Design Guide

SAF™ technology Design Guide

stratasys

Accuracy Compensation

Scaling Factors

When polymers are hot, they expand, when they cool, they contract. When parts are printed and fused, they are in their hot, expanded state, from which they will cool and contract. To compensate for this, the parts need to be scaled up before they are printed to allow them to cool back to their nominal size.

This is achieved using scaling factors which are applied during slicing. The factors will scale the parts up in the X, Y and Z directions. These scaling factors can be tuned using calibration builds.

When using GrabCAD Print, the scaling factors can be entered into the H350 online in Configuration > Buildfile tuning > Default Shrinkage Compensation Factors. When using other build preparation software, the scaling factors will need to be entered into the build processor directly.

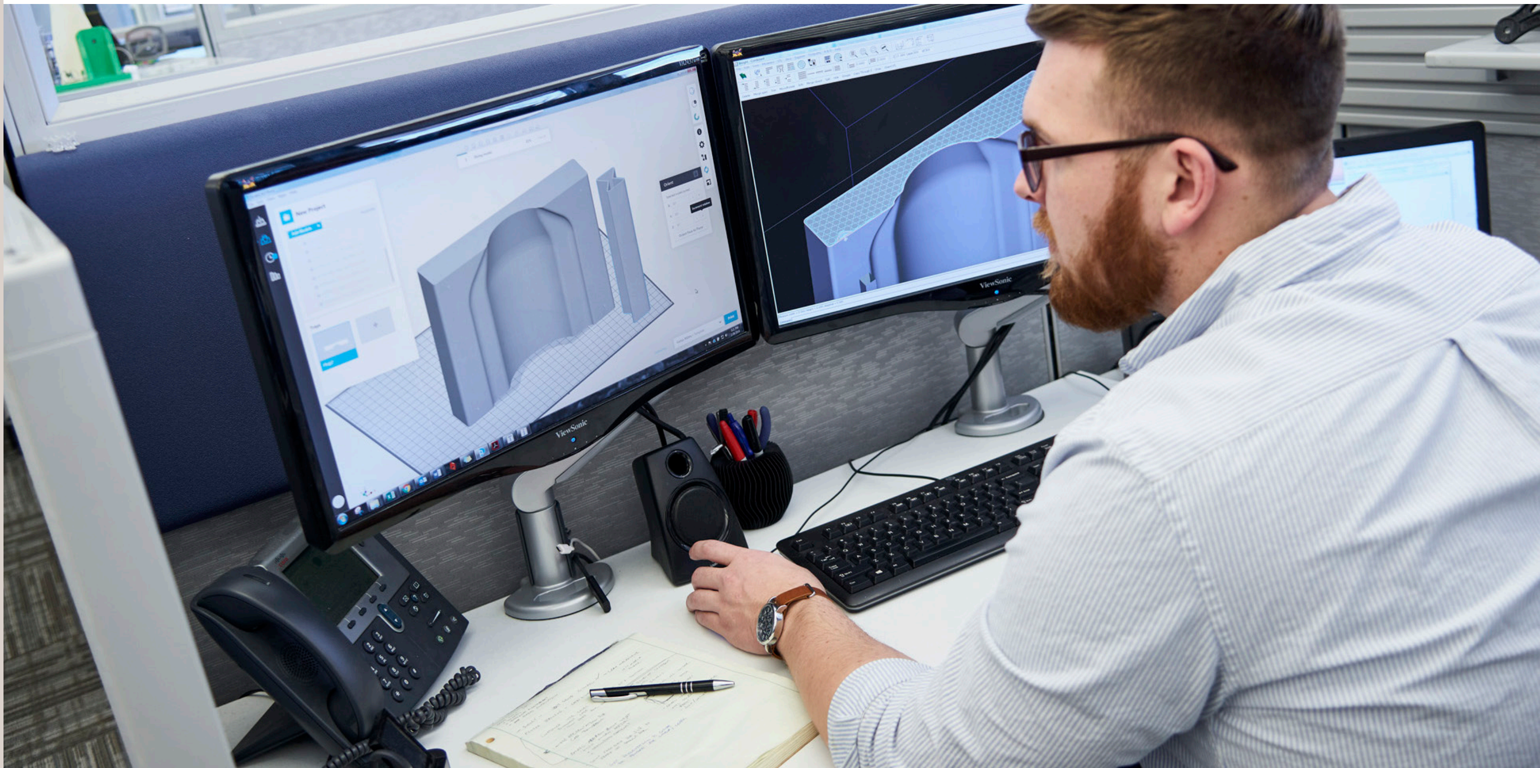
Maximum Part Size

As all parts will be scaled up during slicing, this needs to be considered when talking about the maximum part size (or maximum effective build volume).

Using the scaling factors, the build envelope can be scaled down to give the maximum effective build volume. Any part which fits within this volume will be printable. When using GrabCAD Print, this will be automatically calculated and displayed within the software.

Scaling Factors Summary

- During slicing parts are scaled up in X, Y and Z to compensate for shrinkage
- This can be calibrated per machine
- Due to scaling, the maximum part size/effective build volume is slightly smaller than the total printable area



Border Shaving

During fusion, the printed area exceeds the melt temperature of the material. There will always be some thermal gradient between the printed and non-printed areas. This results in a very small amount of extra material being heated sufficiently to fuse onto the part walls, this is referred to as wall growth, illustrated in Figure 1.

