Republic of Yemen

Ministry of Higher Education and Scientific research

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Design and Implementation of 3D Metal Printer using Selective Laser Sintering

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2024

Acknowledgements:

After thanking and praising Allah…

We would like to express our deep gratitude to Associate Professor Dr. Farouk Al-Fahaidy, our supervisor, guide and mentor, who was more than just an advisor to us, for helping us with advice and providing us with all the knowledge we needed and constantly encouraging us to complete this project and not give up, and thus we will always be indebted to hem.

We also thank those who supported and encouraged us in completing the project, especially the Head of the Mechatronics Engineering Department, Dr. Radwan Al-Badaji.

We thank Dr. Khalil Al-Hattab for the dedicated assistance that helped us in the project steps.

We are deeply indebted to our parents for their love, support and encouragement throughout our lives. We are also very grateful to our brothers and friends.

Abstract

Using one of the most important and modern methods to create metal parts that were difficult to obtain or manufacture using traditional methods, selective laser sintering technology was used, which is a technology used in three-dimensional metal casting, which in turn contributed to saving time, effort and cost.

This research addresses the basic topics for creating this type of printer, which is considered one of the latest technology findings in the world of 3D printing.

The main idea in this research is to exploit resources and combine them with each other to produce complex and durable parts at the same time to solve industrial problems in almost various fields, including commercial, industrial and even medical.

With SLS technology and the development of the

This printer targeted several industries and different types of metals, the most important of which is titanium, through which it is possible to print parts that are sufficient for the purpose to replace bone in the human body. It is healthy and effective and has been used in more than one place around the world.

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Acronyms

3DP: 3D Printing

AM: Additive Manufacturing

CAD: Computer-Aided Design

CAM: Computer-Aided Manufacturing

DMD: Direct Metal Deposition

DMLS: Direct Metal Laser Sintering

FDM: Fused Deposition Modeling

FEA: Finite Element Analysis

RE: Reverse Engineering

RM: Rapid Manufacturing

RP: Rapid Prototyping

SL: Stereolithography

SLA: Stereo Lithography

SLM: Selective Laser Melting

SLS: Selective Laser Sintering

SM: Subtractive Manufacturing

STL: Standard Tessellation Language

Glossary

3D Printing: *The process where a solid object is created from a computer model. The term 3D printing is often used interchangeably with additive manufacturing. Parts are made in plastic, rubber, or metal.*

Acrylonitrile Butadiene Styrene (ABS): *Thermoplastic most commonly used in 3D printed parts. Heavily used when parts need to be dimensionally accurate and durable.*

Additive Manufacturing: *See 3D Printing.*

Additive Metal Manufacturing (AMM): *The 3D printing process which builds metal objects in layers, by binding or fusing powdered metal together.*

Bed: *Another name for a 3D printer build plate. This is the flat surface in which the parts are made.*

Concept Model: *A physical model of a final product which demonstrates its form and feel but which may lack some functionality.*

Curing: *The process of hardening a liquid or other material to produce its final form.*

Direct Digital Manufacturing (DDM): *The production of final products or components using 3D printing technology.*

Direct Metal Laser Sintering (DMLS): *See Additive Metal Manufacturing (AMM)*

Fused Deposition Modeling (FDM): *3D printing process where melted plastic material is extruded from a nozzle, and layers of material are extruded to build* *parts. Both the term and its acronym are trademarks of Stratasys.*

Filament: *This is the wire made from build material which enters the cold end of the extruder, or the heated wire which exits the hot end of the extruder.*

Material Extrusion: *The process of pushing out a melted material (usually plastic), in order to build up a 3D object as it cools and solidifies.*

Polyjet: *3D printing process that builds up an object by jetting a photopolymer though a print head before solidifying it using a UV light. Parts are printed in either a plastic or rubber material.*

Rapid Prototyping (RP): *Construction of a prototype of an object or assembly off a CAD model. Usually done through 3D printing/additive manufacturing.*

Selective Laser Sintering (SLS): *3D printing technology which uses a laser to selectively fuse/sinter together powder to build up a 3D object in layers.*

Selective Laser Melting (SLM): *3D printing technology which uses a laser to selectively melt together powder to build up a 3D object in layers.*

Stereolithography: *A type of photopolymerization which used a UV laser to solidify a photopolymer liquid in order to build up an object in layers.*

STL: *File format originally developed by 3D Systems in 1987, and used in most 3D printing processes to produce parts.*

Chapter 1 Introduction

1.1 Introduction

Traditional methods in the metal parts manufacturing process are difficult and unable to create precise parts and components with small details. With the development of technology and science, new techniques have been discovered that are worthy of replacing traditional processes. One such technology is selective laser sintering (SLS), an additive manufacturing (AM) technique that uses a high-power laser to sinter small particles of polymer powder into a solid structure based on a ternary model. Dimensions. Due to the ability and efficiency of this technology, it has become possible to create a metal printer that works with the technology to benefit from it in many applications required in our daily lives. This printer can be used in several different fields such as osteoporosis. Resolving these diseases usually requires replacing or repairing the body's skeleton, so the demand for orthopedic implants is rapidly increasing.

Orthopedic implants can be made of metal, bioceramic, biopolymer, or biocomposite materials. Due to the mechanical strength requirements of orthopedic surgical implants, surgeons often choose implants made of metal to provide support that allows the patient early mobility and prevents complications. In the dental fields, surgeons prefer to use metals because of their strength, durability, and ease of shaping. This printer makes this easier and more efficient.

With the development of digital technology, Computer-aided design (CAD) technology: 3D printing technology has the advantages of low cost, fast manufacturing cycle, high reproducibility, and shortened processing time. It can also be used in industrial economy through this technology. The part to be created is designed in design programs such as (SOLID WORKS), and in the design process an engineering structure of the required part is developed so that the part is printed with less material, is lighter, and is compatible with ideal surface polishing [1].

It is possible to create 3D metal parts for industrial devices with fine detail and high quality, capable of replacing traditional processes more efficiently and easily . In this paper we review Characteristics of 3D printing methods and metals. Accordingly, we systematically discuss the possibilities for further strengthening and improving them.

1.2 Problem Definition & Motivation

Like other applications, there are some issues we encounter with 3D printed metal parts. These factors, namely thermal stresses, warping, and layer adhesion problems, must be taken into account, because accurate dimensions and surface areas are difficult to achieve unless these factors are addressed before printing. The finished surface of SLS can have a rougher texture because small portions of the powder are slightly sintered on the edge of the part. With a laser printer, you always have some thermal bleed. The powder around your part will harden because it is close to the heat of the part.

There is a problem that may be the most common in all metal 3D printers that operate with SLS technology in particular, and is considered the biggest challenge facing the leading giants in the field, which is the recoating machine, which is the machine that returns a base coating to bare optical fiber sections after splicing. By fusion.

Every company tries to improve this problem in every new version of this type of printer, and this thing was the biggest motivation for creating this printer.

We had a desire to introduce this technology to our country, as it is not known to many. It will save a lot of effort and time instead of ordering parts from abroad. Now any required part that is difficult to obtain can be manufactured locally. Through this printer, we will have more room to develop what we have learned and gain new experiences, and this is of course what any student wants to be one of our incentives for creating it.

The biggest problem remains the costs that did not make our dreams of creating this printer a tangible goal, as after the intense suffering in commissioning this printer, we tried hard to use alternatives, and unfortunately that was at the expense of the success of the project and the establishment of such a printer

1.3 Project Objectives

- *Possibility of obtaining large parts, protruding parts, overlapping parts, and parts dovetailed at an angle of less than 90 degrees, which are difficult or impossible to obtain by traditional forming methods.*
- *Manufacturing parts from different materials according to the required specifications.*
- *Saving a lot of time and effort with high efficiency that cannot be achieved by traditional methods.*
- *Achieving an ideal surface finish helps eliminate many problems that may lead to surgical operations for patients suffering from osteoporosis or with dentists, as the mechanical parts required in such work must be very precise.*
- *making a high-quality machine; precision of 3D metal printers is measured by micro meters, so building the machine to be of a high quality is very important.*
- *advance Yemen development, by manufacturing machines locally.*

1.4 Project Methodology

The project is divided into several main sections, where in each section there are several parts that are mainly included in that section, and some parts that are sub-sections are as follows:

First: the mechanical system. This system includes the mechanical movement in the two-metal powder storage room and the metal printing room, in addition to the movement of the Reactor, the roller transporting the powder from the storage room to the printing room.

Second: The electrical system. This of course includes power sources, power distribution, electrical and electronic materials used, such as motors, motors, electric heaters and the method of connection.

Third: The optical system. This system includes laser rays, lenses and mirrors reflecting the laser rays, the stage of light transmission, the property of optical refraction of the laser beam, the types of transmitting lenses and mirrors that have been used, and the optical power of the laser.

Fourth: The software system, which includes the software environment used, the language used, and how to connect it to the control unit, in addition to the Human interface

In the following parts of the paper, of course, all sections and what they contain will be detailed separately.

1.5 Project Organization

the rest of this project will be organized as follow:

Chapter 2: theory and literature review

introduces and talks about SLS technology, its progress and differences, along with important criteria to consider when printing. In addition to a brief overview of related works, along with a comparison table between our project and other projects from references.

Chapter 3: the proposed system Design and theory of 3D printer

introduces the most important features and technology of the 3D printer, in addition to the most important problems facing the technology and how to avoid them, especially software. Also, the block diagram with an explanation of the blocks in it.

Chapter 4: System Construction and Design

Starting with the design for printing designed by solid Work, with the addition of explanations related to the design.

All internal and external components of the project, including the systems, in detail, with mention of the most important reasons for choosing these parts in these printer systems.

Chapter 5: Conclusion and Future Work Suggestion

A summary explaining the nature of the SS printer, praising the goals we were able to achieve in this printer, mentioning the most important problems and their solutions, and mentioning the most important future suggestions regarding providing the printer with advantages.

Chapter 2 Theory and Literature Review

2.1 Introduction

Additive manufacturing (AM) encompasses a range of technologies that allows physical components to be made, from virtual 3D models by building the component layer-upon-layer until the part is complete. In comparison with subtractive manufacturing processes, in which one starts with a block of material and removes any unwanted material (either by carving it by hand, or by using a machine such as a mill, lathe or CNC machine) until one is left with the desired part, additive manufacturing starts with nothing and builds the part one layer at a time by 'printing' each new layer on top of the previous one, until the part is complete. (Figure 2.1). Depending on the particular technology used, the layer thickness ranges from a few microns up to around 0.25 mm per layer, and a range of materials are now available for the different technologies. These are discussed in the next chapter. The very earliest concepts related to additive manufacturing date back to the end of the 19th century, and early 20th century, with the introduction of layer based topographical maps as 3D representations of terrain, together with a number of methods for using these topological models to produce 3D maps by, for example, wrapping a paper map over the topological models to produce a 3D model of the terrain Photosculpture, which also originated towards the end of the 19th century, and which used a series of different photographs taken from different angles around the object that were then used to carve out the object using each different angled picture as a template, so an initially subtractive process, also had several proposed methods for creating the models using photosensitive materials. Modern additive manufacturing saw its origins in the mid-20th century with a patent, in 1951, by Otto John Munz which could be considered the origin of the modern stereolithography technique. It consisted, essentially, of a series of layered 2D transparent photographs printed on photosensitive emulsion stacked on top of each other. He developed a system for selectively exposing the transparent photo-emulsion in a layer-wise fashion in which each layer was exposed with across section of an object. Much like a modern stereolithography machine, the build platform on which the part was being built *was gradually lowered, and the next layer of photo emulsion and fixing agent was created on top of the previous layer.*

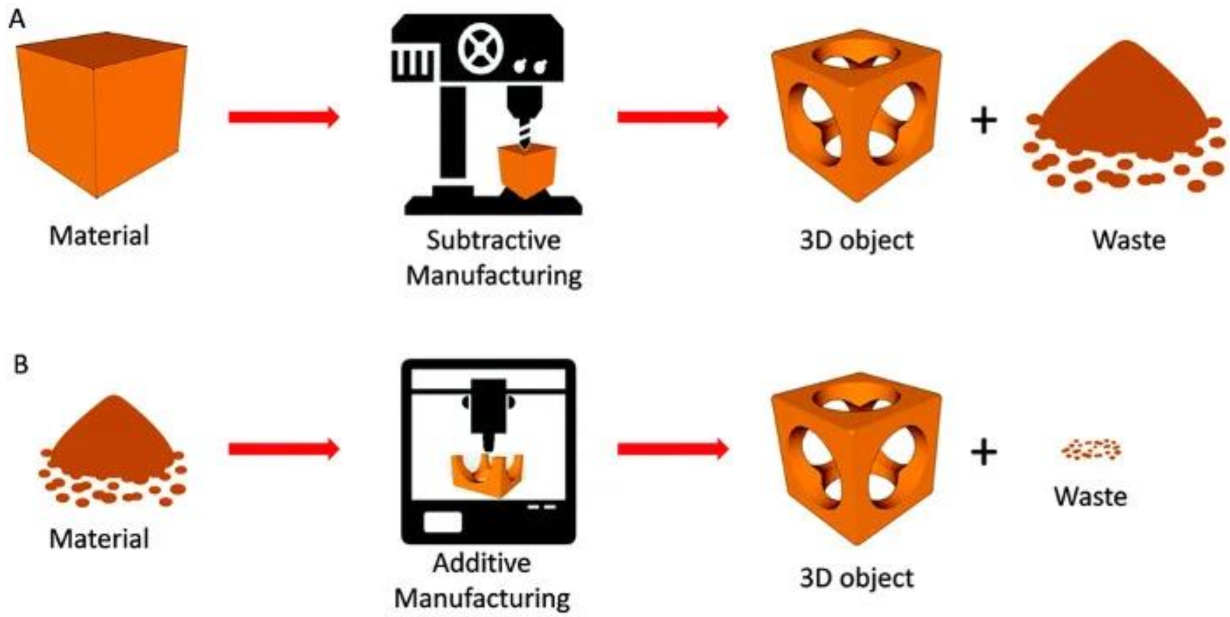


Figure 2.1 Subtractive manufacturing, where one builds a part by removing material from a block, versus additive manufacturing, where one builds the part layer upon layer with losses being comparable.

Once the printing process was finished, the result was a solid transparent

cylinder containing a 3D image of the object. A weakness of this system was that the final real three-dimensional object had to be manually carved or photo chemically etched out of the cylinder as a secondary operation. The following decades saw the development of a succession of new techniques including those of Swainson who, in 1968, proposed a process to directly fabricate a plastic pattern through the selective 3D polymerization of a photosensitive polymer at the intersection of two laser beams (with the patent assigned to the Formigraphic Engine Corporation). Work was also undertaken at Battelle Laboratories, called Photochemical Machining, in which an object was formed by either photochemically crosslinking or degrading a polymer through the simultaneous exposure to intersecting laser beams. In 1971, Ciraud proposed a powder process that can be considered the father of modern direct deposition AM techniques such as powder bed fusion, and in 1979, Housholder developed the earliest equivalent of a powder-

based selective laser sintering process. In his patent, he discussed sequentially depositing planar layers of powder and selectively solidifying portions of each layer. The solidification could be achieved by using heat and either a selected mask, or by using a controlled heat scanning process such as a laser. Other notable early additive manufacturing developments include those of Hideo Kodama, of the Nagoya Municipal Industrial Research Institute in Japan, who developed a number of stereolithography related techniques, and the work of Herbert who, in parallel

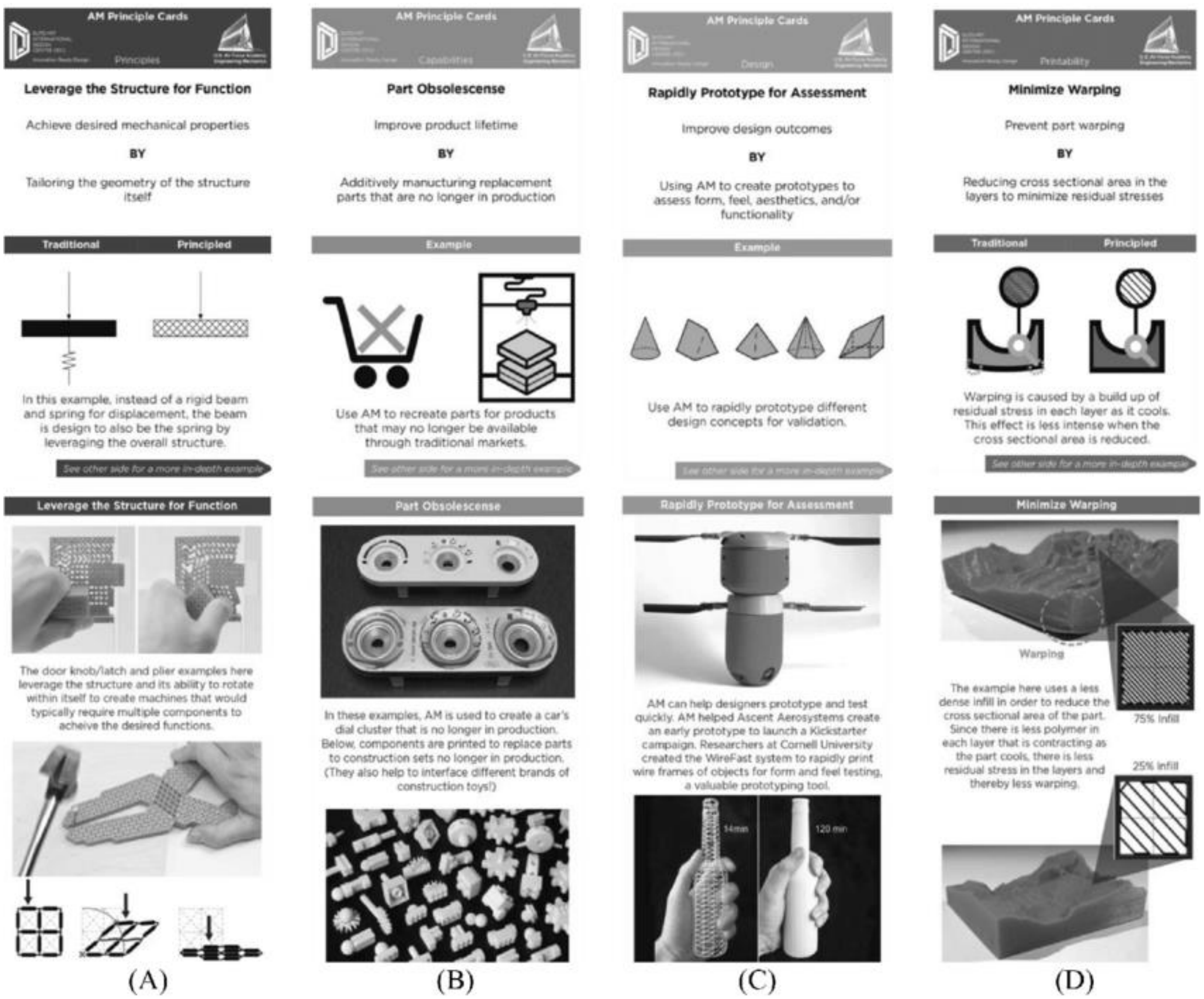


Figure 2.2 Examples of early AM parts by Householder, Kodama, Herbertand Manriquez Frayreand Bourell. Courtesy of Ismail Fidan, Dave Bourell, and IS&T: The Society for Imaging Science and Technology

*with Kodama, developed a system that directed a UV laser beam onto a photopolymer layer, by means of a mirror system on an x–y plotter, to scan a layer of the model. The build platform and layer were then lowered by 1 mm into a vat of resin and the process was repeated. Examples of Householder's, Kodama's and Herbert's parts can be seen in (*Figure 2.2*). Commercial additive manufacturing, as we know it today, with the development of commercially available system did not really begin until 1986, with Charles W. Hull's stereolithography patent. The patent was originally owned by UVP Inc. and the company licensed the technology to their former employee, Charles Hull, who used it to found the start-up 3D Systems. This development saw the first commercial SLA machine appearing in 1988 and, since then, almost every year has seen an exponential rise in available systems, technologies and materials. Even the terminology relating to additive manufacturing has changed a lot over the last three decades. For most of the 1990s, the principal term used to describe the layer-upon-layer manufacturing technologies was rapid prototyping (RP), because the principal use of the various available technologies was to make concept models and pre-production prototypes. Some other terms that have also been used over the years include Solid Freeform Fabrication (SFF) and Layer Manufacturing. In early 2009, however, the ASTM International Committee F42 on Additive Manufacturing Technologies tried to standardize [1].*

the terminology used by the industry and, after a meeting in which many industry experts debated the best terminology to use arrived at the term 'Additive Manufacturing' which, today, is considered the standard terminology used by industry. In their ASTM F2792 10e1 Standard Terminology for Additive Manufacturing Technologies document they defined additive manufacturing as: the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining. Unlike subtractive manufacturing, where material is removed from a larger block of material until the final product is achieved, most additive manufacturing processes do not yield excessive waste material. If a part is properly 'designed for AM', and one is comparing it to a single part produced through *conventional manufacturing, it also typically may not require the large amounts of time needed to remove unwanted material thus, potentially, reducing time and costs, and producing relatively little waste. This, however, should not be misconstrued as AM being able to always make cheaper parts than conventional manufacturing. In many cases it is, in fact, the opposite, because AM is a relatively slow and expensive technology. This is discussed in greater detail in the chapter on the economics of AM. But this depends very much on the AM technology in use and the many possible design parameters that can be used and is, in part, what this book is about. It should be noted, however, that while industry has, generally, adopted the additive manufacturing term, much of the popular press and media continues to refer to additive manufacturing as 3D printing, as this is a term more easily understood by the general public. Some consider the term 3D printing to be focused on lower cost hobby desktop 3D printers, and additive manufacturing focused on higher-end industrial production systems. In this book, when talking about the process, we use the two terms interchangeably.*

2.2 Literature Review

2.2.1 SLS process

*As explained before, Selective Laser Melting (SLS) is an Additive Manufacturing (AM) process used to produce parts by selectively melting the powder layer by layer with a laser beam. This laser beam has enough power to heat up the desired area and melt the metallic powder. The materials used are metal powder, among others, the most used ones are aluminum, titanium, cobalt and nickel-based alloys. As the other 3D technologies, the main advantage of this technology is allowing to manufacture complex parts that would be really challenging or impossible to produce using other conventional processes. That is the main reason why Aerospace Industry is one of the most interested in this technology, as its parts are often complex and weight is an important issue that has to be taken into account. Besides, SLS has a direct impact on medical or prototyping applications since most of the parts are customized and small batches are needed. (*Figure 2.2*) shows a part manufactured by SLS [2].*

*With the stl file, a software is used to slice this model in 2D layers, between 20 and 100 micrometers high. Note that each of these slices will be every one of the layers for the build job once the file is finished. There are several programs to be used for the slicing process and choosing the parameters set, but in this case the software used was Materialise Magics 2017. While the program makes the slices, it must be selected all the parameters for the building that will be used Such as distances, power, etc. Those parameters will be explained further in the following sections. This is also an important step in the process because, despites the SLS process is the same for most machines, different software have different sets of parameters. So, it depends on the user's decision to choose the parameters to be used during all the buildup process. (*Figure 2.3*) shows a slice of one part where the different surface and parameters can be seen. Once the slm file is created, it can be loaded to the machine and start the buildup process.*

Figure 2.3 Example of SLM part, it can't be manufactured with other process due to its complex geometry.

2.2.2 Preprocessing

Before starting the machine and the SLS buildup, there are some steps to be done before, such as creating the data file that the machine will use for the production process (slm file). The most common file format for all 3D printing technologies is stl. This file represents the part by a set of triangles that define the boundaries of the model, no surface roughness, color or any other type of characteristic is within the file. The more triangles to define the part, the better resolution it has, but at the same time more difficulties to work with this file. Therefore, the less triangles, the better for creating the slm file, however it must still have enough of them to ensure the part's resolution and quality see (Figure 2) With the stl file, a software is used to slice this model in 2D layers, between 20 and 100 micrometers high. Note that each of these slices will be every one of the layers for the build job once the file is finished. There are several programs to be used for the slicing process and choosing the parameters set, but in this case the software used was Materialise Magics 2017. While the program makes the slices, it must be selected all the parameters for the building that will be used Such as distances, power, etc. Those parameters will be explained further in the following sections. This is also an important step in the process because, despites the SLS process is the same for most machines, different software have different sets of parameters. So, it depends on the user's decision to choose the parameters to be used during all the buildup process. (Figure 2.4) shows a slice of one part where the different surface and parameters can be seen. Once the slm file is created, it can be loaded to the machine and start the buildup process [3].

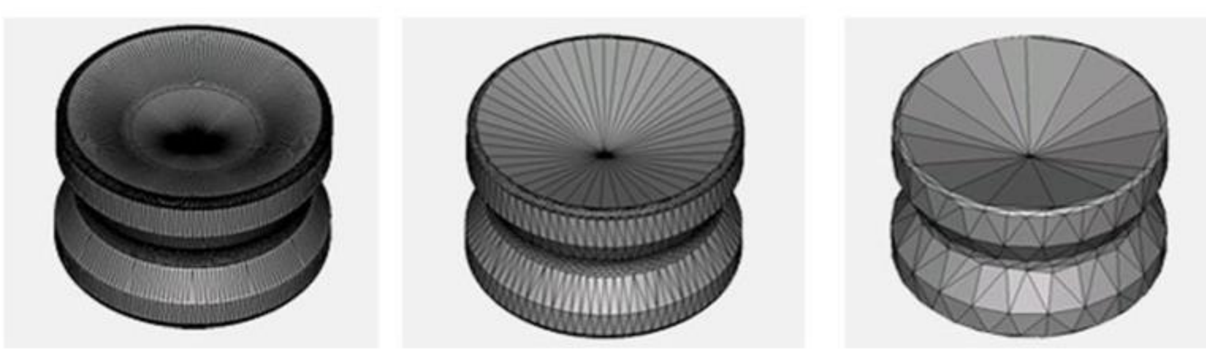


Figure 2.4 From left to right, the same part with less number of triangles, so, less resolution

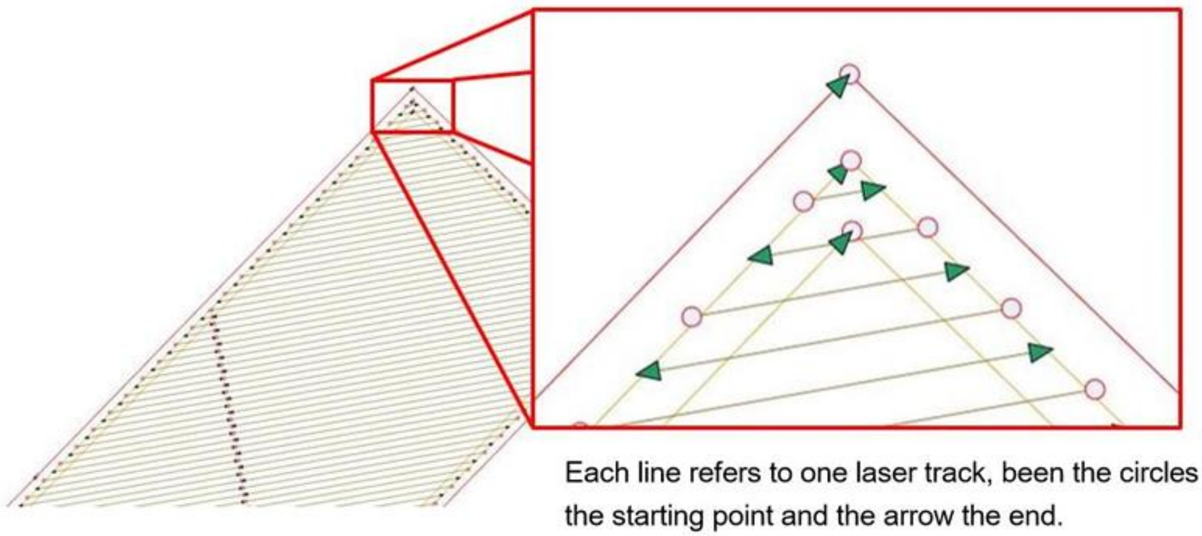


Figure 2.5 Slice of a part where it can be seen the scanning strategy. In the increased picture laser's tracks can be seen

2.2.3 Buildup process

Before explaining the parameters that will be studied, it's important to understand how the buildup process works for better understand of how these parameters can influence the parts' performance. Once the file is loaded on the machine and the process it gets started, the recoater fills the layer with powder

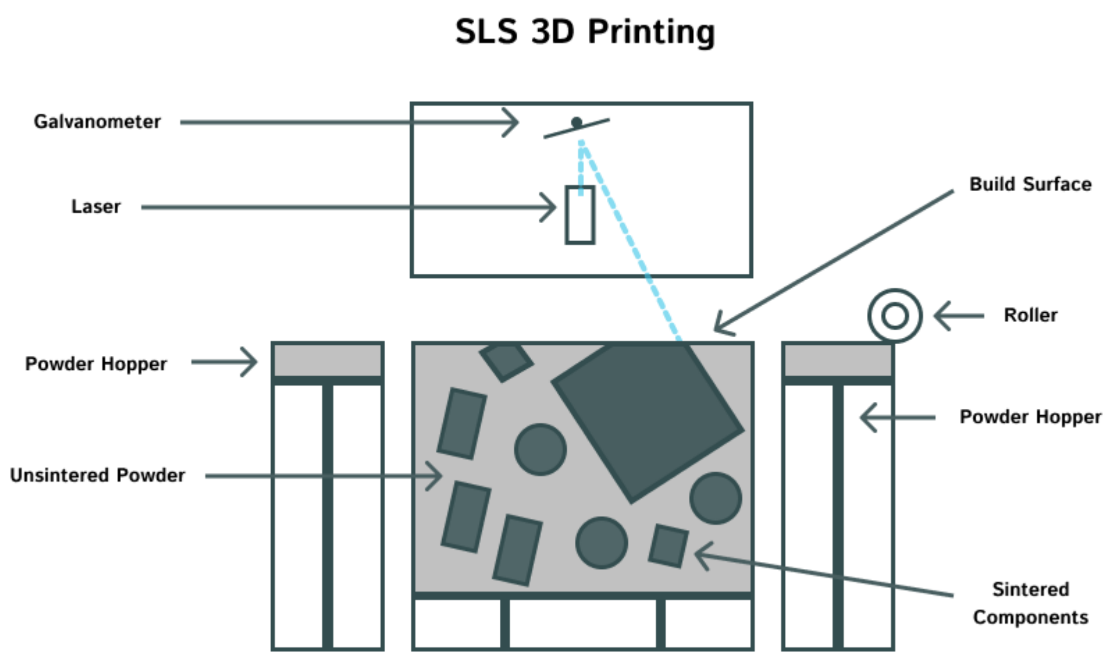


Figure 2.6 Laser focus on parts construction points according to sorting in dedicated programs

of the desired material. Then the laser beam, when reflected with mirrors, hits the desired area and melts the powder within it, which solidifies. Once the laser has finished, the platform will go down and the recoater will fill another layer and so on, till the part is completely built. (Figure 2.5 & 5.6) show two diagrams explaining the SLM process mentioned above. [3]

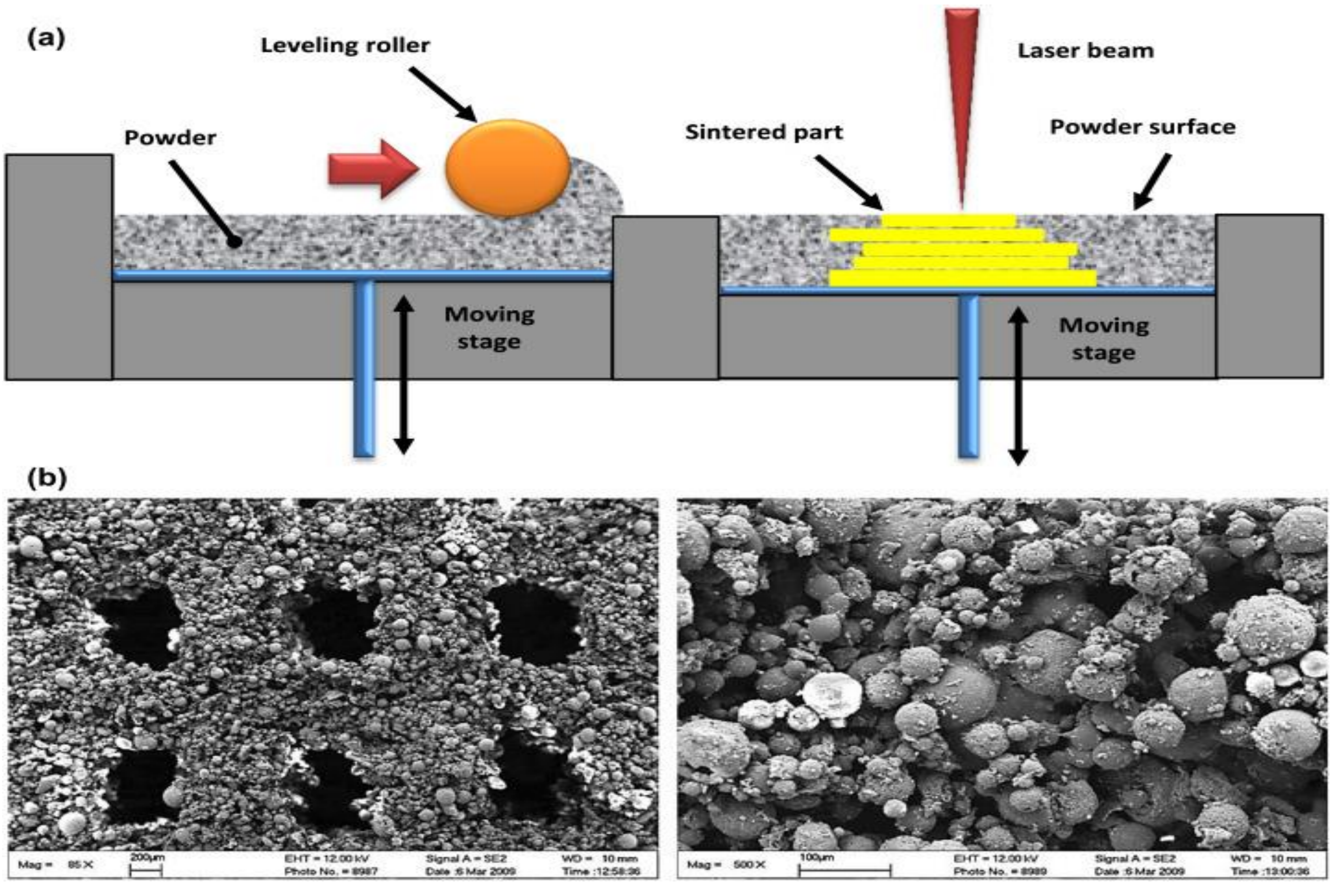


Figure 2.7 Transferring a small amount from the storage room via the mobile scanner to the printing room, showing the cohesion of the metal particles after the laser passes through each layer.

2.2.4 Parameters

There are a multitude of parameters that have a direct influence on the buildup process and, at the end, over the parts' quality. Some of them are inherent to the material chosen such as thermal conductivity, specific weight, melting temperature, among others. It's clear that all of them will have a direct impact on the build job, but there is no possible way to modify them, therefore they are unalterable. They must be taken into account while developing the buildup strategy, but since there is no way to change them, the user must manage it to have the best part's performance as possible by modifying the rest of parameters; see (Figure 2.8) Note that when talking about increasing the parts' quality or performance, these terms always refer to relative density. The main parameters to be tested are explained in the following points.

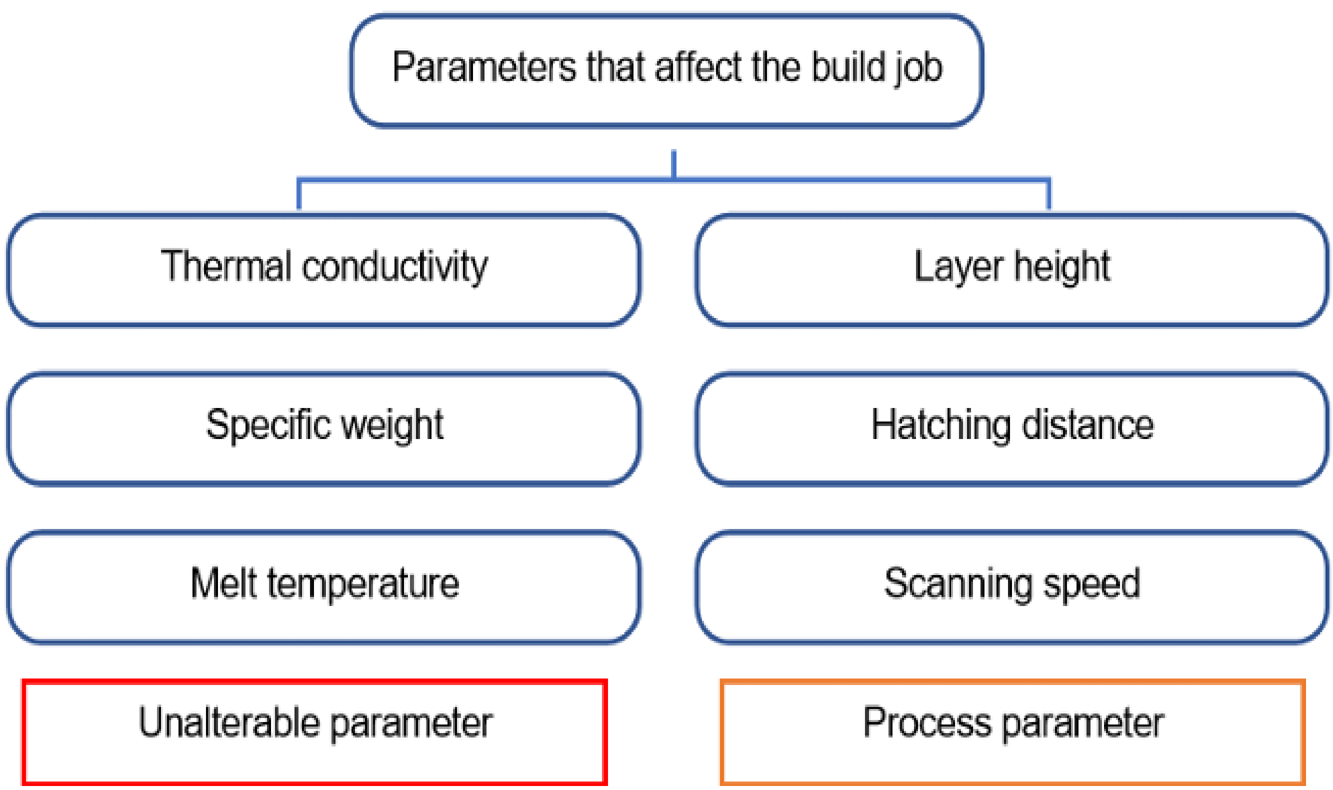


Figure 2.8 process parameters that can be programmed and unalterable parameters

2.2.4.1 Layer Height (h)

As we explained before, the additive manufacturing process produces 3D parts by adding 2D slices layer by layer, so at some point in the process, the distance between each layer must be determined. This distance between layers is called layer height or layer thickness and should be in the range of 0.02 mm to 0.1 mm. The higher this value, the faster the build process will be, as fewer layers will be needed for the same height. It can also be seen through the build rate coefficient, which is used to compare the productivity of processes. This coefficient shows the volume of material produced per hour, usually expressed in cubic centimeters/hour. As we have just seen, the layer height is directly proportional to the build rate, so the higher its value, the more productive the process. In fact, even if it is not reflected in the build rate, the number of layers has a greater impact on the process time, since the repainting time is not taken into account. A repainting machine takes between 5 and 8 seconds to fill the platform. If these few seconds are multiplied by the number of layers, which is usually more than 2000, the time frame for recoating may exceed two hours. But at the same time, the higher this value, the lower the accuracy of the part. (Figure 2.9) shows the effect of layer height on the accuracy of the part.[4]

Also, if this distance is too large, it may lead to poor adhesion between layers and breakage of the part. For all this, the layer height should be as high as possible, but short enough to ensure adhesion between layers and avoid possible breakages.

