely to exhibit warpage, Fast Cooling is not recommended, as it will increase the chances of warpage.

Use a low packing density

Lower packing density allows for better temperature control, thus better homogeneity, improving a part's mechanical properties.

Plots short in height

Minimizing the build height will allow shorter printing and cooling times which also improves the mechanical properties of the printed part.

Optimizing dimensional accuracy

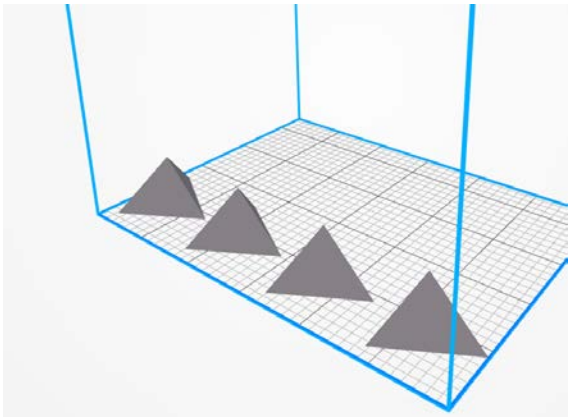
General considerations

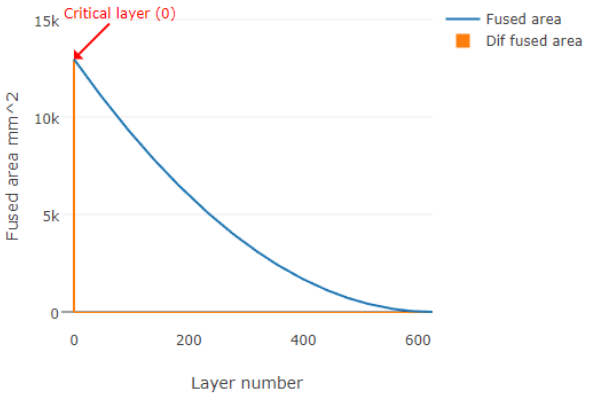
Orientation and positioning recommendations

- Preventing fused area discontinuities:

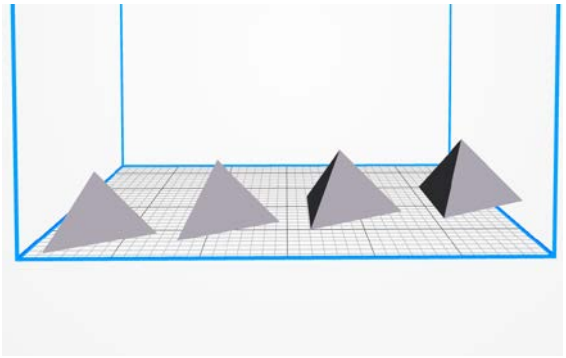
  For example, if we want to print a tetrahedron, we can easily prevent fused area discontinuities by relocating them and placing them in a staircase-like way:

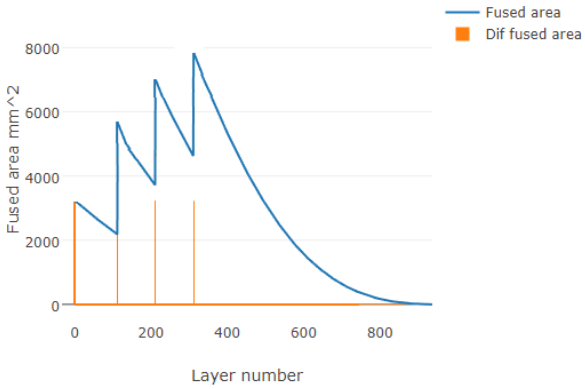
  What should **not** be done:





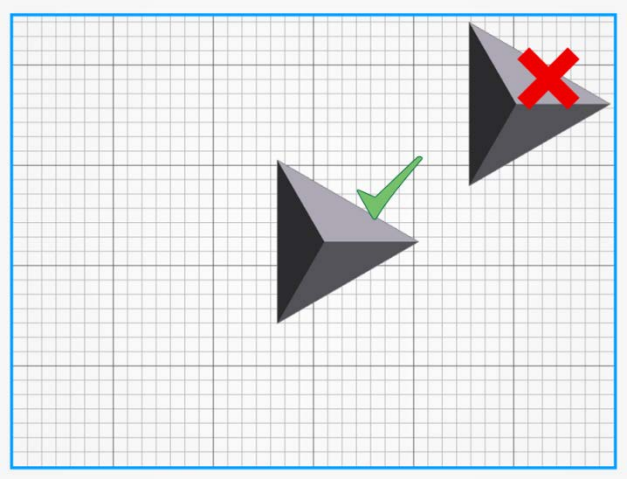
  A better proposal:





- Center the parts:

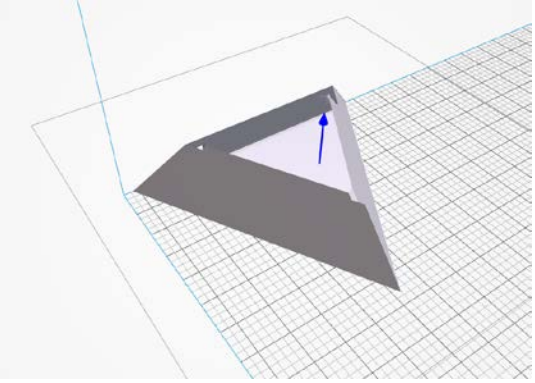
  When possible, place critical parts in the center of the build chamber:



Design modification recommendations

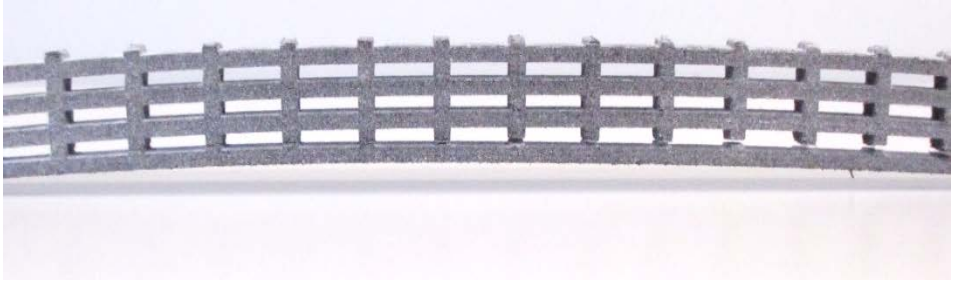
- Making the part hollower:

  Avoiding thick walls, making the part hollower, and creating lattice structures are ways to reduce mass and cost and they will allow you to print with better thermal stability, which will lead to better dimensional control.



Thin and long parts

Long and thin parts are susceptible to having non-uniform cooling, which will cause an uneven shrinkage all along the printed part, which creates a distortion along the part in a certain direction that varies from the nominal shape. Cooling the part uniformly is a key factor to reducing warpage. As a rule, any part that has an aspect ratio higher than 10:1 is susceptible to showing warpage.



Cooling recommendation

To reduce warpage for some of these parts it is strongly recommended to slow cooling by up to 50% more than is recommended.

Orientation and positioning recommendations

One of the main differences between other technologies like laser sintering is that MJF fuses all area layer with one pass. This allows us to reduce warpage along the XY axis. While SLS parts are recommended to be oriented diagonally to reduce warpage, MJF parts are recommended to be placed horizontally to reduce warpage and improve dimensional accuracy (please note that if you want to prevent capillarity you should place the part diagonally).

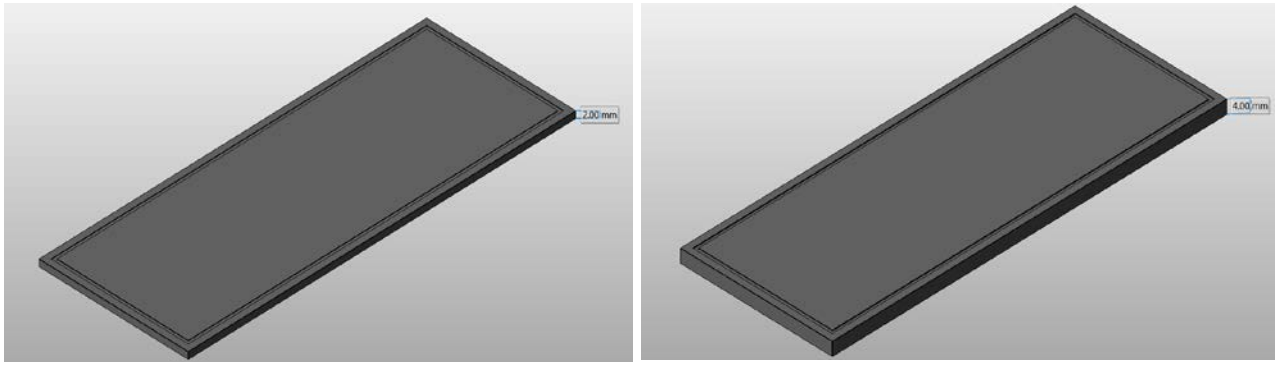
Printing the part as low as possible inside the build chamber will allow the part to cool slower, reducing the probability of warpage.

