DIRECT METAL LASER SINTERING
DESIGN GUIDE

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Introduction

What is DMLS?

Direct Metal Laser Sintering (DMLS) is an Additive Manufacturing method that builds prototype and production metal parts. The process uses a laser to selectively fuse a fine metal powder on a layer-by-layer process based of 3D Computer Aided Design (CAD) data.

What is Additive Manufacturing?

Additive Manufacturing is a process that adds material, usually on a layer to layer basis, to make a 3D object based off the interpretation of 3D data. Additive Manufacturing is also called 3D Printing or Rapid Prototyping. Traditional manufacturing techniques, such as Subtractive Manufacturing, remove material from a piece of stock to create the desired geometry. Subtractive manufacturing usually requires some form of cutting tool such as machining (CNC, mills, lathes), electro discharge machining (EDM), grinders, and cutters. Additive Manufacturing is capable of producing highly complex features and all-in-one assemblies that would be difficult to achieve with subtractive manufacturing techniques.

Typical Component of a DMLS Machine

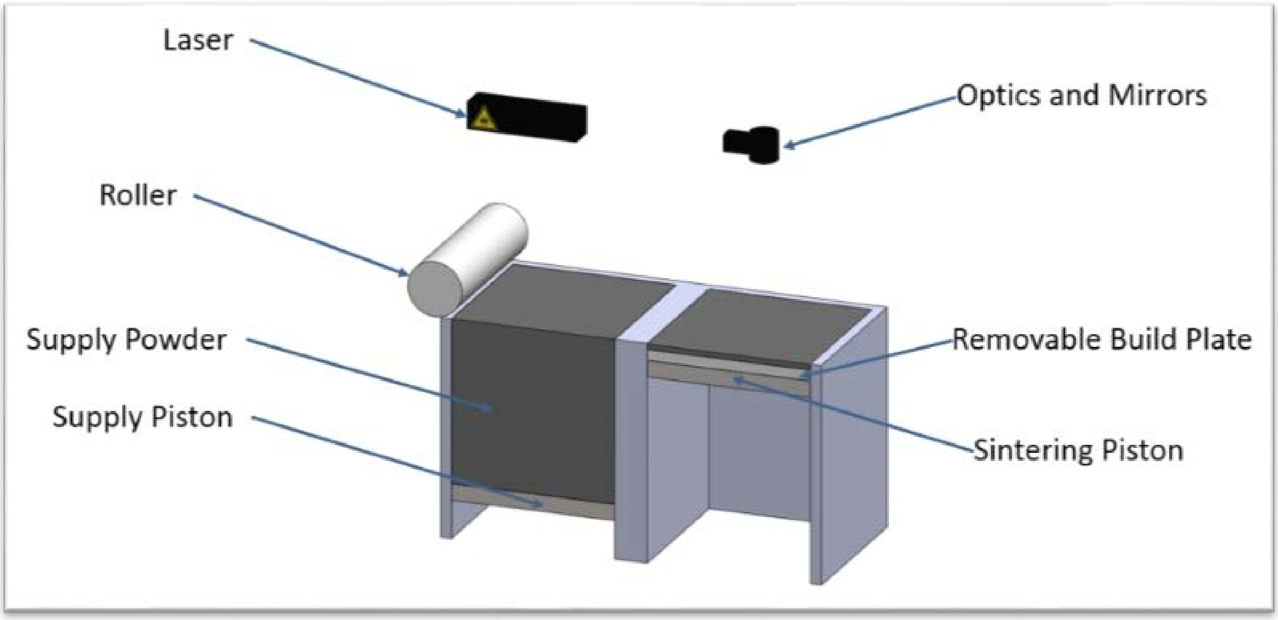


Figure 1. Typical components of a Direct Metal Laser Sintering (DMLS) machine.