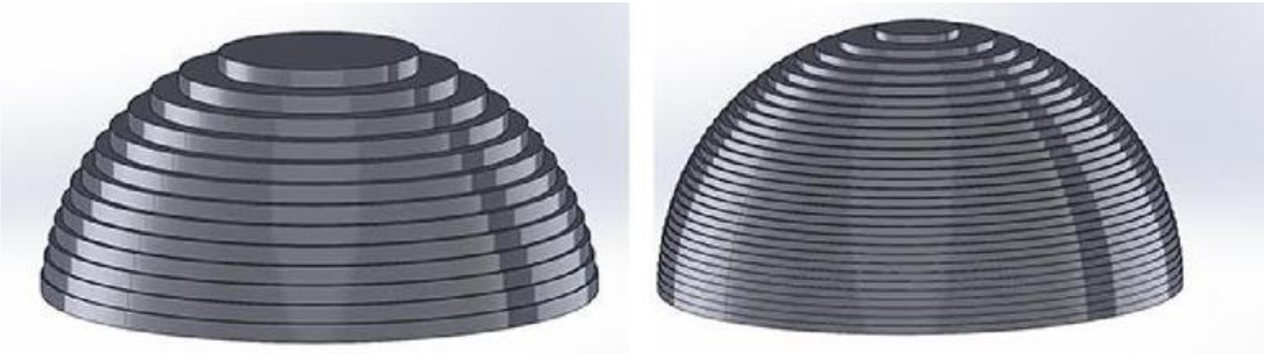


Figure 2.9 Left part has a higher layer height and will be faster to print as there are less layers to produce, but the resolution of the right one will be better.

2.2.4.2 Hatching distance (t)

In order to melt the powder, the laser beam passes through the desired area by making straight paths as can be seen in the slide image in (Figure 2.10). The distance between two adjacent paths of the laser beam is called the hatching distance or path distance. This distance is measured in millimeters and can take values from 0.05 to 0.25 mm.

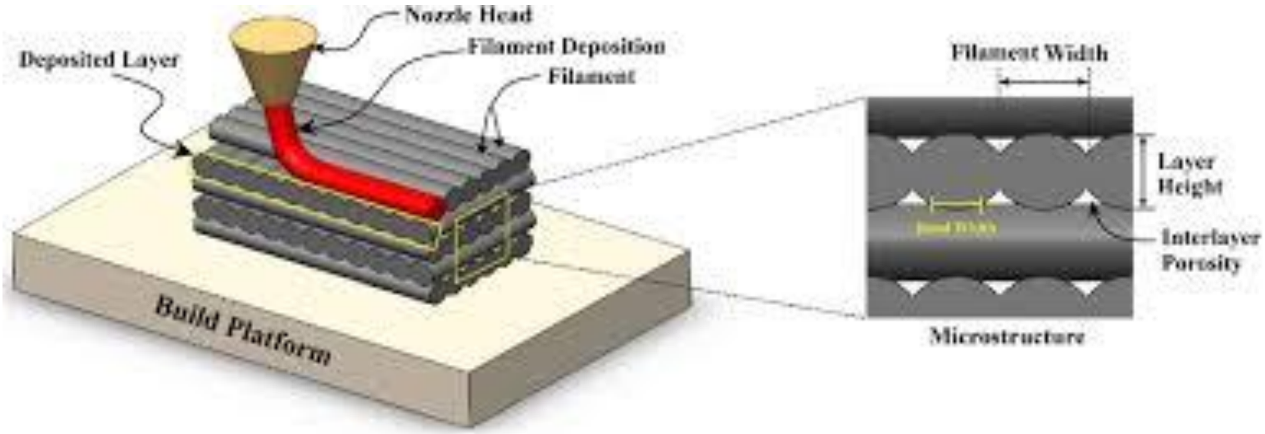


Figure 2.10 SLS process flow chart with laser lines drawn side by side to form the layer.

When the laser beam hits the powder bed, a certain area absorbs this energy and melts. This area can be ideally defined by a circle, where the surface depends on the diameter of the beam. (Figure 2.11) shows a diagram in which

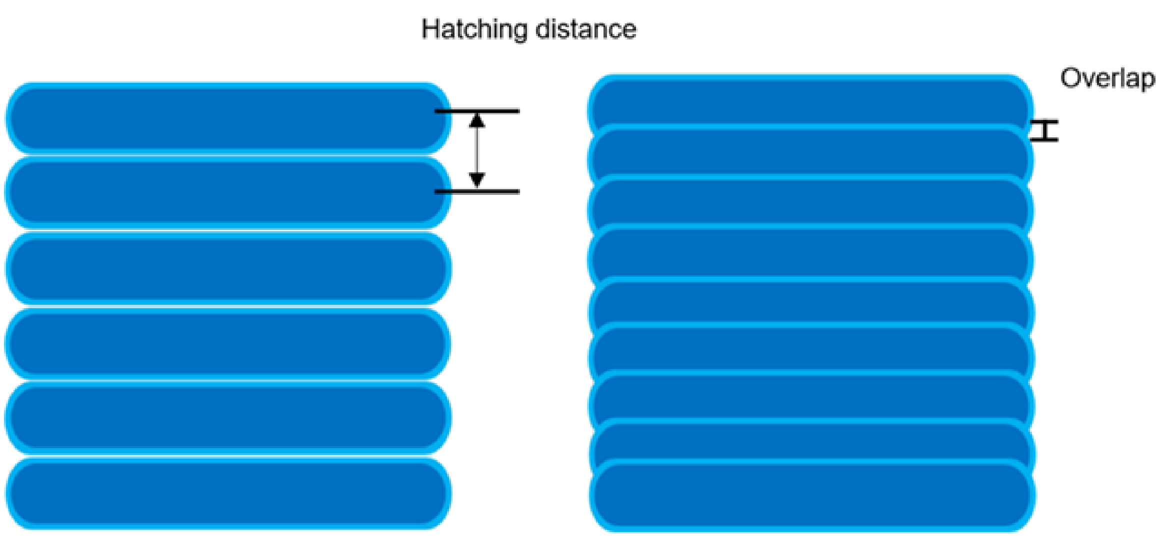


Figure 2.11 Hatching distance has an important impact in the part's quality as in the build rate

layer height and the hatching distance can be seen. Note that the hatching distance refers to the distance between the centers of adjacent laser beam paths. In addition to the layer height, the greater the hatching distance, the higher the build rate and the higher the productivity that can be achieved. But as can be seen in (Figure 2.10), if the paths are too far apart, the powder between them will not melt properly. Furthermore, despite the laser beam melting circles, the outer region is usually lower in energy than the central region. This means that these regions do not melt properly, so the tracks have to be closer together. This causes the tracks to overlap and some of the powder to be hit by two different laser tracks. As with layer height, the goal is to have the highest hatching distance to get the highest yield, but at the same time you have to make sure that the powder is melted properly.[5]

2.2.4.3 Scan speed (v)

Scan speed or just speed, as shown in (Figure 2.12), is the speed at which the laser beam moves measured in mm/s. As mentioned before, the result of its value multiplied by the shading distance and the layer height is known as the build rate. It is important to try to increase its value to obtain the highest possible productivity.

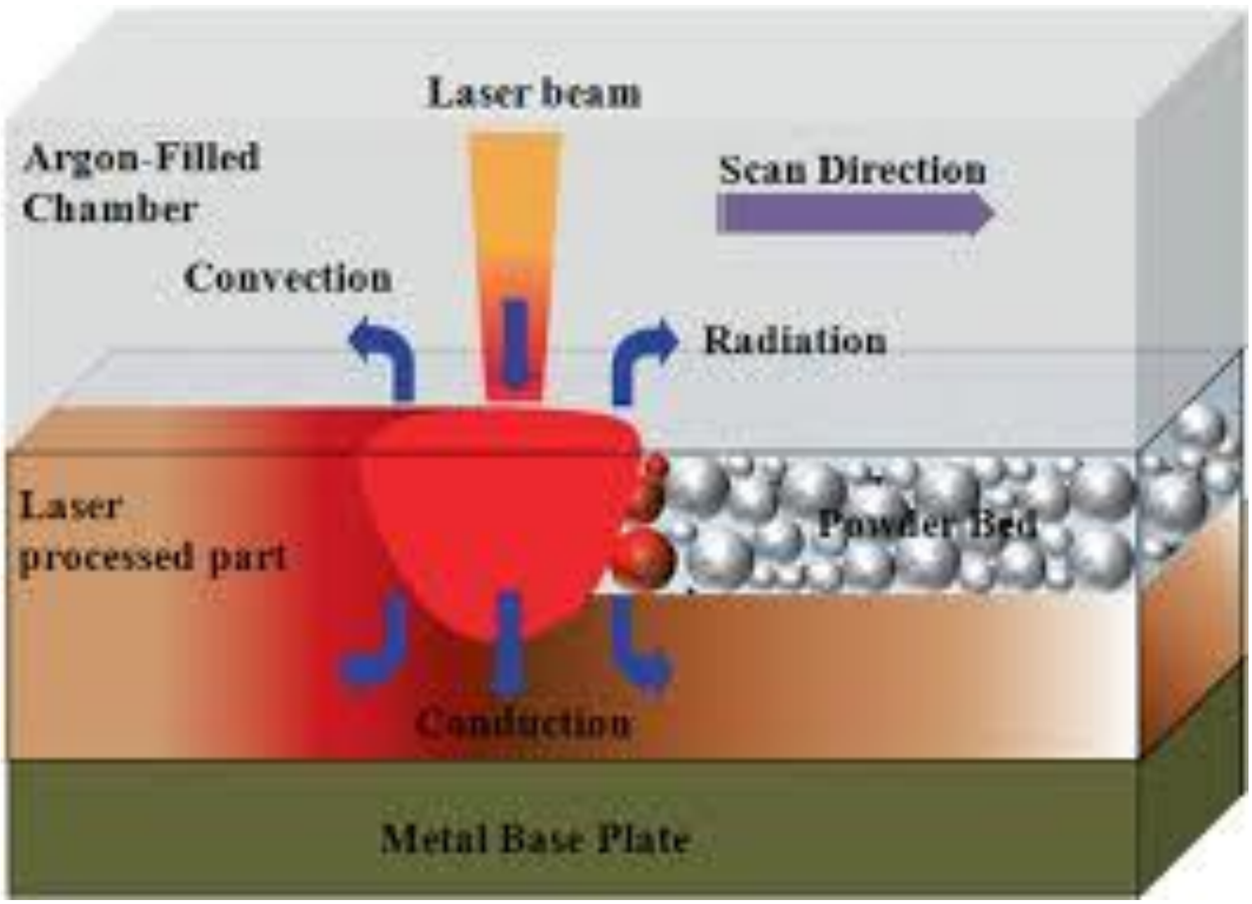


Figure 2.12 Diagram of SLS process, where it can be seen how the laser is melting the powder bed

But we must always keep in mind that if the laser beam speed is too high, it means that it will stay in the same place for a shorter period.This will result in less energy being transferred to the powder bed and this can cause poor melting and the appearance of defects such as pores.

On the other hand, the lower the speed, the longer the laser will stay in the same spot and it can end up with too much energy which will cause the powder to evaporate and also cause pores. For these reasons, the scan speed must be chosen very carefully. As will be explained in the next point, speed and power have a very close relationship and variations on one usually lead to variations on the other as well. For this reason the speed range can vary depending on the power used, the printed materials, etc., and values can range from 300 to 2,500 mm/s.

2.2.4.4 Laser Power (P)

The power of the laser beam, expressed in W, is the main source of energy for melting the powder. The higher this value, the more energy will be transferred to the powder and the higher the temperature will be reached. Depending on the material to be printed, more energy will be needed in order to melt all the powder. If there is not enough power, the powder will not melt properly and the part will have some pores, causing its relative density to decrease. On the other hand, if there is too much power, this can lead to evaporation of the powder and also produce defects. SLS machines are usually installed with lasers whose

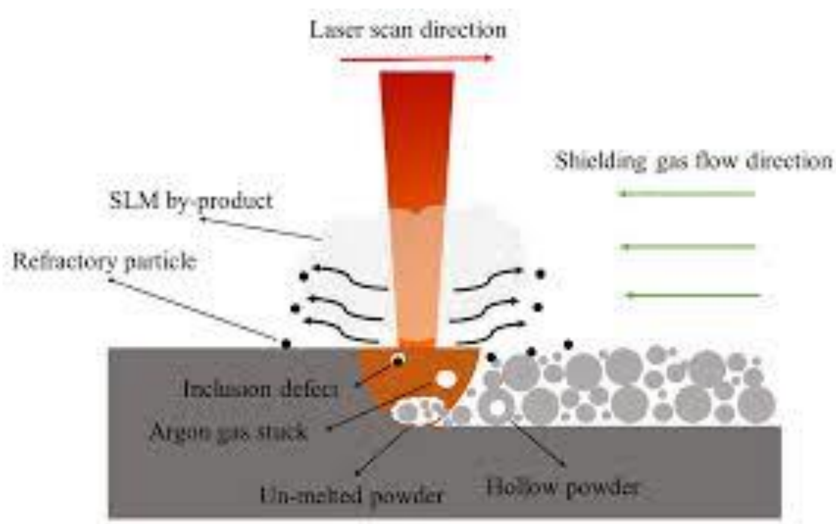


Figure 2.13 Illustration of the heat distribution from the laser to the targeted area nearby

maximum optical power can reach 5-40 W. In order to choose the correct power value, as mentioned earlier, the scanning speed value must be known at least. Power refers to the amount of energy transferred per second, and speed directly affects the time spent in the same area. (Figure 2.13) Heat distribution. Therefore, both values will determine the amount of energy transferred in this area. Moreover, as we explained before, the energy must be chosen very carefully, too much or too little energy will cause pores to appear. Unlike other techniques, this technique has a special and somewhat different thermal system, as two heat sources are required to heat the system before the heat source taken from the laser rays, and this will be explained in detail later [6].

2.2.4.5 Intensity (I)

SLS typically uses thermoplastic polymeric powders and the resultant parts have a useful temperature range of 150-185 °C, while often being weaker compared to traditionally processed materials. See (figure 2.14) As we mentioned earlier about the difference between this technology and other technologies and systems, especially for 3D printers, what is worth mentioning in this system is the high-heating system for the metal powder before printing. This is not limited to facilitating the heating process only, but also for the result, and what is meant here is all the criteria that we mentioned previously. To be in the picture, this printer contains a completely closed area to heat and reduce the heat in the system until the end of printing. To make the heat continuously present within the system, it is necessary to use three different types of heat to print the parts.

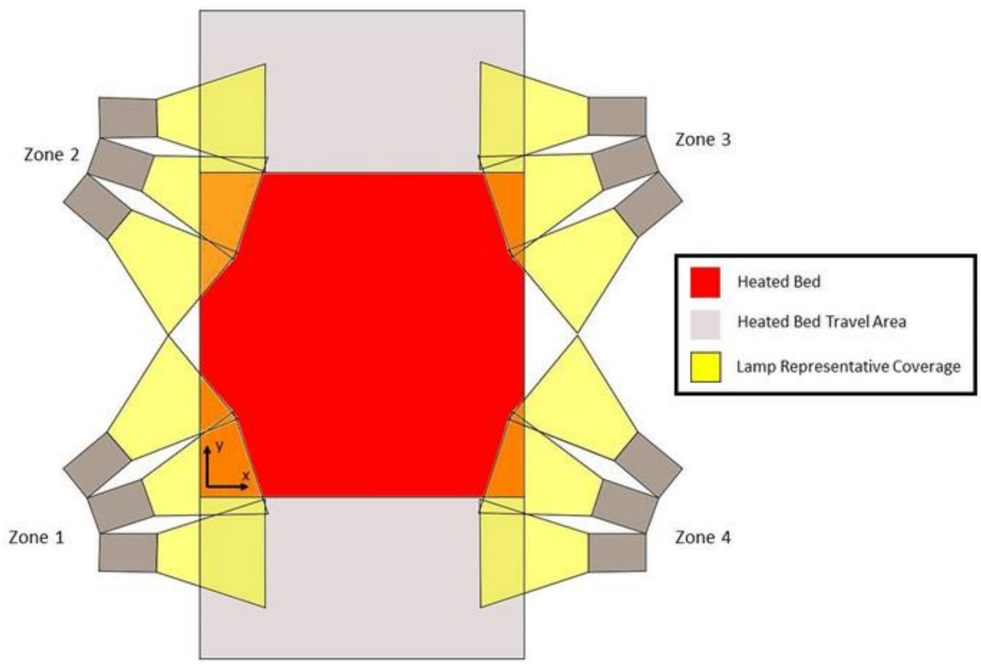


Figure 2.14 Different temperatures found in the same SLS printer for metal printing

A) The coil heater temperature is the temperature at which the entire system is heated to a temperature of 150C, to ensure that the powder is ready for the next stage of heating. (figure 2.15) Printer temperature measurement

Coil heaters, also known as cable heaters, are generally used to supply high watt density in a particular area. They are an important part of many industrial heating solutions. Coil heaters provide instant heating and cooling.

Heating coils work by absorbing heat from the air and releasing it into the refrigerant. The refrigerant then transfers the heat to the outdoor unit, where it is released into the air.

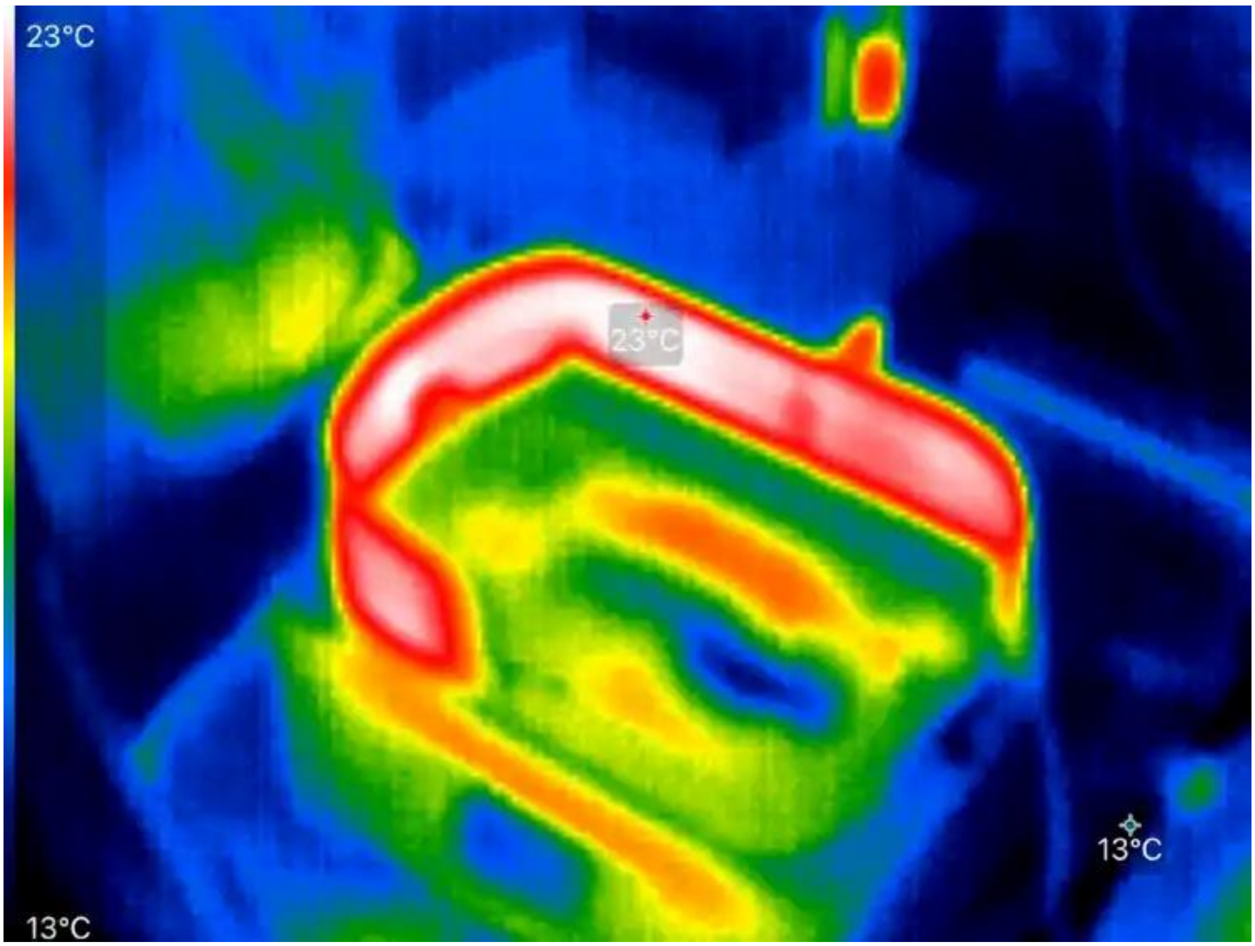


Figure 2.15 A device measuring the temperature of an SLS 3D metal printer to indicate the concentration of excess temperature in the print.

B) *Heat lamps work on the same principles as regular incandescent lamps, but they produce much more infrared radiation. This creates more radiant heat, allowing the heat lamp to be more useful as a source of warmth than a regular lamp.*

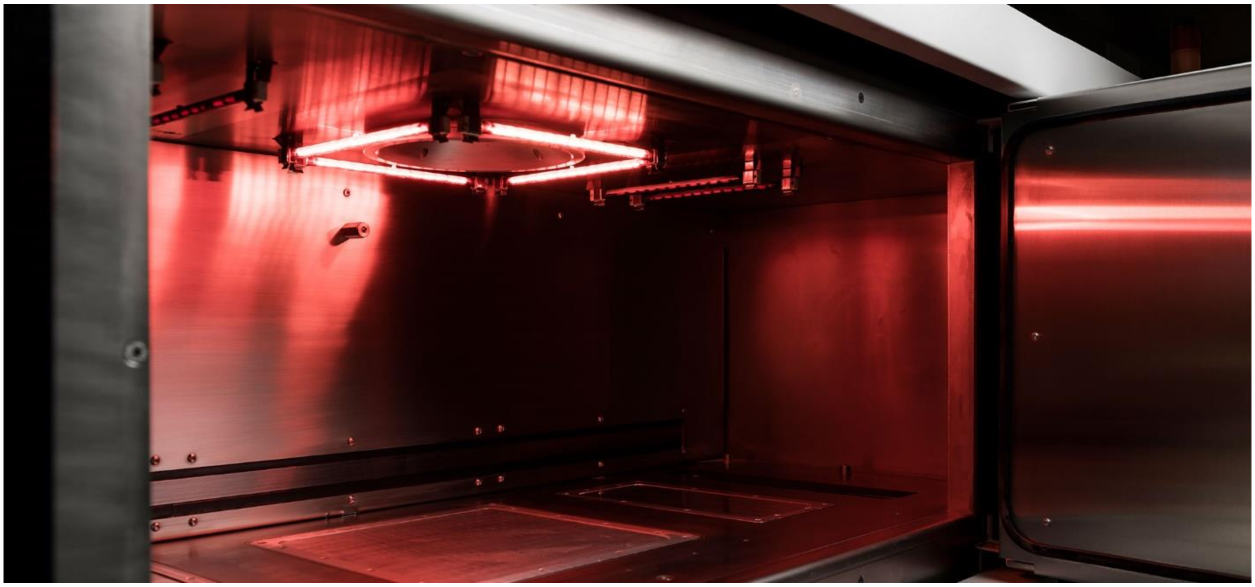


Figure 2.16 Heating lamps are placed vertically directly above the print bed as a position to bring the metal to a temperature before melting.

An electric heater consists of a high-powered incandescent lamp that emits infrared radiation. Synonyms: infrared lamp. electric fire, electric heater. small electric heater. The heating lamps are placed vertically directly above the print bed. See (figure 2.16)

Infrared heaters work by converting electricity into radiant heat. Infrared radiation is part of the electromagnetic spectrum. Heat is the same warm feeling as the winter sun on your face and the heat from a coal fire.

The main function is to increase the temperature of the new layer that will be printed on to the temperature of the powder before melting. Depending on the type of powder metal, the temperature of the heat lamps ranges from 15-25 C

This is enough to make the laser beam include the metal particles while drawing the laser beam on the powder metal

C) *The last parameter to consider is the intensity of the laser beam. In previous explanations, the laser was ideally pictured as a perfect circle*

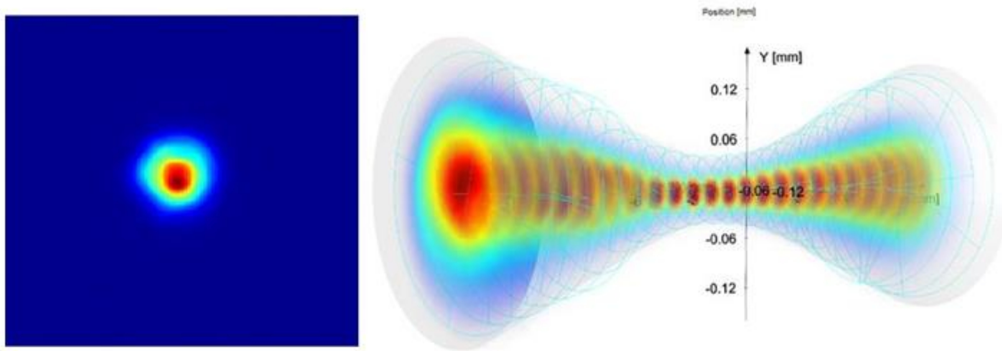


Figure 2.17 Measurement of the laser beam focus. It can be seen that the center of the beam is almost red, is where most intensity is applied.

hitting the powder bed to heat it. This circle has a radius and, therefore, an area that also affects the amount of powder heated by the laser beam. The larger the radius, the larger the area that will be hit and the energy will be delivered throughout it. The result of dividing the energy applied per cm2 of the laser beam spot surface is called the intensity and is

expressed in W/cm2. Since this area can vary greatly, even if the same energy is used, many different results can be obtained due to the size of the laser beam spot. Also,

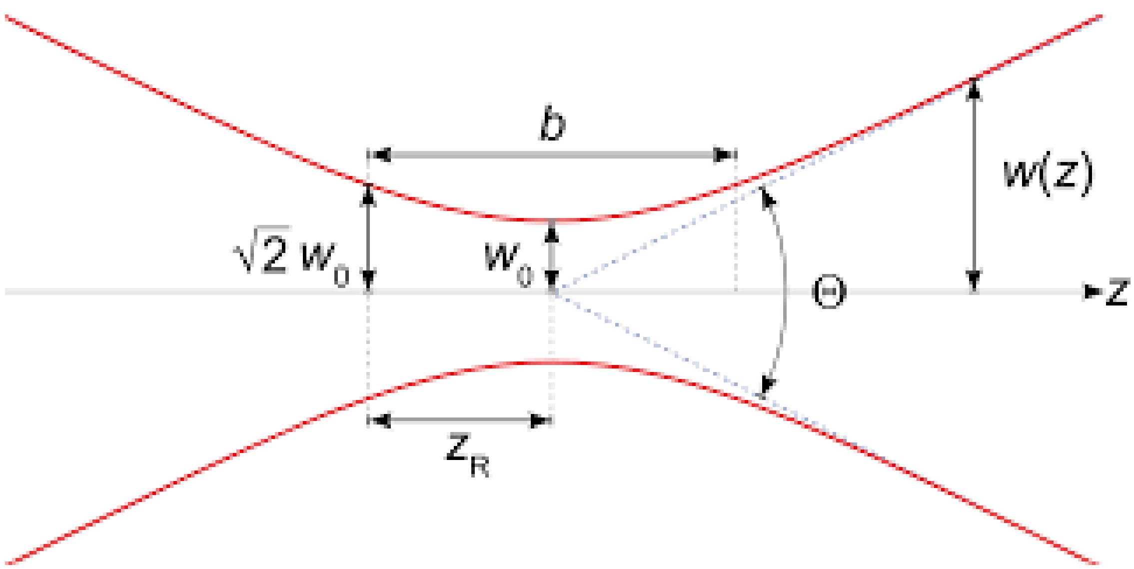


Figure 2.18 Characterization of the propagation of a Gaussian laser beam

the energy is not distributed homogeneously in this spot area, being the center where most of the energy is placed. [6]

The further away from the center you go, the less energy, (figure 2.18) shows a picture of this explanation. To find out the size of the spot or focus of the laser beam, its propagation must be characterized. This characterization is done using some individual parameters depending on the type of laser used. Since the laser used has a Gaussian profile, it has a spot size, where the radius is at a minimum, called the beam waist, and the further we move away from this point, the larger the radius, (Figure 2.17).

2.3 Related Works

In [1] It offers a 3D metal printing system based on printing metal using a moving head that melts the metal and then builds in layers in the same way as 3D printers print plastic. What distinguishes it is getting rid of the closed shape by its ability to melt the metal with the head. It has many disadvantages, but the most important is the delay in printing to cool the metal between each layer.

In [2],[6],[11] He introduced a system that prints through a moving head containing the metal powder through which he creates three-dimensional metal parts by melting it with the head. What distinguishes it is that it melts and prints quickly, but what is wrong with it is that it faces many problems in creating parts of the required size.

In [3] The 3D printing system is presented with the main idea of reducing the cost, but the drawback is that there are many problems that must be eliminated to create usable 3D metal parts.

In [4],[5] A system for one of the modern 3D printers for printing metals. One of its most important features is that it produces 3D metal parts with an ideal surface finish. Its drawback is the very high cost.

In [7],[9] A modern 3D metal printing system is presented. One of its most important features is the creation of metal parts efficiently and quickly. Its most important disadvantage is that the part requires processing that may take days after printing. Otherwise, the printed part will not be suitable for use.

In [8],[12] This system provides a way to print a closed 3D printer at a high temperature by printing polymer-reinforced plastic and cohesive. What distinguishes it is the high temperatures of more than 500 degrees Celsius. What is wrong with it is that it does not print using metals, only using plastics and polymers.

In [10] This system introduced a modern technology for printing three-dimensional metals using SLM technology, which is a technology similar to SLS technology, but there was no closed system for using temperature for printing. A carbon dioxide laser was used, with a power of up to 40 watts of optical power.

2.3.1 Comparison References

Table 2.1 (System Comparison Summary)

References	***mechanical system***	***thermal system***	***Optical system***	***electrical system***
[1]	*Regular axes 3D printer does not work in the modern technology*	*The metal is melted in the head itself at a medium temperature.*	*It does not contain an optical system.*	*Using Arduino as a master controller for a 3D printer*
[2],[6],[11]	*Regular axes 3D printer does not work in the modern technology*	*Using a closed system and high temperature to melt the metal in the head.*	*It does not contain an optical system.*	*Using Raspberry Pi as the main controller in the printer*
[3]	*The axes in this printer contain a laser beam fixed to the logo conversion lens.*	*Use low temperature to melt metal*	*Optical system to convert the laser beam to the required size*	*Using Arduino as a master controller for a 3D printer*
[4],[5]	*The axes contain an expensive head for melting the metal wire.*	*The metal is melted in the head itself at a high temperature.*	*It does not contain an optical system.*	*Using Duet 2 Wifi as a master controller for a 3D printer*
[7],[9]	*The head is fixed and the X and Y axes are scanned by a galvano scanner to reach every point in the print.*	*Uses low temperature to melt metals during printing.*	*It has a modern optical system consisting of a laser beam, lenses and galvano scanner.*	*Using Duet 2 Wifi as a master controller for a 3D printer*
[8],[12]	*Regular axes 3D printer does not work in the modern technology*	*Polymers and adhesives melt at high room temperature.*	*It does not contain an optical system.*	*Using Raspberry Pi as the main controller in the printer*
[10]	*Regular axes 3D printer does not*	*Uses low temperature to melt*	*It has a modern optical system consisting of a*	*Using Arduino as a master*

	work in the modern technology	*metals during printing*	*laser beam, lenses and galvano scanner.*	*controller for a 3D printer*
Our Project	*The head is fixed and the X and Y axes are scanned by a galvano scanner to reach every point in the print. This is because it works with the modern SLS printing technology, which enables the laser to be positioned in a fixed manner and the axes to be distributed to all sides of the printing room through the galvano scanner.*	*We use a low temperature that enables us to bring the powder metal to a pre-melting temperature and melt it through the low temperature coming from the diode laser to reduce impurities and reduce the size of the emitted laser to control the movement of the laser to obtain ideal shapes and finish a perfect surface without impurities.*	*It has a modern optical system consisting of a laser beam, lenses and galvano scanner. This is because it is the basis of the printer with SLS technology, the modern technology for printing 3D metals.*	*We used the SKR V1.4 Turbo as the main controller for the SLS 3D metal Printer because it is considered the best 3D controller at a low price with superior features and a processor speed of up to 120 MHz.*

2.3.2 Advantages and Disadvantages of Related Works

The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the object is created. Each of these layers can be seen as a thinly sliced cross-section of the object.

Three-dimensional (3D) printing is an additive manufacturing process in which a physical object is created from a digital design by printing thin layers of material and then fusing them together [2].

By using the 3D printer theory, the difference lies in the technology used and the type of printed material. In most cases, the basis for the accuracy of the printed parts is based on the printing layers and the distance of the lines through which the part is created. The following are the most important features found in these printers that we tried to benefit from as much as possible and the most important defects that we tried to avoid.

- ***The most important advantages of the machines in related work***
  - *Printing speed in some printers where the metal appears through the head and the use of non-SLS techniques in melting metals and forming shapes.*
  - *There is no need to prepare the printer before printing due to the ease of the thermal system in the printer.*
  - *The use of simple mechanical and electrical parts in some printers leads to their low price and the focus on developing features at a low price.*
  - *The ability of some printers to print precise parts due to the extreme precision in printing parts that cannot be created in a CNC machine or traditional methods such as casting.*
  - *The ability of some printers to achieve a final shape without the need to process the shape after the printing stage, but without using modern metal printing technology.*
  - *Facilitating the process of building some printers by using the moving X and Y axes, such as 3D printers used to print plastic, which facilitates the process of building the printer.*
  - *Some printers have a large working area that allows the printer to print solid metal parts larger than 30 cm using traditional 3D printer techniques.*
  - *Printers use high temperatures up to 500 degrees Celsius in an attempt to create a solid final part without the need for long processing after printing the part.*
  - *Perfect surface finish for solid metal parts printed with metal 3D printers but with X and Y axis moving technology with a moving head.*
  - *Printers have an open system without the need for a closed temperature with large spaces during printing.*

- ***The most important disadvantages of the machines in related work***
    - *The high cost of some printers, which may cost up to three times the price of the printer we made.*
    - *Weak thermal system in some printers, which leads to weak hardness of 3D printed metal parts.*
    - *The need to use many supports to create metal parts in difficult shapes using regular 3D technology.*
    - *The long processing time of metal printed parts printed with 3D printers due to the adhesion and cohesion of the materials which may lead to their collapse without processing.*
    - *Very low temperatures do not allow printing solid, cohesive metal parts that are not susceptible to rapid collapse.*
    - *The surfaces of metal parts printed with 3D printers are not ideal, which leads to changes in the sizes of the metal parts and the need to smooth the surfaces manually.*
    - *The need to use expensive raw materials to print solid metal parts suitable for use in various applications.*
    - *The presence of small spaces to create solid metal parts in some printers, which limits the size of the metal parts that we can take through this printer.*
    - *Consuming more raw materials than necessary to create solid metal parts with 3D printers, which violates the theory of 3D printers and leads to more losses.*
    - *High bonding rate in some solid metal parts printed with 3D printer after processing to bond the internal parts.*
    - *Few raw materials can be used to create solid metal parts because not all metal materials are available in a form that allows them to be used in 3D printers.*

Chapter 3 The Design of the Proposed System Based on SLS 3D Printer

3.1 3D Printing Introduction

In the 20th century, no other invention affected the mankind more than technology did. With the advent of computers in 1950s and internet in 1990s, the fundamental way of doing things has through a massive change. These technologies made our lives better, opened up new avenues and possibilities and gave us a hope for the future. But it generally decades for an ecosystem to be built across a particular technology to take it to masses and achieve the truly disruptive nature of that technology. It is widely believed that 3D printing or additive manufacturing (AM) has the vast potential to become one of these technologies. There is a lot of coverage on 3D printing across many television channels, newspapers and online resources. What really is this 3D printing that some have claimed will put an end to traditional manufacturing as we know it, revolutionize design and impose geopolitical, economic, social, demographic and environmental and security implications to our everyday lives? The most basic, differentiating principle behind 3D printing technology is that it is an additive manufacturing process. And this is indeed the key because 3D printing is a radically different manufacturing method based on advanced technology that builds up parts, additively, in layers at the sub mm scale. This is fundamentally different from any other existing traditional manufacturing techniques. Traditional manufacturing process has evolved a lot over time from hand-based manufacturing to the automated processes such as machining, casting, forming and molding. Yet these technologies all demand subtracting material from a larger block – whether to achieve the end product itself or to produce a tool for casting or molding processes — and this is a serious limitation within the overall manufacturing process. For many applications traditional design and production processes impose a number of unacceptable constraints, including the expensive tooling, fixtures and the need for assembly for complex parts. In addition, the subtractive manufacturing processes, such as machining can result in up to 90% of the original block of material being wasted. In contrast, 3D printing process can create objects directly by adding material layer by layer in a variety of ways, depending on the technology used. Simplifying the ideology behind 3D printing, *for anyone that is still trying to Understanding this concept can be likened to the process of building something with Lego bricks automatically.*

3D printing is an enabling technology that encourages and drives innovation with unprecedented design freedom while being a tool-less process that reduces high costs and delivery times. Components can be custom designed to avoid assembly requirements with complex geometries and intricate features created at no additional cost. 3D printing is also emerging as an energy-efficient technology that can provide environmental efficiencies in terms of the manufacturing process itself, using up to 90% of standard materials and throughout the life of the product through a lighter and stronger design. In recent years, 3D printing has moved beyond being an industrial manufacturing and prototyping process as the technology has become more accessible to small businesses and even individuals. Previously, only large companies owned 3D printers because the size and economics of owning 3D printers made it difficult for small businesses to own them. However, with the rapid decline in the cost of the printer, the technology has become more affordable. Today, smaller and less capable 3D printers can be had for less than $1,000. This has opened up the field to a much wider audience, and as the adoption rate continues to increase on all fronts, more and more systems, materials, applications, services and accessories are emerging.[7]

3.2 Steps of 3D Printing

Every product development process involving an additive manufacturing machine requires the operator to go through a set sequence of tasks. Easy-to-use "personal" 3D printing machines emphasize the simplicity of this task sequence. These desktop-sized machines are characterized by their low cost, simplicity of use, and ability to be placed in a home or office environment.

