Designtech

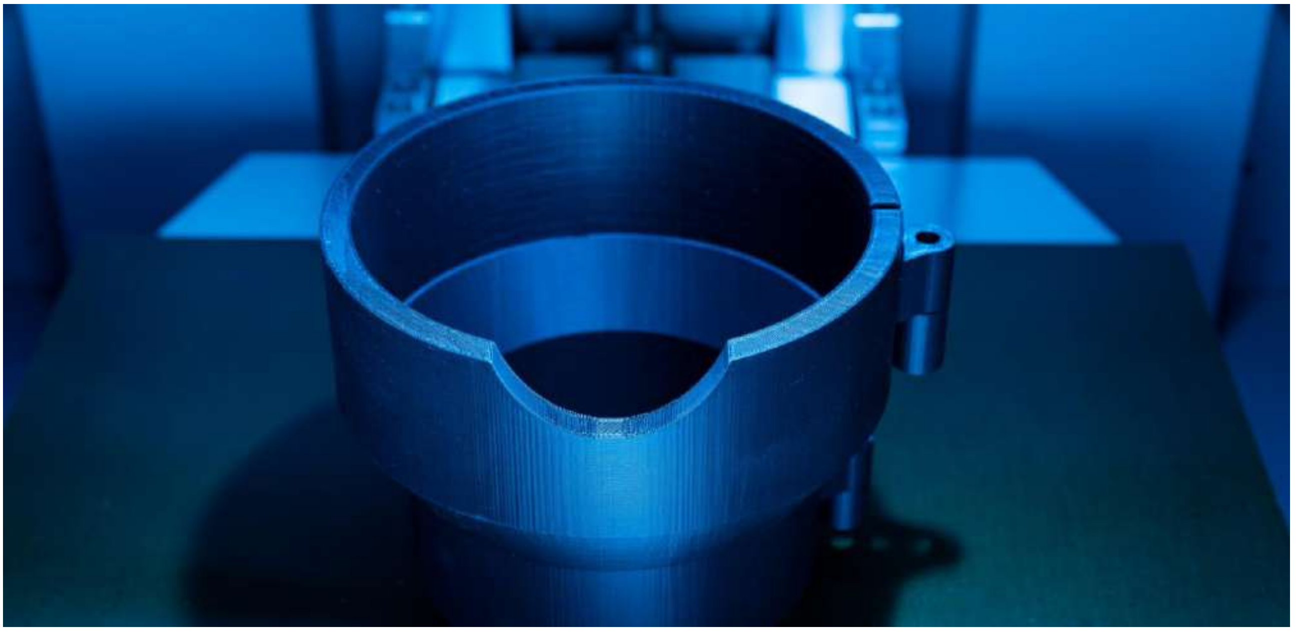
In collaboration with: Roboze

# Design for Additive Manufacturing

Guidelines

*ADDITIVE DESIGN LAB*

# Design for Additive Manufacturing



## INTRODUCTION

Traditional manufacturing techniques remove material from a solid semi-finished product. On the contrary, 3D printing consists in the deposition of material layer by layer until the desired object is created.

The conceptual innovation of this production process enables unprecedented freedom of construction: complex geometries, integrated functions, variable fillings and customized products can be manufactured quickly and without additional costs, giving rise to models that are impossible to create with conventional methods.

As any production technology, in order to fully exploit the potential of 3D printing, it is necessary to design the components considering the additive nature of the process.

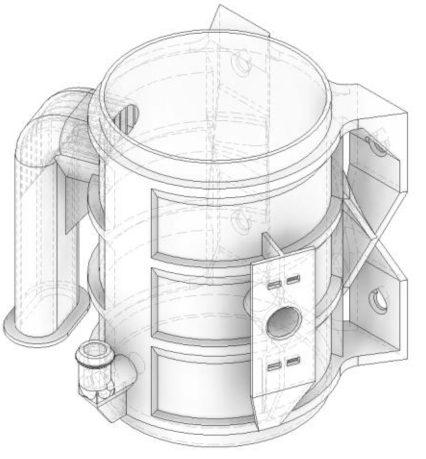
In this guide, you will find the main parameters to consider in order to get the most out of the design, following the key points developed.

On several occasions, we'll mention the loading conditions with respect to the orientation of the print; the properties and behaviors shown in this guide are framed in the context of the Z axis or the XY plane.
This process enables unprecedented freedom of design, allowing the creation of extremely complex geometries characterized by an internal filling that varies in shape and density.

