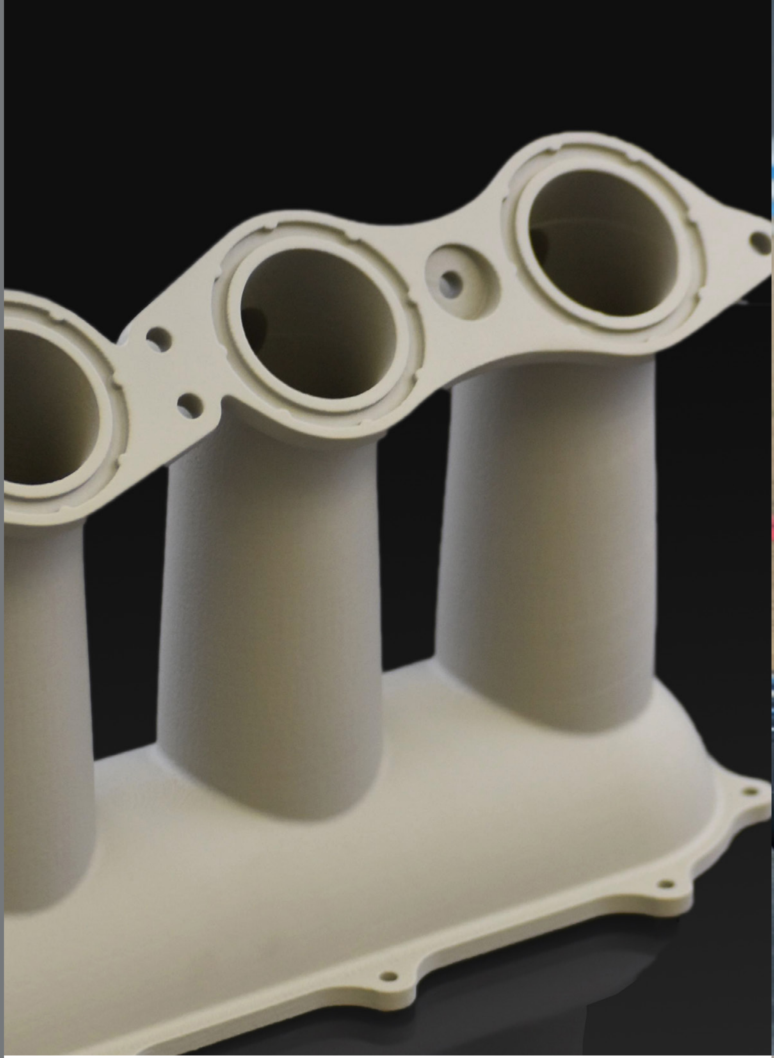
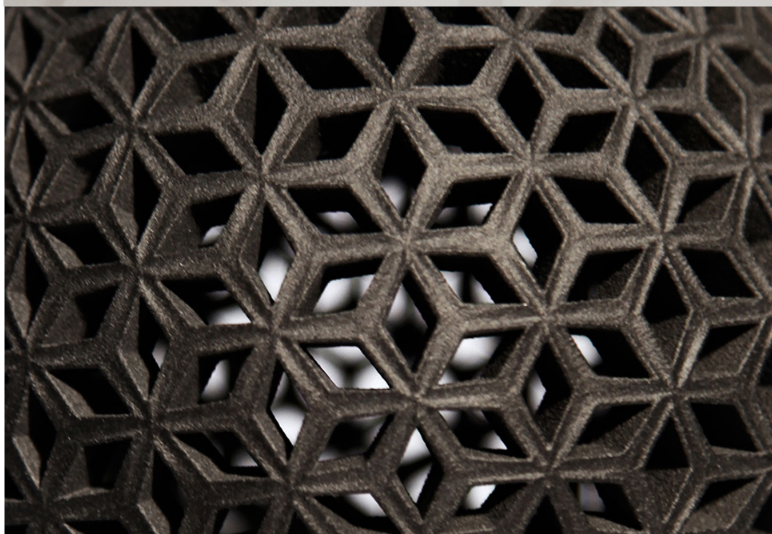


Selective Laser Sintering Design Guidelines



stratasys
DIRECT MANUFACTURING

Contents

Selective Laser Sintering Design Guide

Selective Laser Sintering (SLS) is an additive manufacturing process that builds parts by using a laser to selectively sinter (heat and fuse) a powdered material. The process begins with a 3D CAD file, which is mathematically sliced into 2D cross sections. With the build piston at the top of the build volume, a roller assembly pushes build material from the powder supply to create a uniform layer over the build piston. The scanning system then draws the 2D cross section on the surface of the build material, sintering the material. The build piston is lowered as the powder delivery piston is raised and a new layer of material is placed in the build volume. The next 2D cross section is drawn and the process repeats itself until the object is complete.