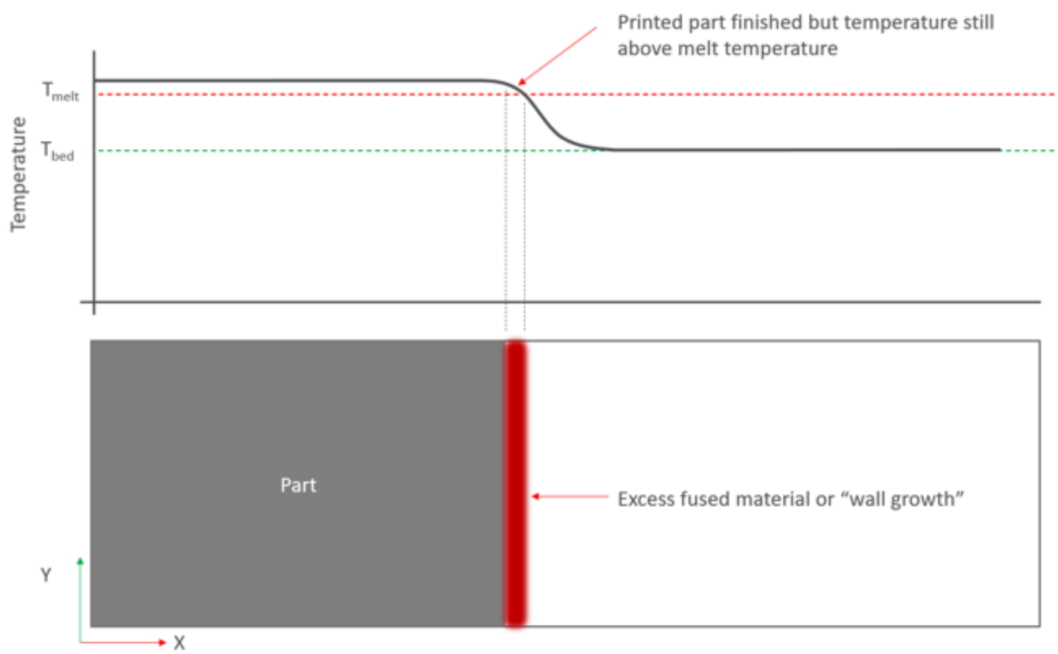


Figure 1

The result of wall growth is that all part dimensions in the XY plane grow by a fixed amount. To compensate for this a process called border shaving is applied to the build slices where a small number of pixels around the edge of all parts are deleted. The process is illustrated in Figure 2.

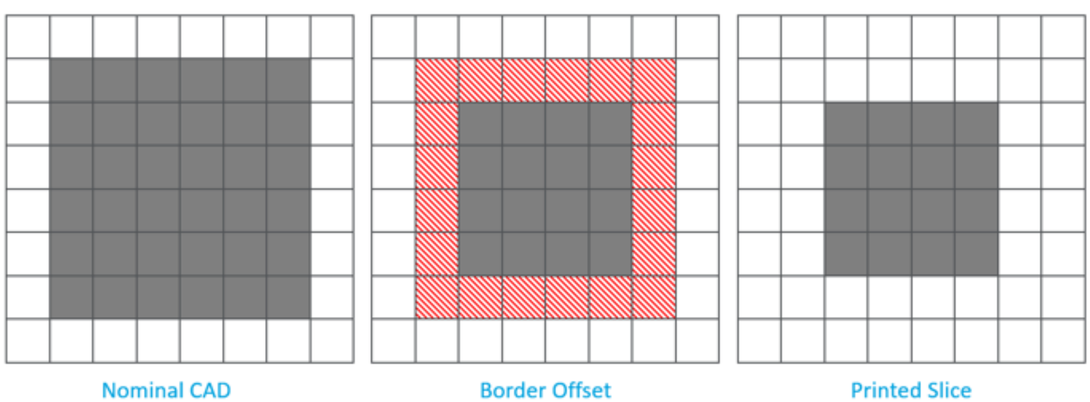


Figure 2

This border shaving allows for wall growth and ensures that the finished part is accurate to the nominal CAD data, as shown in Figure 3.

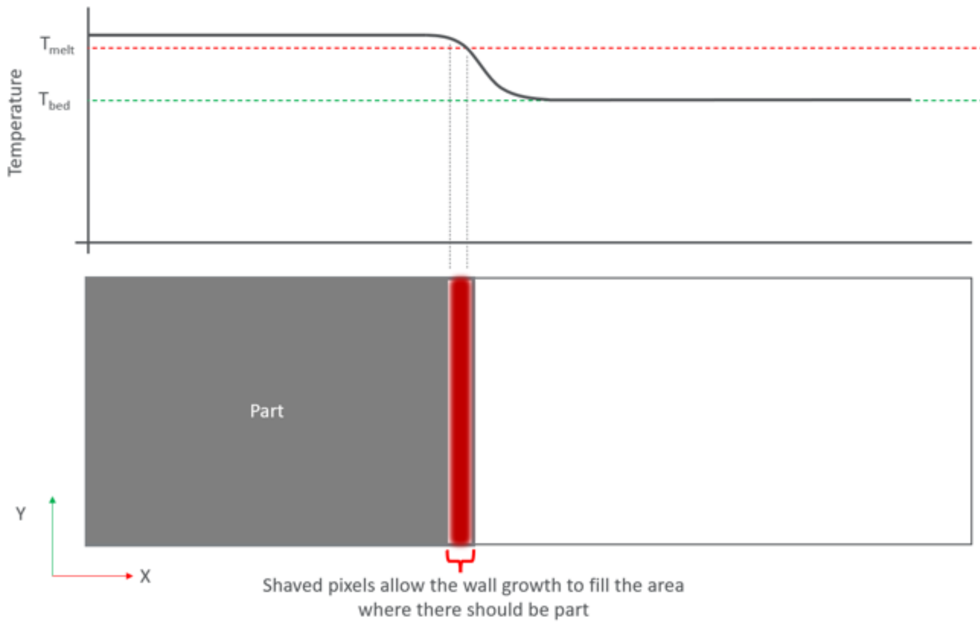


Figure 3

When using GrabCAD Print, the border shaving value can be entered into the H350 online in Configuration > Buildfile tuning > Border Shaving. When using other build preparation software, the border shaving value will need to be entered into the build processor directly. Note that the values used for GrabCAD Print and other software will differ slightly due to implementation. When entered into the H350 online, the “Magics Equivalent” will be displayed for reference, this value should be used in the Magics build processor.