The larger and more "industrial" AM machines are more capable of being tuned to suit different user requirements and therefore require more expertise to operate, but with a wider variety of possible results and effects that may be put to good use by an experienced operator.

Such machines also usually require more careful installation in industrial environments. Where possible, the different steps in the process will be described with reference to different processes and machines [6].

The objective is to allow the reader to understand how these machines may differ and to see how each task works and how it may be exploited to the benefit of higher quality results. As mentioned before, we will refer to eight key steps in the process sequence:

3.2.1 Process sequence of 3D printer

- *Conceptualization and CAD*
- *Conversion to STL/AMF*
- *Transfer and manipulation of STL/AMF file on AM machine*
- *Machine setup*
- *Build*
- *Part removal and cleanup*
- *Post-processing of part*
- *Application*

Producing a part by rapid prototyping (3D Printing) typically involves three main stages at which each sequence comes under:

1- Computer-aided design:

- *Conceptualization and CAD*
- *Conversion to STL/AMF*
- *Transfer and manipulation of STL/AMF file on AM machine*

2. Part building (processing):

- *Machine setup*
- *Build*

3. Post-processing:

- *Part removal and cleanup*
- *Post-processing of part*

• *Application*

But before we can build any part directly in a 3D Printer, there are some important aspects to be taken before choosing a part to be produced, they are called Pre processing guidelines.

Design decisions made at the earliest stages of a project will impact a project's success during the final stage of output. In other words, making the right design decisions up front is essential. During the initial design stages, 3D print designers must strike a balance between aesthetics and practicality. This balance can be influenced by many factors such as the build size of the printer, the type of printer being used, and the materials used for final output. The designer must take all of these factors into consideration to determine the size of the part being produced, along with features such as part thickness and design orientation.

3.2.2 Pre-processing guidelines

Pre-processing means software-based manipulation. This will be carried out on the file that describes the geometry of the part. Such manipulation can generally be divided into two areas, modification of the design and determination of building parameters. Modification of the design may be required for two reasons. First, part details may need adjustment to accommodate process characteristics. For example, shaft or pin diameters may need to be reduced, to increase clearance for assembly, when building in many processes since most processes are material safe (i.e., features become oversized). Second, models may require repair if the STEP, IGES, AMF, or STL file has problems such as missing triangles, incorrectly oriented surfaces, or the like.

Determination of the build parameters is very specific to the AM process to be used. This includes selecting a part orientation, support generation, setting of build styles, layer thickness selection, and temperature setting [8].

Pre-processing guidelines consist of:

1- Part Heights.

2- Build Orientation.

3- Overhangs and Angled Geometry.

4- Repeat Overhangs.

5- Part Thickness.

6- Connected Parts.

7- Fine details.

8- Chamfers.

9- Recesses and holes.

10- Work with Gravity, Bridges, and Arc.

11- Hollow Parts.

1- Part Heights

When designing parts with precise measurements, layer height must be taken into account. If you are printing with a 0.2mm layer and want to print parts with precise measurements, all of the measurements of the printed part must be multiples of 2. In other words, you will not be able to print a part that is 10.35mm long (you will have to either round up or down to 10.2 or 10.4mm). When considering accuracy, think in terms of the number of layers being produced for the object being printed.

2- Build Orientation

When printing your own parts, the build orientation will affect your print times because the orientation of the part will have an effect on the distribution of support. The build orientation will also affect the strength of the part. For example, an object designed horizontally with many protrusions may need less support if printed vertically. In (figure 3.1), the Space Shuttle model was designed to rest on the stand at a slight angle, but this resulted in a large protrusion, requiring many supports. the part was placed on the build plate vertically, resulting in much fewer supports.

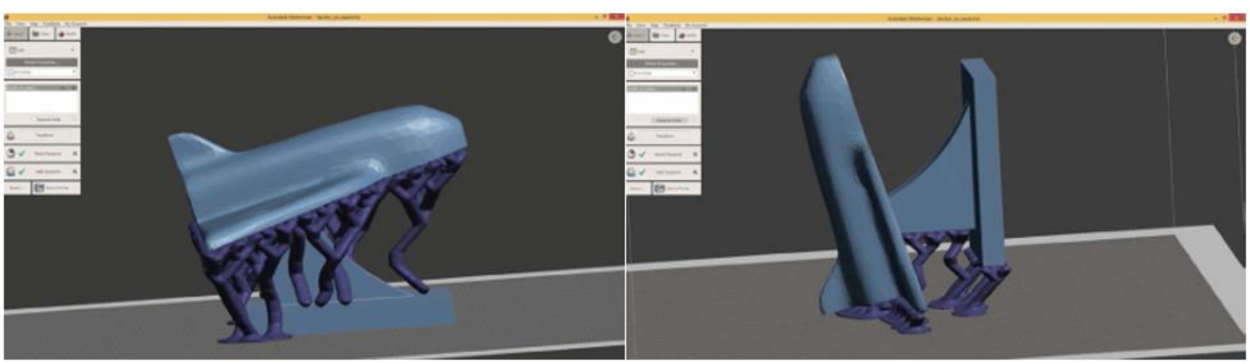


Figure 3.1 The shuttle, when printed horizontally, produces a large overhang that results in many supports being added to the part , When printed upright, the shuttle requires far fewer supports, but the layers of material may be more noticeable in the final 3D-pr

3- Protrusions and Angled Geometry

Printing protrusions at an angle may reduce the number of supports applied to your model. As a general rule, parts that stand at an angle between 0 and 90 degrees will require supports. The number of supports required decreases as the angle between the base of the object and the protrusion increases (see Figure 3.2).

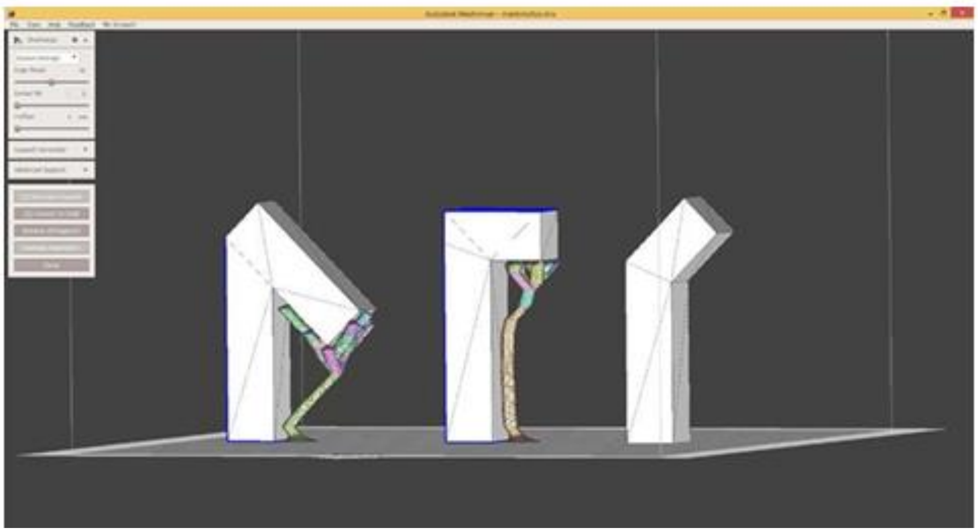


Figure 3.2 Showing variation in sloping angles of an angle and the supports that can result in Meshmixer. When an overhang slopes at a greater angle from the base, supports will be minimal and even completely unnecessary

4- Repeated Overhangs

If an overhang needs to be repeated in a design, keep those overhangs as close together as possible. Examples of repeated overhangs include designs that have multiple ridges, treads, and deep recessed textures. For example, if an artist designs corrugated tube, having large gaps in between the overhanging corrugations as in example A in (Figure 3.3) will necessitate many small supports to ensure the printability of the overhanging features. These small overhangs will be difficult and time-consuming to remove.

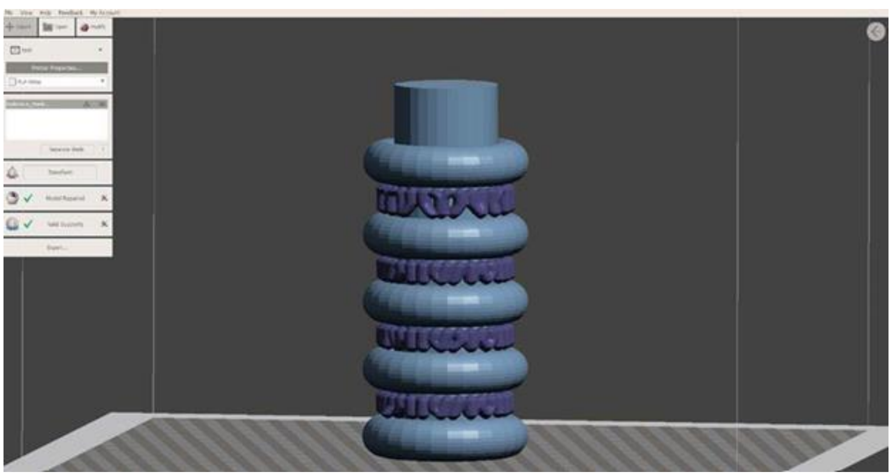


Figure 3.3 Shows the results of adding supports to a part with gaps between the protrusions. These supports will be difficult to remove

5-Part Thickness

The thickness of the part also depends on the layer height. It would be impossible to make parts thinner than the layer height capabilities of the printer. As discussed earlier, parts can be made in sizes multiples of the layer height of the 3D printer being used. While thin parts are possible, they are larger than the layer height capabilities of the 3D printer, and any thin part that requires supports may not survive the support removal process. When designing objects with thin features, good design sense should prevail. It may take some trial and error to determine how well thin parts can withstand support removal, and much of this will depend on the scale of your model. If

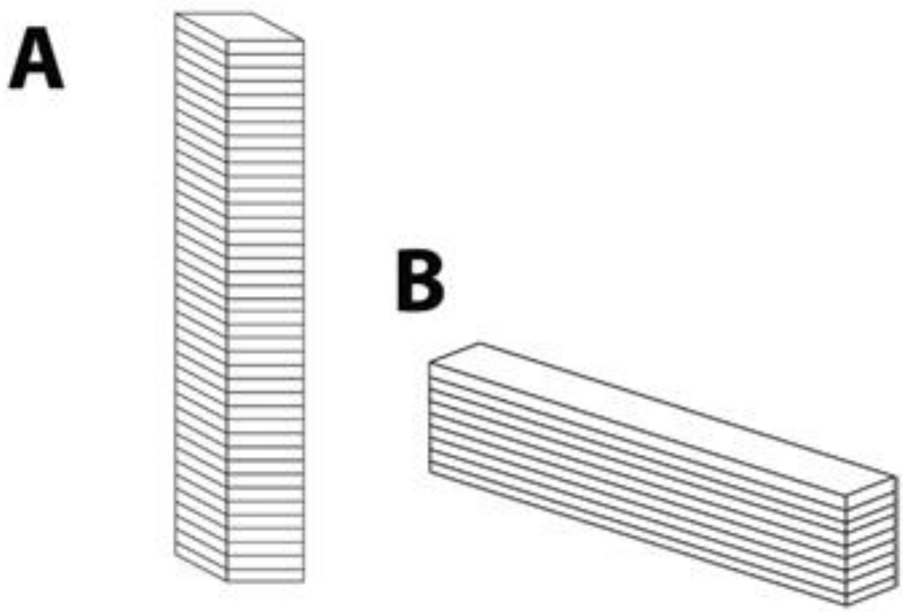


Figure 3.4 Part B is stronger than part A since the layers run across the longest length of part B

thin parts are absolutely necessary, try changing the orientation of the object being printed. Try to have the thin parts run parallel to the printer bed. Also, because of the multiple layers of material, long, thin parts will break more easily when the longest length of the part runs perpendicular to the printed layers. As a general rule, consider each layer as a potential break point for any printed part.

When parts are printed long and thin, there will be more layers extending along the height of the part, and each layer is a stress point that can increase the chance of the part breaking. In (Figure 3.4), Part A has more layers along the height of the part and therefore more stress points that could lead to breakage. Part B is printed with the longest length parallel and level to the build plate. Part B is less likely to break because there are fewer stress points (in other words, layers) along the height of the part [9].

6- Connected Parts

When connecting parts, the part will be weak at the connection point. If the connecting part is also protruding, it may break when the support structures are removed. The temptation may be to make a connecting piece that is smaller (perhaps for aesthetic purposes) than the pieces being connected. If possible, have the two larger parts overlap slightly (do not use a smaller part to connect them).

7- Fine Details

Because of the layer-by-layer process of 3D printing, fine details will be impossible on small objects. For any fine details to be viewable, they should be at least four to five times larger than the layer height used for the printer. For example, details such as an engraved line on a part that is being printed using a 0.2 mm layer height should be at least .4 to .5 mm wide. This same rule also holds true for text on objects. Small text less than a millimeter in height may not print legally [9].

8- Chamfers

Chamfers are a type of bevel that can be added to the corners of objects to flatten out edges. Fillets are another type of bevel used to round out corners. Applying chamfers to overhanging corners not only can help reduce the number of supports needed but may add some style to your design.

9- Cavities and Holes

Sometimes cavities are unavoidable. Deep cavities can be difficult to create because the resulting supports can form deep within the object. These deep supports can be difficult to remove. If you have a significant need for a deep cavity, print the object with the cavities exposed perpendicular to the extruder if possible. Otherwise, do not make the cavities too deep. Also, make sure that the cavity is wide enough to allow the support to be removed if necessary. Examples of deep cavities include the open mouth of a toy character, a deep hole in a part, or a notch added to the geometry, as shown in (Figure 3.5).

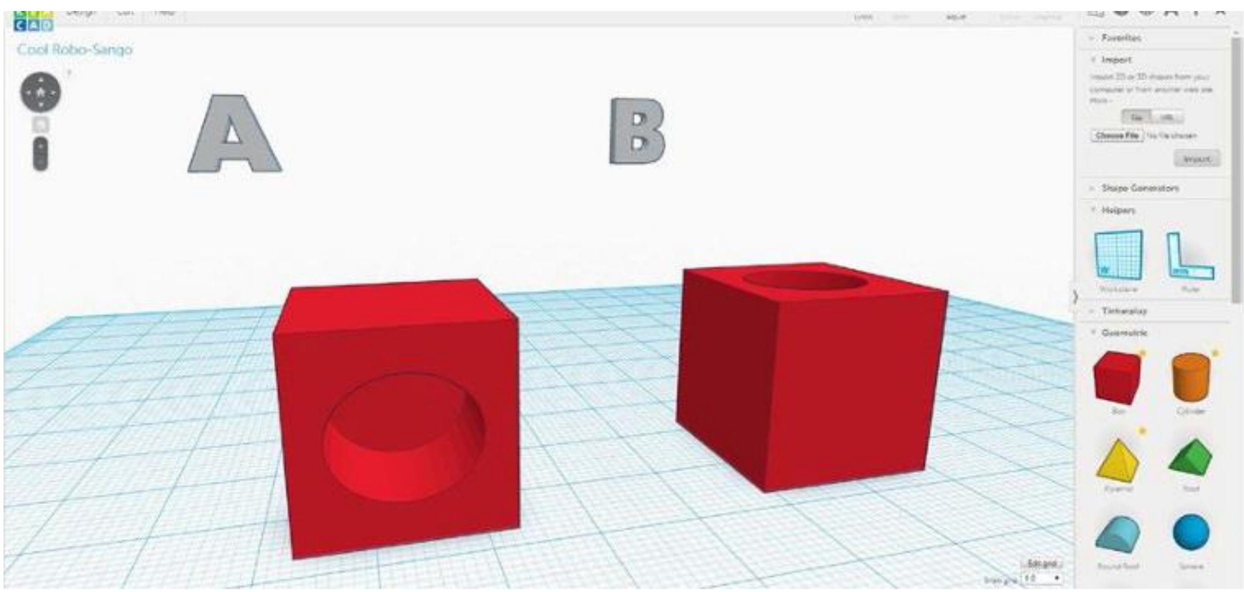


Figure 3.5 Examples of objects with deep recesses

10- Working with Gravity, Bridges, and Arches

Bridges are perfectly possible without supports, and shorter bridges will be easier to print than longer ones. The ends of the bridge columns are actually supports; generally, the support material between them will not be necessary if the distance between the columns is short. Longer bridges will sag because the string will bend between the supports. One way to keep the supports to a minimum is to use bevels, fillets, and arches in the bridge design. (Figure 3.6) shows four bridges. The shortest bridge was the one that was printed with the least sag.

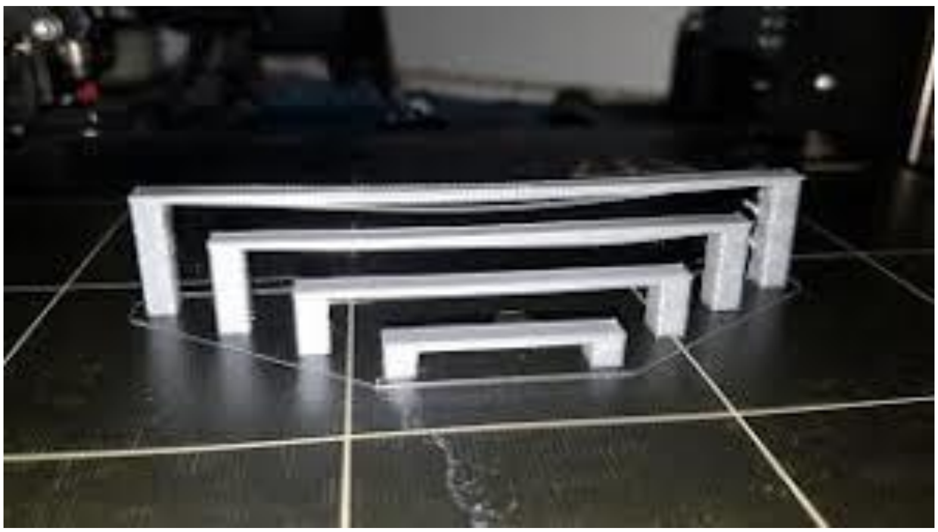


Figure 3.6 Short bridges are possible without additional supports. With longer bridges, filament will droop across the span of the bridge

11- Hollow Parts

With 3D printing, hollow parts are entirely possible. There may be several reasons to make a hollow model. One reason to hollow out a model is to help reduce the amount of material (and therefore significantly less amount of time it would take to print the model) during 3D printing. Another reason is to make hollow boxes and vases out of organic and complex forms.

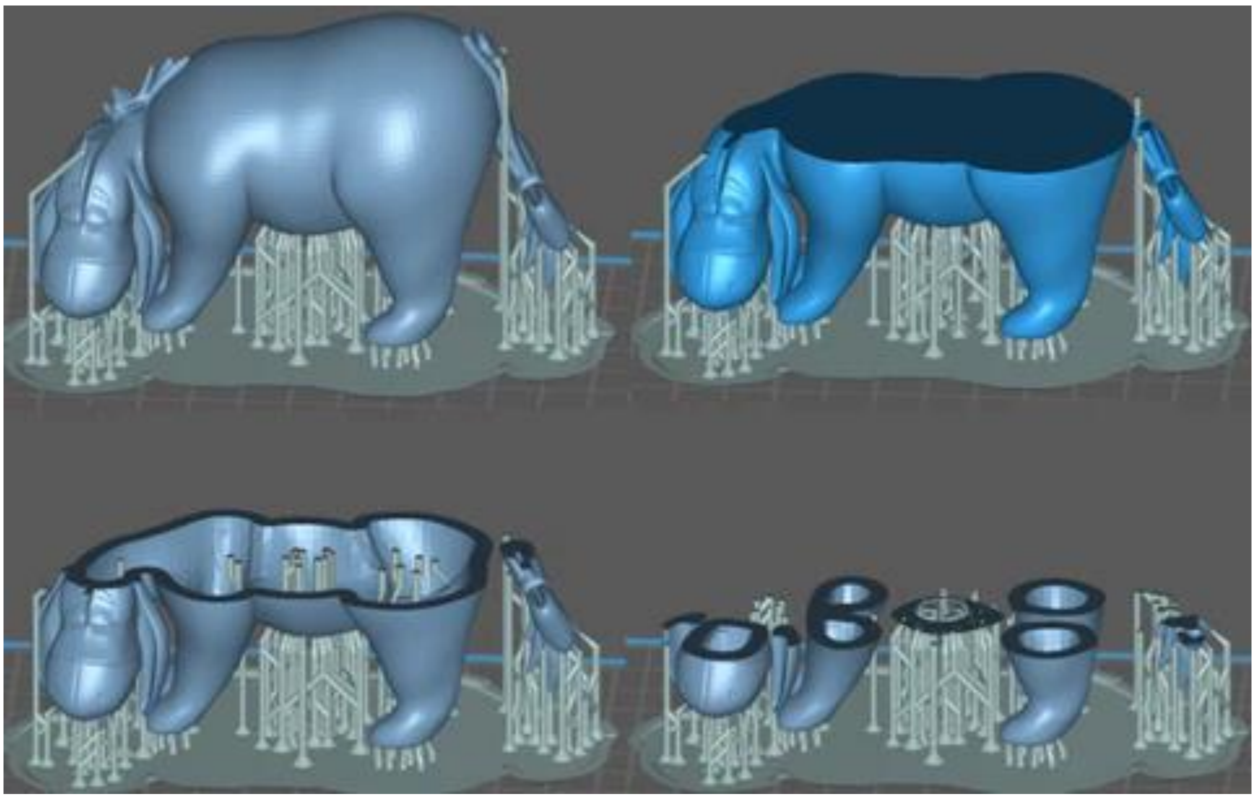


Figure 3.7 Hollow parts can reduce material use

3.2.3 The Eight Steps in Additive Manufacture

The above-mentioned sequence of steps is generally appropriate to all AM technologies see (Figure 3.8). There will be some variations dependent on which technology is being used and also on the design of the particular part. Some steps can be quite involved for some machines but may be trivial for others.

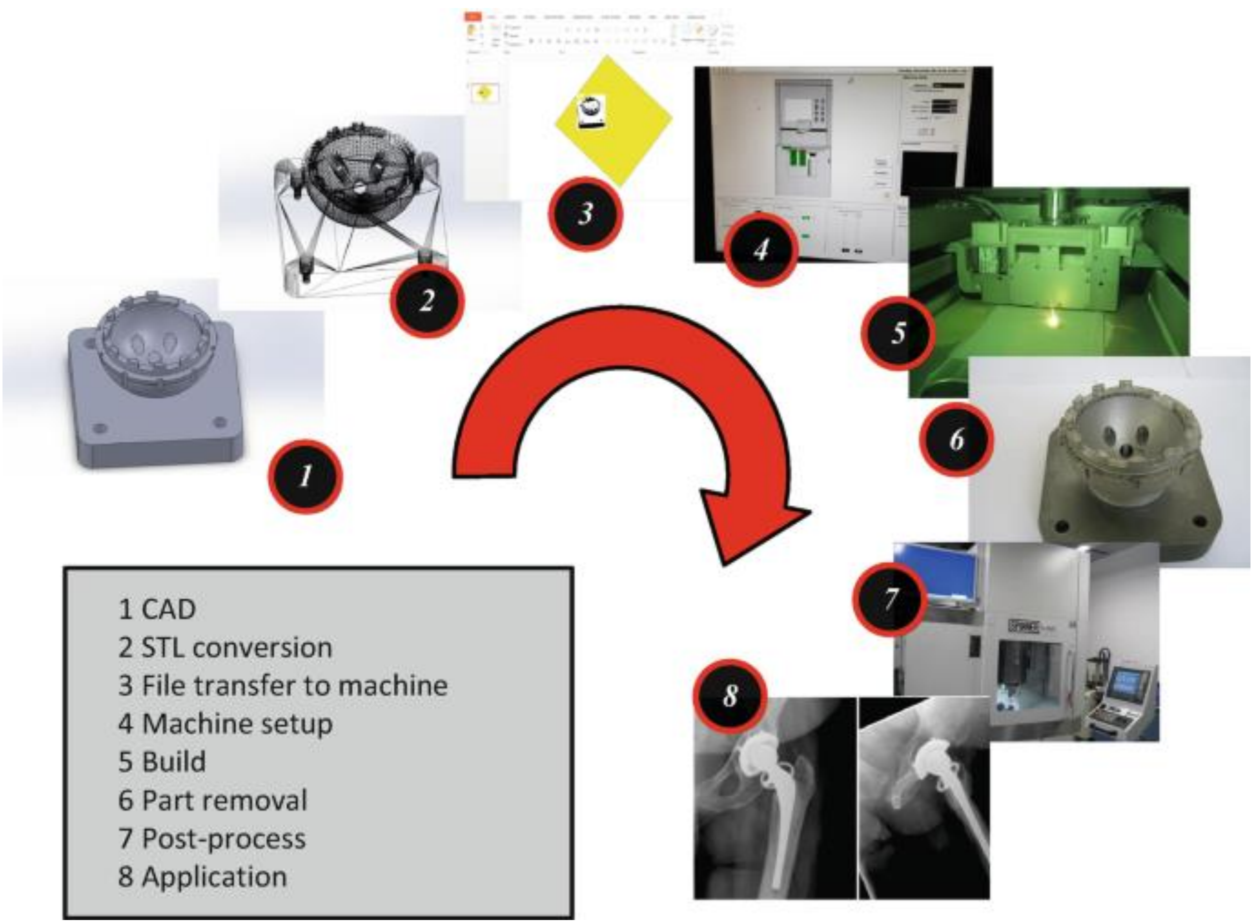


Figure 3.8 The eight stages of the AM process

3.3.3.1 Visualization and Computer-Aided Design

The first step in any product development process is to come up with an idea of the form and function of the product. Visualization can take many forms, from textual and narrative descriptions to drawings and mock-ups. If computer-aided design is to be used, the product description must be in a digital form that allows for the creation of a physical model. Computer-aided design technology may be used to create a prototype rather than build the final product, but in either case, there are many stages

in the product development process where digital models are required. Cad design technology would not exist without 3D computer-aided design. It was only after we gained the ability to represent solid objects in computers that we were able to develop the technology to physically reproduce such objects. This was initially the principle that surrounded computer-aided manufacturing technology in general. Thus, computer-aided design can be described as a direct or simplified computer-aided design process to computer-aided manufacturing (CAD/CAM). Unlike most other CAD/CAM technologies, there is little or no intervention between the design and manufacturing stages of the additive manufacturing process. Therefore, the general additive manufacturing process must begin with 3D CAD information. There may be a variety of ways in which the 3D source data can be generated. This model description may be generated by a design expert via a user interface, by software as part of an automated optimization algorithm, by 3D scanning of an existing physical part, or a combination of all of these methods. Most 3D CAD systems are solid modeling systems with surface modeling components; solid models are often created by joining surfaces together or by adding thickness to a surface. In the past, 3D CAD modeling programs have had difficulty creating fully closed solid models, and models often appear closed to the casual observer but are not actually mathematically closed. Such models can lead to unexpected results from additive manufacturing machines, as different additive manufacturing technologies handle gaps in different ways [10].

Most modern solid modeling CAD tools are now able to generate files without gaps (e.g., "waterproof"), resulting in unambiguous geometric representations of a part.

Most CAD packages treat surfaces as construction tools used to work on solid models, and this has the effect of preserving the integrity of solid data. Provided it fits the machine, any CAD model can usually be created using AM without much difficulty. However, there are still some older or poorly developed 3D CAD programs that can result in solids that are not fully enclosed and produce unreliable AM output. Problems like this are usually discovered once the CAD model is converted to STL format for AM construction.

3.3.3.2 Convert to STL/AMF

Almost every additive manufacturing technology uses the STL file format. The term STL is derived from STereoLithograhy, the first commercial additive manufacturing technology from 3D Systems in the 1990s. As a de facto standard, STL is a simple way to describe a CAD model in terms of its geometry alone. It works by removing any creation data, modeling history, etc., and approximating the model surfaces with a series of triangular faces. The minimum size of these triangles can be set within most CAD programs, and the goal is to ensure that the generated models do not show any obvious triangles on the surface. The size of a triangle is actually calculated in terms of the minimum distance between the plane the triangle represents and the surface it is supposed to represent. In other words, the rule of thumb is to ensure that the minimum offset of the triangle is smaller than the resolution of the additive manufacturing machine. The conversion to STL is automated in most CAD systems, but there is a possibility of errors during this stage. Therefore, a number of software tools have been developed to detect and correct such errors if possible.

STL files are an unordered collection of triangle vertices and surface normals. As such, an STL file does not contain units, color, material, or other feature information. These limitations of the STL file have led to the recent adoption of the new "AMF" file format. This format is now an ASTM/ISO international standard format that extends the STL format to include dimensions, color, material, and many other useful features. As of the writing of this book, several major CAD companies and AM hardware vendors have publicly announced that they will support the AMF format in their next-generation software. Thus, although the term STL is used throughout the rest of this textbook, an AMF file can simply be substituted wherever an STL appears, as the AMF format has all the benefits of the STL file format with far fewer limitations.

STL file repair programs, such as MAGICS from the Belgian company Materialise, are used when there are problems with the STL file that might prevent the part from being built properly. With complex geometries, such *problems can be difficult for a human to detect when examining CAD or STL data that is later generated. If the errors are small, they may go unnoticed until after the part is built. Therefore, such software can be applied as a checkpoint to ensure that there are no problems in the STL file data before the build is done. Since STL is essentially a surface description, the corresponding triangles in the files must point in the correct direction; in other words, the surface normal associated with the triangle must point to which side of the triangle is outside the part versus inside it. Thus, a cross-section that corresponds to the layers of the part in a region close to an inverted normal vector may be the opposite of what is desired. In addition, complex, discontinuous geometries may cause the vertices of the triangle to be misaligned. This can result in surface gaps [11].*

Different additive manufacturing techniques may react to these problems in different ways. Some machines may process STL data in such a way that the gaps are bridged. However, this bridge may not represent the desired surface, and it may be possible to include unwanted additional material in the part. While most errors can be detected and corrected automatically, there may also be a requirement for manual intervention. Software must therefore highlight the problem, pointing out what are thought to be inverted triangles, for example. Since the geometry can become quite complex, it can be difficult for software to determine whether the result is actually an error or something that was part of the original design intent.

3.3.3.3 Transfer to AM Machine and STL File Manipulation

Once the STL file has been created and repaired, it can be sent directly to the target AM machine. Ideally, it should be possible to press a "print" button and the machine should build the part straight away. This is not usually the case however and there may be a number of actions required prior to building the part.

The first task would be to verify that the part is correct. AM system software normally has a visualization tool that allows the user to view and manipulate the part. The user may wish to reposition the part or even change the orientation to allow it to be built at a specific location within the machine. It is quite common to build more than one part in an AM machine at a time. This may be multiples of the same part (thus requiring a copy function) or completely different STL files. STL files can be linearly scaled quite easily. Some applications may require the AM part to be slightly larger or slightly smaller than the original to account for process shrinkage or coatings; and so, scaling may be required prior to building. Applications may also require that the part be identified in some way and some software tools have been developed to add text and simple features to STL formatted data for this purpose. This would be done in the form of adding 3D embossed characters. More unusual cases may even require segmentation of STL files (e.g., for parts that may be too large) or even merging of multiple STL files. It should be noted that not all AM machines will have all the functions mentioned here, but numerous STL file manipulation software tools are available for purchase or, in some cases, for free download to perform these functions prior to sending the file to a machine.

3.3.3.4 Machine Setup

All AM machines will have some setup parameters specific to that machine or process. Some machines are designed to run only a few specific materials and give the user few options to change layer thickness or other build parameters. These types of machines will have very few setup changes that need to be made from build to build. Other machines are designed to run a variety of materials and may also have some parameters that require optimization to suit the type of part being built, or allow parts to be built faster but with less accuracy. These machines can have many setup options available. It is common in more complex cases to have default settings or save files of pre-set settings to help speed up the machine setup process and prevent mistakes. Typically, an incorrect setup will result in building a part. However, the final quality of that part may be unacceptable.

In addition to setting the machine program parameters, most machines must be physically set up for build. The operator must check to ensure that enough build material is loaded into the machine to complete the build. For machines that use powder, the powder is often screened and then loaded and leveled into the machine as part of the setup process. For operations that use a build plate, the plate must be inserted and leveled in relation to the machine axes. Some of these machine setup processes are automated as part of the build start-up, but for most machines, these processes are done manually by a trained operator.

3.3.3.5 Build

Although benefitting from the assistance of computers, the first few stages of the AM process are semiautomated tasks that may require significant manual control, interaction, and decision making. Once these steps are completed, the process switches to the computer-controlled building phase.

This is where the previously mentioned layer-based manufacturing takes place. All AM machines will have a similar sequence of layering, including a height adjustable platform or deposition head, material deposition/spreading mechanisms, and layer cross section formation. Some machines will combine the material deposition and layer formation simultaneously while others will separate them. As long as no errors are detected during the build, AM machines will repeat the layering process until the build is complete.

3.3.3.6 Removal and Cleaning

Ideally, the output from an AM machine should be ready for use with minimal manual intervention. While this may sometimes be the case, more often than not, parts require a significant amount of post-processing before they are ready for use. In all cases, the part must be separated from the build platform on which the part was produced or removed from excess build material surrounding the part. Some AM processes use additional materials beyond those used to make the part itself (secondary support materials). The following chapters describe how various AM processes require these support structures to help prevent the part from collapsing or bending during the build process. At this point, it is not necessary to understand exactly how support structures work, but it is important to know that they must be handled.

While some processes have been developed to produce easily removable supports, there is often a significant amount of manual labor required at this stage. For metal supports, a wire EDM machine, band saw, and/or milling equipment may be required to remove the part from the base plate and supports from the part. A degree of operator skill is required to remove the part, as mishandling of parts and poor technique can result in damage to the part [10] .

Different AM parts have different cleaning requirements, but suffice it to say that all processes have some requirements at this stage. The cleaning stage can also be considered an initial part of the post-processing stage.

3.3.3.7 Post-Processing

Post-processing refers to the (usually manual) stages of finishing the parts for application purposes. This may involve abrasive finishing, such as polishing and sandpapering, or application of coatings. This stage in the process is very application specific. Some applications may only require a minimum of post processing. Other applications may require very careful handling of the parts to maintain good precision and finish. Some post-processing may involve chemical or thermal treatment of the part to achieve final part properties. Different AM processes have different results in terms of accuracy, and thus machining to final dimensions may be required. Some processes produce relatively fragile components that may require the use of infiltration and/or surface coatings to strengthen the final part. As already stated, this is often a manually intensive task due to the complexity of most AM parts. However, some of the tasks can benefit from the use of power tools, CNC milling, and additional equipment, such as polishing tubs or drying and baking ovens.

3.3.3.8 Application

After post-processing, the parts are ready for use. It should be noted that although the parts may be made from materials similar to those available from other manufacturing processes (such as molding and casting), the parts may not behave according to standard material specifications. Some additive manufacturing processes by their nature create parts with small voids trapped within them, which can be a source of part failure under mechanical stress. In addition, some processes may cause the material to deteriorate during construction or cause the materials to not bond, bond, or crystallize in an optimal manner. In almost every case, the properties are anisotropic (different properties in different directions). For most additive manufacturing processes for metals, rapid cooling results in microstructures that are different from those produced by conventional manufacturing. As a result, parts produced by additive manufacturing behave differently from parts made using a more conventional manufacturing approach. This behavior may be better or worse for a given application, so the designer must be aware of these differences and take them into account during the design phase. AM materials and processes are improving rapidly, so designers must be aware of the latest developments in materials and processes to determine how best to use AM to meet their needs.