This layer-by-layer manufacturing process allows for the direct fabrication of complex parts that would be cost-prohibitive, if not impossible, to produce through traditional manufacturing processes. For example, interior features, undercuts and negative draft are not an issue for SLS fabrication.

Simply put, the only thing that differentiates a prototype from a production part is that the production part meets all the design requirements including physical properties, dimensional tolerances, appearance and cost. Typically, prototype parts involve compromises in one or more areas and almost always involve compromises in physical properties.

Design Considerations	Specifications
Build Volume	26.5 x 13.5 x 20”
Layer Thickness	.004” - .006”
Standard Tolerances	± 0.015” or ± 0.002”/”, whichever is greater

While the Selective Laser Sintering process has been used effectively as a prototyping tool for years, recent advancements in materials and process control have resulted in the fabrication of parts that are suitable for many production applications.

At this time, SLS production parts material options are limited to various nylon materials. While optional fillers such as glass, carbon and aluminum can be used to enhance the physical properties, careful consideration must be given to the material properties.

Benefits & limitations of SLS production

The primary benefit of SLS production is that very complex shapes can be produced without tooling in a very short period of time. The primary limitation is that as production volume increases, other production methods are usually more cost effective.

Since Selective Laser Sintering is a Direct Digital Manufacturing (DDM) process that does not involve tooling, the benefits of the process increase as the complexity of the design increases. This runs counter to traditional manufacturing processes where additional design complexity usually involves greatly increased time and expense.

SLS production is economically viable for low-complexity designs only when the production volume is so low that the tooling and other NRE expenses cannot be amortized over a large volume of parts. At the other end of the extreme, SLS production can be economically viable for even large production volumes if the design is of such sufficient complexity that it would be difficult or impossible to fabricate the part with any other method.

As with any fabrication process, the maximum benefit is achieved if the design itself takes the manufacturing process into account. For example, the duct assembly in Figure 2 includes 4 custom components, 12 fasteners, adhesives and multiple assembly steps.

This assembly, however, can be replaced with a single SLS production part, as shown is Figure 3, resulting in fewer components, reduced weight, increased strength and no required assembly. Clearly, designing parts for SLS production has significant advantages in that many limitations of traditional manufacturing do not exist.

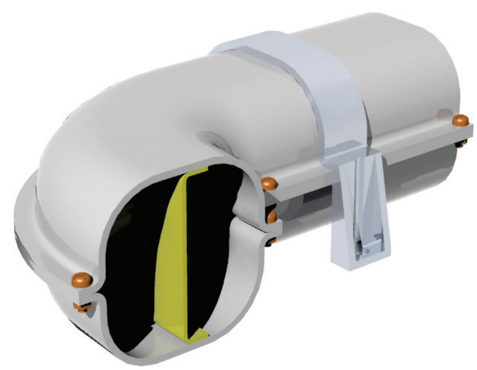
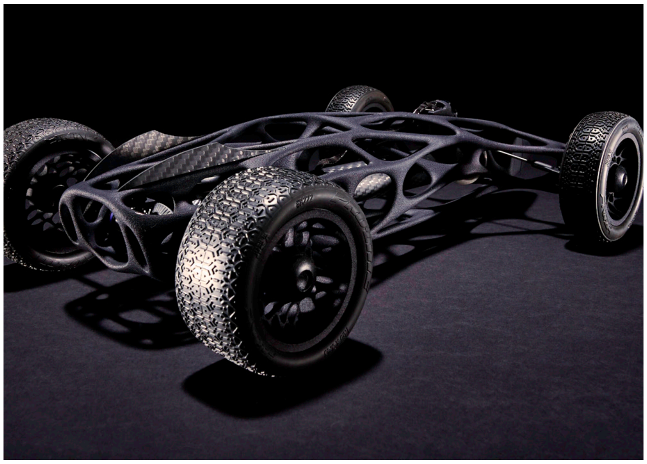


Figure 2: Original duct assembly

Figure 3: Integrated SLS duct

SLS production design considerations

This document does not attempt to address all the possible issues involved in designing mechanical components, but it will address the primary differences between designing parts for injection molding and SLS production.



As with any manufacturing process, a number of issues can impact the performance of a particular design. One of the key advantages of SLS production is that the SLS prototypes can be used to quickly and easily verify the design. As with parts designed for other manufacturing processes, parts designed for SLS production benefit from prototyping early and often.