Fine Feature Resolution

Understanding the need for, and implementation of, border shaving it’s important to understand the fine feature resolution of the H350. When a fine feature is present in the XY plane there is a risk that the application of border shaving will delete the feature completely or at least lead to under sizing of the feature. This is illustrated in Figure 4.

Where fine features are required, better results are obtained by printing with the thin dimension in Z. A minimum feature size of 0.5mm is recommended, although advanced users with an understanding of border shaving may be able to achieve less than this.

Recommended minimum feature size	0.5mm

Border offset should be considered when printing any thin feature or fine detail, examples are:

- Fins
- Living hinges
- Labels and text

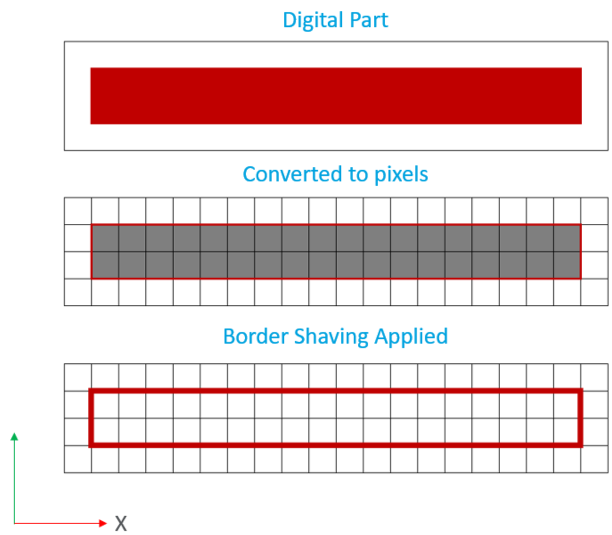


Figure 4

Border Shaving Summary

- Border shaving deletes pixels around the edge of parts in each slice to improve accuracy
- Border shaving only occurs in the XY plane, not in Z
- Be aware that very thin features in the XY plane can be made smaller/deleted completely when shaving is applied
- 0.5mm is the minimum feature size
- Thin dimensions should be in the Z direction

Nesting

Nesting refers to arranging parts inside the 3D space of the build chamber. Decisions made at this stage can have a significant influence on the part quality. The same part, from the same machine, could be sold or scrapped solely depending on the choices made during nesting.

Minimum Model Spacing

The closer parts can be nested together, the more parts can fit into a build. This improves the productivity of the machine and lowers part cost, however, it's important not to go too close as parts can fuse together or make depowdering difficult.

Minimum model spacing will depend on the part geometry - large, chunky parts are referred to as having a lot of "thermal mass". They will absorb a lot of energy during printing and heat the powder around them more. Smaller parts with thin walls have less thermal mass and could be nested closer together without issues. The idea is illustrated in Figure 5, large solid blocks a 0.5mm spacing fuse together but thin-walled shells do not.

A general recommendation for minimum model spacing is given below, however as discussed, some parts could be nested closer than this while others may require more space. When using nesting software like Magics, the minimum model spacing needs to be calculated after the parts are scaled, this is not required in GrabCAD Print.

Safe minimum model spacing	1.5 mm

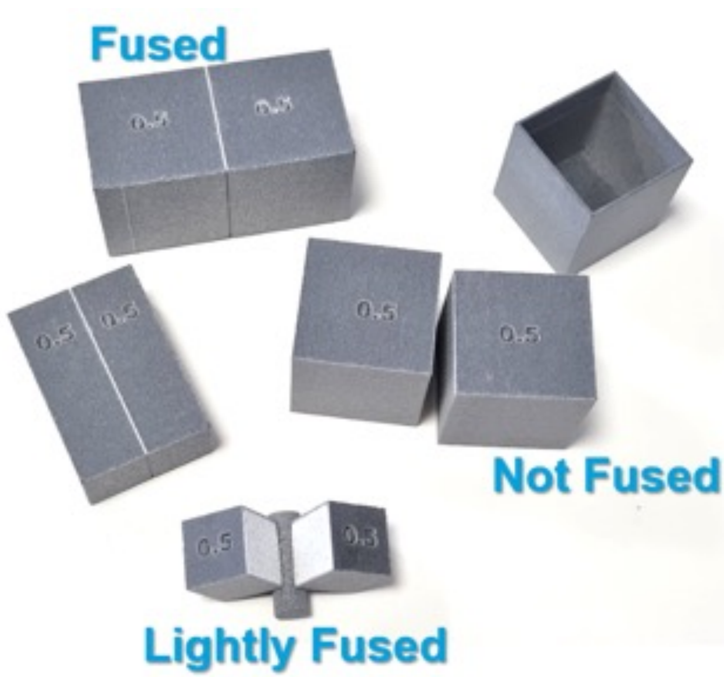


Figure 5

Mechanical Properties - Orientation

Strength is almost perfectly isotropic, and it is only EaB which reduces as the dogbone approaches 90˚ (vertical).