Typical DMLS Build Process

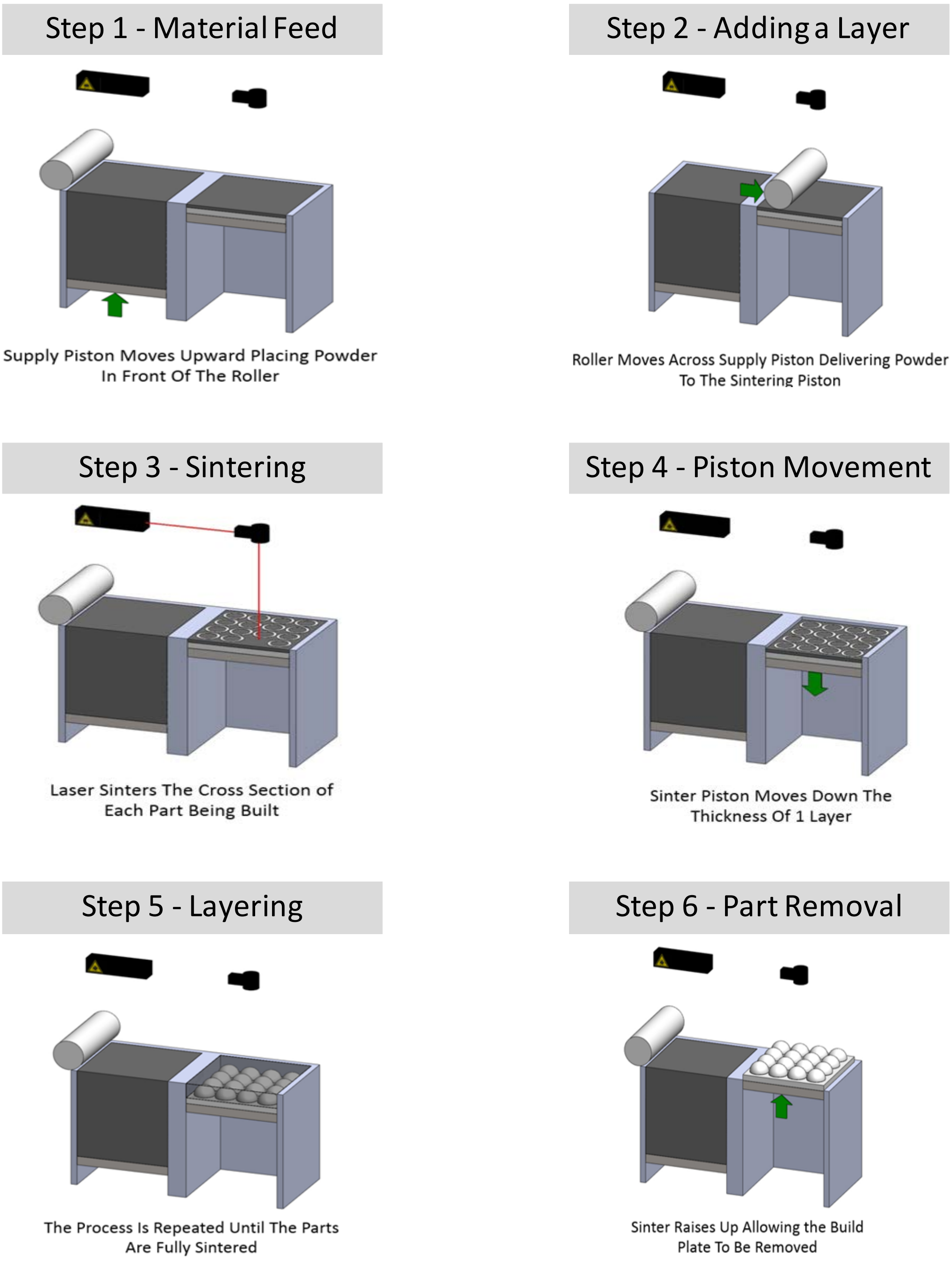


Figure 2. The typical Direct Metal Laser Sintering (DMLS) Process.

What are the Typical Uses and advantages of DMLS?