In many ways, designing parts for SLS production is very similar to designing parts for injection molding, with a few key differences:

- Undercuts, negative draft and interior features are not a problem for SLS parts.
- SLS parts should have a minimum wall thickness of 0.040 inches (1.0 mm).
- Holes in large blocks of material will be smaller than specified due to "hoop" shrink. Keeping wall thickness at 0.120 inches (3.0 mm) or less will minimize this effect.
- The SLS process adds a natural 0.015 inch (0.4mm) radius, so it's not necessary to add a break edge radius, unless additional stress relief is required. If a radius of less than 0.015 inch (0.4mm) is specified, the natural 0.015 inch (0.4mm) radius will be constructed.
- The SLS process is capable of constructing 90° interior corners. It is recommended that a 0.015 inch (0.4 mm) radius fillet be designed on all interior corners for stress relief.

Material considerations

SLS production materials are typically based on nylon powder, with optional fillers such as glass, carbon or aluminum. Sintered nylon differs from injection-molded nylon in a number of key areas, such as elongation at break. While typical injection-molded nylon may have an elongation at break of over 100%, SLS materials range from 2-28%.

Stratasys Direct Manufacturing provides a wide varity of SLS materials suitable for SLS production applications. Detailed material specifications are available from *www.stratasysdirect.com*. The general information provided below is helpful in understanding some of the material issues associated with designing SLS production parts.

Physical properties

Stratasys Direct offers a range of SLS materials to address a variety of production applications. Nylon 11 is a high-elongation polyamidebased material specifically formulated for direct digital manufacturing. Glass, carbon and aluminum filled materials are also available.

Colors

SLS materials are available in white, grey and black, although not all materials are availabe in each color. Basic coloring for SLS is also available with Stratasys Direct's coloring process. Colors available with this process are red, orange, yellow, green, blue and black.

Design guidelines

Bosses

Bosses are used for attaching fasteners or accepting threaded inserts. The boss diameter should be 2.0 and 3.0 times the diameter of the insert to provide sufficient strength and to minimize hoop shrink. The height of the insert should not exceed the height of the boss, as hoop shrinkage may occur below the level of the boss. As with injection-molded parts, ribs and gussets can be added to the boss for increased strength. See Inserts for more information. It is not necessary to add draft to the boss.

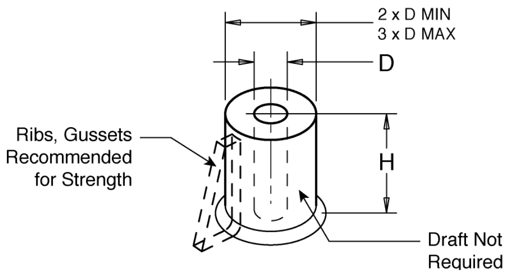


Figure 4: Boss design

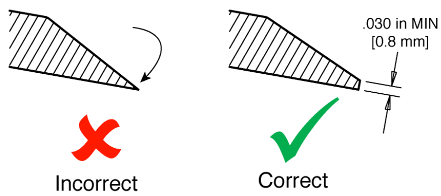


Figure 5: Feathered edges

Feathered edges

Feathered or knife-edges should taper to no less than 0.030 inches (0.8 mm).

Design guidelines

Draft

Draft, or lack thereof, is not an issue for SLS parts.

Inserts

With the SLS process it is not possible to build parts around metal inserts. The insertion must take place as a secondary operation. Threaded inserts with adhesives are recommended. For additional information on inserts, please see page 6.

Interior features

One of the significant benefits of the SLS process is that interior features, such as stiffeners, baffles, ribs and struts can be designed and constructed as one integral part.

Joints

SLS materials can be bonded with a variety of adhesives. Lap joints, with a 0.010 inch (0.3 mm) bond line clearance, are the preferred joint method. The recommended joint overlap is 3-5 times the wall thickness.

Joint performance can be adversely affected by temperature, bonding and mixing techniques,

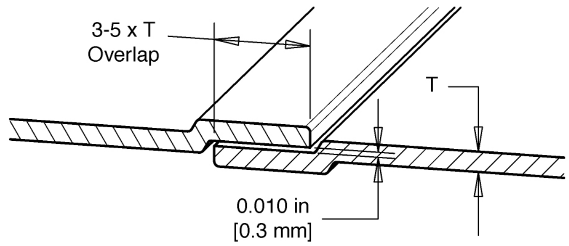


Figure 6: Joint design

joint geometry and other factors. Stratasys Direct strongly recommends that a vigorous prototyping program be used to validate any SLS production designs that include joints.

Stratasys Direct continuously evaluates potential SLS adhesives. Good results at room temperature have been obtained with the following adhesives:

- 3M™ Scotch-Weld™ Epoxy Adhesive DP460
- 3M™ Scotch-Weld™ Epoxy Adhesive DP-8010
- Loctite 97434 Fixmaster® 4 Minute Epoxy
- Loctite Hysol – EA – 9394 Epoxy

Design guidelines

Living hinges

A living hinge with SLS materials is possible with a secondary annealing process. Without secondary processes, living hinges for a few cycles are possible.