# Design - Basic Concepts

Additive Manufacturing enables a design freedom that we have never seen before: complex geometries and custom parts can be produced quickly and at no extra cost, resulting in models that are impossible to create with conventional methods.

However, as with any other production technology, if you want to fully exploit the potential of 3D printing, you have to take into account the additive nature of the manufacturing process, from the design phase to the *.gcode generation.
The first step for an optimal additive manufacturing is understanding how the 3D model will be printed.



Given the additive nature of this technology, printed objects can show different characteristics depending on the direction along which the measurement is made; this phenomenon is called anisotropy and can concern not only the mechanical properties of the part, but also its physical and technological properties.

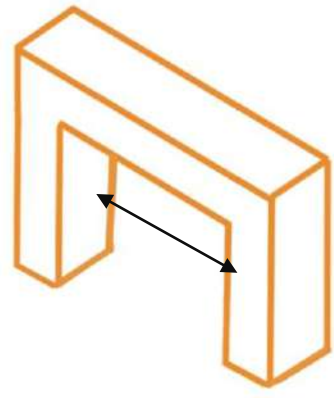
Therefore, it becomes important to establish the orientation of the model in the print volume as it can exert a significant influence on:

- the amount of time and material used for the job;
- the dimensional accuracy or the surface finish, for example due to the "staircase effect";
- the mechanical properties of the part.

# Design - Basic Concepts

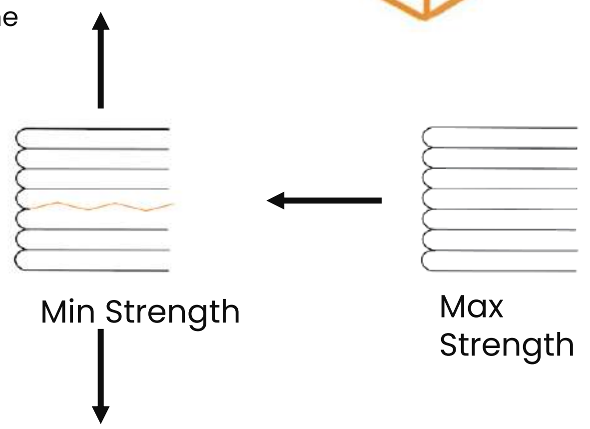
## ORIENTATION OF THE PARTS

In general, to reduce costs and printing time, the part should be arranged in such a way as to maximize the surface that is in touch with the build plate in order to minimize the use of the support structures. However, according to the complexity of the model, this could not be enough.
In fact, it would be necessary to avoid excessively long bridges and take advantage of the maximum printing inclination angle in order not to have to generate supports.



To overcome this problem, it is possible to include support chamfers inside the part or alternatively replace the circular holes on the vertical walls with teardrop structures.

However, the orientation of the model in the print volume must also take into account the stresses it has to withstand during operation.

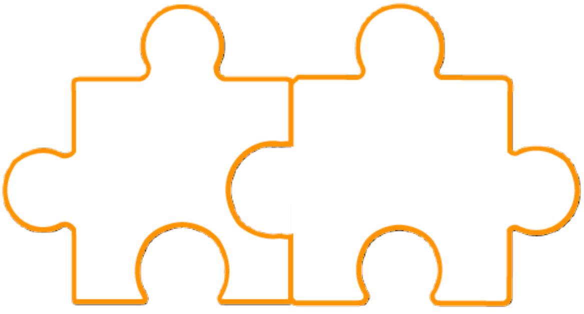



If you image additive manufacturing as a series of welds, it is easy to understand how the application of forces that tend to separate the layers can be critical for a printed part.
For this reason, the designer must consider lower tensile strength along the Z axis, and he has to orientate functional models in such a way that the vector of the maximum force lies parallell to the buildplate.

## ASSEMBLY

Based on these considerations, it is always recommended to spend some time to evaluate the potential advantages deriving from the division of the model into several parts to be assembled.

Sometimes this may be useful to reduce the amount of support structures or to enhance the mechanical response of the part to a particular stress.