Typical Uses

DMLS creates fully functional parts out of metals such as Cobalt Chrome, Stainless Steel, Titanium, Inconel, and many others. The typical users of DMLS follow under these needs:

- **Those who need parts quickly** – DMLS parts are often produced and turned in 1-3 days.
- **Those who have a highly detailed or complex part** – Difficult to machine parts, custom medical pieces, hollowed or lightweight parts, and artistic pieces fall in this category.
- **And those who design parts going through rapid or continuous revision changes** – product development efforts and iterative designs are produced successively or parallel using DMLS.

Part Complexity

A key advantage of DMLS is the ability to produce parts that cannot be made using traditional manufacturing techniques. To gain the most advantage from manufacturing with DMLS, engineers should design parts with complex geometries, such as integrated fastening features, long and narrow channels, custom contours, and metal mesh structures. DMLS enables all-in-one assemblies that reduce parts count, assembly time and opportunity for failures by combining multiple parts into a single design.

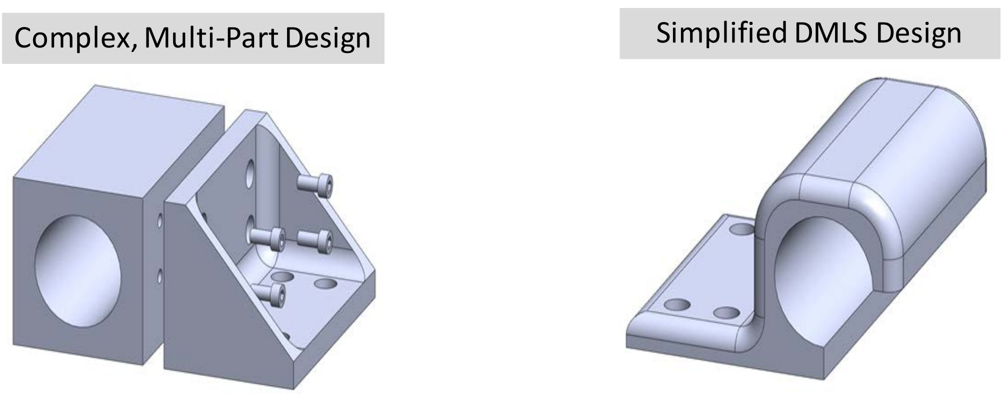


Figure 3. DMLS can be used to significantly simplify and streamline assemblies.

In specialized applications, the weight of the part is important criteria of the design. Using subtractive processes for manufacturing of these parts will dramatically increase the manufacturing time and cost due to the amount of material removed. DMLS is an optimal process for these parts as both manufacturing time and cost are reduced as volume decreases.

Speed

Speed is an important aspect of the design and manufacturing process. Both the quality of the product and the overall time to market are driven by the ability to produce physical models in a timely manner for fit and function tests, peer review, and market feedback.

Here, additive technologies allow for faster and more efficient concept review and prototyping. Thus, DMLS parts are commonly used during pre-launch activities for product testing; whereas, the final product is made with a tooled part (i.e. die casting, metal injection molding, sand casting). DMLS parts are commonly used to validate designs as part of final product quality assurance as well as stand in for product parts early in product life.

DMLS parts do not require tooling (e.g. molds, jigs, fixtures, gauges etc.), which reduces initial part manufacturing lead time from months to days. Thus, additive technologies such as DMLS presents a tremendous value for product customization and change by offering way to create short run, customized products without incurring expensive tooling changes.

Disadvantages of DMLS

High Volumes

When considering a manufacturing technique some of the factors to consider are lifetime volume and the ability to make changes to the part. If a part design is stable, unchanged throughout its lifetime, and the quantities are high, traditional manufacturing processes are less expensive. This is especially true for simple designs that cannot benefit from the geometric complexities that DMLS is capable of producing.

Limited Build Size

DMLS machines generally come in one of two sizes: 4” x 4” x 3” and 10” x 10” x 12”. While these build sizes are large enough to build a wide array of parts, larger parts (often the ones made in lower quantities) are still not able to fit within the build envelope.