Also, it's recommended to avoid printing near the borders of the print chamber area so that the part can cool down the part more uniformly.

It is also important for warpage reduction to perform all the maintenance, especially the fusing lamp, heating lamp, and thermal camera glass cleanings.

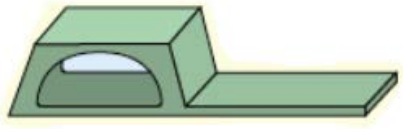
Design modification recommendations

- Longer walls need to be thicker than short ones, because the thinner the part is, the more pronounced warpage it will have because it won't be stiff enough to bear the internal stresses.

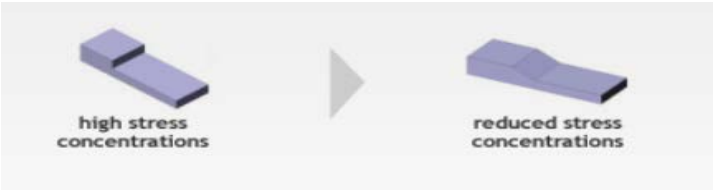


Flat Planes - 2mm and 4mm thick

- Hollow thick parts more, and design ramps between transitions:

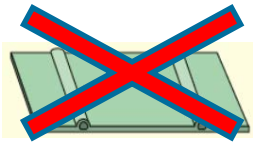


Complex parts with localized heavy sections



Reducing the stress concentration in the transition of the sections with different thicknesses

- Avoid placing a part's ridges or ribs on large flat areas, because they generate thermal gradients due to their non-uniform cooling:



Parts with small features or holes

The best resolution in MJF printers is achieved along the horizontal plane; Whenever it is possible place the part horizontally (if the last area to finish being printed is small). Features that require the highest resolution should be placed on the XY plane. Cylindrical bodies, however, should be oriented vertically as much as possible.