3.3 Block Diagram

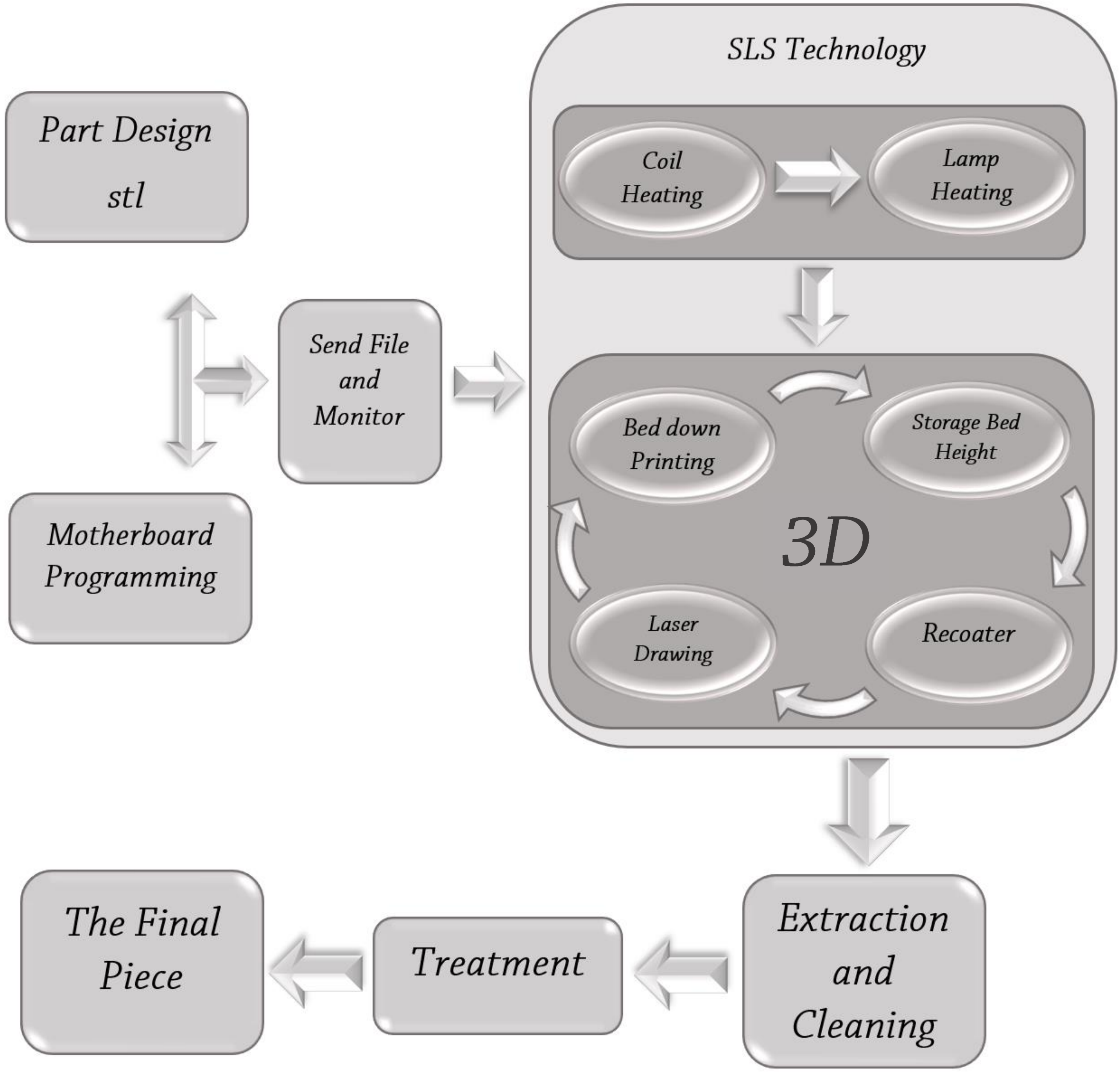


Figure 3.9 Step by step block diagram with order for SLS 3D printer technology for metals

3.3.1 Part Design stl

STL is a de facto standard, a simple way of describing a CAD model in terms of its geometry alone. It works by removing any creation data, modeling history, etc., and approximating the model surfaces with a series of triangular faces. The minimum size of these triangles can be set in most CAD programs and the goal is to ensure that the models that are created do not show any obvious triangles on the surface. The size of a triangle is actually calculated in terms of the minimum distance between the plane that the triangle represents and the surface that it is supposed to represent. In other words, the rule of thumb is to ensure that the minimum offset of the triangle is smaller than the resolution of the AM machine. The conversion to STL is automatic in most CAD systems, but there is a possibility of errors during this stage. So, there were a number of errors that could have occurred during this stage [11].

3.3.2 Motherboard Programming

Programming the printer on this modern technology in the world of 3D printers, SLS technology, requires a huge effort. Speaking of such technology, it was necessary to find a modern technical program to match the minute requirements of the printer, so the choice fell on Klipper is an open-source 3D printer firmware developed by GitHub user KevinOConnor. Unlike traditional 3D printer firmware, Klipper is meant to work with a 3D printer mainboard alongside an additional single-board computer, like a Raspberry Pi or similar.

Klipper can perform calculations at a significantly faster rate compared to onboard microcontrollers. Faster calculations translate to smoother and more precise movements of your 3D printer's motors. Improved precision results in higher print quality and reduced print times.

Highly Customizable: Klipper is also highly customizable, similar to Marlin. However, it usually requires a bit more technical knowledge to set up and use *because it involves configuring both the firmware on your 3D printer and the external computer interface.*

3.3.3 Send File and Monitor

This stage is hardly a transition from software and programs to mechanical parts. It is worth mentioning the use of SKR V1.4 Turbo, which is one of the most important controllers in 3D printers and CNC today at the time of writing this paper because it was able and worthy to achieve what no other controller could achieve in terms of processing speed. The most important point for which this controller was mentioned under this item is correcting errors if any exist. Despite the high reliability of the controller, it was necessary to use monitoring systems to ensure complete accuracy of the printing process.

3.3.4 SLS Technology

Selective laser sintering (SLS) is an additive manufacturing (AM) technique that uses a laser as the power and heat source to sinter powdered material (typically nylon or polyamide), aiming the laser automatically at points in space defined by a 3D model, binding the material together to create a solid structure. It is similar to selective laser melting; the two are instantiations of the same concept but differ in technical details. SLS (as well as the other mentioned AM techniques) is a relatively new technology that so far has mainly been used for rapid prototyping and for low-volume production of component parts. Production roles are expanding as the commercialization of AM technology improves.

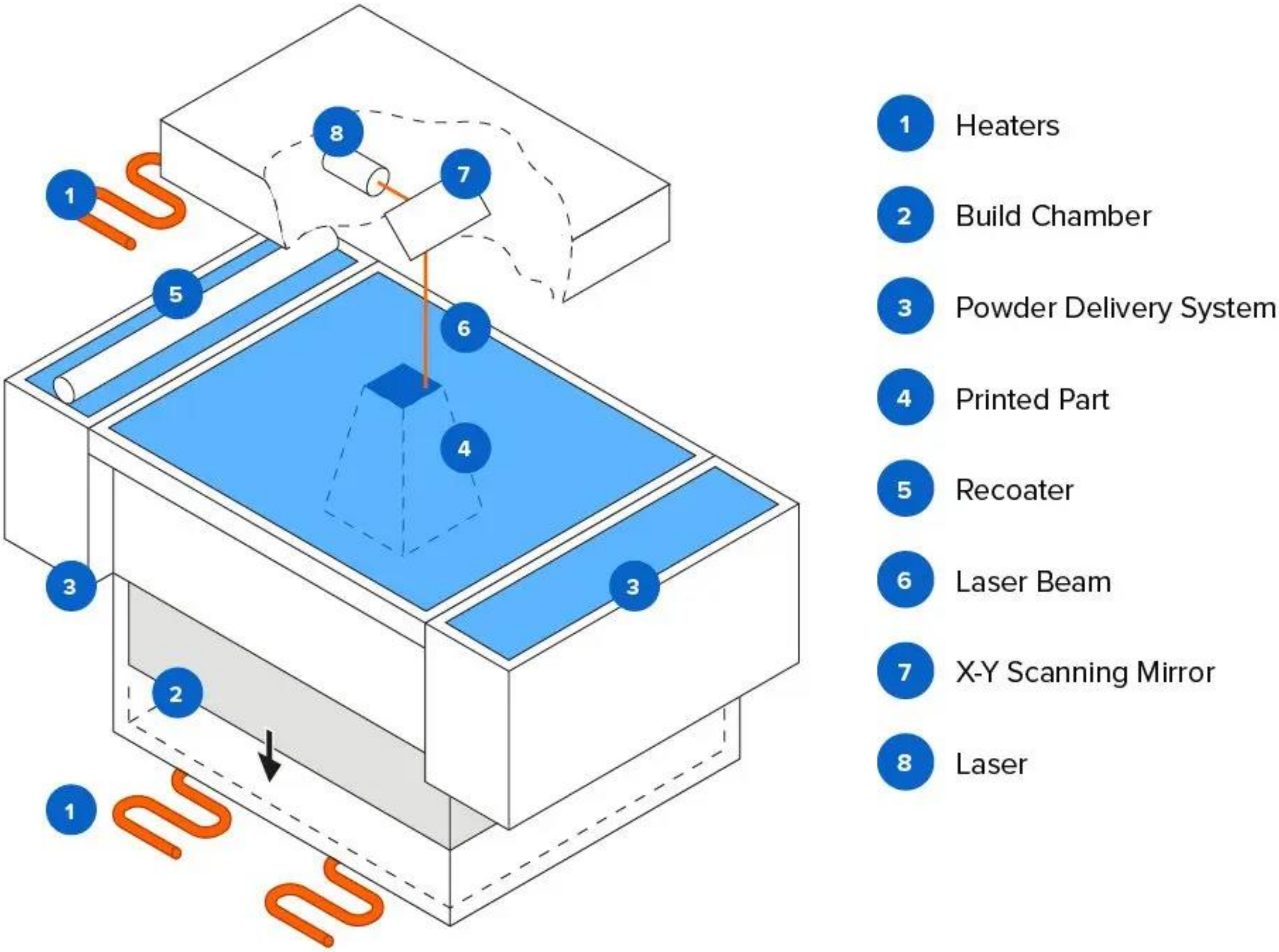


Figure 3.10 Selective laser sintering (SLS) is an additive manufacturing

*1.**Coil Heating*** *To raise the engine temperature to the required level, there was no reason for the temperature to rise, and given the high temperature. The first is the FART file in Figure 5. We raised the temperature of the printer chamber to 150°C, making all the hot powder ready for printing in advance.*

*2.**Lamp Heating*** *The heater lamp is what subjects the powder to the pre-fusion temperature. At this stage, the temperatures required to heat the pre-fusion differ. There are metals that require 175C, such as copper and aluminum, and in the case of iron, it needs 180C. Of course, we are talking about the powder metal that can Work on it in this printer.*

*3. **Bed down Printing** Before explaining the parameters to be studied, it is important to understand how the building process works to better understand how these parameters affect the performance of the parts. Once the file is loaded onto the machine and the process begins, the recoater fills the layer with the powder of the desired material. The laser beam, when reflected by the mirrors, then hits the desired area and melts the powder inside, which hardens. Once the laser is finished, the platform will descend and the recoater will fill another layer and so on, until the part is completely built.*

*4. **Storage Bed Height** This stage is mentioned in the previous item, as explained. The relationship between the printing and storage rooms is an inverse relationship. Whenever one of them rises a degree, the other falls a degree, and vice versa.*

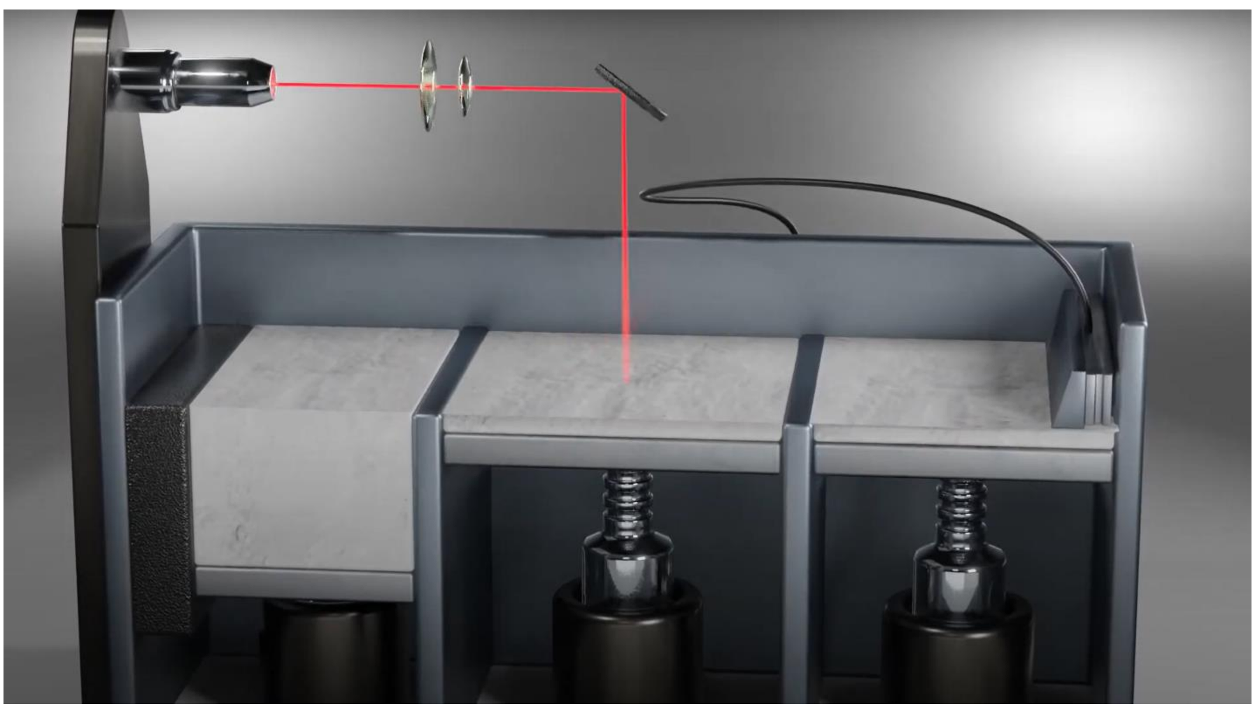


Figure 3.11 The relationship between the printing and storage rooms is an inverse relationship

*5. **Laser Drawing** Laser Scanner System is a linear Gantry system of X and Y cartesian coordinates, it consists of many components that works together to give a linear precise movement of the laser scanner head. Reflecting Mirrors are used to deliver, manipulate, split and focus the laser beam. Collimating lens is placed directly after the laser diode. It forms the divergent lasers' diode light into the parallel beam. Again, there are several ways how to collimate the beam, but most commonly used is an aspheric lens. Focal length of this lens is then in correlation with the diode divergence angle. You can do the same job with plano-convex or even double-convex lenses. But you will achieve the best beam quality with an aspheric lens [8 & 12].*

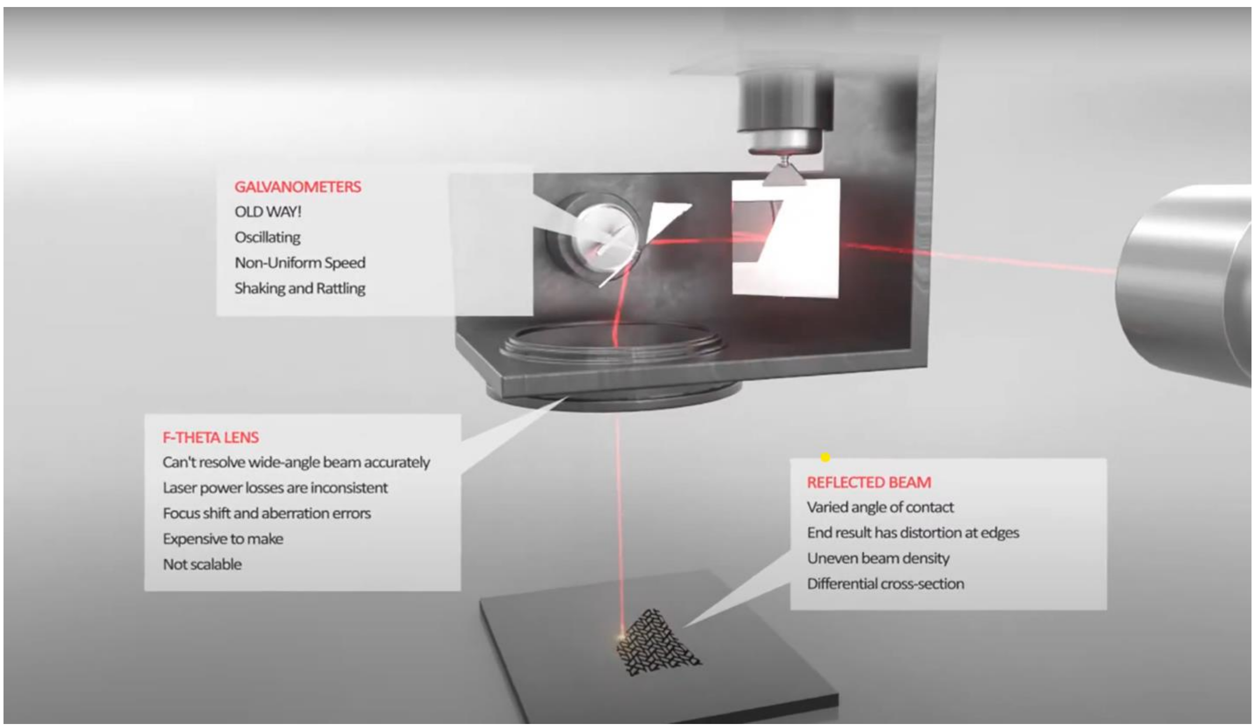


Figure 3.12 linear precise movement of the laser scanner head

*6. **Recoater** The repainting machine is a linear X-axis elevator; its main function is to transport the aluminum powder from the storage room to the construction room by sweeping the powder by the repainting machine blade.*

3.3.5 Extraction and Cleaning

the printed part is extracted from inside the printing room and of course it is full of impurities, metal powder and some adhesions. Here the cleaning stage takes place, through which the part is without any excess powder and can be fully identified to move to the final processing stage [8 & 12].

Figure 3.13 Cleaning of finished printed parts buried in powder metal

3.3.6 Treatment

Like other powder-based additive manufacturing techniques, SLS parts must be cleaned of excess powder after printing is complete. Once the part is finished printing and removed from the 3D printer, there are three basic steps to follow: extract the part, recover the powder, and blast with media. Some printers require heat treatment.

Figure 3.14 Example of what the part looks like before and after the final processing stage before use.

3.3.7 The Final Piece

The surface finish produced by SLS is a bit rougher than other 3D printing technologies—it typically ranges anywhere from 100-250 RMS—but it still works reasonably well for most functional prototypes.

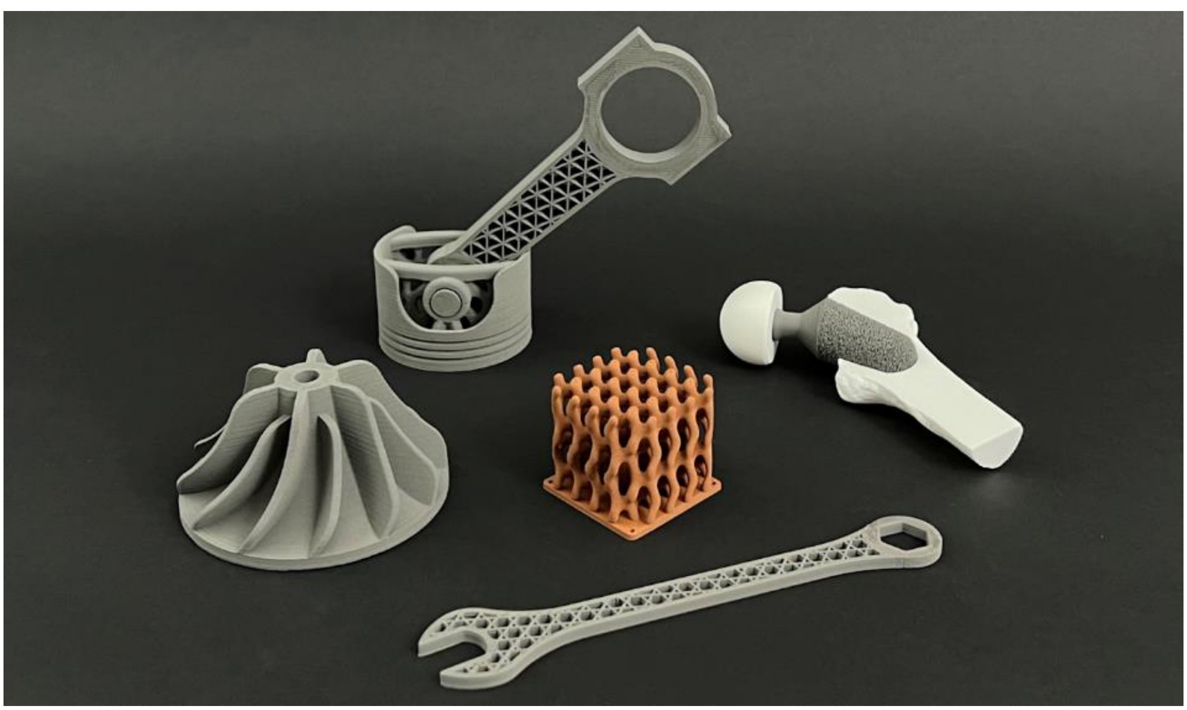


Figure 3.15 Example of several SLS printed metal parts ready for use.

Chapter 4 System Construction and Design

4.1 Introduction

Today, 3D printers have spread all over the world and are used in many

applications in manufacturing complex parts, so metal 3D printers must be designed for high-precision manufacturing, and therefore their components must be

reliable. There are many designs for 3D printers, and each design has its advantages and disadvantages. The construction mechanism greatly affects the quality of the final product or part. The right choice of the type of mechanism and linear platform components gives you a high-quality final product without

deformations or defects. The design of an SLS 3D printer depends on how all the axes of the components move together with the work table and the feed chamber in addition to the developed optical system and thermal system.

4.2 Exterior and Interior Design

There is some difference in the design that was done with the solid work and the final shape that was done on the ground due to the availability of aluminum in the local market, and its high price. The aluminum panels were replaced with other aluminum pieces called (private sector) in the local market, and the columns were replaced with aluminum in (90 degree shape), and this is what will be mentioned and explained in detail when talking about the project pieces.

4.2.1 Interior Design

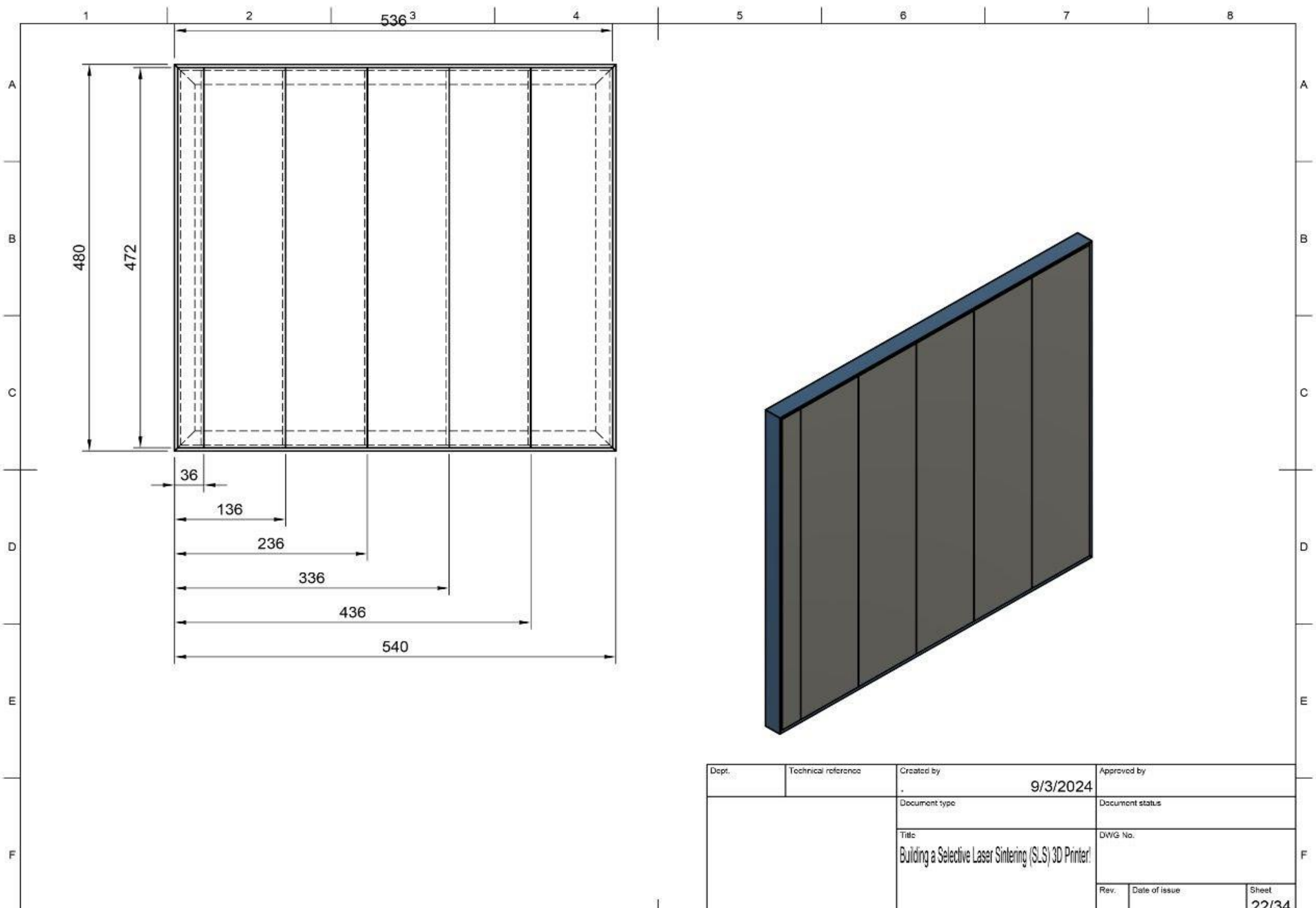


Figure 4.1 The so-called private sector that was used instead of aluminum sheets and it forms the interior and exterior parts and this is one of the pieces that were used in the interior part

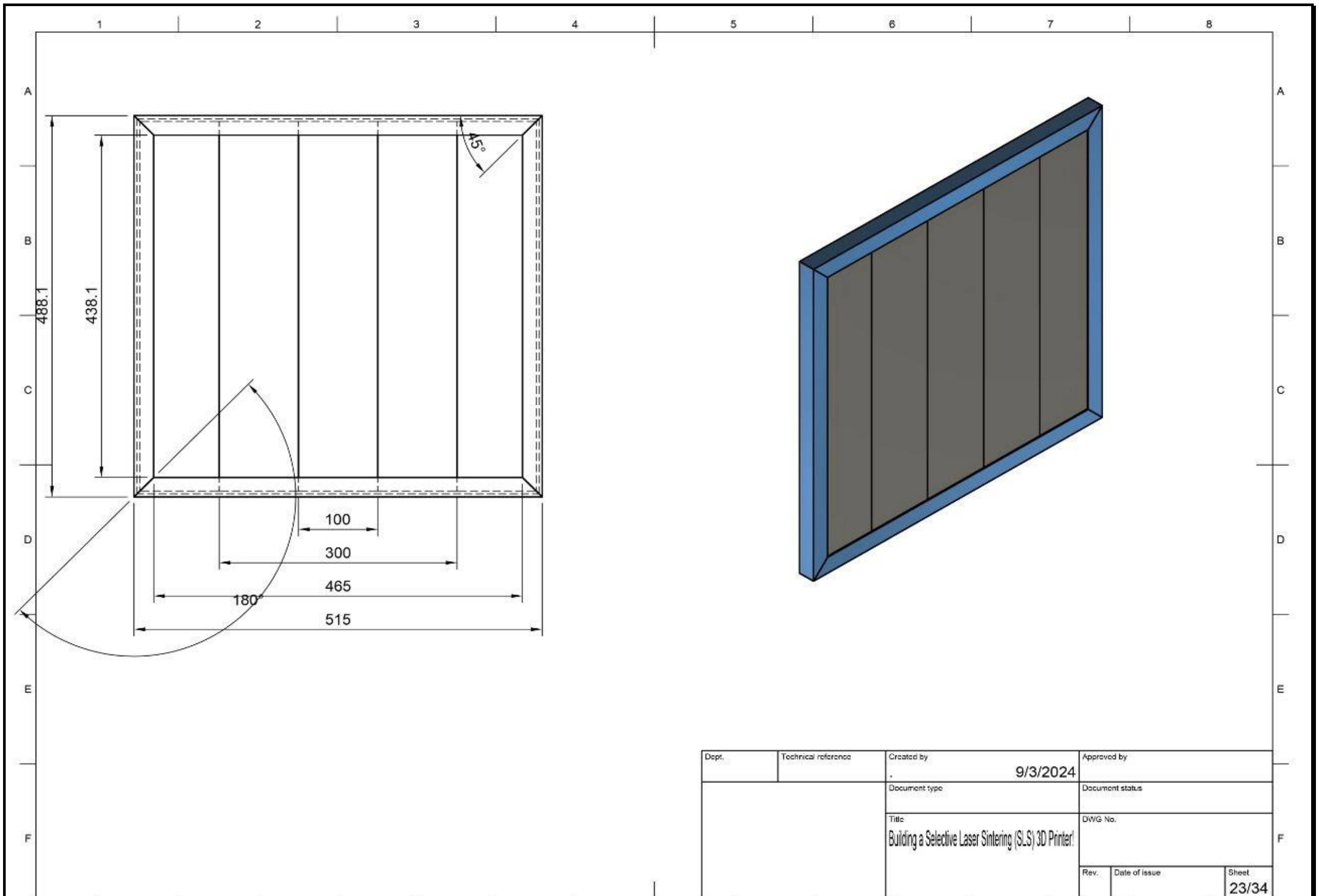


Figure 4.2 This wall forms the inner layer and forms the outer layer, and the middle is filled with heat-resistant wool.

It is worth noting that if there is no thermal insulation wool in the middle between the inner wall and the outer wall, the heat that helps heat the metal powder will be transferred from inside the printing room to the outside, and thus the temperature of the printer outside will be higher than the necessary temperature, more than the room temperature, and this may cause a technical defect in the printer that must be repaired in the future, so the wall was used in two layers using a 90-degree angle and filling the middle with thermal wool to prevent heat from transferring from the inside to the outside easily, and also because of the low efficiency of the aluminum used in the project instead of panels.

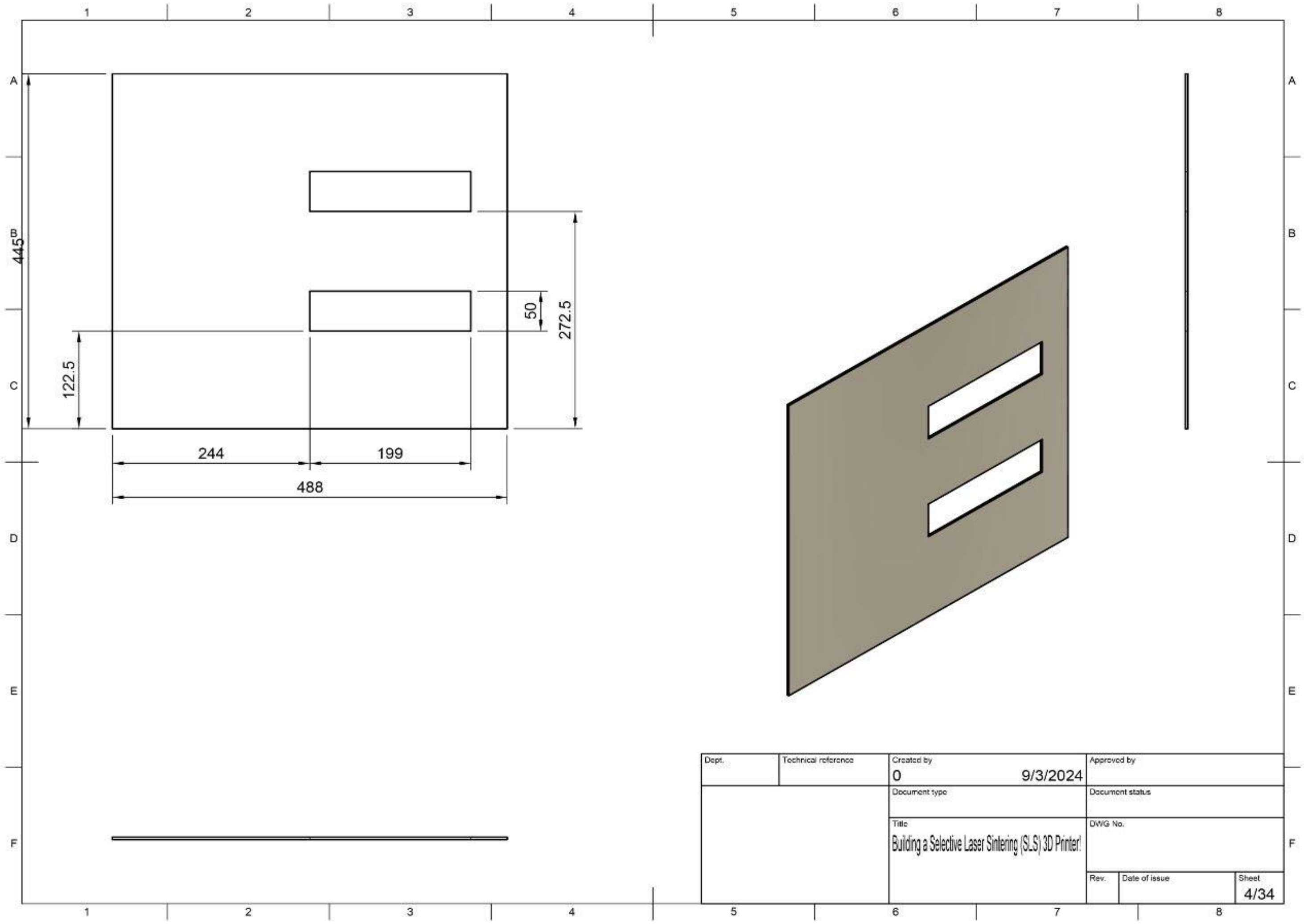


Figure 4.3 An insulating wall isolates the thermal file, the printing bed and the storage so that heat is not transferred directly to the powder.

The use of an insulating wall between the thermal file and the internal printing chambers is the powder store to avoid direct heat transfer to the printing chamber and the store to avoid melting the metal on the side opposite the hot file and to distribute the heat in the printer perfectly. If this wall does not exist, it is easy to say that a large part of the printing chamber will be held together by the metal and will be unable to complete the required shape, noting that the printing chamber is no larger than 10 cm in size.