Pre and Post Processing

Most think of DMLS as a metal 3D printer and as such, associate the simplicity implied from those processes. Preparation of the data before being sent to the DMLS machine and the post processing afterwards can be time consuming. All modern manufacturing processes have before and after steps. CNC for example requires the programming of tool paths, machine setup, cutting and grinding, polishing de-burring afterwards.

Prior to being sent to the DMLS machine, part support structures are designed and built. This step may take up to an hour and may determine success or failure the job. Support structures are explained in further detail on page 7 of this guide.

DMLS post processing consists of:

1. Removing the part(s) from the build plate with a band saw, wire EDM, or handheld rotary cutoff tool.
2. The support structures are then removed from the part using hand tools or CNC machining.
3. Other optional finishing steps
    a. Polishing
    b. Grinding
    c. Machining – turning, milling, facing, tapping
    d. Heat Treatment

Support Structures

DMLS parts need support structures for:

1. anchoring the part to the build plate
2. reducing or eliminating warping
3. supporting overhanging geometry

Unlike other laser and powder based additive technologies, DMLS parts move around in the build envelope if not properly secured to the build platform. Movement of the part occurs from the act of spreading a new layer of powder over the previously sintered layer or larger cross sections of the metal part warping during the sintering process. Movement of the part during the build will cause failures in part accuracy and could potentially lead to machine crashes.

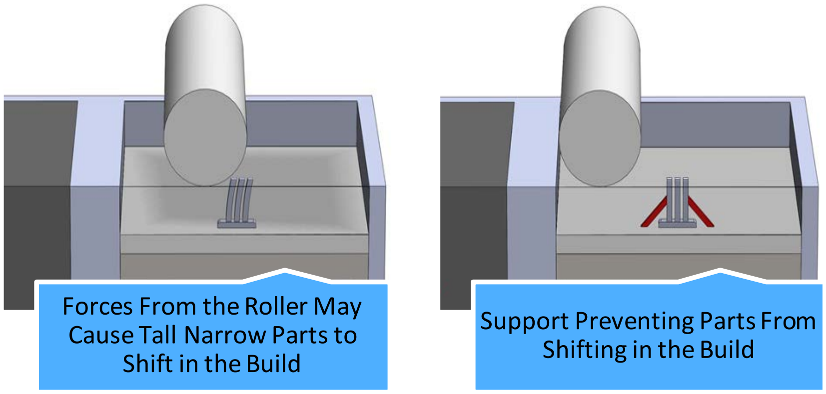


Figure 4. Fragile parts can be supported to decrease risk of a failed build.

A further reason support structures are required is to support overhanging geometry. Examples of these types of geometry are horizontal surfaces, large holes in the horizontal access, angled surfaces, arches, and overhangs.

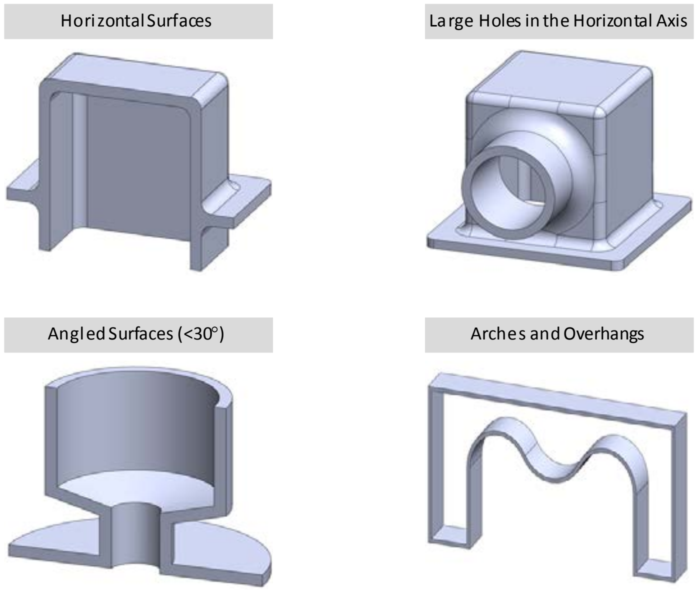


Figure 5. Overhang geometry may require support structures to successfully build using DMLS.