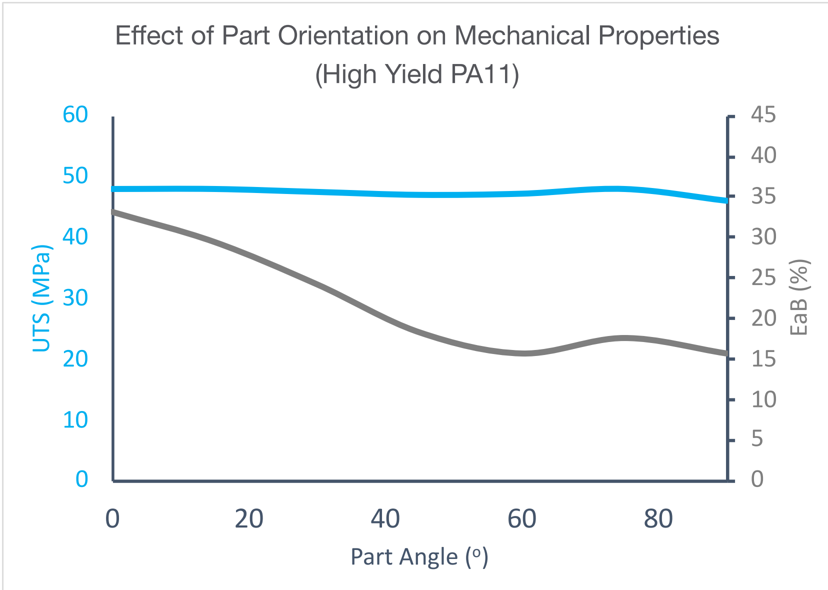


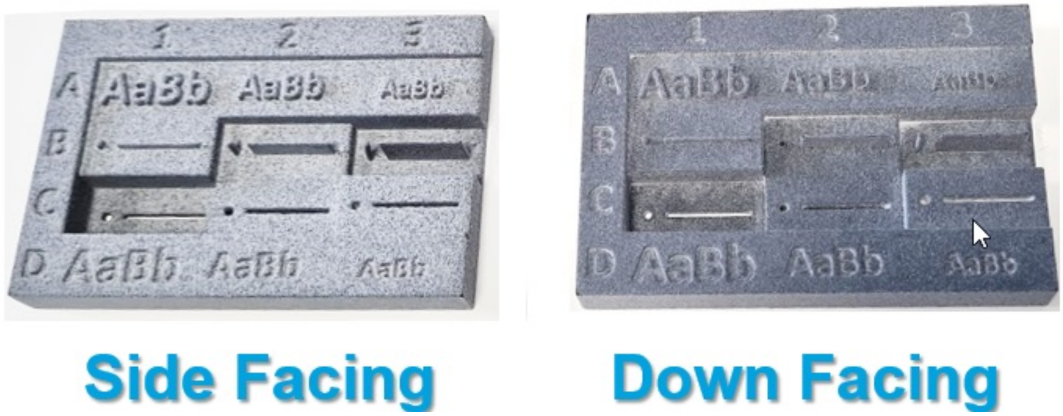
Figure 6

Aesthetics – Orientation

Downfacing material will appear smoother with less visible or defined layer lines. The best geometry to illustrate this is a sphere, as pictured in Figure 7.

Surfaces where the aesthetics are critical should be faced downwards in the build for the best results. If the part geometry does not allow for all critical surfaces to be faced downwards (opposing faces need to have good aesthetics), then making the faces side facing is a good compromise.

Figure 7



Shallow Angles

Flat surfaces positioned at shallow angles often have aesthetic issues due to layer lines. To minimize these, the surface can either be faced downwards or it can be rotated to a greater angle from horizontal, this will increase the number of layer lines on the surface and give a more uniform appearance.

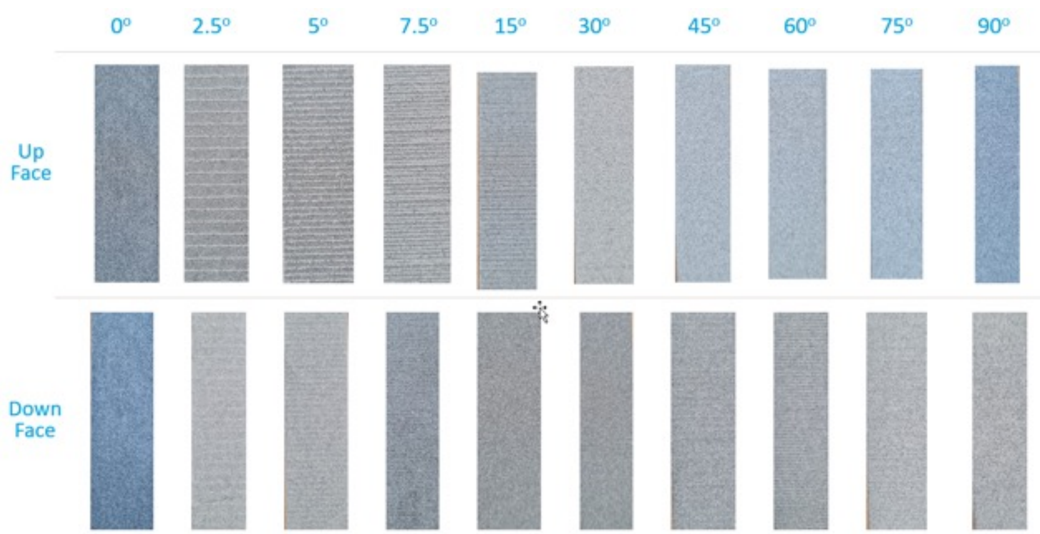


Figure 8

Minimum angle for good aesthetics (>0˚)	20˚

Depowdering Features

Removing all powder from parts is critical to creating an end use part. The ease of depowdering of some features is influenced by their orientation in the build.

Within each slice of the build, enclosed regions of powder have more heat trapped in them, which make the powder harder to remove after the build. Orienting feature like holes away from vertical allows for more heat to escape during printing, making the powder softer and easier to remove.

Depowdering is also improved by allowing air/tools/blast media to pass through a feature. Through features depowder more easily and completely than blind ones. Some guideline hole depths are given in Figure 10.