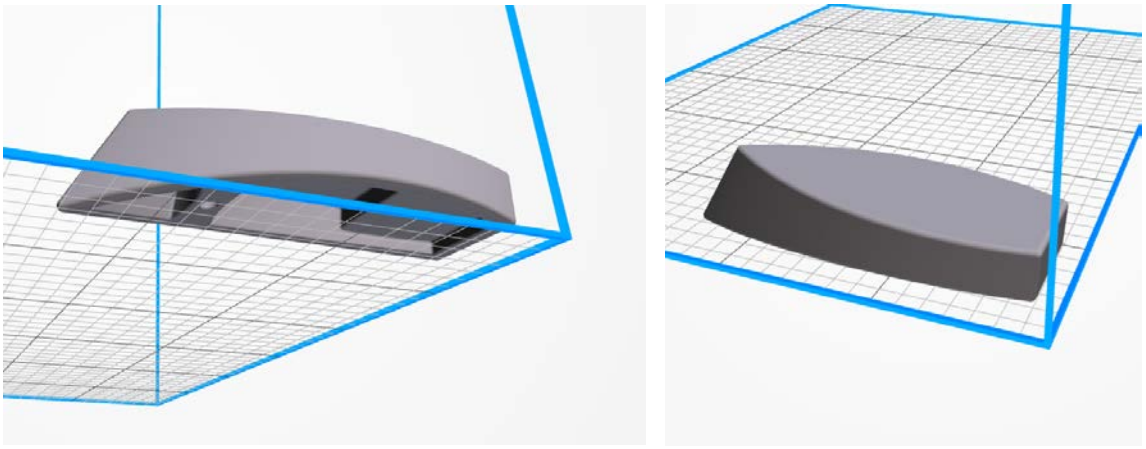
Examples

Toy sailboat

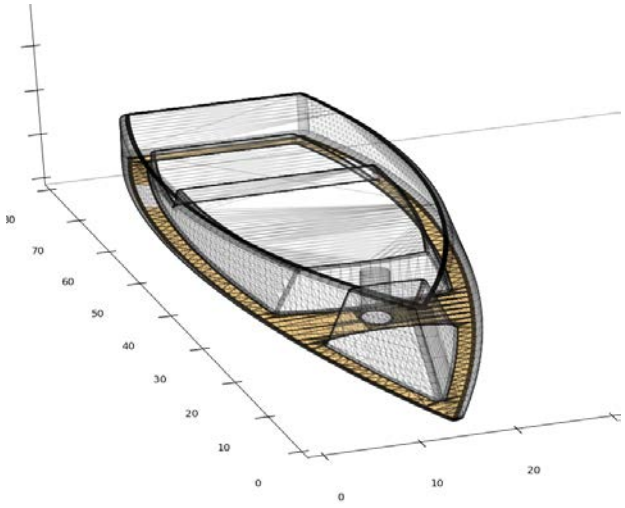
First, it can be observed that in the middle of the sailboat we have a hole in which we will introduce the sail, and as it's a toy, the most important attribute is its look and feel:



The visible area of the final part will be the top of it, therefore this area must be placed face down in order to increase smoothness:



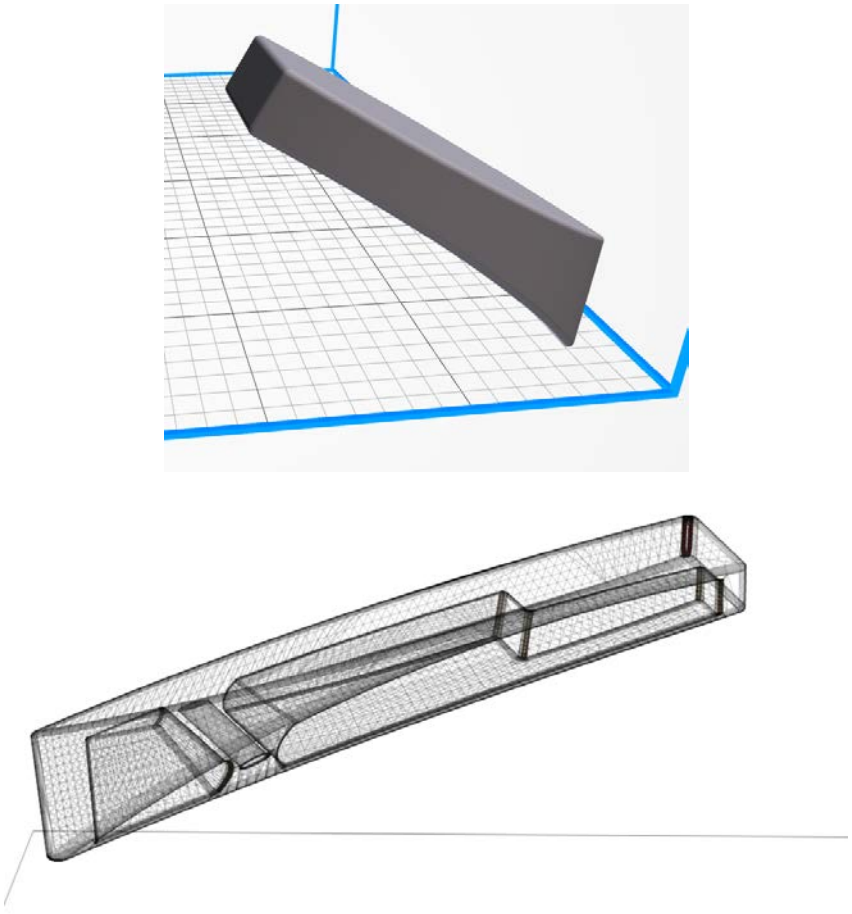
If we print the part with the orientation shown above, we will see the difference between layers in the surfaces that have an angle less than 20º to the horizontal plane:



This defect is called stair-stepping and can be avoided by placing the surfaces so that they have an angle higher than 20 degrees to the horizontal plane.