Types of Support Structures

Several methods are employed to support overhanging geometry. Depending on the part and surrounding features each method has it positives and negatives.

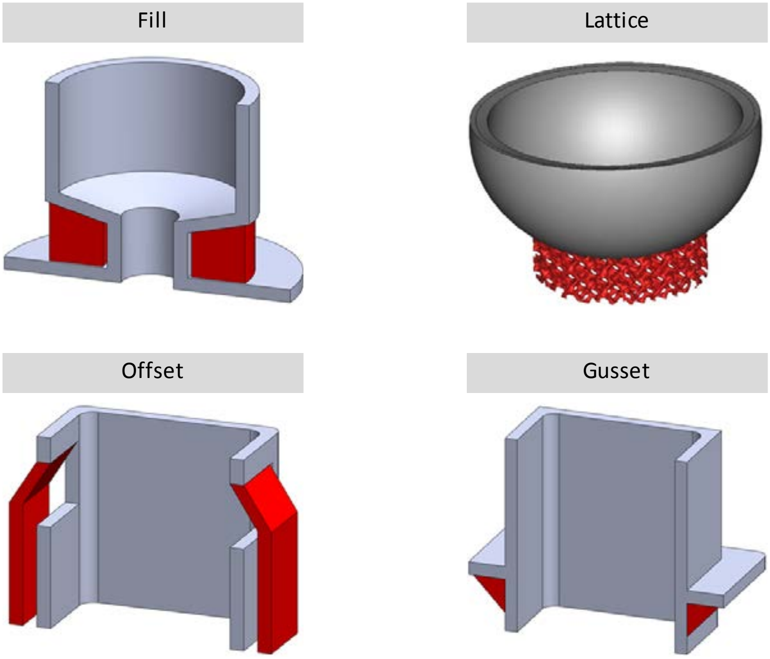


Figure 6. Many methods are available for properly supporting a part during a DMLS build.

Other Factors

Part Strength During the Build

During the build process parts are subjected to forces from spreading and compacting of new layers. Tall thin parts are susceptible to these lateral forces, causing inaccuracy in the parts' features due to improper design or lack of support structures.