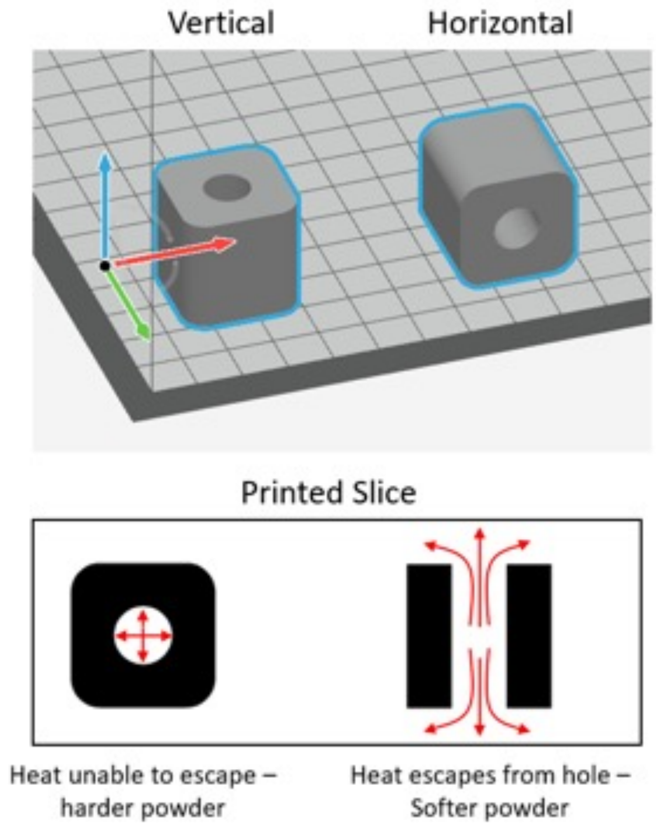
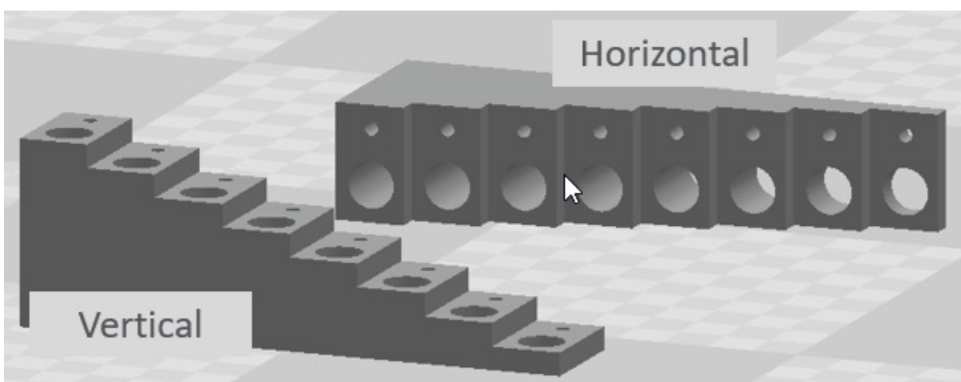


Figure 9



Hole Diameter	10 mm		3 mm	
Hole Type	Blind	Through	Blind	Through
Horizontal	30 mm	Max (40 mm)	10 mm	20 mm
Vertical	25 mm	Max (40 mm)	5 mm	10 mm

Figure 10 - Depowderability of features after one cycle through a Dyemansion Powershot C

Clearances and Fits

When printing a shaft in place, the challenge is removing the powder from the interface. As with depowdering holes, performance is improved by rotating the interface away from vertical.

The clearance required to print a shaft in a hole and still move depends on the surface area of the interface (diameter of shaft, length of interface etc.). Some guidance numbers are given below in Figure 12. Note that the clearance is half the difference in diameter between hole and shaft, as illustrated in Figure 11 E.