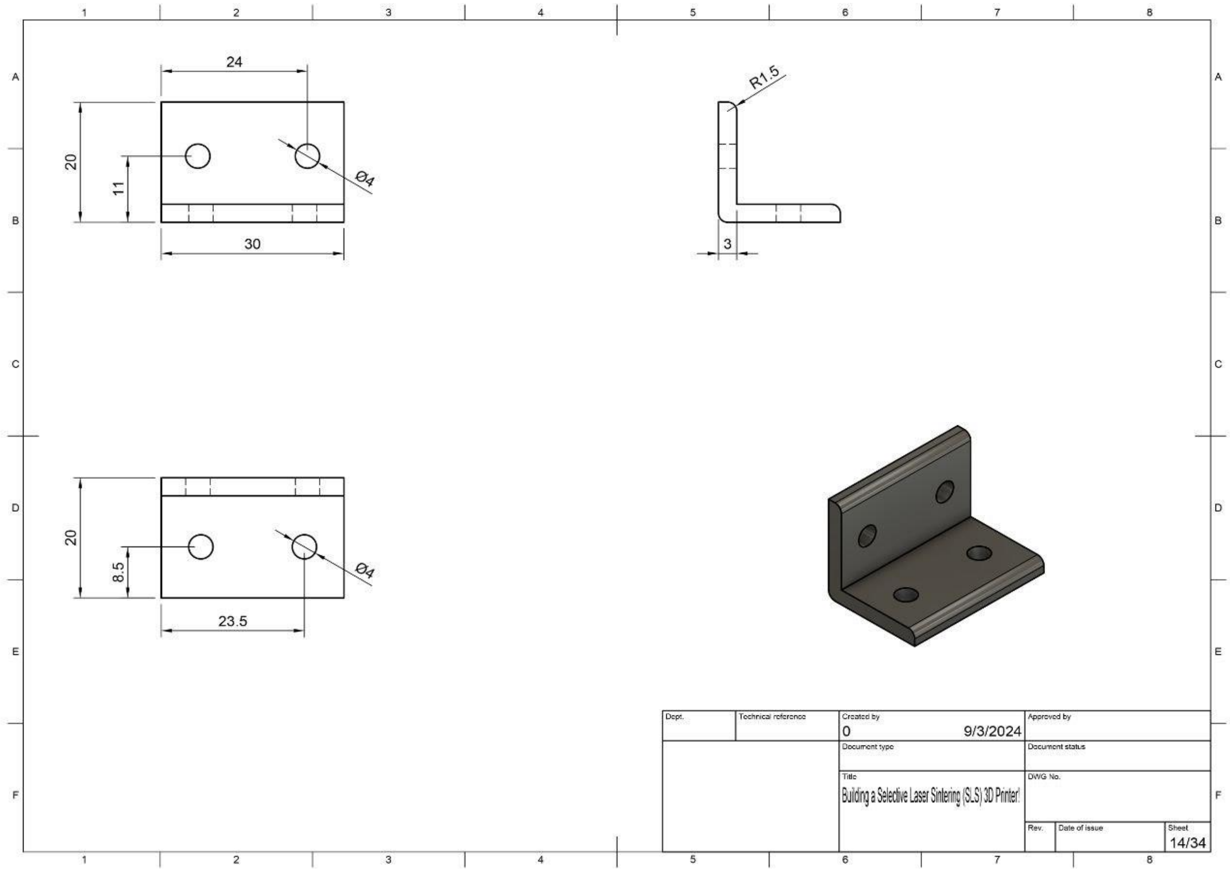


Figure 4.4Angle to fix the wall, the first in a vertical position and the second in a horizontal position

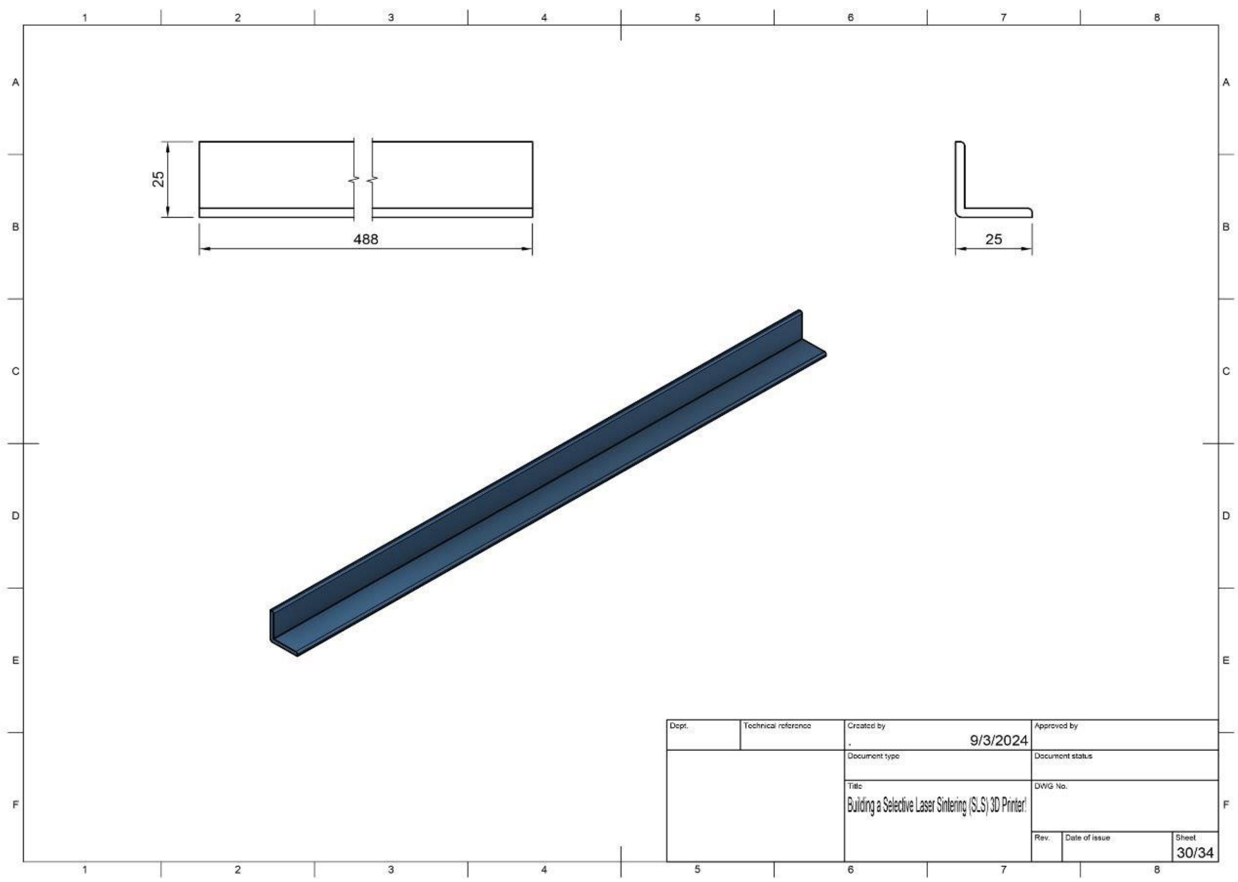


Figure 4.5 90 degree angle shape used instead of extruded aluminum columns

4.2.2 Exterior Design

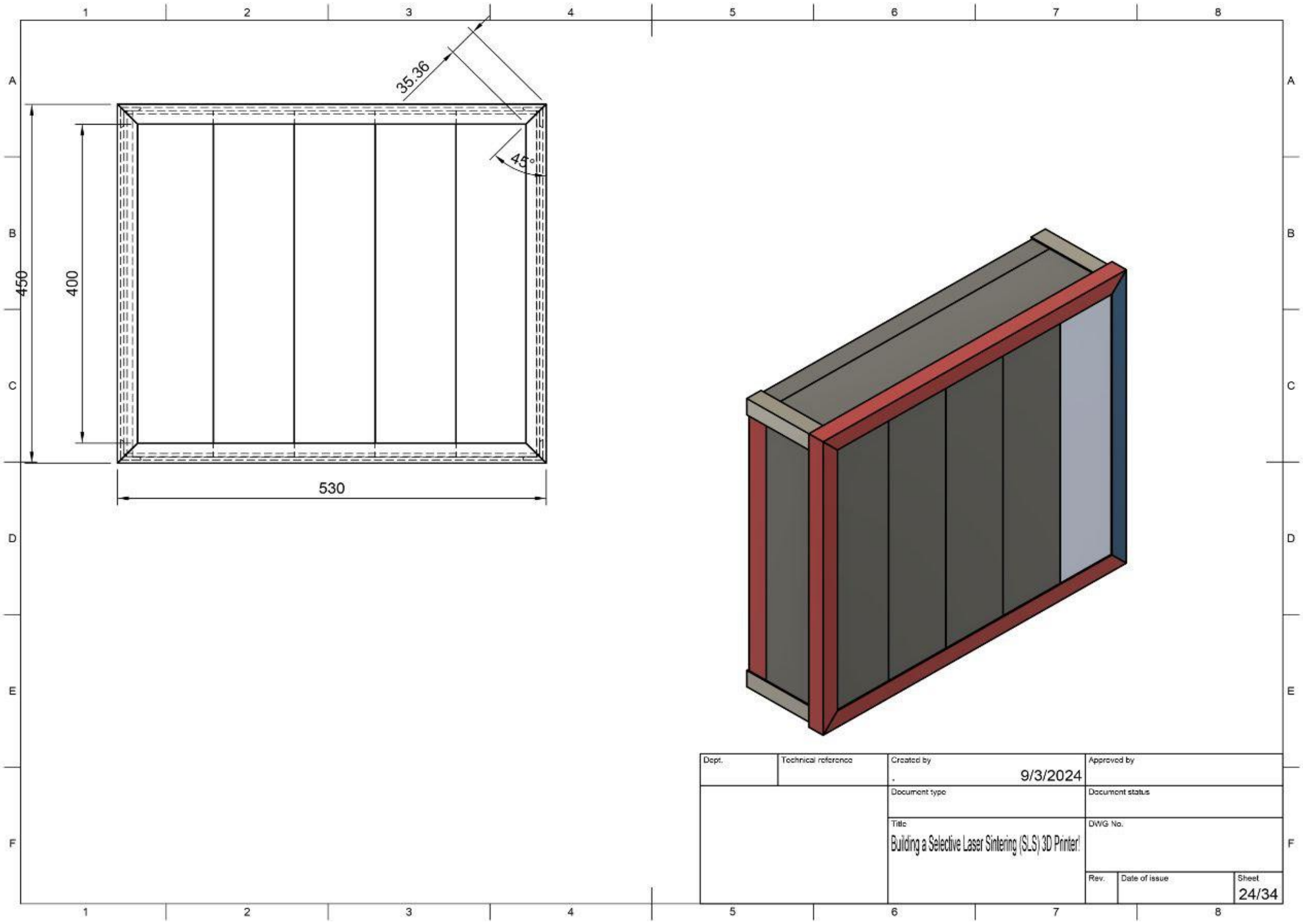


Figure 4.7 Wall shape with inner space filled with heat-resistant insulating wool

The external wall designed for the sides and base of the printer used is special aluminum and aluminum at a 90 degree angle. In this aluminum, there is a void and it has a thickness of 2 mm. Of course, it is considered somewhat weak, but with the presence of supports that allow the wall to enter the pieces into each other, it was possible to build a suitable wall through which the printer can be placed in the shape in the design. We will later review with pictures the shape of the printer in reality, similar to what was designed using the same aluminum in the design.

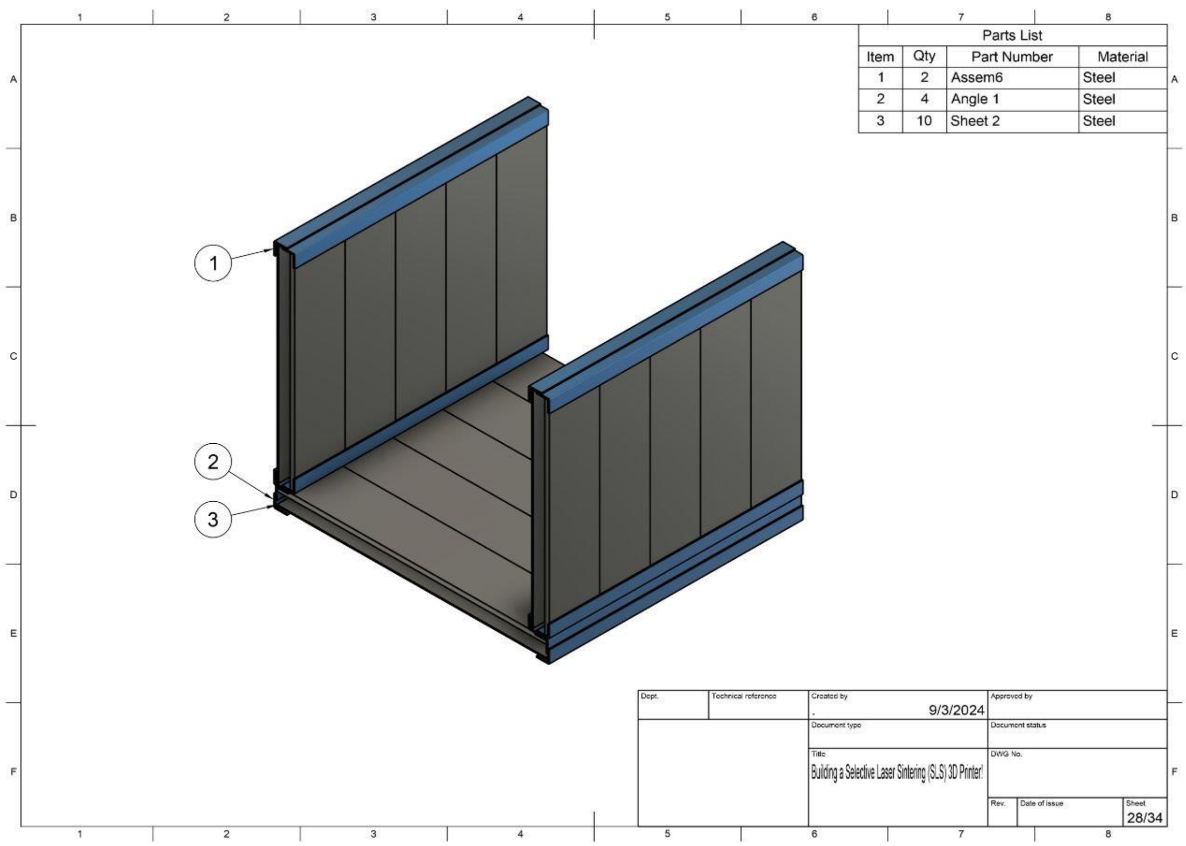


Figure 4.8 Fixing two walls with a base made of aluminum, private sector, and a 90-degree angle

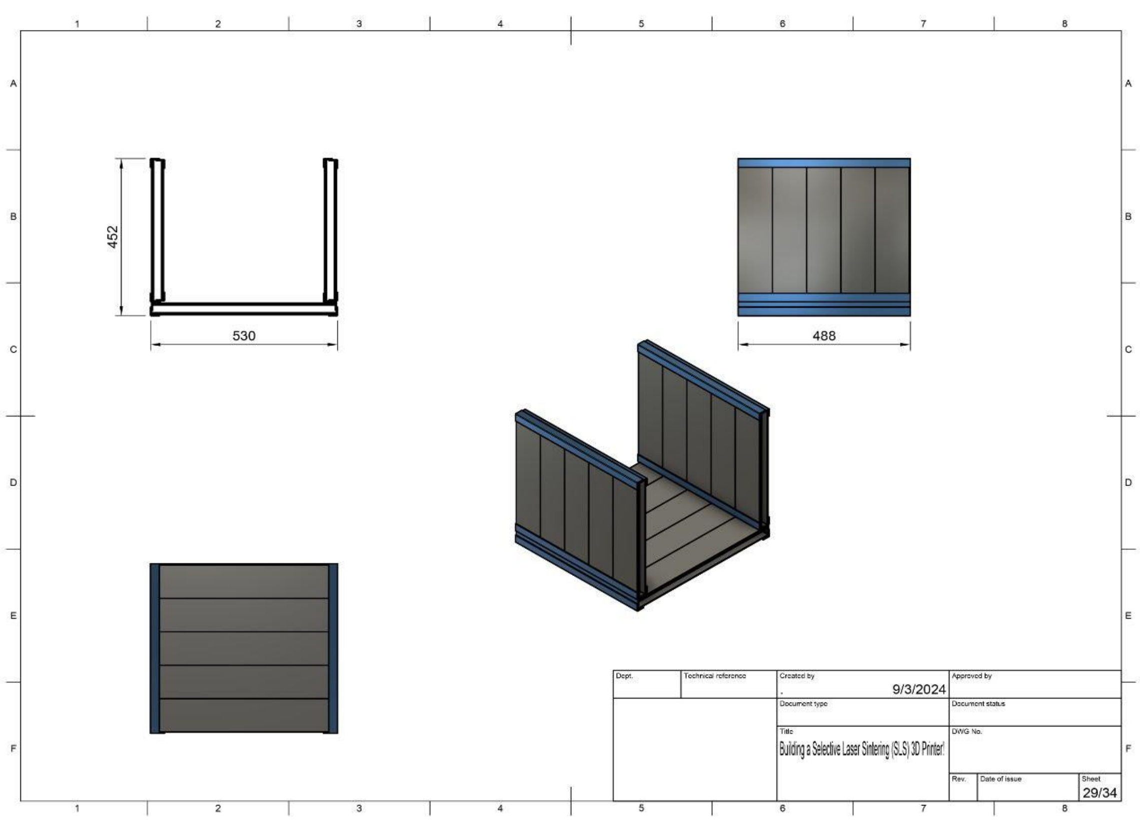


Figure 4.9 From another angle, the shape of the two walls and the base attached to each other to form the printer.

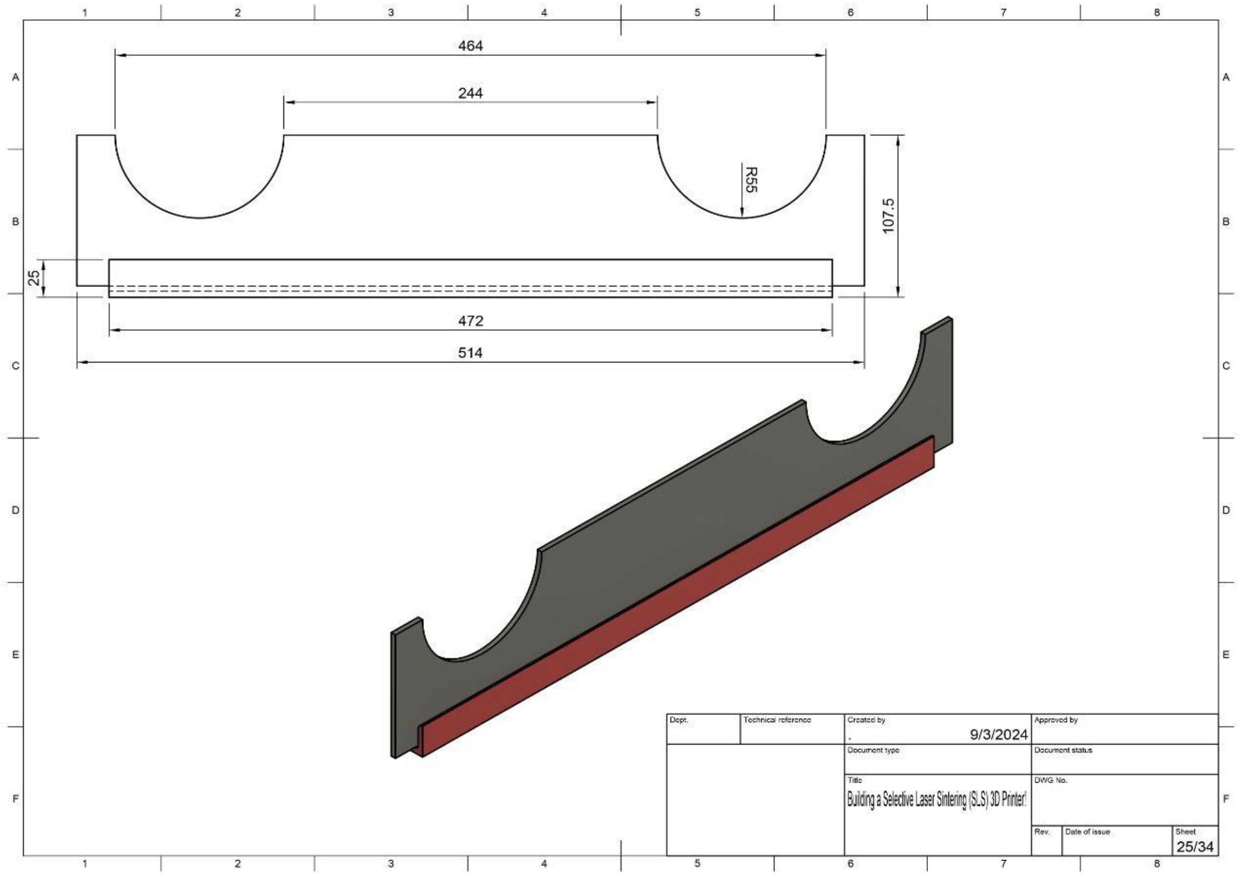


Figure 4.11 One of the corners of the ceiling with two outlets for installing fans of the cooling system for the electronic sector

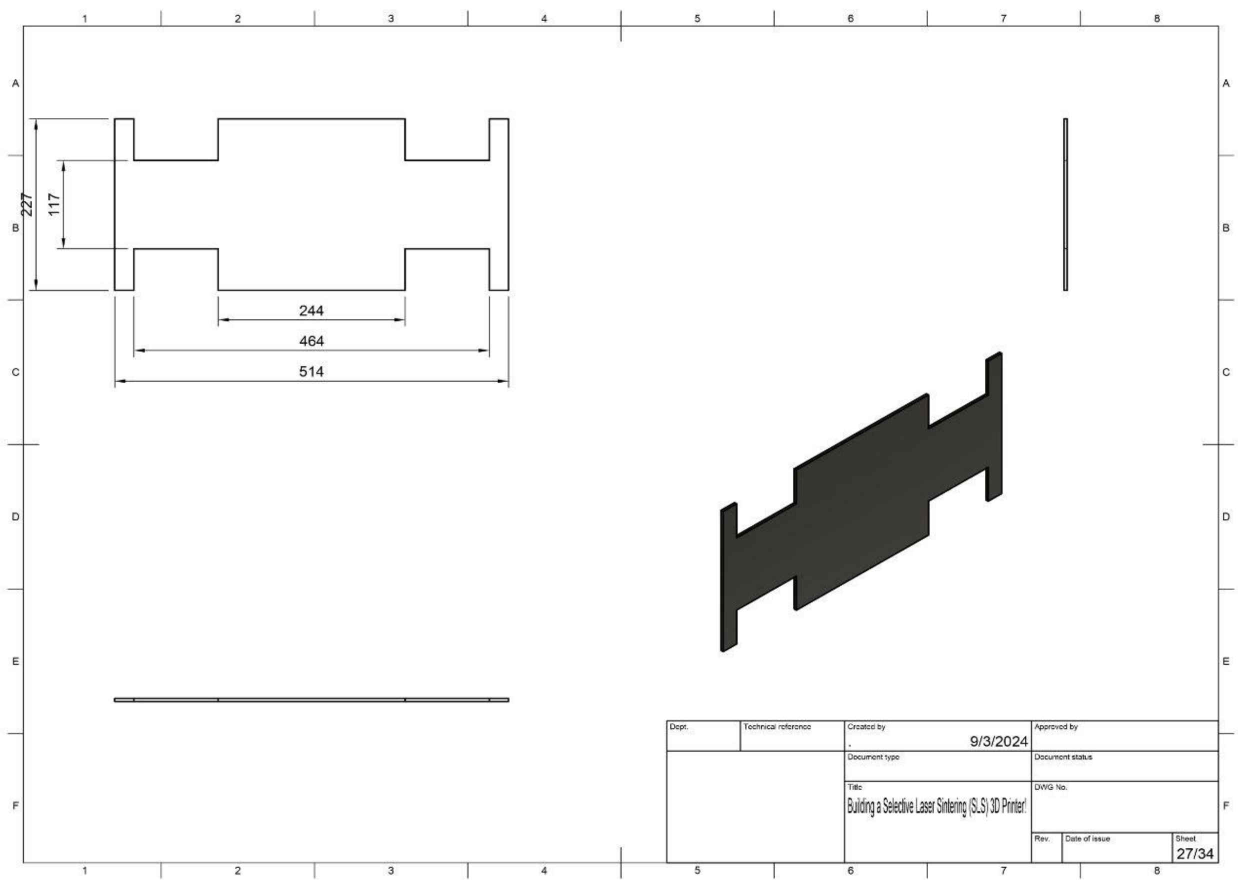


Figure 4.12 The middle area in the ceiling above the electronic sector room with fan outlets for the electronic sector cooling system.

Parts List			
Item	Qty	Part Number	Material
1	4	L 2	Steel
2	1	Plat 2	Steel
3	4	L3 200MM.	Steel
4	5	4 I 428	Steel
5	3	Plat 4	Steel
6	8	Roll 1	Steel
7	8	Radial ball bearing_68_iso_ISO 15 RBB - 488 - 12,SI,NC,12_68	Steel
8	2	Plat roll 1	Steel
9	5	L6 124mm	Steel
10	4	Plain washer large grade ac_iso_Washer ISO 7093 - 8	Steel
11	4	Hex screw gradeab_iso_ISO 4017 - M8 x 40-N	Steel
12	4	Hex flange nut gradea_iso_ISO - 4161 - M8 - N	Steel
13	4	Hex nut gradec_iso_ISO - 4034 - M8 - N	Steel
14	1	Plat 3	Steel
15	1	L 7 240MM	Steel
16	3	Angle 2	Steel
17	4	Socket head cap screw_iso_ISO 4762 M4 x 16 - 16N	Steel
18	1	Zaql	Steel
19	2	Plat 6	Steel
20	2	Plat 7	Steel
21	2	Plat 8	Steel
22	2	Part11	Steel
23	2	Plat 10.	Steel
24	2	L 400mm	Steel
25	1	Assem7	Steel

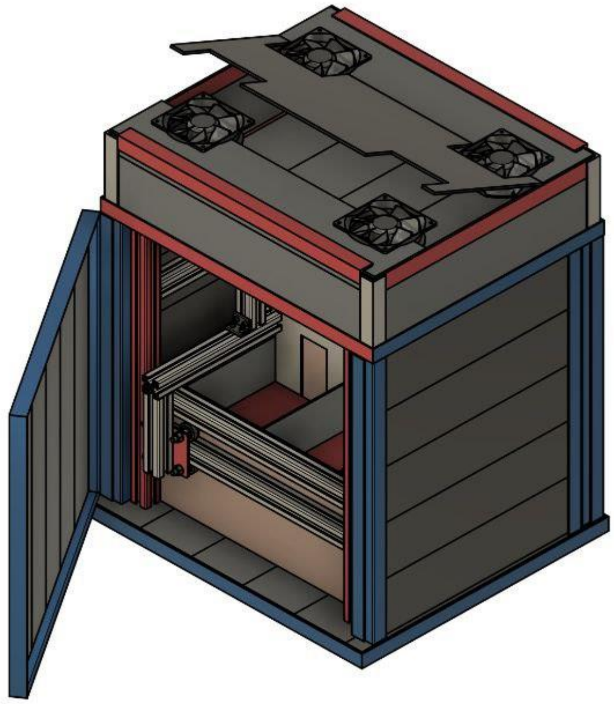


Figure 4.13 General illustration of the printer assembled together. What is mentioned in the table explaining the number of sectors used inside and outside the printer

4.3 Hardware and Software Requirements

4.3.1 Hardware Requirements

4.3.1.1 Mechanical System

1. The Structure

The external and internal walls of the printer are made of aluminum for several reasons, including reasons related to printing in general and engineering reasons. The most important of these reasons are the light weight of aluminum, its rapid cooling, its inability to reduce heat for a long time, and the slow transfer of heat from one area to another. Therefore, aluminum was used to be the structure on which this printer is based. Unfortunately, due to the high price of aluminum, it was important to replace the aluminum sheets with what is called (private sector aluminum) in the local market. It was important to use aluminum sheets with a thickness of 5 mm, and they were replaced with another aluminum with a thickness of 2 mm, with a gap of 10 mm between its two ends, which made its size larger and difficult to use. After several attempts, we were able to use it in different ways to form the internal and external structure of the printer, which made the project larger by several centimeters, which made its size slightly larger, but within the permissible framework. The figure (4.14) shows the aluminum used in the project and the following figures show the places where private sector aluminum was used.

Figure 4.14 Private sector aluminum used in the project instead of aluminum sheets with an explanation of the vacuum gauge and aluminum thickness

This aluminum is characterized by the presence of two areas at the top and bottom that allow two pieces to stick together, and thus more than one piece can be stuck together at the same time to build the wall with the required length. It is worth noting that sometimes it requires a shorter or longer length of the pieces when they are assembled together, as the length of one piece is 100mm. If we assemble five pieces together, we get 48 cm, due to the overlapping of two pieces with each other, the distance between them is reduced.

Figure 4.15 Use of special aluminum cutouts in the construction of the printing room and the warehouse

Figure 4.16 Use of private sector aluminum to build an insulating wall between the hot file and the printing chambers and the store to avoid direct heat reaching the printing bed.

To build the frame we had to have columns which are called extruded aluminum columns and unfortunately because they are rarely available and expensive in the local market they were replaced by aluminum in the form of a 90 degree angle. The width of this aluminum is 30 mm and the thickness of this aluminum is 3 mm. It was difficult to use it instead of extruded aluminum, but after many attempts, we were able to use it in several different shapes in different parts of the printers to meet our required need for extruded aluminum columns. Some pictures will explain the places where this aluminum was widely used in the printer.

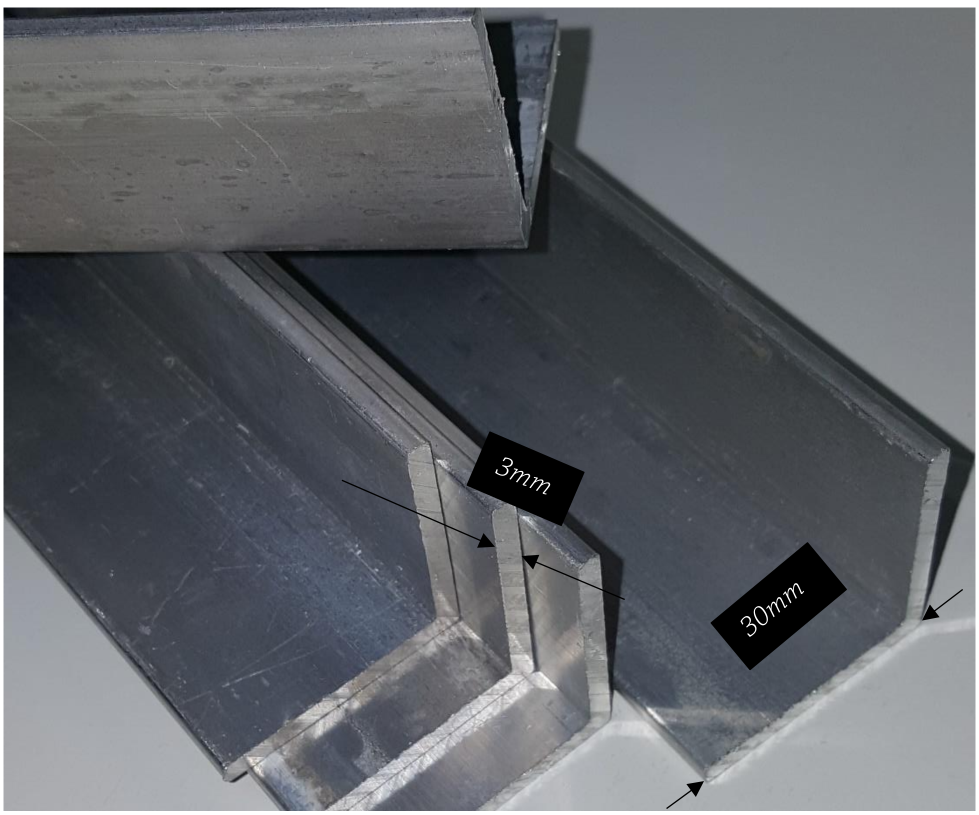


Figure 4.17 Illustration of the 90 degree angle aluminum used instead of extruded aluminum columns, with an explanation of the size of this aluminum

Although the shape of aluminum is different from the extruded aluminum columns, we used this type of aluminum in several different uses for the printer, including as columns for the printer outside and inside, and to tighten the shape of a horizontal column with another vertical one, and also in fixing, knowing that *we used a metal saw to cut some parts as required. Figure (4.17)shows the thickness of the aluminum used instead of the extruded aluminum columns. Note that it was also necessary to use a metal file after using the saw to smooth the edges of the aluminum.*

Figure (4.18 & 4.19) are examples of places where 90 degree aluminum has been used.

Figure 4.18 example of using aluminum at a 90 degree angle in a place to raise the printing rooms and the warehouse, after it was cut with a saw and its edges were smoothed

Figure 4.19 Example of using aluminum at a 90 degree angle at the laser descent area from the upper electronics chamber to the heated printing chamber.

2. Ball screws

Ball screws are feed screws that provide high efficiency due to the rolling motion of the balls between the screw shaft and nut. The drive torque is less than one-third that of a conventional sliding screw, making it ideal for power saving of the drive motor. Precision Ball Screw with Finished Shaft Ends SDA-VZ.

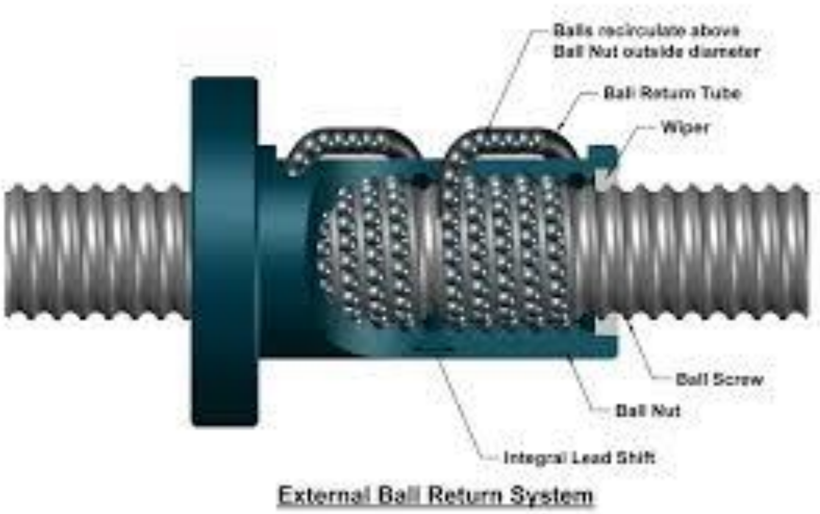


Figure 4.20 example of ball screw explaining its shape and the mechanism by which it works

Figure (4.20) shows how it works, and Figures (4.21 & 4.22) show where it is used, where three columns were used in this nature, two columns with a length of 50 cm and a column with a length of 30 cm used in the printing and storage rooms, where these two rooms work in reverse and they represent the SLS technology in the printer, where in the printing room it stores the shape after finishing printing, and it represents the Z axis of the printer.

Figure 4.22 Ball screw columns used for transferring the printing room and warehouse, 50cm long and 8mm diameter, responsible for vertical movement up and down.

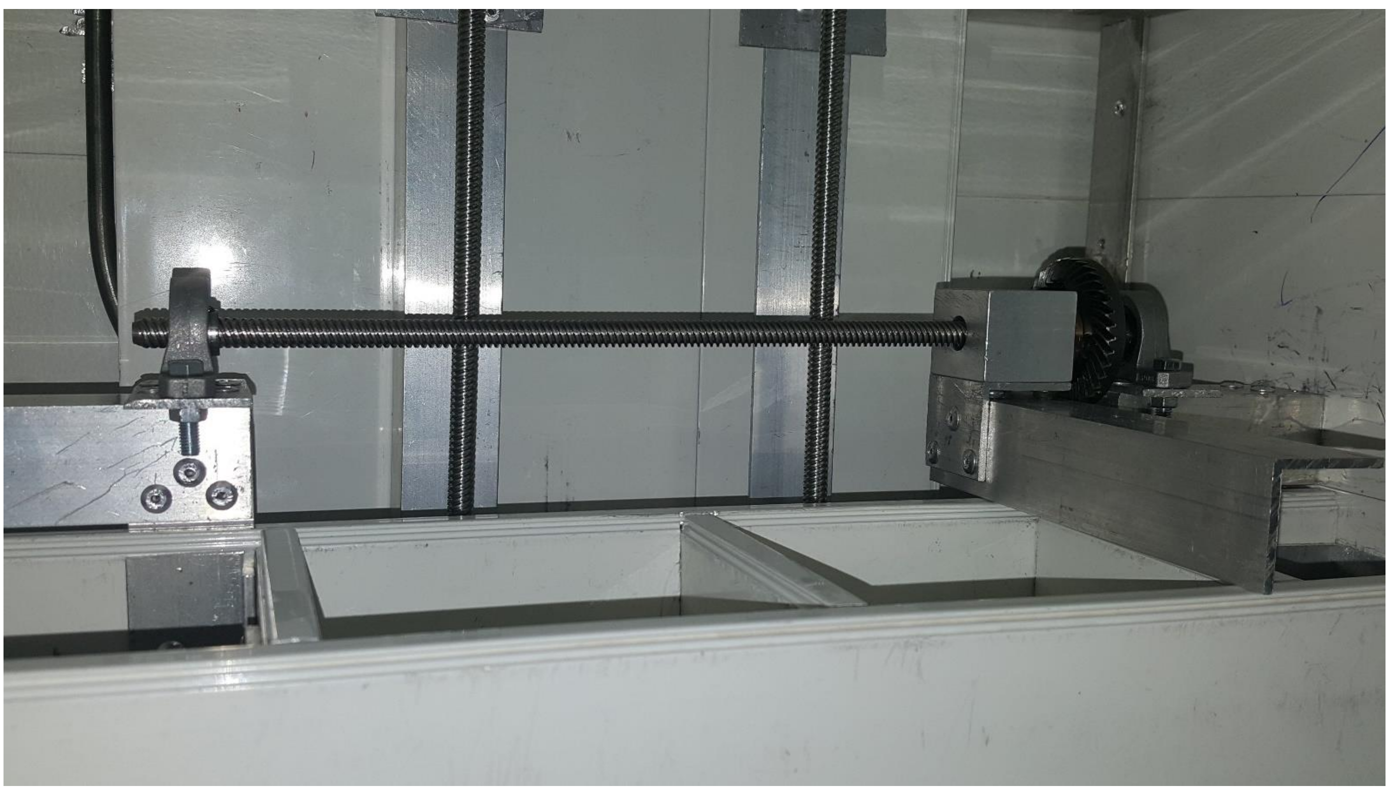


Figure 4.21 The 30cm long, 8mm diameter ball screw shaft is used horizontally to move the scanner on the X axis to transfer the powder from the storage room to the printing room

3.Linear Guide Rail

Linear guides play the role of easily and smoothly guiding linear motion while bearing loads in order for machines to operate precisely and efficiently. They are an indispensable part of linear components in devices such as machine tools and semiconductor manufacturing equipment. Figure (4.23) shows the linear motion path that allowed the storage and printing chambers to move linearly on the conveyor shaft.

Figure 4.23 The vertical movement path in the printing room and the storage room is the Y-axis movement and the horizontal movement path of the scanner to transfer the powder in the X-axis.

4. bearings

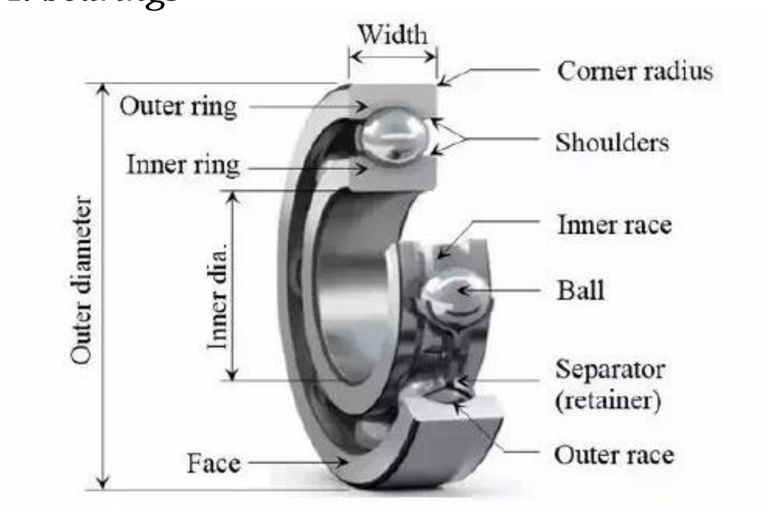


Figure 4.24 Components of the circular ring that allows three upward and downward movement are connected to the conveyor shaft.

Bearings are "parts that assist objects' rotation". They support the shaft that rotates inside the machinery. Machines that use bearings include automobiles, airplanes, electric generators and so on.

To facilitate the rotational movement of the transmission shaft, it was necessary to use a ring that helps with rotation, not fixed internally but fixed externally. Therefore, the bearing was used to assist the transmission shaft in horizontal or vertical rotational movement.

A bearing is a machine element that constrains relative motion to only the desired motion and reduces friction between moving parts.

Figure 4.25 A rotating ring used to fix columns, with two nuts fixed at the ends of the ring to secure it to the column.

5. straight gear

A straight-cut gear is a type of gear with teeth that point straight out from the center. Compared to helical gears, they make full contact each time and for longer periods, almost as if they're slamming into place against each other.

Figure 4.26 example for Straight gear and how does it stuck in each other to convert move from vertical to horizontal or the opposite

As the name suggests, the actual gear teeth point directly at the center point of the gear instead of forming a helical shape like the standard gears on almost every other road car on the planet.

Which is used to convert linear motion from vertical to horizontal, which is why it was used in the printer.