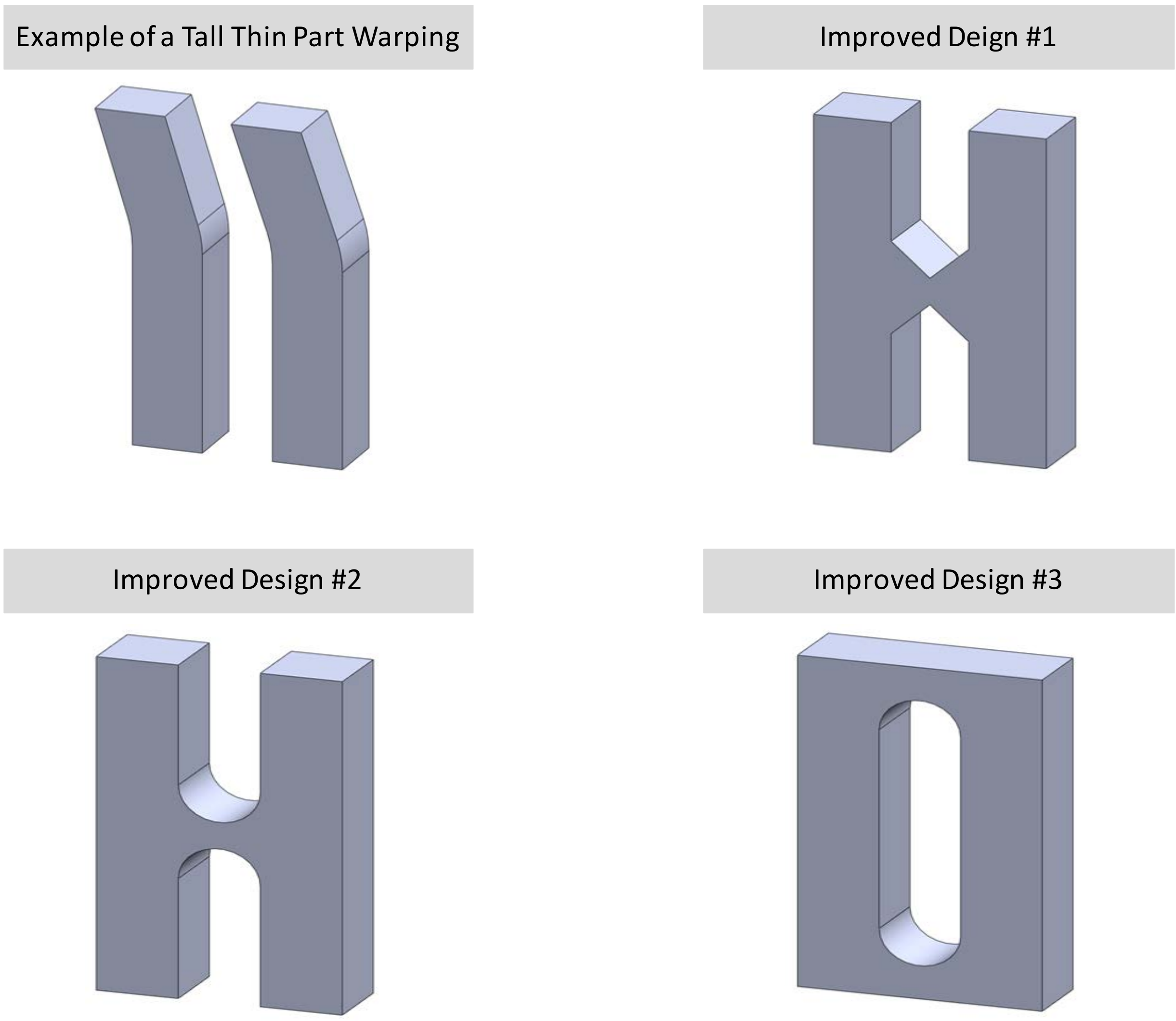
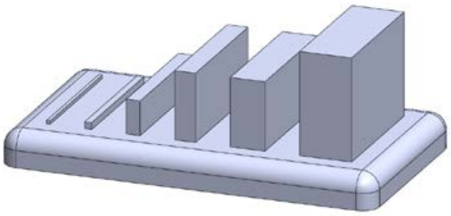


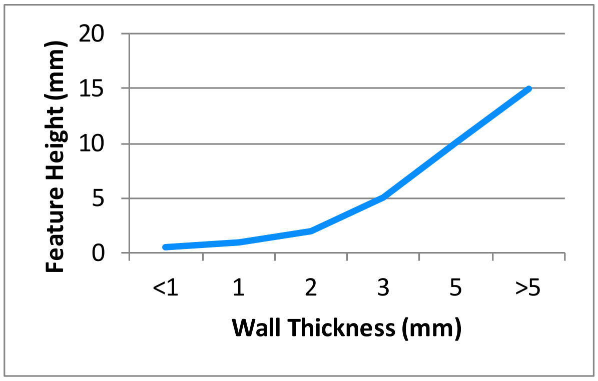
Figure 7. Examples of high-risk designs and ways to mitigate the risk.

Load Bearing Features

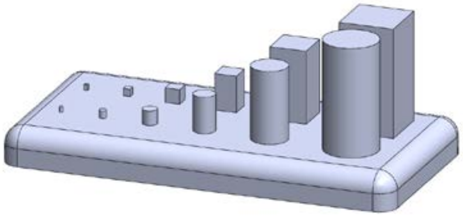
Load bearing part features require further guidelines for height to cross sectional ratios to ensure feature integrity. The figures below describe feature height to wall thickness ratios of load bearing walls and pins.