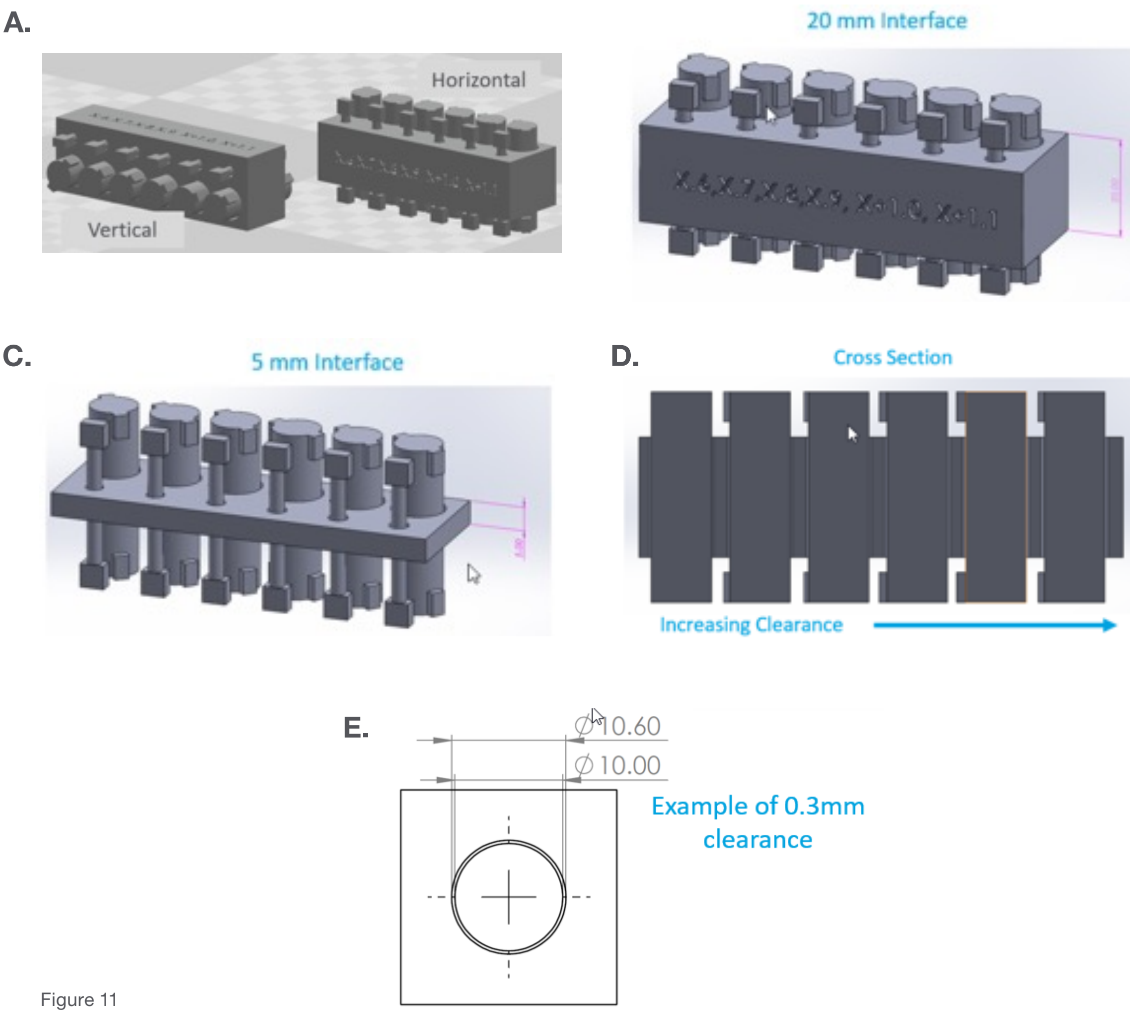


Figure 11

Shaft printed in place

Shaft diameter	10 mm		3 mm	
Interface length	20 mm	5 mm	20 mm	5 mm
Horizontal	0.8 mm	0.6 mm	0.6 mm	0.6 mm
Vertical	1.1 mm	0.8 mm	0.6 mm	0.6 mm

Figure 12

Printing parts to assemble after printing

If the parts of an assembly are printed to be assembled after printing, then much closer fits are possible as powder removal is not an issue. Clearances as low as 0.05mm are possible. Position in the build volume is not critical however interfacing features should be built in the same orientation to ensure the best fit.

Labels and Text

Labels and text can be printed with good resolution using the H350, however consideration needs to be made to border offset. Text is considered a fine feature, so it needs to be greater than the minimum feature size previously discussed. This minimum feature size applies to the smallest element of the text, not the overall size, Figure 13.

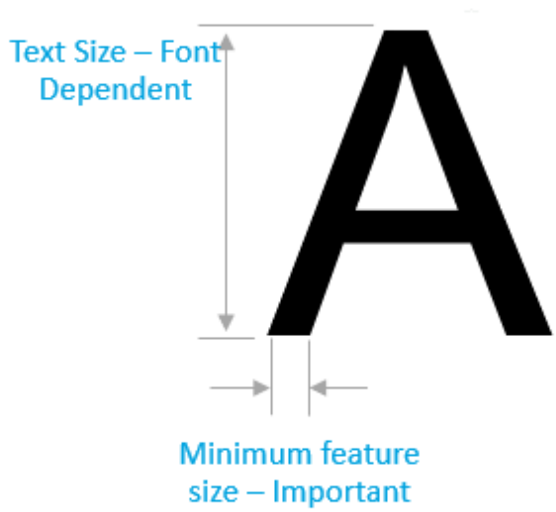


Figure 13

Example minimum text size	Arial: Size 14

Embossed or Debossed

Both embossed (extruded from the part) and debossed (cut into the part) are possible, however better resolution and smaller text is possible with debossed text. Debossed text is a negative feature in a printed area whereas embossed is a positive feature in blank space. The result is that when the border offset is applied to debossed text the letters are enlarged, whereas embossed letters lose pixels and become smaller or are deleted.

Border offset is only applied in the XY plane, so generally text will look best when printed on a side facing surface, Figure 14.

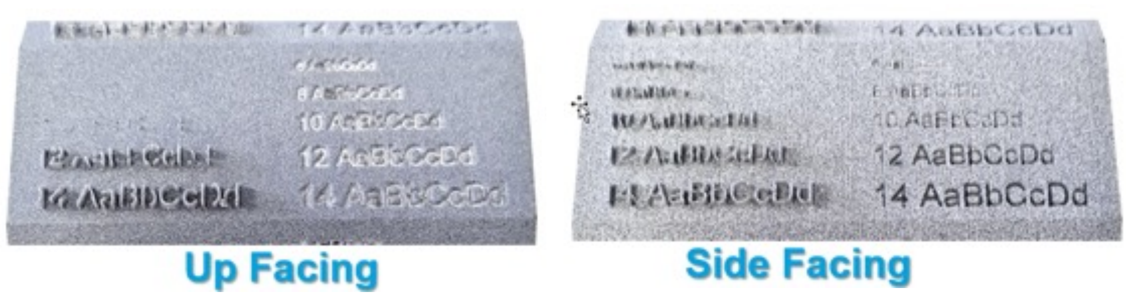


Figure 14

Pixel Stepping

When slicing, CAD models are converted from continuous digital space to discrete pixels. At some point, a decision has to be made whether a pixel should be filled or not. Although uncommon, this can lead to an issue known as pixel stepping, where single pixel height lines appear on side walls of parts, often forming random, sharp edges patterns, shown in Figure 15.