Minimum feature size

The minimum practical SLS feature size is 0.030 inches (0.8 mm).

Radius

The SLS process adds a natural radius of 0.015 inches (0.4 mm) to all sharp corner radii.

Ribs, gussets, fillets and bulkheads

There are no special design requirements for ribs, gussets, fillets or bulkheads, other than to stay within the guidelines for wall thickness.

Snap latches

Limited use integral snap latches are possible with existing SLS materials.

Surface finish / texture

Average surface finish is 125-250 RMS finish, depending on the SLS material selected. Surfaces can be hand sanded smoother. SLS materials can also accept most coatings, textures, printing or other special finishes.

Thick walls

SLS plastic materials, like any other plastic material, shrink as they solidify. Thick walls and large blocks of material will cause excess heat and shrinkage, resulting in geometric deformations. The process is much more tolerant of thick walls than injection molding, but these should still be avoided where unnecessary. Wall thickness should be between 0.040 and 0.120 inches (1.0 to 3.0 mm).

Dimensional accuracy

Typical tolerances are ± .015 inches (0.4 mm) or ± .003 inch/inch (0.1 mm/mm), whichever is greater. Tighter tolerances may be offered on a case-by-case basis.

Inserts

Selection

Stratasys Direct Manufacturing recommends the use of miniature stainless steel non-locking Keensert® inserts (series KNCA) and an epoxy adhesive for SLS production parts. See *www.keensert.com* for information on Keensert inserts. The recommended adhesive is 3M Scotchweld Gray #2216.

Installation

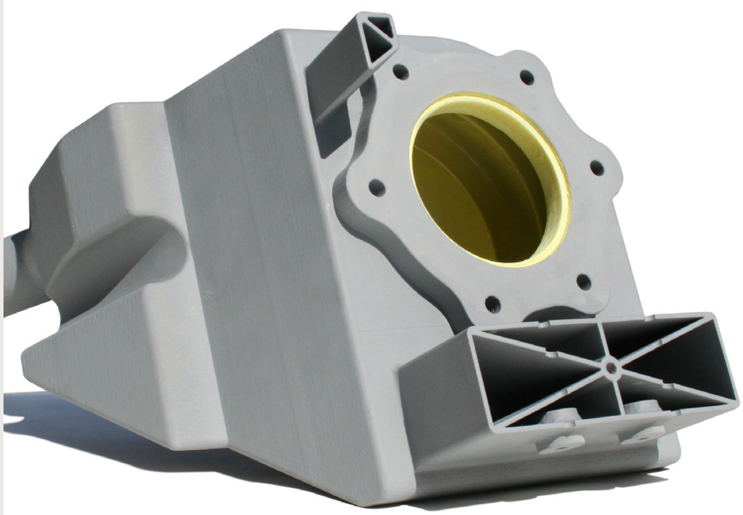
Follow the specified installation instructions for drilling and tapping the part. Prior to threading the insert, apply a thin coat of epoxy to the threaded part and install the insert per the Keensert instructions.

Application example

SLS fuel tanks

Small fuel tanks, such as those in UAVs (Unmanned Aerial Vehicles) and UGVs (Unmanned Ground Vehicles) are ideal applications for SLS production. In addition to time and low production volume cost advantages over bladder tanks or rotomold tanks, SLS fuel tanks can easily incorporate unique design features to improve performance, capacity and reliability. Unique design features include:

- Bulkheads, passages and anti-slosh partitions
- Internal passages and vent lines
- Conformal designs that maximize volume within both organic and inorganic shaped structures such as fuselage and wing sections
- Variable wall thickness and internal support structures for optimizing strength/weight ratios



SLS fuel tank design considerations

- Nylon 11 is the preferred SLS material for fuel tanks. This polyamide material is well known with proven applications in the petroleum industry – so gasoline, diesel and jet fuels are not a problem.
- Recommended wall thickness 0.080 inch (2 mm).
- Minimum wall thickness 0.060 inch (1.5mm). Thinner wall sections may be built, but must be reviewed by Stratasys Direct Project Engineering on a case-by-case basis.
- Minimum radii on all corners should be 0.060 inch (1.5mm).
- Inside of tank must be accessible to removing powder and cleaning.
- Tank must fit in single build volume (x by y by z) so it can be constructed in one piece.
- Integrated internal fuel lines must have at least 0.100 inch (2.5mm) inner diameter (I.D.) and no sharp bends that would prevent clean out.
- Sealing of the inside using Buna-N, PR-1005-L or equivalent slosh and drain type sealer is recommended.
- The final design must be prototyped and thoroughly tested before it can be submitted for SLS production.

Stratasys Direct Manufacturing Locations

Belton, TX | Eden Prairie, MN | Tucson, AZ

P 888-311-1017

E info@stratasysdirect.com

STRATASYSDIRECT.COM