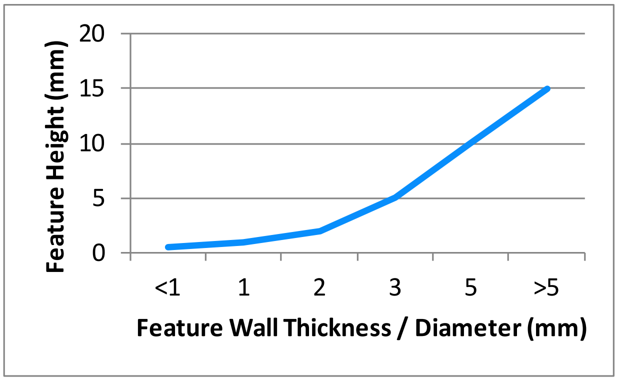
Load Bearing Walls





Load Bearing Pins





Distance Between Part Features

During the DMLS process the laser creates a melt pool that is slightly wider than the laser diameter from heat dissipating into the surrounding powder. This will cause features that are close to each other to bond together or create a section of sintered powder that cannot be removed from between sintered areas in the part. Distance between features must maintain a distance of 0.4-0.5mm to adequately remove powder and allow for part movement.

Accuracy

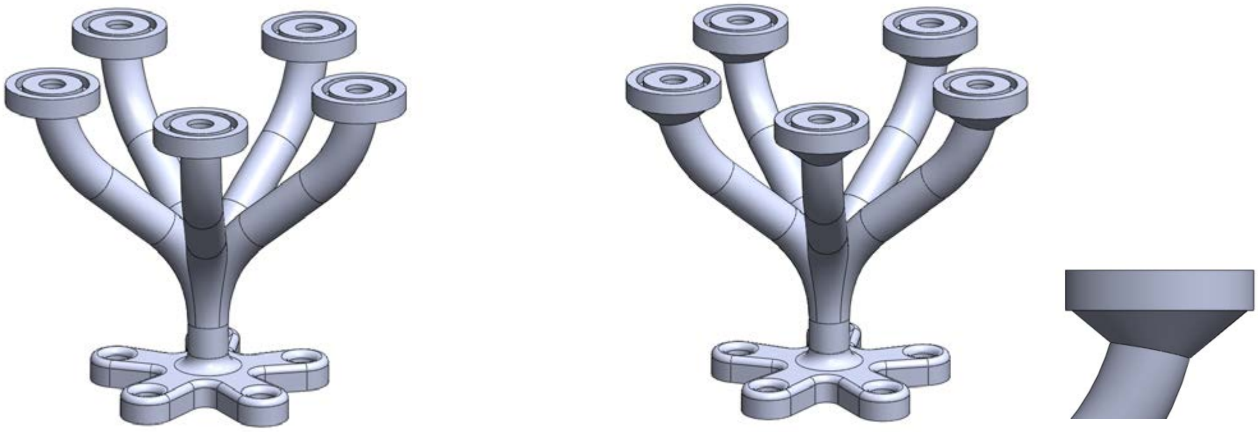
- Positive features hold an accuracy of 20-150µm without any post processing. Negative features, such as holes smaller than 50mm, will typically be slightly undersized by 100-150µm.
- Surface finish will vary from material to material, however an unfinished part will have a surface finish of µm RA from 2-5.

How to Use this Information to Influence Your Designs:
The quoted price of parts is heavily influenced by factors such as support structure design and removal of support factor. Therefore, minimizing the amount of support structure required will decrease design time, build time and post processing required. The best way to accomplish this is to make the geometry as self-supporting as possible.