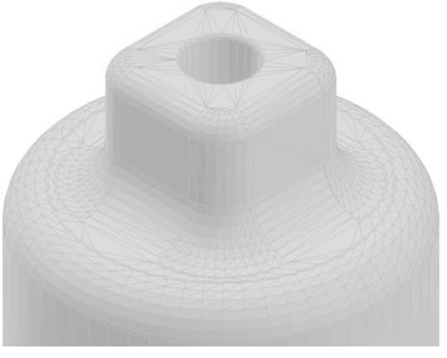
Moreover, in case of critical details within a particularly large model, it is recommended to make an isolated print that allows to validate geometries and printing parameters.

This makes it possible, for example, to check that joints and fittings are adequate.

# Design - Basic Concepts

## MESH SETTING

Once the three-dimensional model has been created, the last step of the design is to export it in a stereolithographic file to be upload into the slicing software. The * .stl format uses a series of interconnected triangles (called "mesh") to recreate the geometric surface of the solid part.



The higher the number of those triangles, the higher the resolution and the weight of the mesh. Meshes with excessively low-resolution lead to low quality prints. Meshes with unnecessarily high resolution, on the other hand, result in oversized files that are difficult to process with the slicer.

To have a perfectly balanced mesh, it is suggested to make sure that the export settings from the CAD modeling software are on "high quality" and include:

**Rope height** = 0.001 mm (one micron)
It is the maximum distance between the surface of the mesh and that of the original model

**Angular tolerance** = 15 °
It is the limit angle included between the perpendicular lines of adjacent triangles

The generation phase of the mesh may lead to errors that result in unsuccessful prints.
To be sure that the model is correctly printable, it is always recommended to correct the STL file in advance with an analysis software (Netfabb, Meshmixer, Trinkle, Sculpteo ...) before importing it into the slicer.

Below you can see the application to a real case of the concepts just described.

# Case study – Rethinking the duct

The ducts are elements used for the transport of an air flow in heating, ventilation or air conditioning systems.
In the aerospace sector, the characteristics required for the manufacture of a duct include a good strength / weight ratio, self-extinguishing and a controlled and traceable production process.

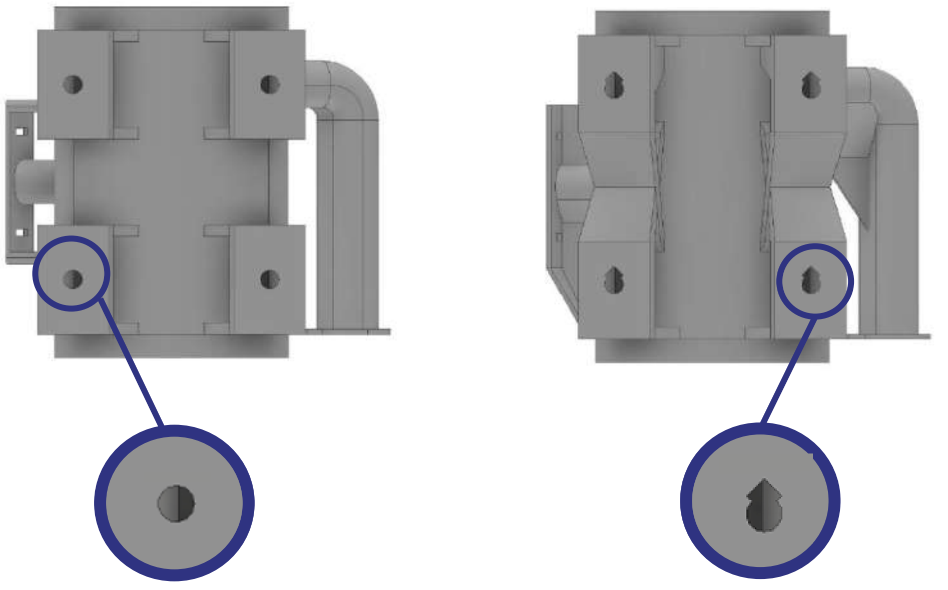
Today it is possible to create 3D printed ducts with complex geometries, impossible to achieve with traditional technologies, by using innovative approaches which allow faster maintenance operations and improve the efficiency of the entire process.

To demonstrate cost and time efficiency, the Roboze 3D Parts team conducted a design optimization study on an aerospace duct starting from a model made with traditional production techniques..