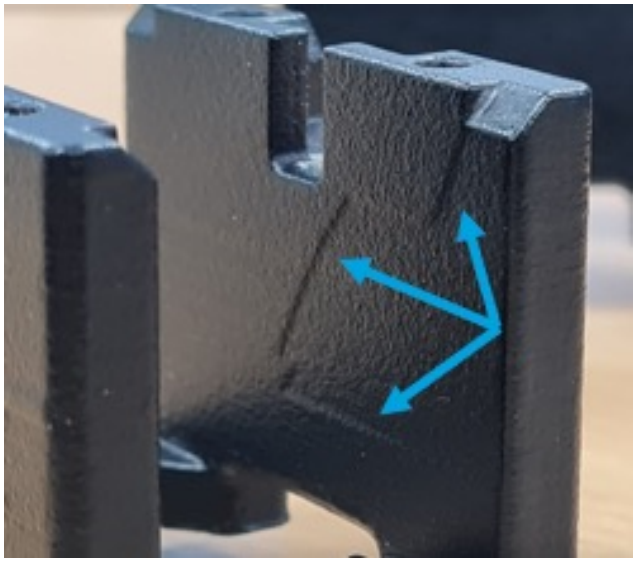


Figure 15

Different slicing software will produce slightly different results due to differences in the way numbers are rounded and handled. Using GrabCAD Print, pixel stepping is a rare issue, however if it occurs on a part then the best solution is to rotate the flat model faces away from the X, Y and Z planes, Figure 16.

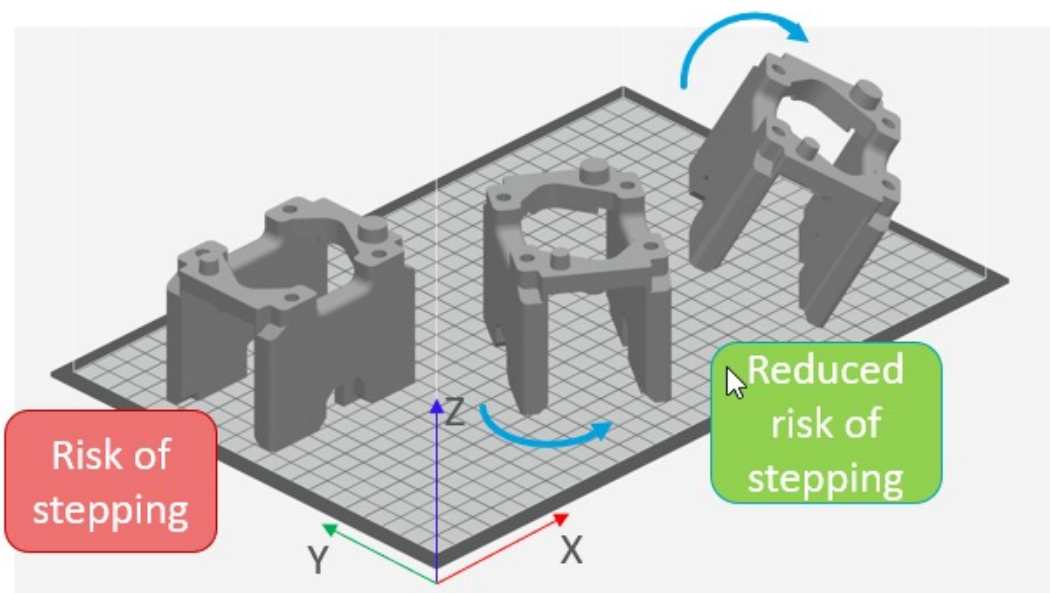


Figure 16

Design for SAF

More Complex, More Efficient

The support-free nature of SAF enables a greater level of geometric freedom when designing parts. This requires a shift in perspective from conventional, and even other additive manufacturing. With SAF it is possible to increase the complexity of the parts while at the same time reducing the cost.

Honeycombing or latticing parts, as well as topology optimization and other advanced techniques bring no additional requirements for supports or fixturing and only serve to reduce material usage. A simple example is shown in Figure 17 where a functionally identical, conformal vice jaw is produced was 75% less material.

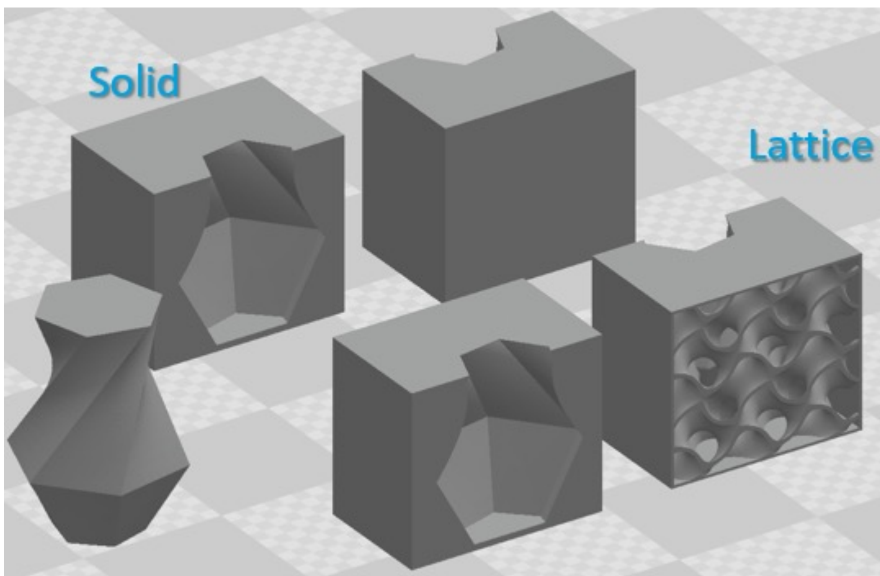


Figure 17

Powder Removal

It is generally recommended that the geometry be left open somewhere to facilitate powder removal. It is however possible to not do this and still save on material.

As loose powder is less dense than printed material and required no HAF to be used, you can still reduce part cost even if the powder is left trapped, although the savings, cost and weight, will be lower.

Threads and Inserts

The resolution of SAF enables fine features such as threads to be directly printed into the part. These threads will not be suitable for load bearing, engineering applications, however, for light duty uses, such as holding covers in place, they may be suitable and save a post processing step. When printing threads, the hole can be either horizontal or vertical, however cylindricity will be slightly improved by printing vertically.