Try to Build Self Supporting Geometry:
- Angles ≤ 30°
- Utilize chamfers and fillets on corners and features
- Implement features for weight and volume reduction

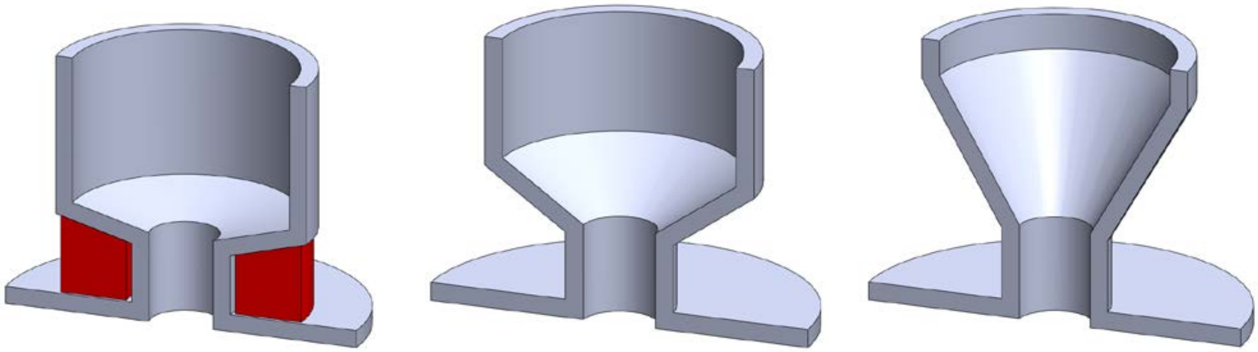
EXAMPLE #1

In this example the flanges towards the top of the part will cause a problem. The bottom facing surface of the flange will require some form of support. Adding a chamfer or a fillet to the overhanging geometry makes it self-supporting.



EXAMPLE #2

In this example the sloping angle of geometry is changed, making it self-supporting. Note that angles from 30°- 45° will self-support with some surface roughness and angles >45° will have a smoother surface finish.



Non Self-Supporting

Angled Surfaces (30°- 45°)
Self-Supporting with Rough Surface Finish

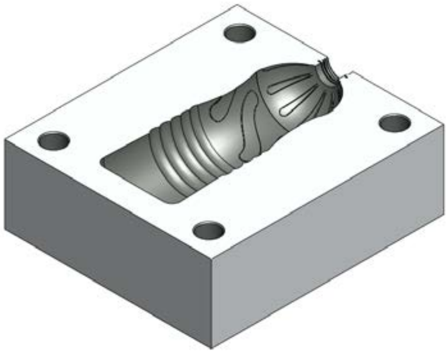
Angles Surfaces (>45°)
Self-Supporting with Smooth Surface Finish

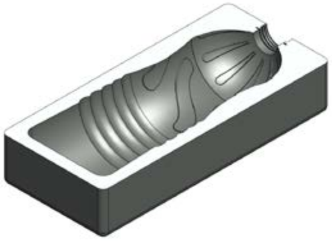
EXAMPLE #3

The price of DMLS parts is heavily influenced by build time and the amount of material being used.

The surface area to volume ratio of a part plays a large role in determining the quoted price of a given part. A part with reduced mass allows for a lower price because it takes less time to build, uses less material, and has a higher success rate of being produced correctly the first time.

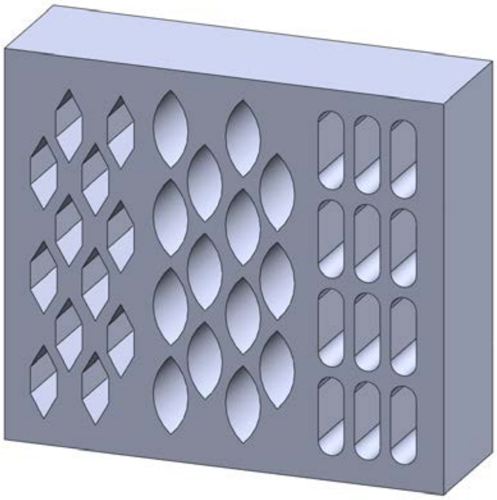
The volume of a part is decreased, either by redesign or by using another manufacturing process to create the geometry, the overall part price will go down significantly. In this example the important features of a mold are built using DMLS and the surrounding material is milled to save of overall assembly cost.





EXAMPLE #4

Reduce mass and volume by using self-supporting features in the vertical axis.



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