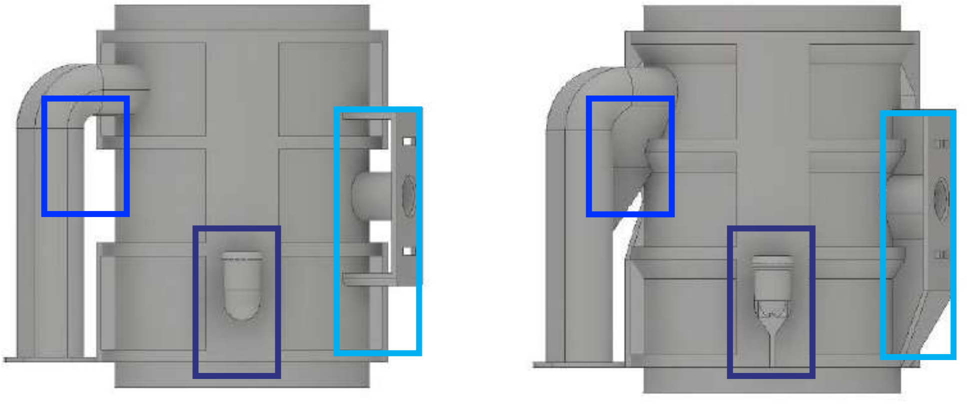
The AM duct in Carbon PEEK was printed in a ROBOZE ARGO 350 with an HVP extruder at 450 ° C and a stable chamber temperature of 160 ° C.
The body has a 100% infill.

# Case study – Rethinking the duct

The 3D Parts experts started by rethinking the geometry of the circular holes on the vertical walls with teardrop structures using 45 ° angles.
This operation avoided the generation of supports while keeping the function of the structure unchanged.
The advantage translates into a reduction of supports, with consequent reduction of the material.



Afterwards, the 3D Parts team made chamfers to eliminate walls with 90 ° hollow corners.



This process, although apparently it may seem that it adds some material to the production of the part, it actually eliminates a part of the supports with a considerable saving in terms of time and material used.

# Case study – Rethinking the duct

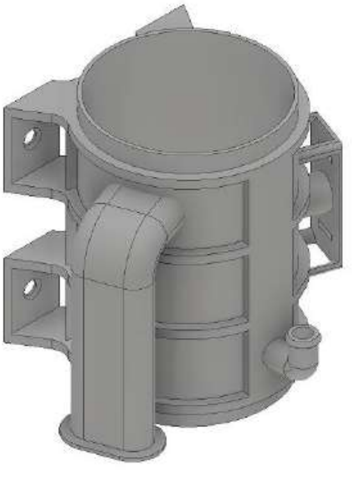
Subsequently, self-supporting structures were inserted inside the elbow ducts.

This allows to avoid supports inside the duct that would be impossible to remove. This solution is also effective in terms of the performance of that portion of the part where the air flow is expected.

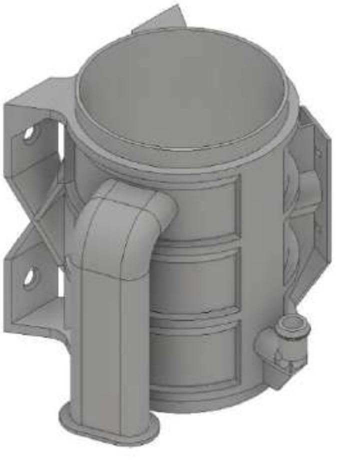
This solution has brought advantages in terms of fluid dynamic performance but also in terms of savings, with tangible results summarized in the table shown below, which compares the 3D production of a replicated part of the traditional manufacturing (PLA) and a part designed for additive manufacturing. (Carbon PEEK).

In this way it was possible to reduce printing times by 55% compared to the previous geometry with a material saving of 35%. In terms of production efficiency, the optimized part was ready to be used without having to spend time on post-production operations.

Production through additive solutions like Roboze allows, through layer-by-layer deposition, to build the geometry regardless of how complex it is.



**BEFORE**



**AFTER**

# Results

| OPTIMIZED PART | NOT OPTIMIZED PART |
|---|---|
| **Actual cost**<br>Printing time: 10 hours (reduction of 55%)<br>Material: 260 gr (35% reduction) | Printing time: 22 hours<br>Material: 390 gr |
| **More efficient production**<br>Cleaner parts, no supports<br><br>Ready to use | Removal of supports and cleaning of all surfaces of the part<br>Post processing required for cleaning |
| **Innovative structures**<br>Guides that work as support<br>Freedom of geometry | None<br>Limited by traditional manufacturing capabilities |

*Comparison between the 3D production of a replicated part of not optimized part and optimized part*

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