We had to put all the electronics outside the print box, so we created a room for the electronics to keep them, so we put the motors on top. This way, we couldn't get horizontal motion on the x-axis to move the powder metal scanner from the *stock bed to the print bed. So we used the straight gear to convert the vertical motion on the y-axis to horizontal motion on the x-axis to move the scanner smoothly to do the job during printing.*

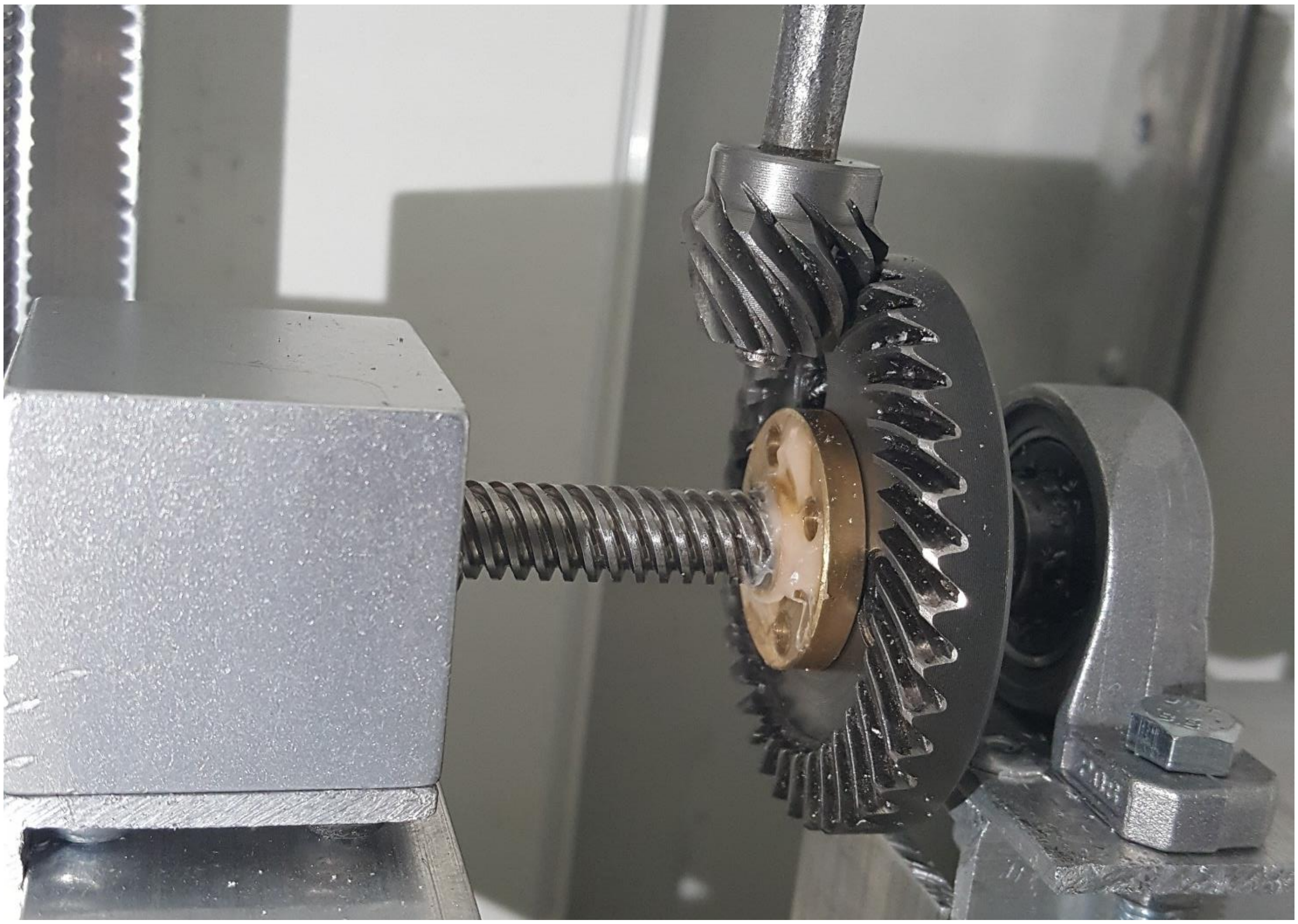


Figure 4.27 Converting the vertical movement on the Y axis to the horizontal movement on the Z axis in the scanner that transfers the powder to the printing medium.

6. door lock

Figure 4.28 Door lock to be able to close the door during the printing phase

7. Door Hinges

Door movement joints when opening and closing The door is for the upper ceiling in the electronic part room in case we need to replace the part or maintain something, and the other door is for the main printer, through which the metal powder can be poured and the printed parts can be extracted.

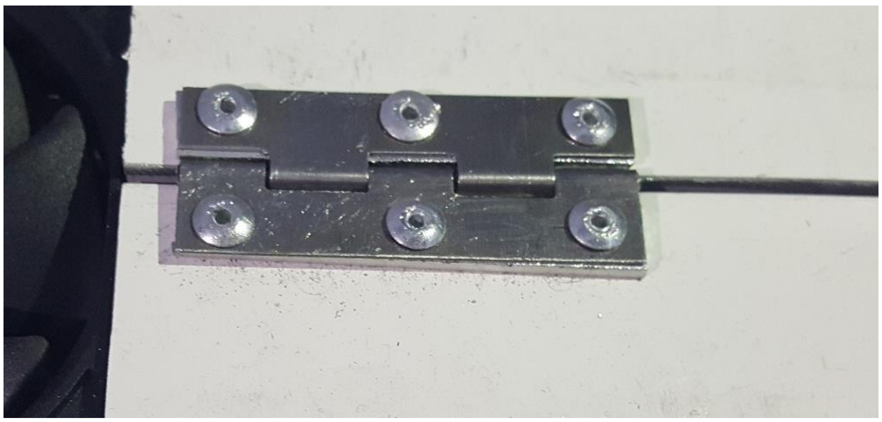


Figure 4.29 Upper door hinge for electronic parts room

Figure 4.30 Main door hinge of the printer to access the print bed

8. Screws and Nuts

Figure 4.31 Rivets were the basis for attaching aluminum.

Figure 4.32 Bolts and nuts to attach and secure the rest of the parts to the printer.

4.3.1.2 Thermal System

thermal system, as previously mentioned in the first chapters, there is a thermal system that includes three different temperatures. The first starts with the hot file, which in turn heats the temperature of the printer in general to target the powder to heat it to a temperature of up to 150 Celsius. After this temperature, the optical heaters placed directly above the room begin to heat the face of the powder that will be drawn on through the laser. The heating in the optical heaters is according to the melting point of the material. What the optical heater must do is bring the material to the pre-melting point so that the laser draws on the heated face with a power of 5W optical power to complete the process of drawing a layer of the part to be printed, this process is repeated several times until the final three-dimensional shape is formed to be used as requested.

1. *Coil heater*

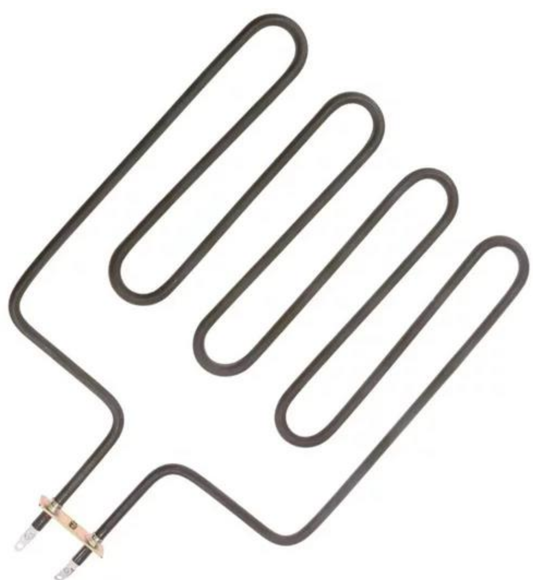


Figure 4.33 The thermal file that heats the printer to bring the powder temperature to 150 degrees

Figure 4.34 Thermal file installed inside the printer behind the insulation wall, one meter long, from the local market

2. *Lamp heater*

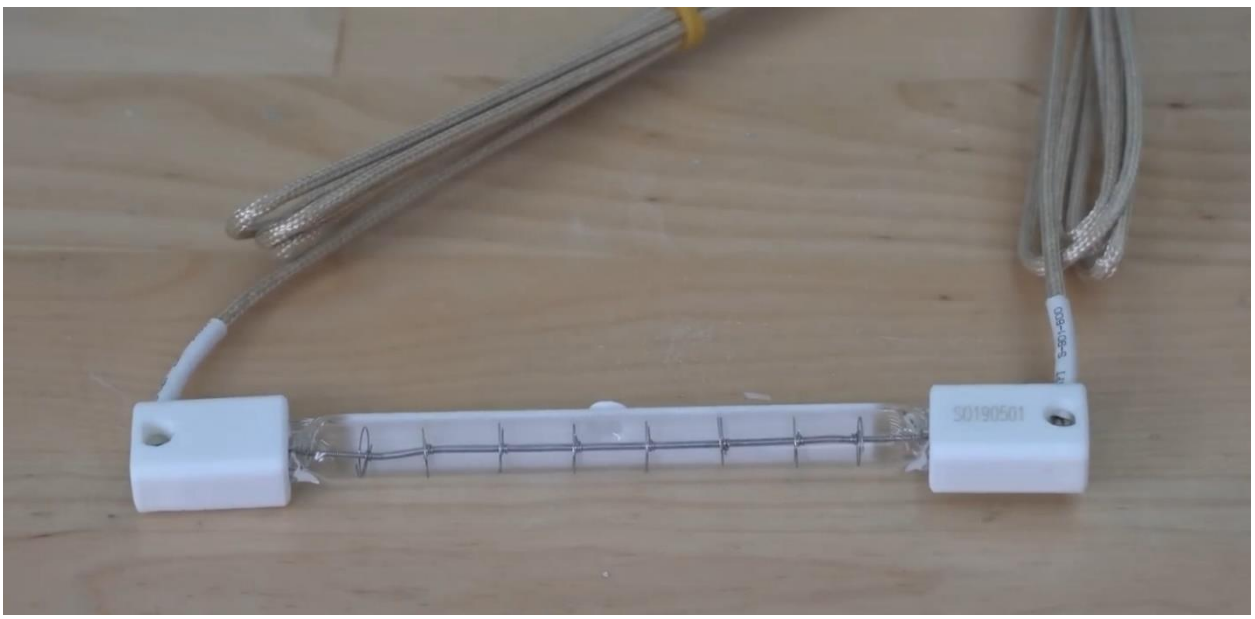


Figure 4.35 Lamp heaters are mounted directly above the print bed to heat the metal powder to a pre-melting temperature.

The heater is shown in Figure (4.35). The heater lamp is what subjects the powder to the pre-fusion temperature. At this stage, the temperatures required to heat the pre-fusion differ. There are metals that require 175C, such as copper and aluminum, and in the case of iron, it needs 180C. Of course, we are talking about the powder metal that can Work on it in this printer.

Because of the use of the thermal system in this application, it was necessary to find solutions that could be used to reduce the temperature inside this printer due to the presence of some electronic parts that operate in the printer and also to prevent the transfer of heat from inside the printer to the outside. For this purpose, heat-resistant materials were used to reduce the damage of heat outside the printer and at the same time work to trap the heat inside the printer to be able to print the parts perfectly without any problems from the beginning of printing the part until its end.

3. *Fabric Insulator*

The external appearance of the printer does not show the details of what is inside it, but we had to install two walls with a space between them. In this space, a thermal fabric was used, which is heat-resistant. The shape (69) shows

Figure 4.36 Through live experimentation, it is clear how much insulating wool can withstand temperatures, even if they are direct.

the extent of its heat resistance, knowing that it can withstand more than 1000 degrees Celsius, which is much more than the temperature in this printer. The Figure (4.37) shows where it was used in this printer, and the Figure (4.38) shows the shape of the heat-resistant wool before use.

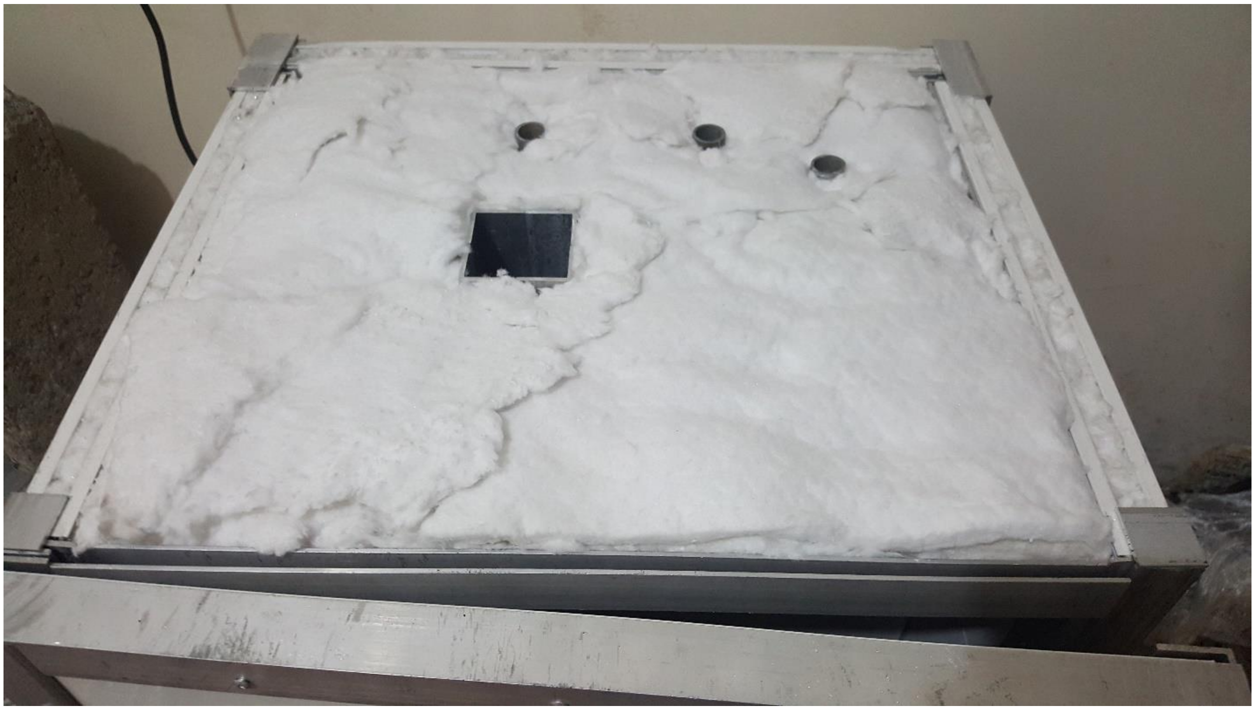


Figure 4.37 Heat resistant wool between the inner and outer wall and between the printer and the electronic parts room to protect from the heat of the printer

Figure 4.38 Heat resistant wool or fabric with a tolerance of more than 1000 degrees Celsius and withstanding direct fire

4. Teflon

The insulation used between the internal and external walls, and of course I had to think about insulating the project's columns, so Teflon was used to install them between the structure and the external wall of its printer. Figure (4.39) shows the type of material used in this printer and the location in which it is used. Polytetrafluoroethylene (PTFE) is a fluoropolymer and is known by its trade name Teflon. The unique properties of PTFE include non-reactivity, hydrophobicity, low coefficient of friction, and good insulating properties. Its temperature tolerance may reach 500°C or more, and it is used in many thermal and other applications.

Figure 4.39 Heat-resistant Teflon material to prevent heat transfer from inside to outside through the printer's aluminum frame.

Teflon is used in many thermal and non-thermal applications due to the many properties that this material contains, including high elasticity, high endurance, and heat resistance. In this application, teflon was used as a heat-resistant material, as it is placed between two walls, the inner wall of the printer and the outer wall, which separates the aluminum structure to prevent contact between the two walls, which may help in direct heat transfer.

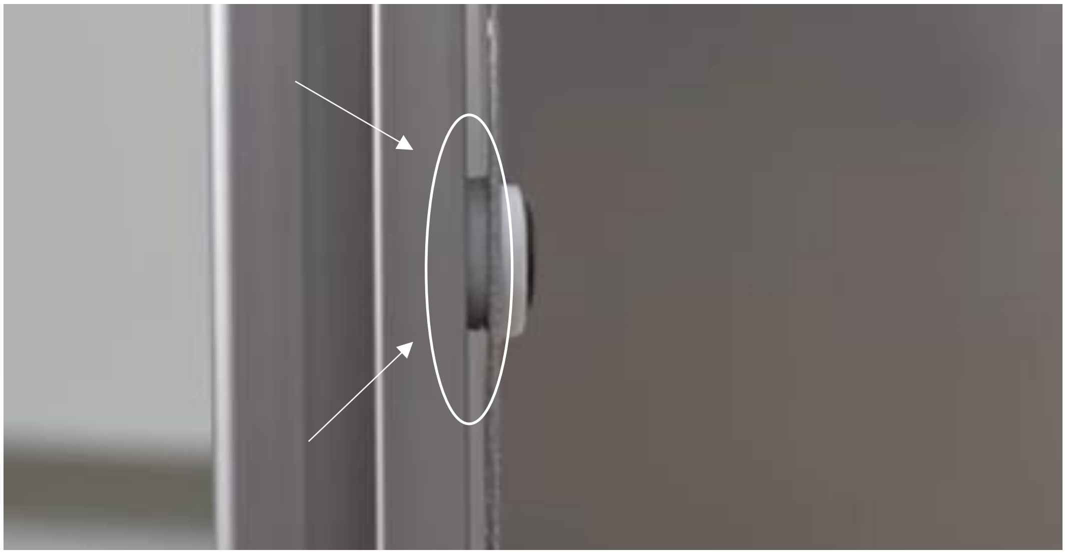


Figure 4.40 Example of where to place the heat-resistant insulating material between the inner and outer walls of the printer.

5. *sealing tape*

Heat resistant sealing tape, width 20 mm, heat resistant tape which in turn prevented the heat leakage at the printer door by making the printer door open and close easily. It was necessary to find a solution to this problem which in turn was used heat resistant tape as on one side there is adhesive and on the other side there is insulating fabric which allowed the heat to be contained inside the printer.

Figure 4.41 Heat Contractor Insulation Tape with Tape Size and Thickness

4.3.1.3 Optical System

1. Diode Laser

As for the thermal system and the optical system, there is a very strong link between them, which is the diode laser, as it is considered one of the two systems due to the use of the laser temperature to sinter the metal, although it is considered one of the optical systems.

The force that was the largest ring in melting and shaping the powder into the desired part taking into account the size and precise measurements, a laser had to be used in this application, and a laser diode was used because there are many advantages that can be provided to the project while not encountering some of the common problems. First: Definition of diode laser.

A diode laser (or diode laser) is a semiconductor device that undergoes stimulated emission to emit coherent light. Laser diodes provide high power for their size and produce energy-efficient laser radiation.

Figure 4.42 laser diode with a power of 12v and 40w and an optical power of no more than 5w

Laser diodes are the most common type of laser produced, with a wide range of uses that include fiber optic communications, barcode readers, laser pointers, CD/DVD/Blu-ray disc reading/recording, laser printing, laser scanning, and light beam light.

In this application, it was used as a final point for cohesive metal powder particles according to the required shape in the form of cohesive layers on top of each other, knowing that it is natural that there are some simple problems that were able to be solved The laser beam emits a wide, oval shape, and this makes it difficult to form moderate lines in the oval shape. Therefore, we transform and shrink the laser beam to become circular in shape and with a smaller diameter, so that it becomes easier to draw and form shapes and less produces unwanted impurities, which in turn reduces the sharpness of the shape. The end surface in Figure (4.42) is a picture of the used laser diode with a power of 12v and 40w and an optical power of no more than 5w, depending on the powder used in the project.

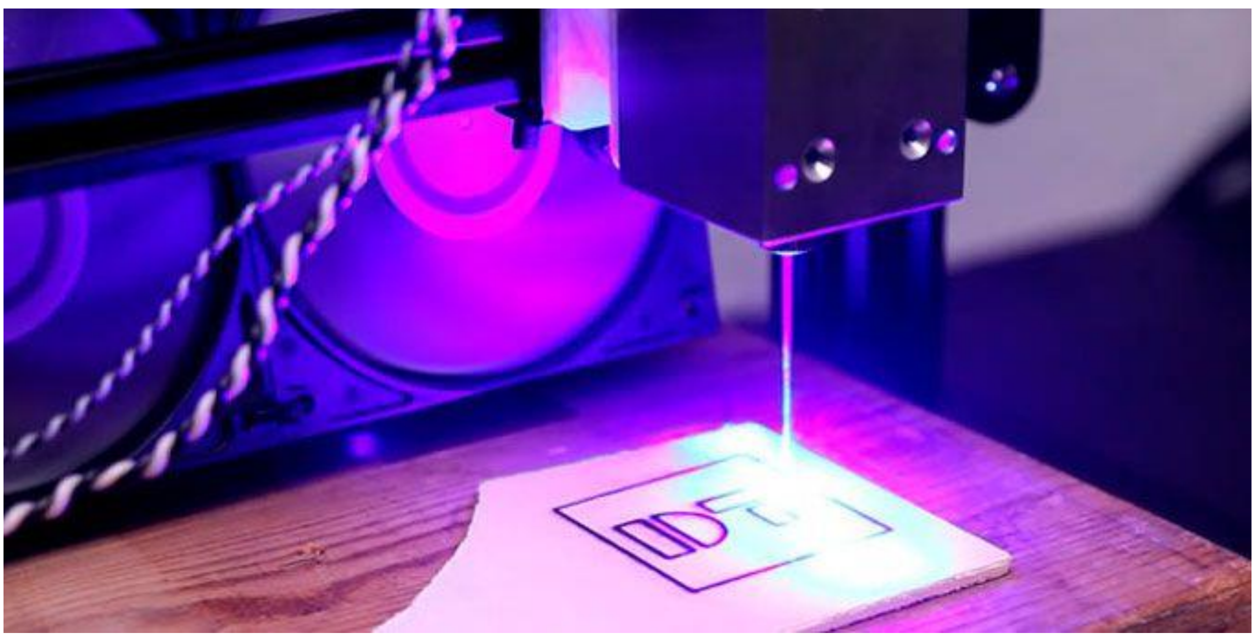


Figure 4.43 Example of the amount of laser beam emitted from a laser diode for drawing on parts

3. ***convex lens***

The convex lens is one of the most important parts of the optical system, due to its conversion of the laser shape from an oval shape to a circular shape, knowing that the oval shape emanating from the laser beam cannot be seen with the naked eye due to its sharpness and small size. If the laser is used in its oval shape, it will be difficult to draw on the powder and determine the required shape accurately due to the presence of increasing edges in the oval shape, which is different from the circular shape. Therefore, the laser beam had to be converted to the required shape so that we can print the required parts with extreme accuracy to obtain the required size and without any problems that may affect the shape of the printed part. Figure (4.45) shows the importance of the presence of the lens [3].

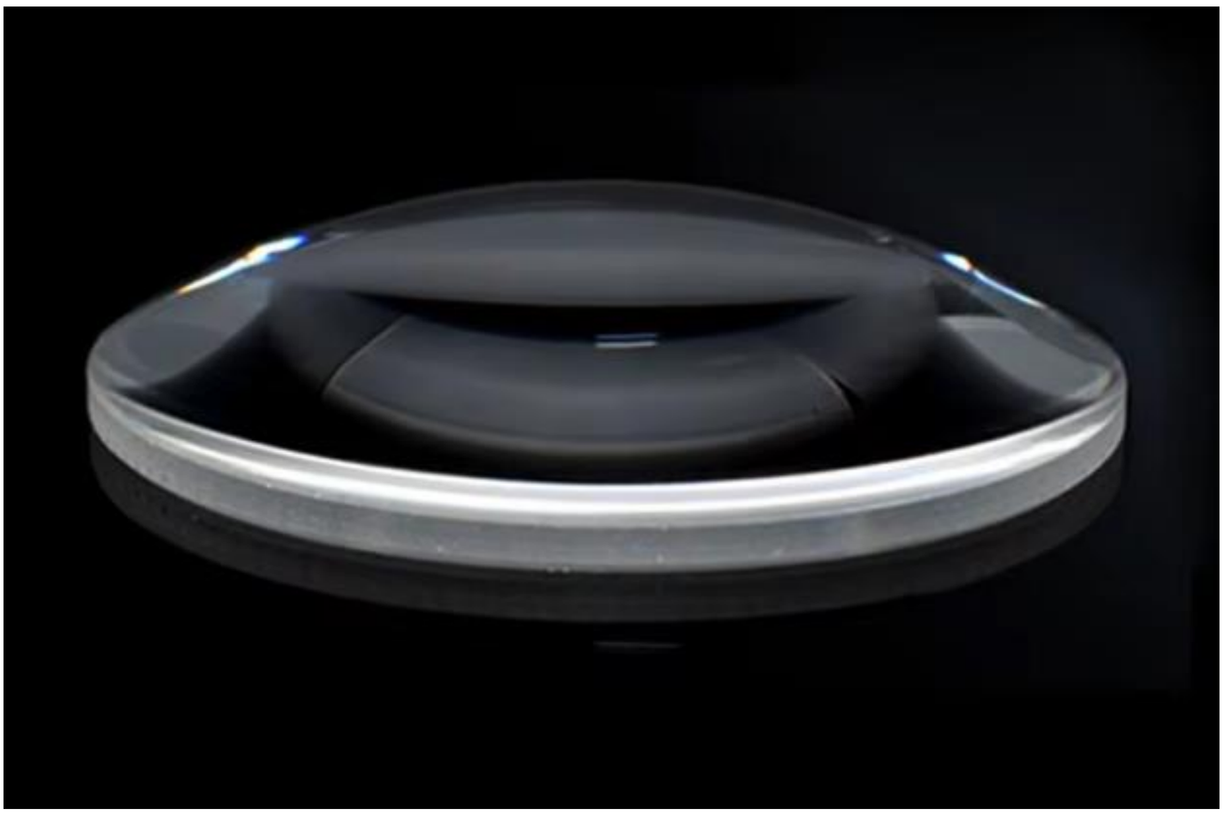


Figure 4.44 Plano-convex lens D30.4 F50 C6 E1.7

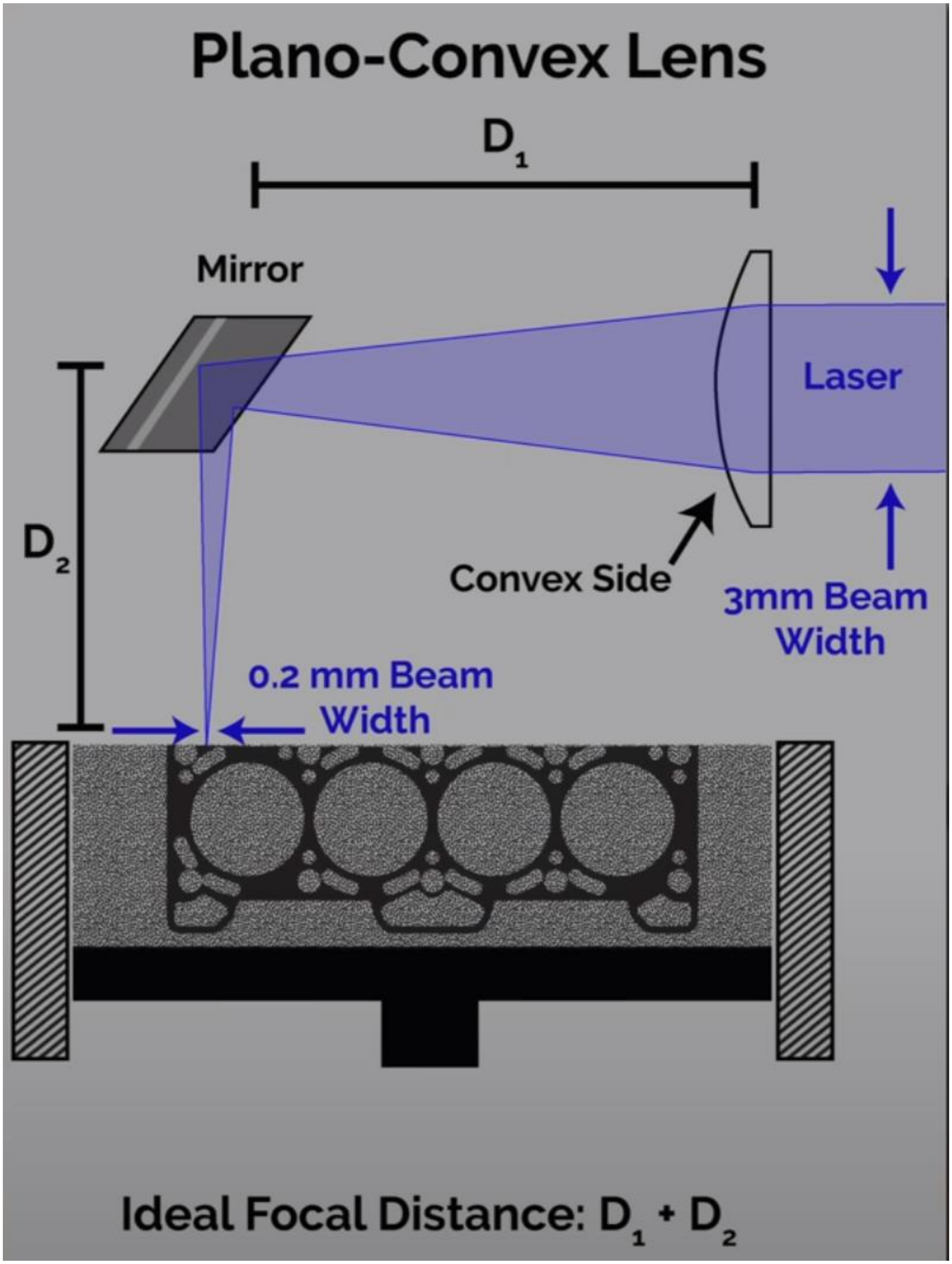


Figure 4.45 The convex lens used in the project to reduce the diameter and size of the laser to the required size of 0.2 mm.

4.Galvanometer Scanner

A scanner of Galvanometer Optical Scanner is a drive source which drives a mirror and consists of oscillating motor and position detector. The factors that should be considered in particular when selecting a galvanometer scanner are:

(1) scanner size and

(2) scan angle.

The scanner size is selected by the mirror size, and the scan angle is selected by the optical system design. We, Citizen Chiba Precision, use an optical analog sensor as the position detector.

The feature of the motor for galvanometer scanner is that it uses a specialized motor for rotating in a limited angle. By structurally limiting the rotation angle, there are advantages such as:

(1) The commutator and brush required for DC motors and the magnetic pole sensor for commutation required for brushless motors, are not required.

(2) It reduces friction factors of the motor.

(3) The coreless motor structure enables highly responsive and highly accurate angle control.

The galvanometer scanner is required to move to the target angle at high speed. Therefore, as it is clear by the equation of motion stated in the rotary motion system: Rotation Torque [N・m] = Inertia [kg・m2] × Angular Accelerationα [rad/sec2] , it is important to generate high torque instantaneously and to have a small rotor inertia in order to obtain rapid acceleration.

Scanner Sizes

As we mentioned earlier, the scanner size is selected by the mirror size. All of our scanners are optimally designed according to the mirror size. Our model numbers, such as GVM-0930 and GVM-1445 for example, have 4 digits numbers and first two digits indicate the diameter of the scanner.

It is important to use by the optimal combination of mirror size and scanner size.

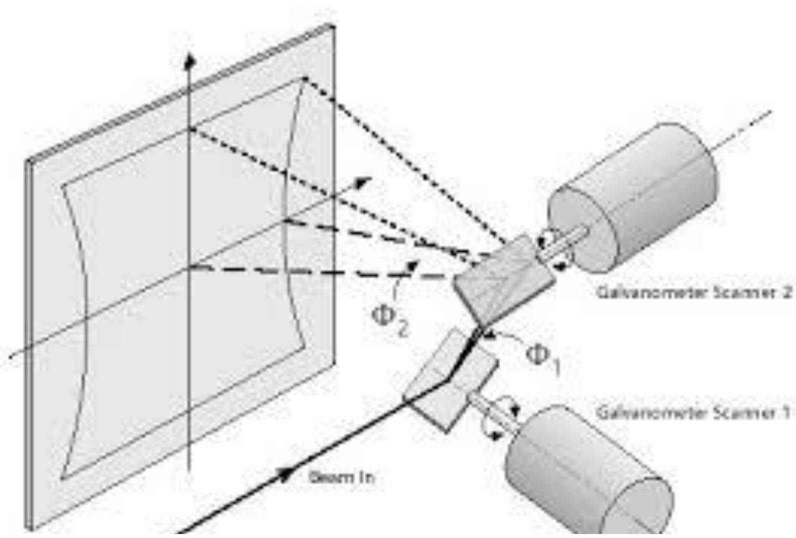


Figure 4.46 Explain the distance of the galvano scanner's access angle by reversing the rituals.

Scan Angle

Our galvanometer scanner can drive in the scan angle up to ±10° to ±20°(mechanical angle) as standard. Linearity, which affects accuracy, tends to deteriorate above ±10°. We can set the maximum scan angle to less than ±10° according to the specifications. Please ask our sales representatives or authorized distributors for more details. The length of the connection cable between the scanner and the driver is also included in the model number. Large scanners, larger than GVM-2260, have a direct cable connection. Small scanners, smaller than GVM-1445, use a dedicated extension cable (GCxx) to connect with the connector [3].

The cable length affects the electrical resistance and inductance of the scanner, and relates to the operating speed of the scanner. In general, a short cable has lower electrical resistance and small inductance which is advantageous for operation. However, our standard products have almost no effect on performance even with maximum three (3) meters long cable.

Since the cable transmits the analog position signal output from the scanner sensor, we use a noise-proof cable.

Shape of the Output Shaft

galvo scanner shafts the shape of the mirror holder differs according to the scanner size. For scanners larger than GVM-2260, we fix a holder with a mirror on the output shaft. You can remove the mirror simply by loosening the screw.

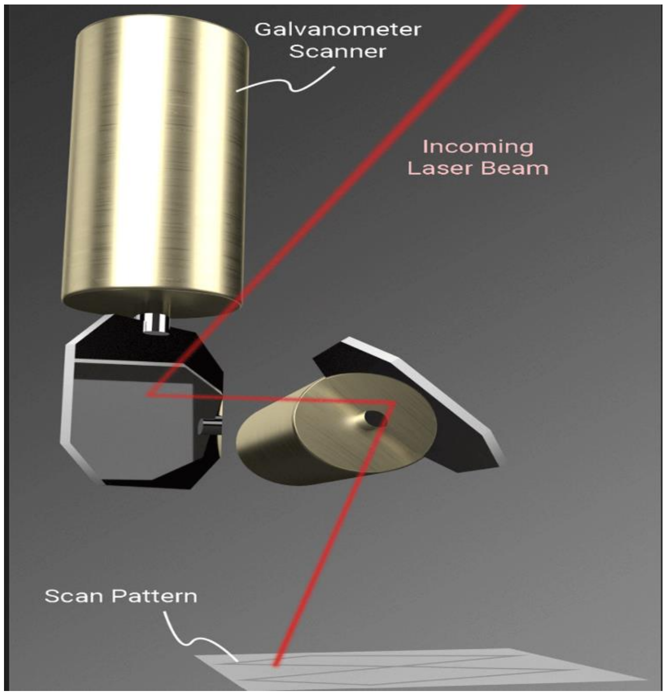


Figure 4.47 Laser transmission through galvano scanner between the X and Y axes of the printer

For scanners smaller than GVM-1445, the mirror holder is glued directly to the output shaft. Therefore, the mirror cannot be removed to replace but the inertia can be kept small, which is advantageous for operation. Because such a small inertia difference can be a significant effect, this shape is our standard for the small scanners.

It is possible to glue the mirror provided by the customer. Please feel free to ask our sales representatives or authorized distributors.

Mirror Angle Against Cable Outlet and With/Without Mirror

The cable outlet and mirror position can be selected based on the structure around the galvanometer scanner and its posture.

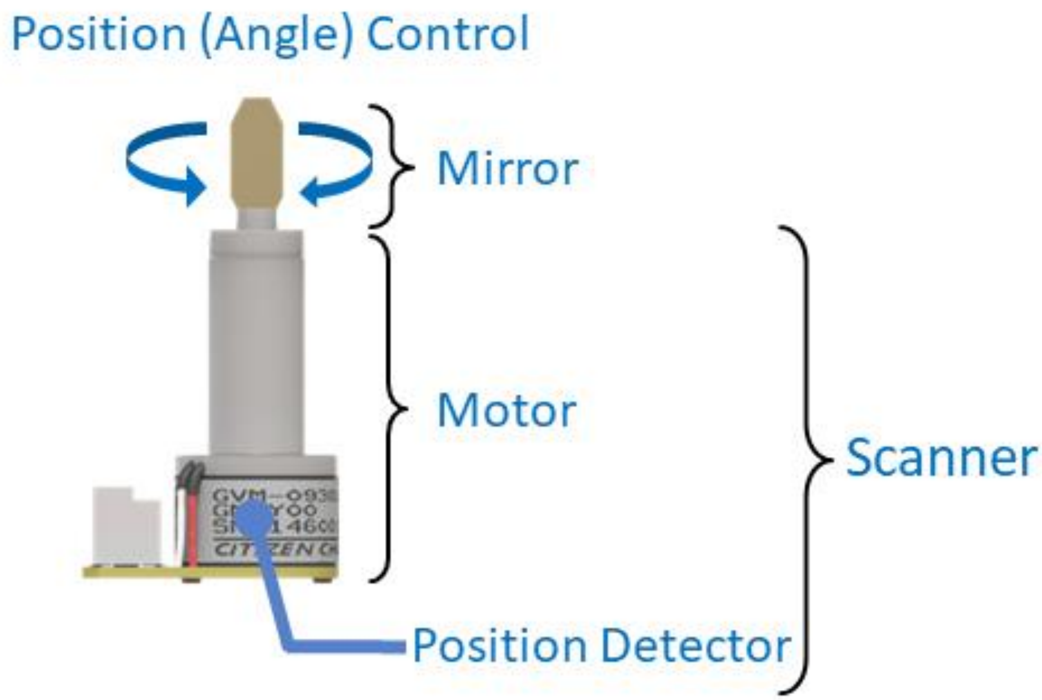


Figure 4.48 The type of motor used in the galvano scanner is the servo motor, which is capable of moving in a precise motion in micro units.

Position Detector

Our position detector uses patented optical analog sensor. We are sorry that we do not have a digital galvanometer scanner (digital galvo) equipped with an encoder at this moment.