Also, as we are going to end up with a large fused area, we will unfortunately see the capillarity effect on the part's top surface.

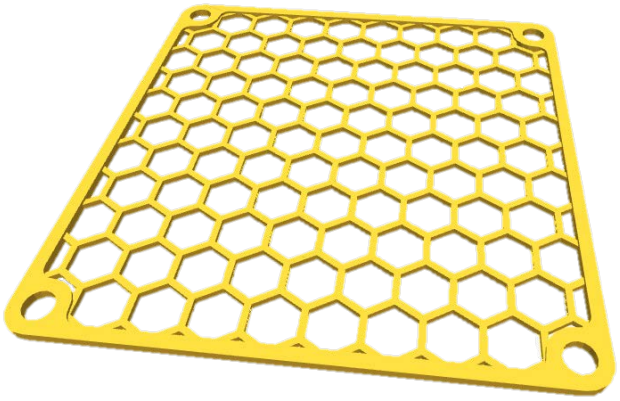
To prevent capillarity and stair-stepping, all the while maintaining the smoothness of the visible area: once you have placed the part face down you should rotate the part 30 degrees, like in the following picture:



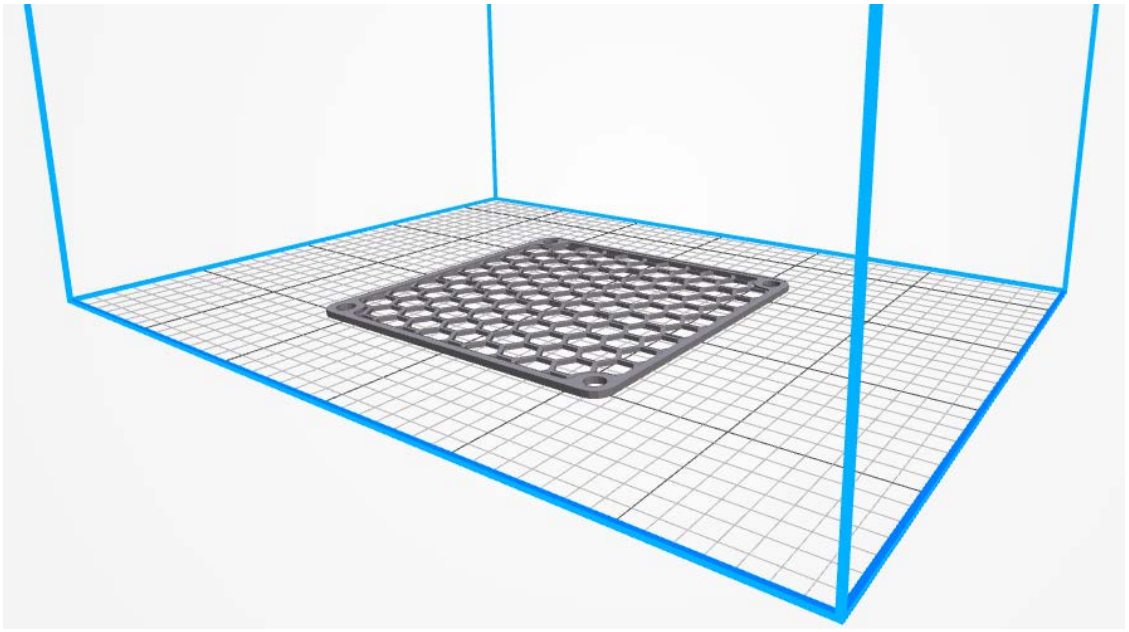
As can be observed in the figure above, the hole to insert the sail won't be printed along the XY plane, where the best resolution is achieved. This is a trade-off that we must accept in order to maximize the part's look and feel.