Since the material produced by SAF is 100% dense and fused, it would also be possible to tap threads into a blank hole, however this has few benefits over directly printing the threads as the improved accuracy is unlikely to be necessary in a light duty application. For functional threads, the recommended technique is to print a blank hole and use a threaded insert. SAF materials are all compatible with heat-set inserts. Follow the insert manufacturer's guidelines on hole sizes and torque specs.

Texturing

Texturing is a technique applied in many manufacturing techniques to distract the eye, break up patterns and hide minor defects. The same can be applied in SAF, usually with the goal of disguising layer lines.

Textures can be applied to CAD models using a variety of software. The resolution of the H350 allows for detailed textures to be printed, however the minimum feature size and application of border offset needs to be considered carefully.

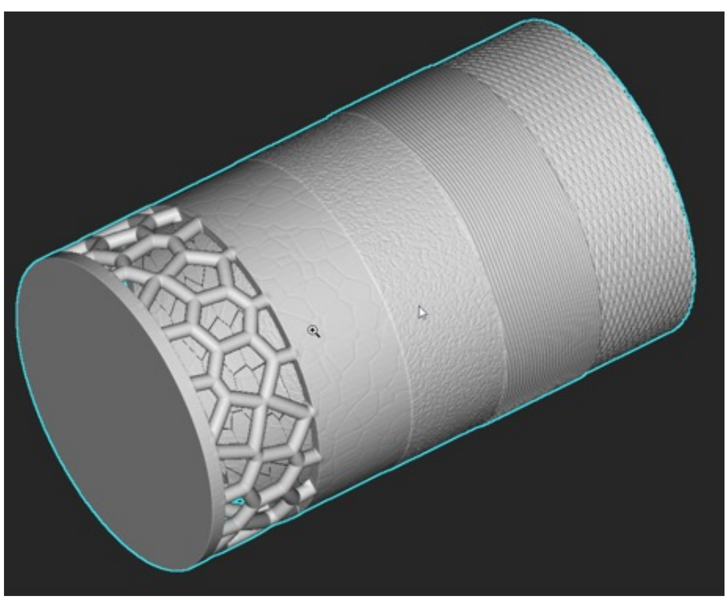


Figure 18

Design for Nesting

The more parts that can be fit into the H350 build volume, the more productive the machine can be, and the lower the part cost. Especially when targeting higher volumes of parts, marginal improvements in nesting efficiency can yield significant savings.

When designing a part for SAF, thought should be given to nesting the parts. An example of a puck to hold a component on a conveyer belt is shown below in Figure 19. The initial design has a square base and can pack 75 parts into the volume.

Without changing the functionality of the parts, leaving the mounting slots untouched, the design has been modified to improve nesting. As shown in Figure 20 this improves the nesting and allows an additional 45 parts to fit in. Over a volume production run, this significantly improves costs.

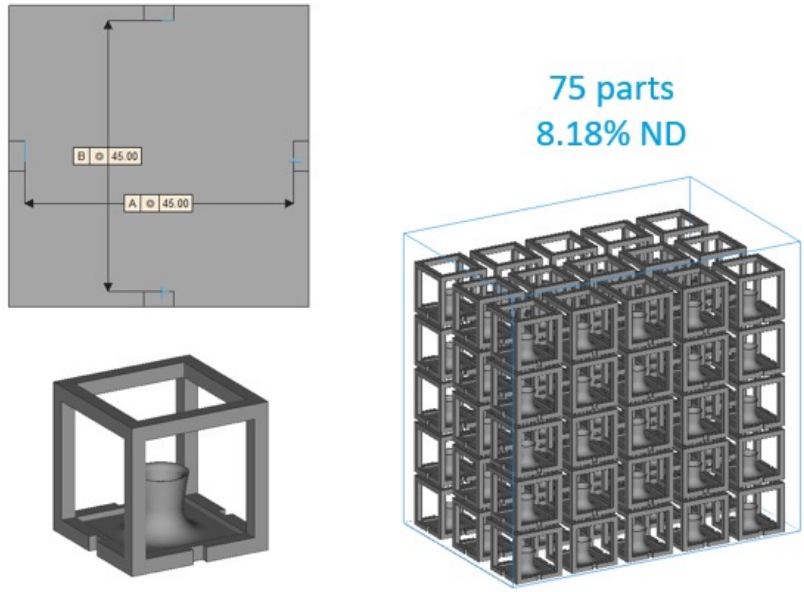


Figure 19

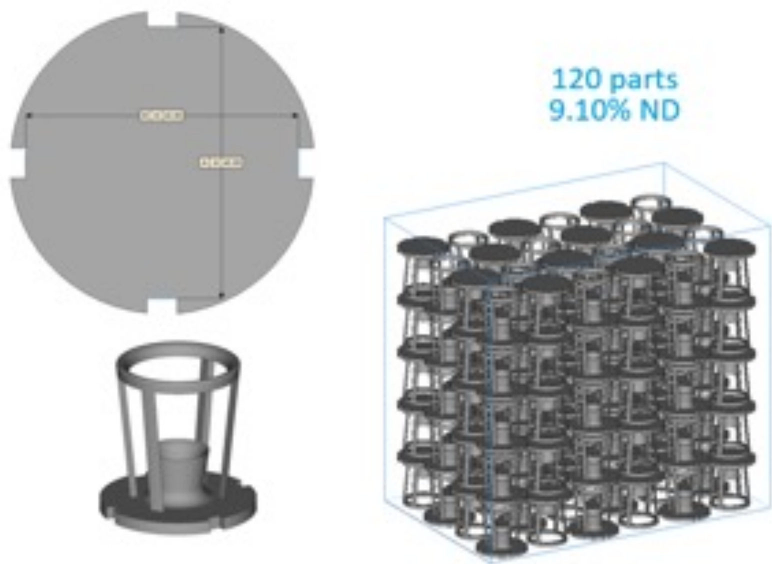


Figure 20

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