The analog position detector (optical) detects the angular position by emitting laser beam on the reflector attached to the shaft end and it converts the reflected laser beam to voltage by the light receiving element. Our position detector is light in weight and suitable for high-speed operation because it only requires to attach reflector to the moving part. Since there are individual differences in LED (the light source) and photodiode (the light receiving element), it is necessary to adjust the driver for each galvanometer scanner. And also, in order to reduce the drift by the temperature characteristics of LED and the photodiode, the correction circuit is incorporated in the driver. So, we deliver by pairing the adjusted driver and the scanner together in link [7 & 9].

The digital position detector attaches a rotary encoder to the end of the shaft and it outputs angle information by digital signal. High positioning accuracy can be expected by using a high-resolution encoder. The advantage for high position accuracy is that the encoder is less susceptible to temperature changes and noise. However, since the encoder has a larger inertia than the reflector, and it takes a long time to process due to calculation and signal conversion, these would become the disadvantages for high-speed operation. And also, digital position detector is more expensive than analog position detector.

There are advantages and disadvantages to analog and digital, and neither is superior, and they should be used in the right place.

Figure 4.49 The galvano and servo motor that represent the X and Y axis of the printer.

4.3.1.4 Electrical System

1. Driver of Galvano Scanner

Driver is the device which receives various feedback signals from the position detector and supplies power to control the mirror position (angle). It calculates the command signal to supply the power by comparing position command signal and position detector signal.



Driver Specification

Model		GVD0 - ****** - **	GVD1 - ****** **	GVD2 - ****** **
Power	Power Voltage	±15V or ±24V	±15V or ±18V to ± 30V	±15V to ±30V
	Output Current	2.5A RMS	5.0A RMS	2.5A RMS
	Peak Current	10A	11.5A	10A
Command Signal Input	Voltage (Differetial)	±3V ／±5V ／±10V	±3V ／±5V ／±10V	±3V ／±5V ／±10V
	Input Impedance	20kΩ (At diffential input)	20kΩ (At diffential input)	20kΩ (At diffential input)
Monitor Output	Position Output	±1.5V ／±2.5V ／±5V	±1.5V ／±2.5V ／±5V	±1.5V ／±2.5V／± 5V
Function	Input Signal	Servo ON	Servo OFF	Servo OFF
	Output Signal	Ready	Position / Speed / Current / Position Error Alarm / 90% Load Warning	Position / Speed / Current / Position Error Ready
	Protection	Over Heating	Over Heating	Over Heating
		Over Position	Over Position	Over Position
		Over Current	Over Current	Over Current
		Sensor Error	Sensor Error	Sensor Error
			90% Load Warning	
			Power Source Voltage Drop Error	
Ambient Temperature Range		0 ～+50℃	0 ～+50℃	0 ～+50℃
Dimension		93 x 57.5 x 31 mm	101.6 x 66.5 x 30.8 mm	58.6 x 54 x 31.6 mm
Weight		60g (With heat sink)	90g (With heat sink)	55g (With heat sink)

Figure 4.50 information about three types of drivers available for galvanometer scanners

The device which outputs the position command signal as mentioned above is controller.

The controller commands the driver to position the mirror according to the purpose, and the driver controls the galvanometer scanner to follow this mirror position command signal.

Citizen Chiba Precision has three types of drivers available for galvanometer scanners:

GVD0 for general-purpose

GVD1 for high power-purpose

GVD2 for small scanners (0930S / 0930L, 1445S / 1445L)

They are different in performance, size, and optimal application especially GVD2 is miniaturized by limiting the use to small scanners.

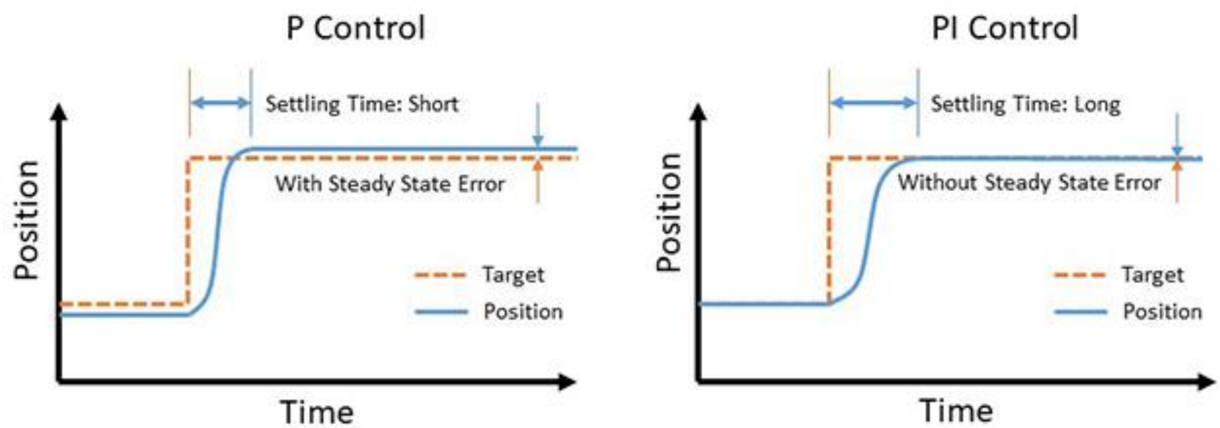


Figure 4.51 The Differences in control system for P and IP

Their biggest difference is the instantaneous maximum current (peak current). The scanner generates acceleration (torque) proportional to the flowing. The larger the size in mirror inertia and acceleration, the larger current is required to obtain more torque.

All of drivers have two control methods called P Control and PI Control and please chose one according to the application. P Control focuses response speed, and PI Control focuses position reproducibility.

P Control compares the command signal and the position feedback signal for a proportional calculation. It operates at high speed but its position reproducibility is inferior for it does not have a means to correct steady position deviations.

PI Control calculates time integration (Integral) in addition to P Control. High position reproducibility can be obtained because the steady position deviation is integrated and corrected. However, because it requires integration time, it is inferior to P Control in speed.

Super-compact high speed driver for MediaLas CTR 6212 galvo scanners.

oscillation prevention circuit

over temperature protection

optional coil temperature calculator

differential input up to 10 V control voltage

Easy mirroring by using two on board jumpers

LEDs for realtime status signaling

Very small dimensions, just 63x50x35mm

Adjustment for Picture Size, Servo Gain, LFD, HFD, Offset and linearity. Inverting jumper. Needs source of +/- 18-30VDC at 1A per voltage. Step time can be as low as 100uS at small step, with CTi 6210HB galvos and small mirrors.

The PID servo controller interprets the feedback signals of the position sensor compared to the target signal of the input and transmits the voltages and currents to the motor necessary to reach the desired position are rapidly as possible. The high-speed control loop with integration link delivers excellent, responsive movement with the fast acceleration and braking ramps which are necessary for the fastest positioning movements and the lowest jump times. The damping links ensure that settling times are kept as short as possible. This made is possible to achieve further gains in terms of precision and reproducibility.

On the driver itself, the axis movement can be inverted with a jumper. The inputs are designed to be fully symmetrical, allowing for floating earth actuation. This drastically reduces earth loops or interference. This makes it possible, with a two-wire cable, to eliminate interference, as the interference signals cancel each other out. Power connector and signal connectors are separated. Buffered position outputs also fed out of the connector.

The MicroAmp is very durable when it comes to overheating on the output stage. The integrated protection against overheating switches the output stage off if the temperature is too high, so that no defect occurs. To ensure sufficient cooling, the MicroAmp should be mounted to an adequately dimensioned metallic surface. The temperature on the back part of the heat sink should be below 70°C [7 & 9].

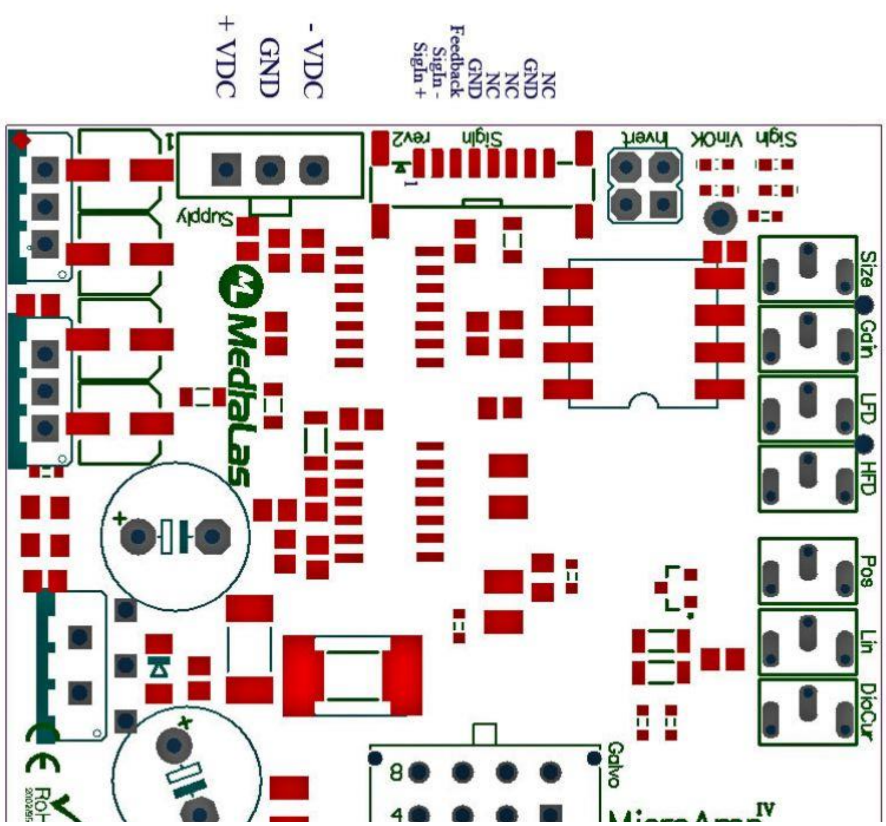


Figure 4.52 Galvanometer controller diagram for temperature exceeding 70°C

2. The Main Controller

SKR V1.4 Turbo

Watching 3D Printers lay down individual planes of material to build items one layer at time is always a beautiful sight, and as but wonder about what exactly is going on under the hood. Fortunately, although that does interest us, it's not vital to enjoy the benefits of 3D Printing, and we're quite lucky that so much development has gone into the industry, as this means we don't have to start from scratch, and we can nowadays simply buy powerful and multi-functional Controller Boards to do all of the hard work for us, while we reap in the benefits of high quality prints among other cool features.
This is why we get so excited with each and every new motherboard we bring in, and this is especially so with the BigTreeTech SKR V1.4 Turbo Controller Board, as this board is filled to the brim with amazing features, while maintaining a cost that even rivals the original Arduino Mega2560 with RAMPS combo.

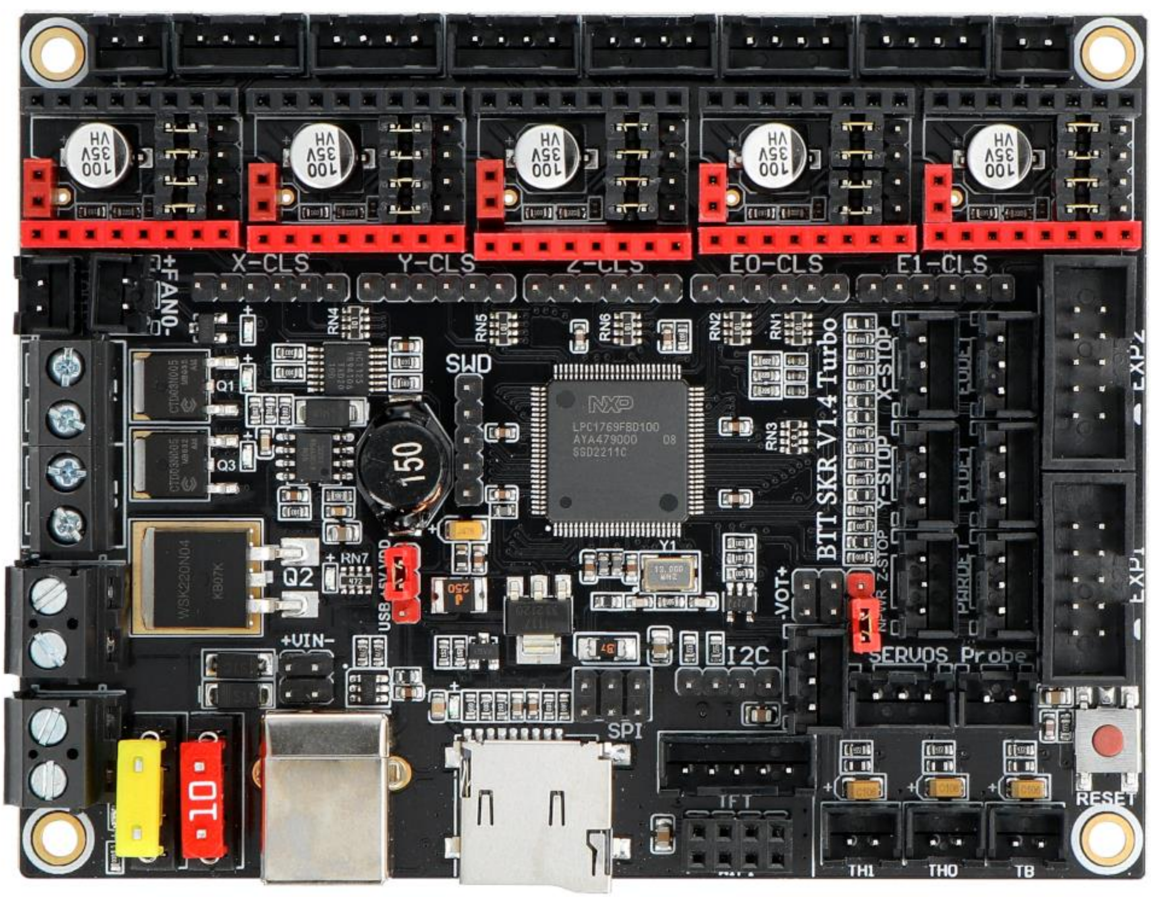


Figure 4.53 SKR V1.4 Turbo

With all of the very best features from the past few years of 3D Printer component development, as well as some fantastic features that are unique to the BigTreeTech SKR Motherboard range, there are very few controller boards that can quite compete with the speed, efficiency and overall functionality of the BigTreeTech SKR V1.4 Turbo.
Please Note: The SKR V1.4 Turbo is exactly the same as the original SKR V1.4 Motherboard, but features a faster 120MHz LPC1769 Processor instead.
but is rather a massive upgrade that is compatible with an impressively wide range of 3D Printers. And while the BigTreeTech SKR V1.3 Motherboard was certainly an amazing addition to the range, this more recent V1.4 edition really steps up the game with even more functional ports, better power delivery around the board, more interfacing options for both drivers and motors, and even a novel dual Z-stepper output to accommodate dual-z capabilities without having to splice or split any wiring!
So, without further ado, let's dive into the three key features that we simply love about the BigTreeTech V1.4, and what kinds of cool benefits this board offers:

- *An Affordable 32bit Processor – Although this isn't a new feature compared to the SKR V1.3, it's awesome enough to make it into the top three features for the SKR V1.4 Turbo. This is because, for years, 8bit boards dominated the market and performed extremely well, although with all of the more modern improvements, firmware updates and other minor upgrades along the way, 8bit boards simply can't offer the quality that can achieve in 3D Printing. This is why get so excited with the fact that anyone can now enjoy a 32bt motherboard for relatively cheap, for faster potential printing speeds, smoother arches and curves, and overall more power to accommodate future upgrades and advances as 3D Printing continuously evolves.*
- *More Interface Ports for Extras: When taking a glance at the layout of this board, it's easy to see that the SKR V1.4 Turbo has been specially designed for maximum functionality, offering extra ports all over the board for even more features. These new ports include a secondary Z-Output for dual z-axis setups, more fan ports for control box and enclosure cooling, specialised ports for a Servo and Sensor Probe, as well as dedicated RGB LED and WiFi ports too. And of course, just like the SKR V1.3, these boards also offer the specialised ports for closed loop steppers like the MKS SERVO42A and MKS SERVO57, for Makers*

who really like to take their 3D Printing to the next level. These extra interfacing options not only add to the functionality of the board, but also allow you to really customise your 3D Printer, and we've honestly been very impressed with just how many extras BigTreeTech managed to fit onto this sleek and stylish board.

- *Improved Design & Layout: Although this is a relatively minor upgrade compared to the previous two, it is a welcome addition nonetheless, as this new design has removed some of the redundant parts like jumper configuration pin-sets, while replacing those with integrated functionality instead. A good example of this is how sensorless homing on the SKR V1.3 would need to be defined by the jumpers before powering up the board, whereas now you can simply define it within the firmware without having to power down the board.*

, but don't quite need the 120MHz processing speed, then you should definitely take a look at the standard BigTreeTech SKR V1.4 Controller Board, which offers all of these awesome features, but without the extra 20MHz. Furthermore, although it's quite uncommon, if you're planning on using some of the newer 5V extras, such as the RGB LED Port or a Servo-based levelling sensor, then you may want to get the BigTreeTech SKR V1.4 DC-DC Edition, which includes a specialised DC-DC Module for effectively delivering power to the board for heavier 5V power draw applications.

Please Note: This board can operate on both the main DC power input as well as USB power, and you need to choose between the power inputs by using a jumper over the 3 onboard pins with the "VDD" & "USB" labels in order to avoid causing unexpected damage. However, it must be noted that this board cannot actually print from USB power, which means that the USB power select is primarily just for interfacing with the board when setting up or flashing firmware.

Additional Note: It's important to realise that this board does not come with Stepper Drivers included, so if you don't have any spare stepper drivers, be sure to check out the stepper driver compatibility of this board below, and then consider getting a few drivers from dedicated Stepper Driver Category.

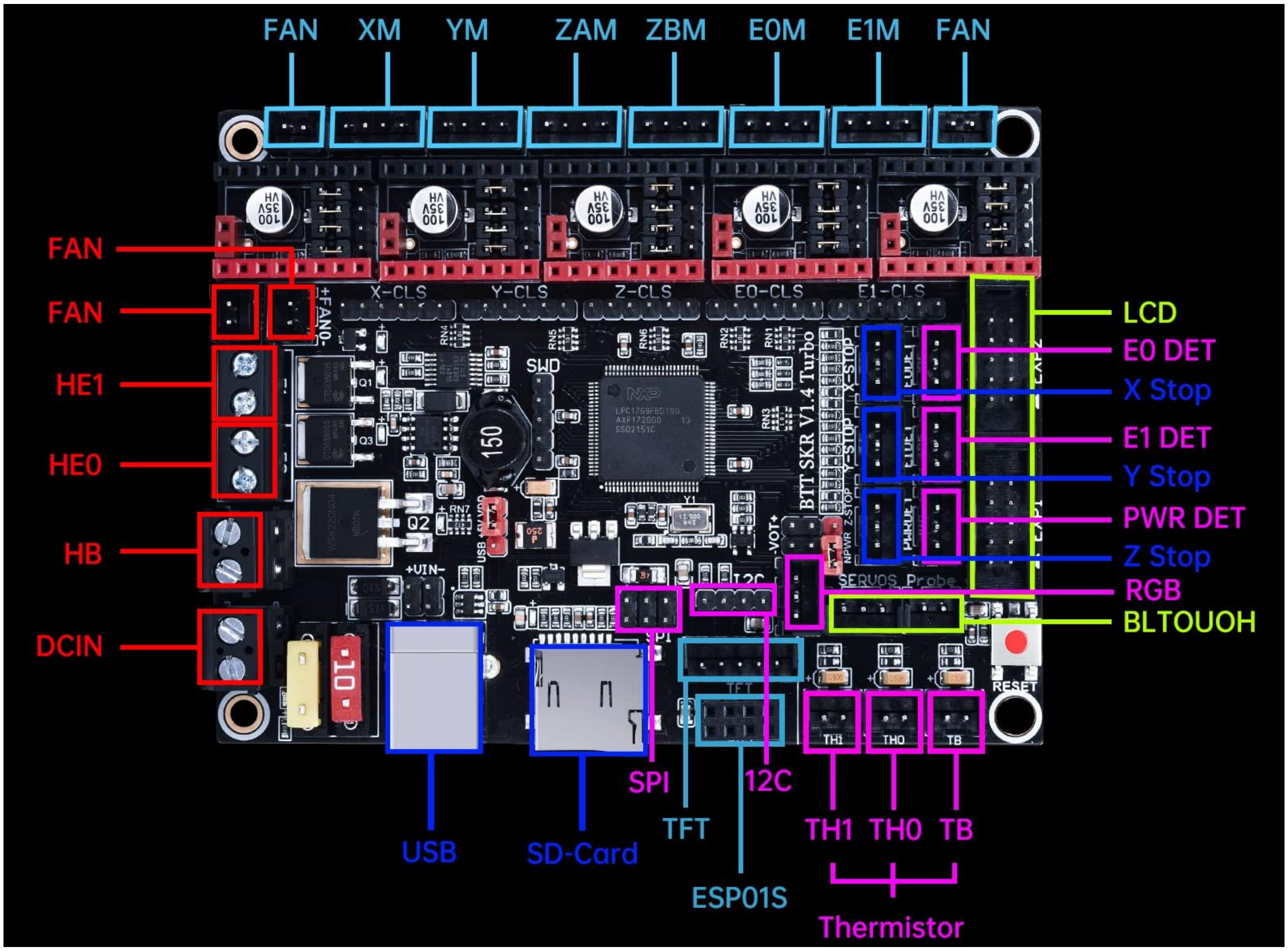


Figure 4.54 writing diagram

Specification of the Bigtreetech SKR v1.4 Turbo 32-bit motherboard

- *Supply voltage: 12 V to 24 V DC*
- *Logic voltage: 3.3 V*
- *Processor: ARM Cortex-M3*
- *Clock frequency: 120 MHz*
- *Supported printer types (according to motion kinematics): XYZ, Delta, Kossel, Ultimaker, CoreXY*
- *Supported communication interfaces: SPI, I2C, WiFi*
- *Compatible with stepper motor drivers supporting Step / Dir and UART modes*
- *Communication: USB type B socket, microSD card reader*
- *Dimensions: 109.67 x 84.3 mm*

4. *Power Supply*

MEANWELL LRS-350 series is a 350W single-output enclosed type power supply with 30mm of low profile design. Adopting the input of 115VAC or 230VAC (select by switch), the entire series provides an output voltage line of 3.3V, 4.2V, 5V, 12V, 15V, 24V, 36V and 48V. The model LRS-350-12 is the most popular 12v power supply in the Switching Power Supply in the market.In addition to the high efficiency up to 89%, with the built-in long life fan LRS-350 can work under -25~ +70℃ with full load. Delivering an extremely low no load power consumption (less than 0.75W), it allows the end system to easily meet the worldwide energy requirement.LRS-350 has the complete protection functions and 5G anti-vibration capability; it is complied with the international safety regulations such as IEC / UL 62368-1. LRS-350 series serves as a high price-to-performance power supply solution for various industrial applications.

Features

- *Brand MEANWELL*
- *12V DC 29A output*
- *AC input voltage range: 90 ~ 132VAC/180 ~ 264VAC*
- *Rated power: 348W*
- *Withstand 300VAC surge input for 5 second*
- *Protections: Short circuit / Overload / Over voltage / Over temperature*
- *Forced air cooling by built-in DC fan*
- *Built-in cooling Fan ON-OFF control*
- *1U low profile*
- *Withstand 5G vibration test*
- *LED indicator for power on*
- *No load power consumption < 0.75W*
- *100% full load burn-in test*

- *High operating temperature up to 70℃*
- *Operating altitude up to 5000 meters (Note.8)*
- *High efficiency, long life and high reliability*
- *3 years warranty*

Applications

- *Industrial automation machinery*
- *Industrial control system*
- *Mechanical and electrical equipment*
- *Electronic instruments, equipments or apparatus*

Figure 4.55 MEANWELL LRS-350

5. *Stepper motor*

Stepper motors are so named because each pulse of electricity turns the motor one step. Stepper motors are controlled by a driver, which sends the pulses into the motor causing it to turn. The number of pulses the motor turns is equal to the number of pulses fed into the driver.

A Nema 17 stepper motor is a stepper motor with a 1.7 x 1.7 inch (42 x 42mm) faceplate. Nema 17 high torque stepper motors provide great value with no quality sacrifice.

Name :	Nema 17 stepper motor
Model :	17HS4401
Step Angle :	1,8 ° ± 0,09 °
Rated voltage:	DC 3. 6 V
Rated Current :	DC 1,5 A / Phase
Holding Torque:	≥ 420mN. M
Maximum no load Starling frequency :	≥ 1900 PPS
Weight :	255 g

Figure 4.56 Nema 17 stepper motor with some details

The version with a step angle of 0.9° is more precise than the typical 1.8° version of the motor.
These motors are engineered to provide the highest possible torque but minimize vibration and audible noise.
A wide range of motor windings and stack lengths are readily available, or the motors can be customized to meet your machine requirements. We can also have the windings customized to perfectly match your voltage, current and maximum torque at operating speeds.

NEMA stepper motor sizes depend on the frame size of the stepper motor. NEMA means the standards set by "National Electrical Manufacturers Association", which is comprised of 560 major electrical manufacturers in the United States, primarily consisting of manufacturers of equipment and devices for power generation, transmission, distribution, and power applications.
The purpose of standard setting is to eliminate misunderstandings between electrical product manufacturers and users and to specify the safety of these product applications [1].

6.Temperature Sensor

S81 RTD Temperature Probes

A temperature sensor is a device that is designed to measure the degree of hotness or coolness in an object. The working of a temperature meter depends on the voltage across the diode. The temperature change is directly proportional to the diode's resistance. It consists of a thin film of platinum on a plastic film. Its resistance varies with temperature and it can typically measure temperatures up to 850 °C. Passing current through an RTD generates a voltage across the RTD. By measuring this voltage, you can determine its resistance and, thus, its temperature.

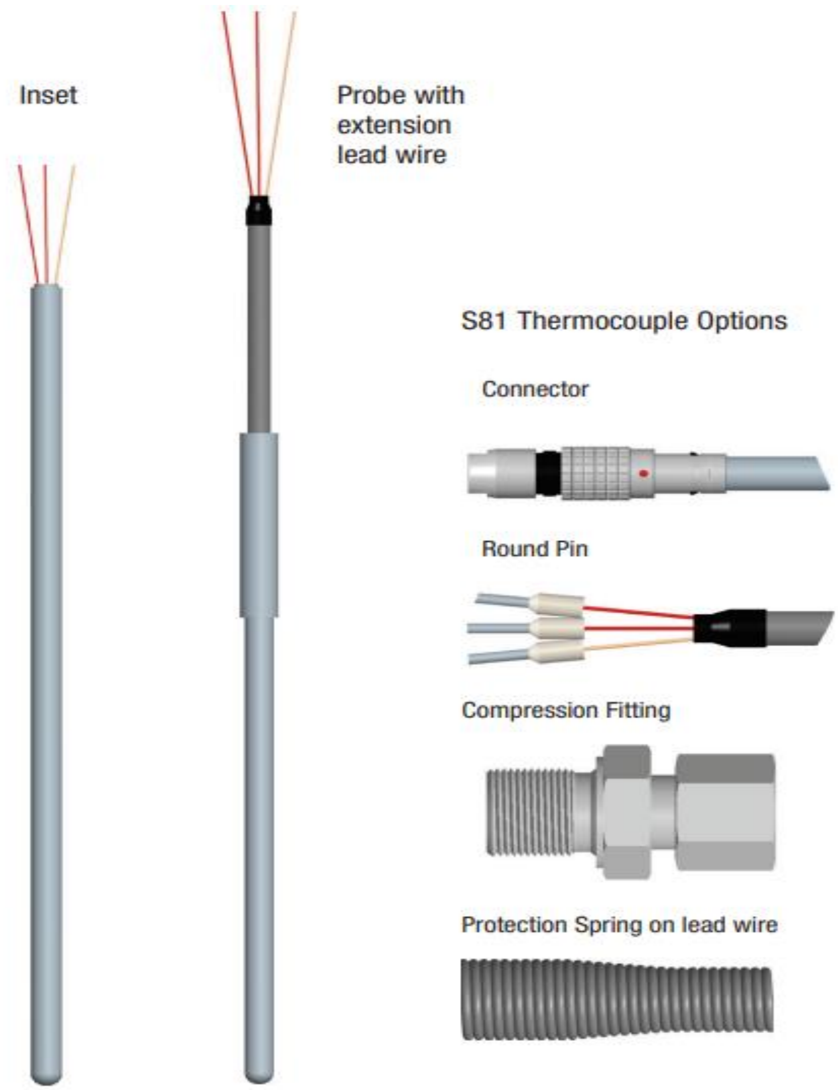


Figure 4.57 S81 RTD Temperature Sensors l Components and Installation

Resistance Temperature Detector (RTD) A resistance temperature detector, or RTD, changes the resistance of the RTD element with temperature. An RTD consists of a film or, for greater accuracy, a wire wrapped around a ceramic or glass core. Platinum makes up the most accurate RTDs while nickel and copper make RTDs that are lower cost; however, nickel and copper are not as stable or repeatable as platinum. Platinum RTDs offer a highly accurate linear output across -200 to 600 °C but are much more expensive than copper or nickel.

These probes may be supplied with either single or dual elements. The probe can be suplied with extension lead wire, process connection connectors. The lead wires can be PVC, silicone, PTFE or fiberglass insulation.

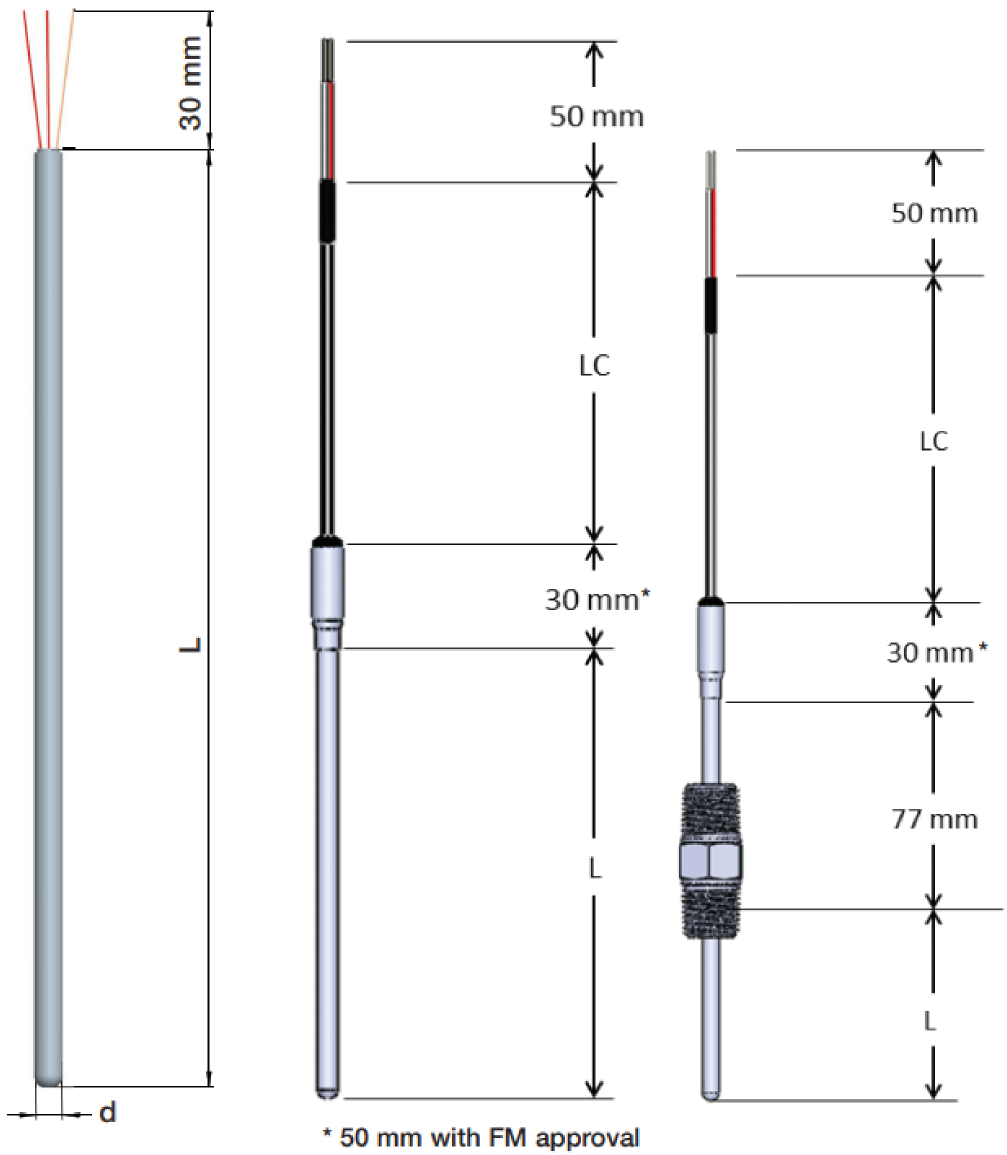


Figure 4.58 S81 RTD Temperature Sensors I Full size probe without attached wire

7. Reed switches

Magnets have a natural tendency to attract many things. Though not perceived as a real force, but it does attract human attention when a force acting invisibly draws things to itself. By harnessing this power, humans have made wonderful inventions like the electromagnet and discover lossless conduction phenomenon like superconductivity. Among these many inventions, was the application of magnetism to switch from ON state to OFF and vice-versa in precision devices. One such switching device, which works not by the principles of electricity, but magnetism, is the Reed Switch. Reed switches work like an electromechanical relay switch, while the latter conducts current, the former conducts magnetic flux which is the quantitative measurement of magnetic field on a surface. First Invented by Bell Laboratories, reed switches today have a length of just a few millimeters and are used in numerous applications that range from a simple coffee maker to rain gauge, and satellite TV positioning.

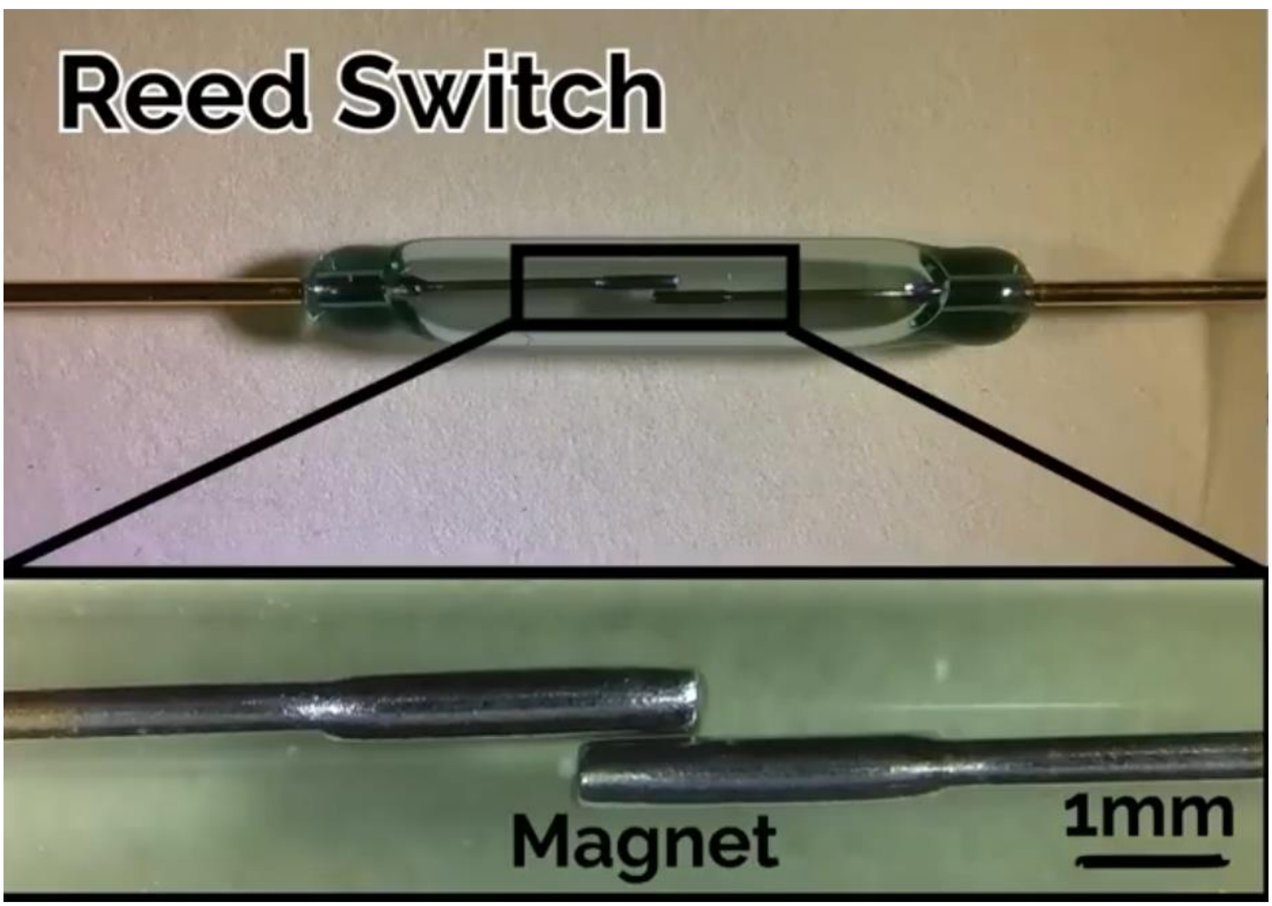


Figure 4.59 zoom in on the magnetic of Reed switch

- *Structure*
  a Single Pole Single Throw (SPST) Normally Open Switch. One of the most common types, it is a simple switch that connects two terminals (SPST). When not in use, the switch is open and does not conduct (Normally Open). The structure of reed switch is quite clear right from the first sight. it is an assembly of connecting leads and a glass capsule. The glass capsule is hermetically (air tight) sealed It is achieved by partially annealing the capsule after the reed switch is made. Reeds also undergo the process of annealing like the glass capsule so that iron-nickel based ferromagnetic material does not retain any magnetism after the magnetic field is taken off. Making the capsule air tight ensures that switch is least affected by variable ambient temperature and pressure conditions. The process of sealing is usually carried out at elevated temperatures so that reed switch does not break down at high voltages like 240V.
- *The Reed*
  The name "Reed" is derived from a slender and tall species of grass which is known by the same name. The ferromagnetic material along with the contact area resembles a slender 'reed' grass structure with its flattened end. As the name suggests, the reed is the heart of the switch and ideally is sensitive to slightest of change in the magnetic field. The iron-nickel part is joined to the connecting leads through soldering. Tin is plated over the iron-nickel leads in order to facilitate easy and long-lasting soldering process. The reeds have reasonable elasticity with the intention that they can bend and connect when magnetic field is applied and get restored when the field is withdrawn. The magnetic field has to be strong enough so that it can cross the threshold of restoring. The reed shown in the image below has one end in a flattened rectangular shape where Rhodium, Ruthenium coat has been done. The flattened end can have a circular or any other polygonal shape as per the application of the switch.
- *Working: In order to make the Reed switch work, it can be:*
  - *Placed parallel to a magnet.*
  - *Placed between magnetic coils.*

8. Cooling source

Since the application is thermal and everything needed to heat and deliver the powder metal to a pre-melting point, this is considered hostile to some external parts to operate, and what is meant by some are the electronic parts.