Accurate honeycomb structures

If you want to print this structure optimizing its dimensional accuracy, the first thing you must notice is that it is very similar to a big flat plane, therefore the part is more prone to suffering warpage:



In order to prevent this, it is recommended to orient the part so that its height is minimized. Place the part as centered as possible and increase cooling time up to 50% more than the recommended:

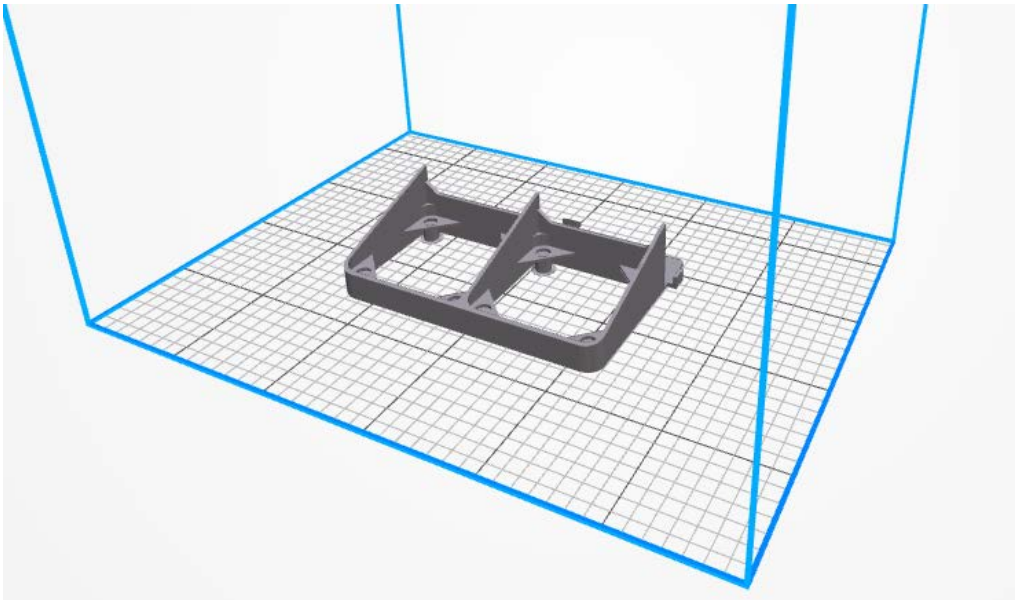


With this proposal, we are cognizant that some top areas will be affected by capillarity, but as the part is thin, only slight capillarity will be seen.

Dual fan mounts for automotive applications

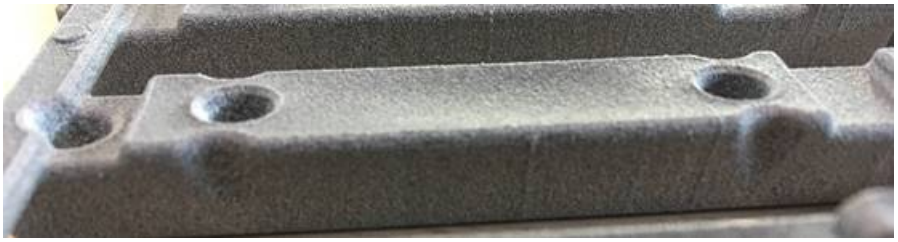
Most automotive applications require high elongation and impact resistance values. To achieve these values it is recommended to use the Mechanical print mode and cool the job as fast as possible. For the following part pictured below, you should consider the following:

- The Job that contains this part should be as small as possible
- Fast cooling will improve elongation and impact resistance
- Use the Mechanical print mode



Appendix: Part quality defects

Sinks



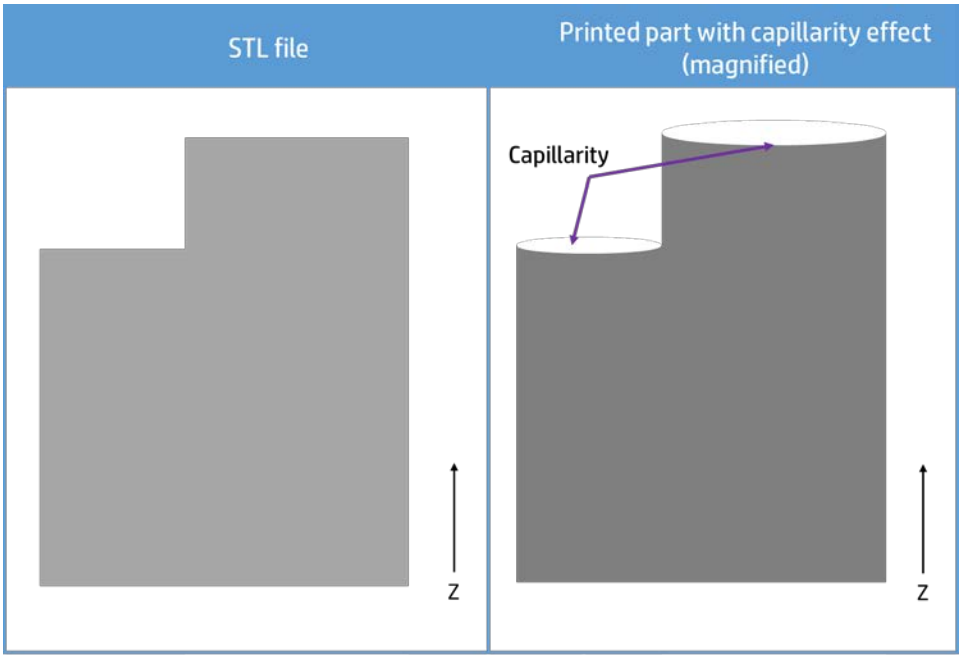
For parts that are thick and dense you might experience a local shrinkage on the surface of the part. This is more frequent on top surfaces.

To minimize this problem you can follow the instructions to print dense parts:

- Hollow the part more
- Tilt the part
- Try to print in the Fast print mode

Capillarity

This effect appears due to the interaction of the agents and the powder. When a layer is fused, it behaves as a fluid and tends to raise up on the borders (as does water inside a glass), which ends up showing up in the final part. You can see that the top surface of the part has raised borders compared to the rest of the area, which is in a lower position.



Orient the part correctly in order to minimize its top surface area, to reduce the visibility of the defect.

Abraded tops

Abraded tops appear when there is a big area to fuse at the end of printing a part. In this situation, the printer adds a considerable amount of detailing agent to avoid thermal bleeding, causing this irregularity on the surface.

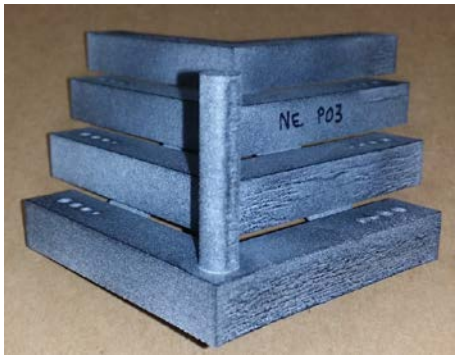


Orienting the part correctly in order to minimize its top surface area is the key to completely neutralizing the possibility of this defect. This picture below shows the same part after being printed with an inclination of 45º to minimize its top surface area.



Elephant skin

Elephant skin appears when the white powder surrounding the part on the print bed is cooler than the defined powder temperature; slight local shrinkage can be seen.



Elephant skin is due to not properly controlling the bed temperature; this can be avoided by cleaning the Fusing and Heating lamp glasses and the Temperature camera glass.

Also be sure that the Temperature camera sensor is calibrated and your printer's lamp irradiance has been fine-tuned. For irradiance calibration, please see the newsletter "Part quality tuning - HP Jet Fusion 3D Printer."

If this problem persists after cleaning the glasses and calibrating the printer, please place the parts in the build chamber as centered as possible (avoid positioning them close to the borders of the print bed).

Hollowing the parts can help reduce this defect. Also, elephant skin can be seen on massive parts when they are printed in close proximity to one another due to detailing agent interacting between parts. Placing massive parts farther apart from each other than what is recommended (10 mm) is the key to preventing elephant skin.

Stair-stepping

Stair-stepping is a phenomenon that appears when printing using layer-by-layer processes.

It can be prevented by placing the parts correctly in the print chamber. Surfaces placed upside down are smoother; this effect largely helps to remove any chance of stair-stepping. To completely prevent stair-stepping, avoid positioning surfaces with angles less than certain values to the horizontal (XY plane), depending on layer thickness. The minimum and maximum thickness values recommended for the current print profiles (at 80 microns) are the following:

	Visible stair-stepping	
Layer thickness (microns)	Minimum angle	Maximum angle
80	0	20