Care was taken to place them on the top of the printer for easy access, especially if maintenance or replacement of some parts is required.

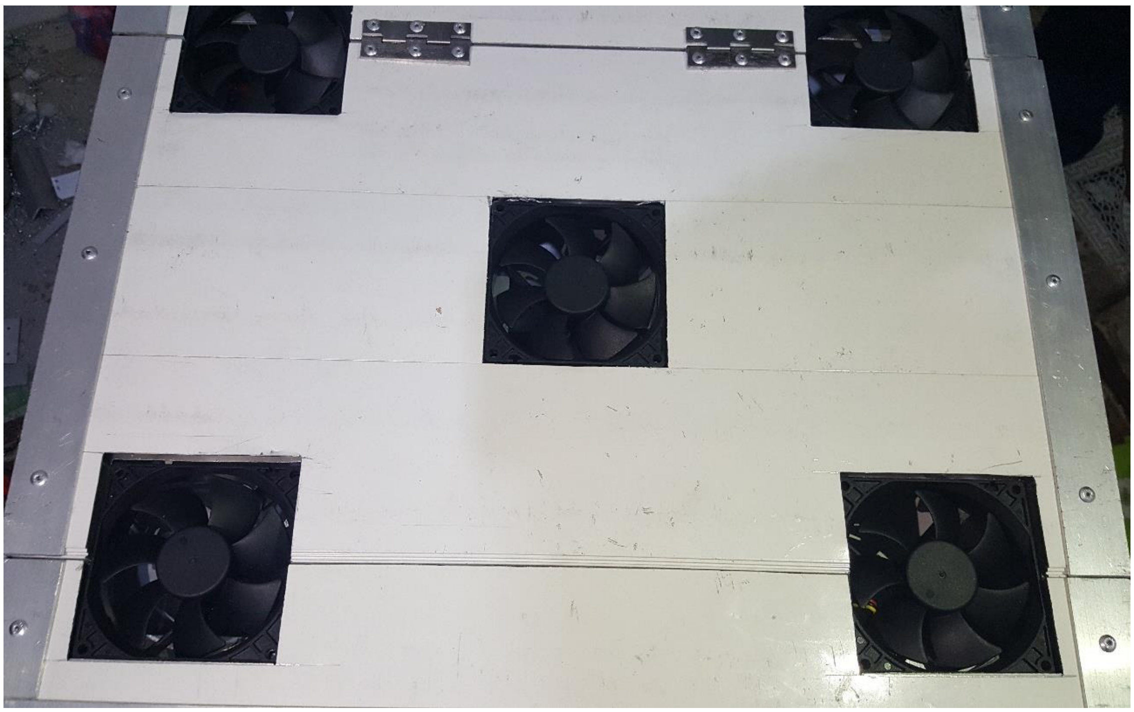


Figure 4.60 The cooling system is located above the ceiling of the electric room in the printer.

Care was also taken to enlarge the area of the thermal insulation wool, but an external cooling source such as fans had to be used to maintain the coolness of the electronic parts of the converter, controller, drivers, and other parts, and the 12-volt fans were sufficient for the purpose of cooling.

4.3.2 Software Requirements

More formally, a software requirement can be defined as a feature or non-functional constraint that the software must provide to fulfill the needs of users and other stakeholders. Requirements represent the core functionality that software must deliver in order to be useful and meet business process or user goals.

Software requirements for a system are the description of what the system should do, the service or services that it provides and the constraints on its operation. The IEEE Standard Glossary of Software Engineering Terminology defines a requirement as:

A condition or capability needed by a user to solve a problem or achieve an objective

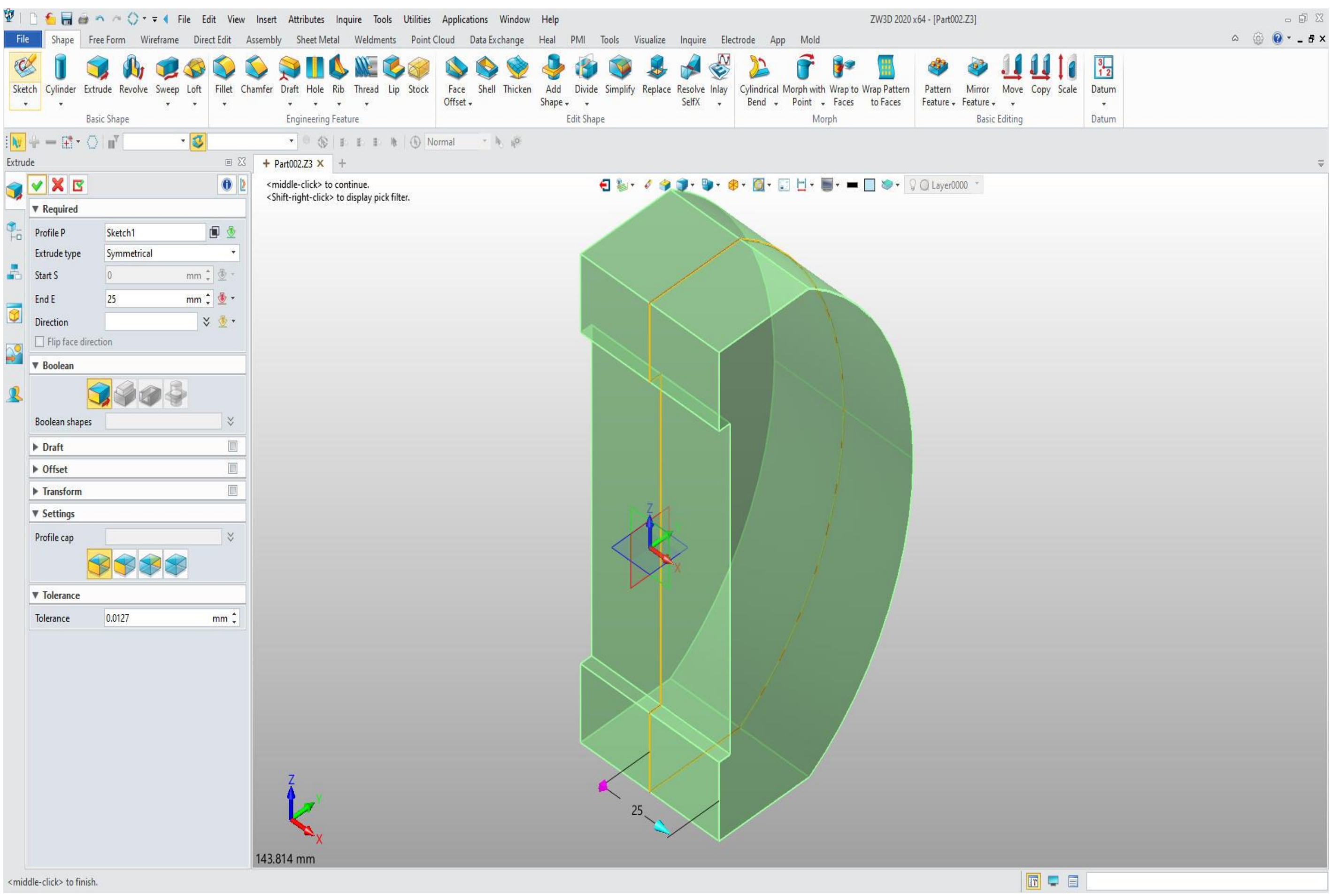


Figure 4.61 modeling using one of the CAD programs

A condition or capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification, or other formally imposed document

A documented representation of a condition or capability as in 1 or 2

The activities related to working with software requirements can broadly be broken down into elicitation, analysis, specification, and management.

Note that the wording Software requirements is additionally used in software release notes to explain, which depending on software packages are required for a certain software to be built/installed/used.

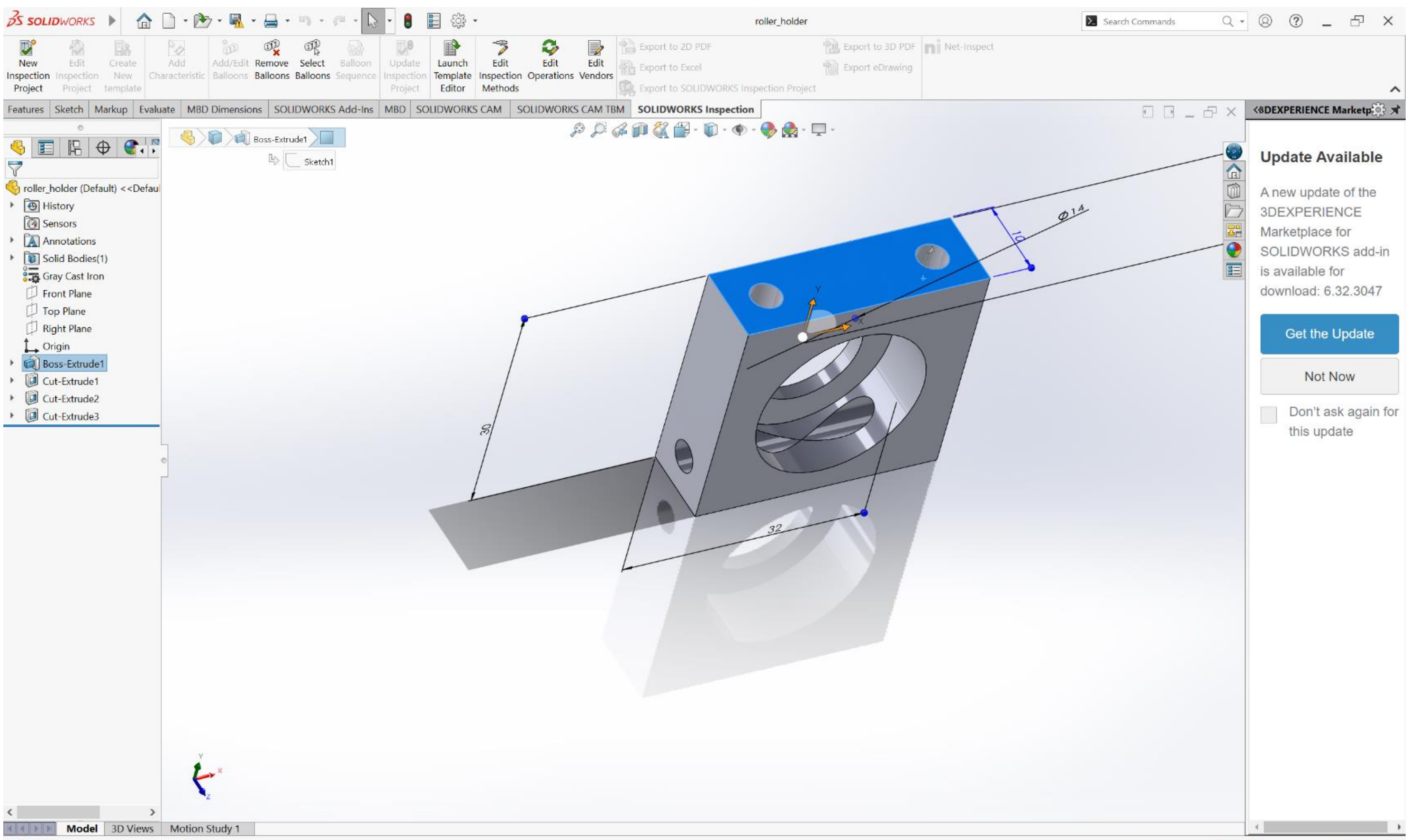


Figure 4.62 design by using the solid work program

STL files interpret the geometrical surfaces of 3D models created with the help of CAD software. Though other file formats exist, the STL format is simple to understand and use. STL files describe, interpret, or encode these surfaces in a series of small triangles, called tessellation or tiling. The complexity of the models or designs is proportional to the number of triangles used and the resolution of the 3D image. In addition, 3D STL files work hand-in-hand with the slicer software to make the job of 3D printers a reality.

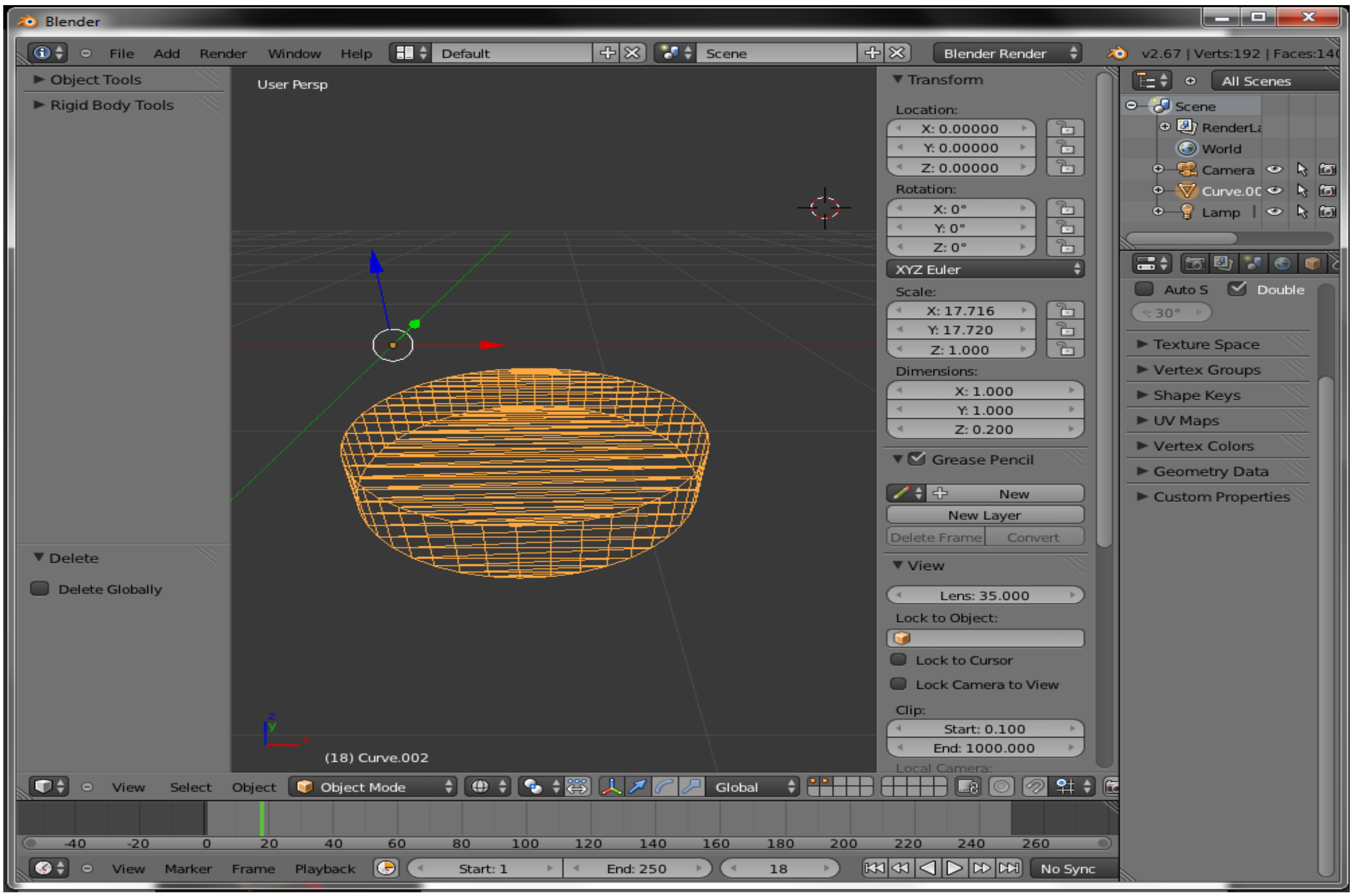


Figure 4.63 Create an STL file for the part after designing it, defining the part's features, details, and initial monitoring.

Origins of the STL File Format

The use of STL files in 3D printing technology dates back to 1987. 3D Systems created the STL files for 3D printing under the authority of Chuck Hull, who was then president. The STL file was incorporated in their stereolithography (SLA) *printing technology, a manufacturing technology that uses a photosensitive resin to build objects in layers. However, since the inception of STL files, the underlying principle has not changed much. It still encodes the surface geometry of objects in a standard triangle or standard tessellation language.*

modeling in CAD software or you can use solid work software program, you can create any part you want to print by a 3D SLS metal printer

Modeling

If you want to print a 3D object, you naturally need to obtain a digital model of the object. Modeling will turn the object you want to print into a digital model that can be printed on a 3D printer. You can create 3D models with 3D modeling software (such as CAD software for 3d printing). Of course, you can also download the model files other users create. The STL files are widely used in rapid prototyping, 3D printing, and computer-aided manufacturing (CAM). The ideaMaker Library of Raise3D will also provide you with a platform where you can share and obtain 3D modeling models and settings files.

Slicing

When you have a designed model, you can use specific slicing software such as ideaMaker to slice the model. The purpose of slicing is to allow the 3D printer to calculate the route and the amount of filament required when printing the model. Just like building a house, you need to calculate the steps to build and the amount of wood needed. ideaMaker will generate a GCode file, which is essentially a long list of instructions, and then the 3D printer will read the GCode instruction to build the model.

ideaMaker is a powerful slicing software, which can create personalized configurations according to different printers, filaments, and models, it can also automatically create precise support structures. Therefore, ideaMaker will provide you with more possibilities for creativity [12].

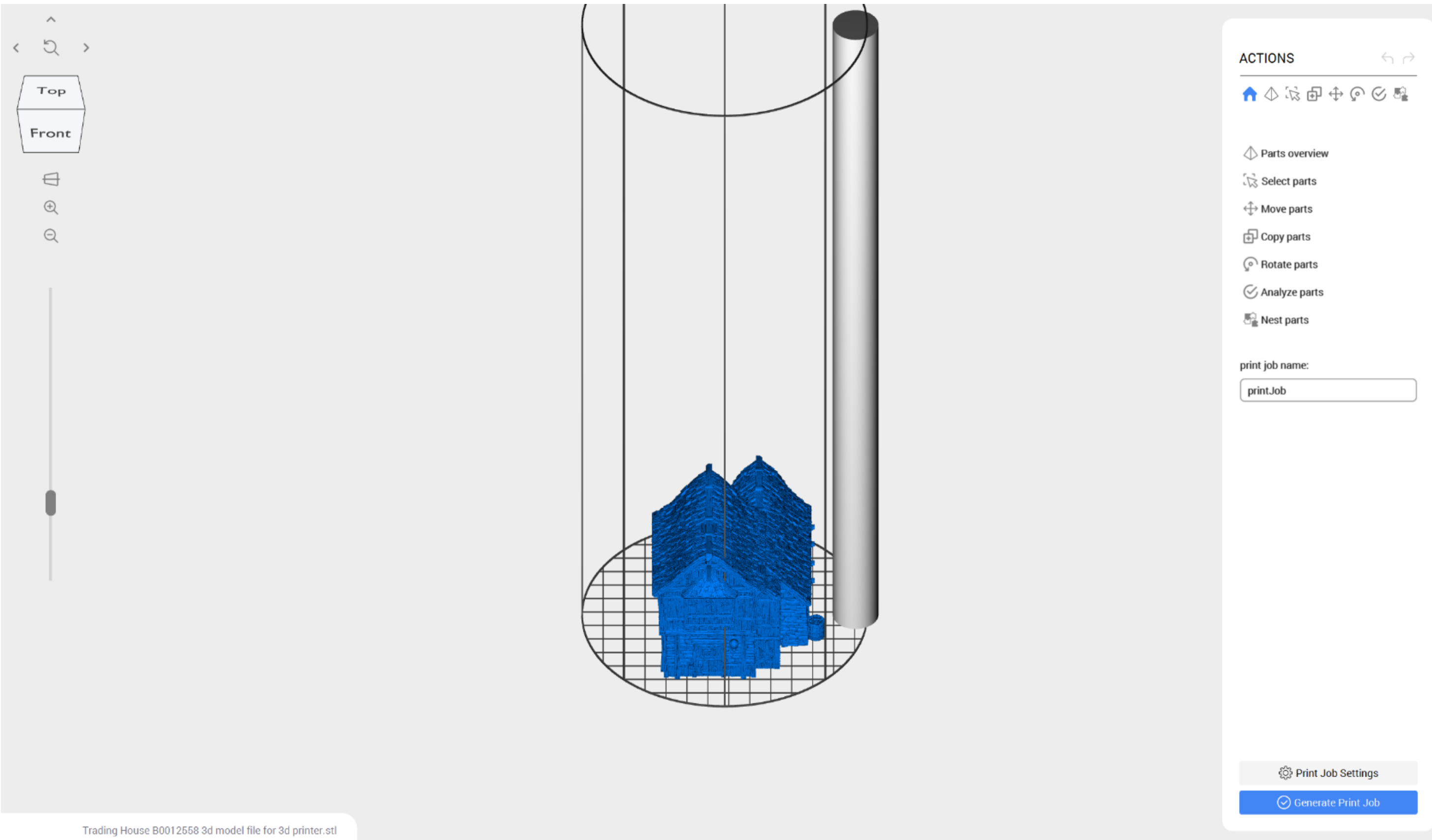


Figure 4.64 Arrange ready-to-print shapes in the arrangement programs for SLS 3D metal Printer

Place the final shape ready for printing in the shape arrangement programs during printing in order to know if the shape needs supports and if there is a defect in printing the shape in the vertical or horizontal direction by changing the direction of the shape and arranging the shapes if there are many shapes and avoid printing at the edges to avoid ruining the shape and not obtaining the ideal measurements.

- *Select or create a 3D model using any desired CAD software like*
- *SolidWorks and save the model as an .STL file.*
- *Open Slic3r and add the model(s) to the workspace. Perform any*
- *orientation/translation movements of models and then export the G-code*
- *Open the G-code post-processing script in MATLAB and set the laser*
- *power to 50%, scan speed to 650 mm/s and enter the number of objects*
- *(models) that were placed in the workspace. Run the script with the input*
- *file as the Gcode generated previously by Slic3r.*
- *Open Mach3 and load the G-code that was generated by the Slicer*

- *software.*
- *Turn the power on for the SLM 3DP control box. Using the Mach3 console,*
- *actuate the feed pistons (B axis) in the downward direction by at least half*
- *of the height of the model being built. While placing a straight edge across*
- *the build piston, actuate it in the upward direction at least 1 mm above the*
- *piston assembly then actuate it in the downward direction until the surface*
- *of the piston is level with the top of the piston assembly. This is done to*
- *account for any backlash in the lead screw.*
- *Load the feed piston to the top with Aluminum powder.*
- *Put the laser safety glasses on and turn the power on for the laser module.*
- *From this point onwards it is important that laser safety glasses are worn*
- *at all times to avoid eye damage – also ensure other people are isolated*
- *from any radiation – e.g. by locking the door.*
- *The build sequence can now be initiated by clicking "Cycle Start" on the*
- *Mach3 interface. For the first couple of operations, it is recommended that*
- *the build sequences are closely monitored to ensure that the machine has*
- *been set up correctly.*
- *When the build has completed, the power to the laser can be switched off*
- *and the build lead screw allowed to cool for at least 30 min.*
- *Once the powder bed has had sufficient time to cool, the powder can be*
- *removed from the build piston and feed piston using a small wet and dry*
- *vacuum cleaner. If the powder cake is to be re-used it is recommended that*
- *a new vacuum cleaner is purchased and dedicated to this job to avoid*
- *contamination.*
- *Remove the part(s) using a paint scraper or similar. Once the build volume*
- *is empty, use a rag and solvent (ethanol or similar) to wipe the build plate*
- *clean.*

Chapter 5 Conclusion and Future Work Suggestion

5.1 Conclusion

In this project, we used one of the most important methods in 3D printers, which is SLS technology, to enable us to create solid metal parts with an ideal surface finish that can be used for several different purposes. It is also possible to change the metal powder used to print flexible and strong parts such as metals, which will improve the industry in general. Our goal in this project is to provide solid metal parts that are rarely found in local markets and are expensive if they exist. We tried hard to reconcile saving time and effort with specific capabilities to raise the status of the local market in Yemen and to provide parts that are difficult to obtain for local markets in general. Our application of this printer targets several parties, including commercial, medical and industrial. Through research and experiments, we achieved the following:

- *Create a modern 3D printer that works with SLS technology to create solid parts, and from it the metal powder can be changed to create metal parts from different materials with suitable sizes and an ideal surface finish.*
- *Saving time and effort: Instead of using traditional methods to create some metal parts, they can now be produced in an SLS printer, saving both effort and time. Also, saving time by creating some parts that cannot be made using traditional methods and ordering them from foreign markets can now be made locally and at a low price.*
- *Facilitating the methods of creating metal parts by dispensing with traditional methods and using technology by designing the parts through design programs and then printing them using a printer so that the process is completed in a fully automated manner.*
- *Reducing waste generated by CNC machines to build metal parts through SLS technology and recycling the powder used after each printing process.*

5.2 problems and solutions

We faced several problems in building this printer. These problems can be mentioned in the following points:

- *The high prices of aluminum sheets and extruded aluminum columns made it necessary to use aluminum in the printer due to its corrosion and heat absorption properties. We replaced the aluminum sheets and columns of the extruded aluminum with the latest aluminum available in the local market at a lower cost called the private sector, but this solution did not improve the quality of the printer.*
- *The absence of some electronic parts in the local markets that cannot be replaced by another part due to their importance in the project.*
- *The presence of some expensive electronic parts led to their replacement with other inexpensive parts to complete the project.*
- *Exclude some suggestions that would develop the printer and increase its features and record these suggestions among future suggestions for developing the printer.*

5.3 Future Work Suggestion

It takes a long time to talk about future proposals to develop the project because of the advancement of technology in the modern era. It cannot be said that there are projects that have reached the point of being self-sufficient in their development. In fact, they are being released with versions and updates that are more advanced than their predecessors. In this project, we faced many problems, including the high prices of some electronic parts and some boosters that could have increased the efficiency and features of the project, which made us think about focusing on ending the project and recording the advantages and development for the future. Therefore, there are many future proposals that can be made to improve, develop and increase the efficiency of the printer.

- *Building a monitoring system that is limited to the presence of a thermal camera inside the printer connected to an external screen to follow the printing of the part moment by moment. Through this feature, it is possible to know if any problem occurs during printing and it is possible to follow up and identify the point at which the printing of the part reaches.*
- *Replace the regular scanner with a three-motion cylinder scanner to speed up the process.*
- *Replacing some parts with others of higher quality and better efficiency to increase the advantages of the printer.*
- *Create a small machine with a vibrating system that sifts the powder for easy recycling for use again.*
- *Create a small, high-powered suction cup to be able to completely suck up the powder and not waste it for recycling and to facilitate the process of cleaning the parts after printing.*
- *Developing the processing of printed parts and introducing heat treatment to ensure the quality and hardness of the parts and their reaching the required size.*
- *Expanding the print chambers or bed allows us to print larger metal parts.*

References

[1] *Low cost 3D printing of metals using filled polymer pellets (2022) a Univ. Lille, Arts et Metiers Institute of Technology, Centrale Lille, Junia, ULR 2697– L2EP Lille, France bUniv. Lille, CNRS, Centrale Lille, UMR 9013– LaMcube– Laboratoire de Mécanique, Multiphysique, Multiéchelle, Lille, France c CRITT-MDTS, Charleville-Mézières, France*

[2] *Modification of a desktop FFF printer via NIR laser addition for upconversion 3D printing (2024) [a]Institute of Sensors, Signals and Systems, Heriot-Watt University, EH14 4AS, Edinburgh, United Kingdom UMDO, Instituto de Ciencia de los Materiales, University of Valencia, Valencia, 46980 Spain Applied Physics Department, University of Valencia, Valencia 46980 Spain*

[3] *High-performance polymer 3D printing – Open-source liquid cooled scalable printer design (2022) Department of Mechanical and Industrial Engineering, Norwegian University of Science and Technology, Trondheim, Norway Department of Civil and Environmental Engineering, Center for Sports Facilities and Technology, Norwegian University of Science and Technology, Trondheim, Norway*

[4] *Development and validation of a low-cost polymer selective laser sintering machine 2020 [a] School of Engineering and Built Environment, Griffith University, Queensland, Australia [b]Innovative Cardiovascular Engineering and Technology Laboratory, The Prince Charles Hospital, Brisbane, Queensland, Australia [c]University of Queensland, Brisbane, Queensland, Australia [d]Department of Mechanical and Aerospace Engineering, Monash University, Melbourne, Victoria, Australia*

[5] *Li Yang ,Keng Hsu ,Brian Baughman, Donald Godfrey , Francisco Medina , Mambally kalathil, Menon and Soeren Wiener," Additive Manufacturing of Metals: The Technology, Materials, Design and Production", Springer International Publishing AG 2017.*

[6] *TEKNIC, "How to Choose the Best Linear Actuator for your Application", 2020.*

[7] *Hyub Lee, Mun Ji Low, Nicholas Tham, Murukeshan Vadakke Matham, "Lasers in additive manufacturing: A review", Article in International Journal of Precision Engineering and Manufacturing-Green Technology, 2017.*

[8] *Lasergods, "Laser Lenses, Optics, and Focus - LaserGods.com", 2020.*

[9] *LMC Laser Services Pty. Ltd., "www.lmclaser.com.au", 2014.*

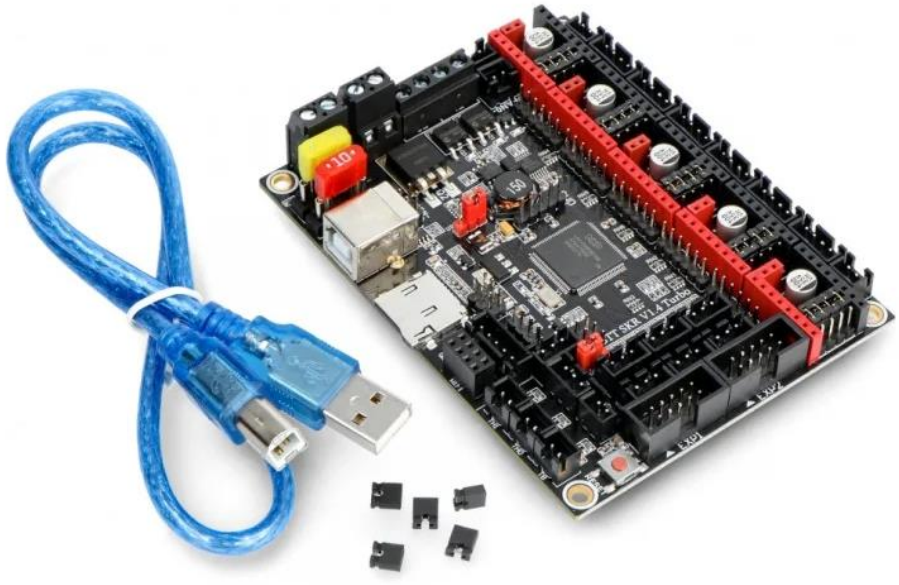
[10] *Graduation Project Thesis: 3D Metal Printer [Design, Simulation, and Fabrication] using Selective Laser Melting (SLM) 2021*

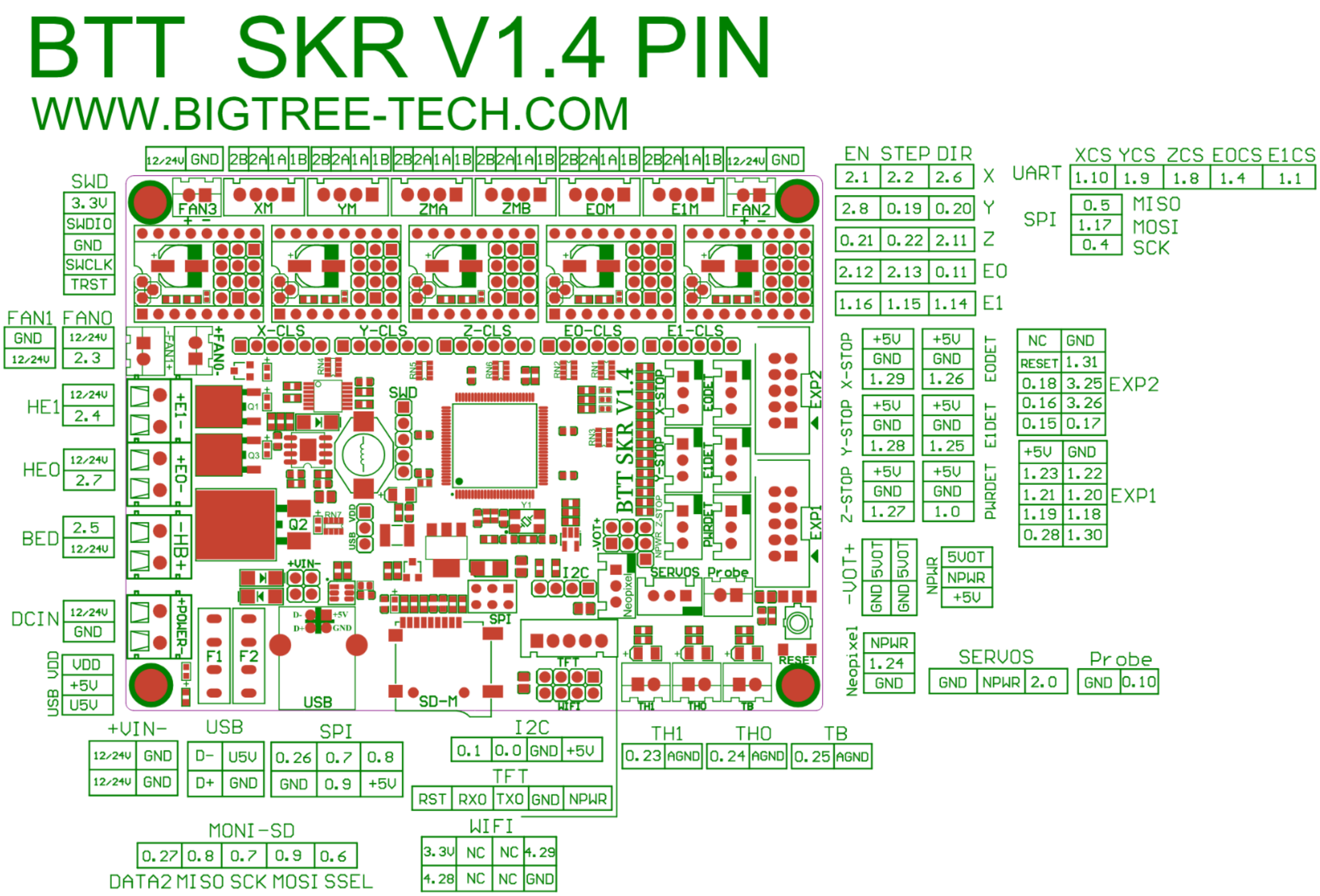
[11] *THORLABS, "GVS011 and GVS012 Large Mirror Diameter Scanning Galvo Systems", 2011. [15] https://www.orientalmotor.com/products/pdfs/2012-2013/A/usa_st_pk_motor_only.pdf [16] Martin Mapley, Yidi Lu, Shaun D. Gregory , Jo P. Pauls, Geoff Tansley, Andrew Busch, "Development and validation of a low-cost polymer selective laser sintering machine", HardwareX 8 e00119, 2020.*

[12] *High-performance polymer 3D printing– Open-source liquid cooled scalable printer design 2022 a Department of Mechanical and Industrial Engineering, Norwegian University of Science and Technology, Trondheim, Norway bDepartment of Civil and Environmental Engineering, Center for Sports Facilities and Technology, Norwegian University of Science and Technology, Trondheim, Norway*

Appendices

Appendix a




BTT SKR V1.4 PIN
WWW.BIGTREE-TECH.COM
12/24V GND 2B 2A 1A 1B 2B 2A 1A 1B 2B 2A 1A 1B 2B 2A 1A 1B 2B 2A 1A 1B 2B 2A 1A 1B 12/24V GND
FAN3 XM YM ZMA ZMB E0M E1M FAN2
SWD
3.3V
SWDIO
GND
SWCLK
TRST
FAN1 FAN0
GND 12/24V
12/24V 2.3
HE1 12/24V 2.4
HE0 12/24V 2.7
BED 2.5 12/24V
DCIN 12/24V GND
USB VDD
VDD
+5V
U5V
X-CLS Y-CLS Z-CLS E0-CLS E1-CLS
SWD
BTT SKR V1.4
I2C
SERVOS Probe
Neopixel
USB
SD-M
TFT
WIFI
RESET
EXP1 EXP2
F1 F2
EN STEP DIR
2.1 2.2 2.6 X
2.8 0.19 0.20 Y
0.21 0.22 2.11 Z
2.12 2.13 0.11 E0
1.16 1.15 1.14 E1
UART
XCS YCS ZCS E0CS E1CS
1.10 1.9 1.8 1.4 1.1
SPI
0.5 MISO
1.17 MOSI
0.4 SCK
X-STOP Y-STOP Z-STOP
+5V GND 1.29
+5V GND 1.28
+5V GND 1.27
E0DET E1DET PWRDET
+5V GND 1.26
+5V GND 1.25
+5V GND 1.0
EXP2
NC GND
RESET 1.31
0.18 3.25
0.16 3.26
0.15 0.17
EXP1
+5V GND
1.23 1.22
1.21 1.20
1.19 1.18
0.28 1.30
-VOT+
GND 5VOT
GND 5VOT
NPWR
5VOT
NPWR
+5V
Neopixel
NPWR
1.24
GND
SERVOS
GND NPWR 2.0
Probe
GND 0.10
+VIN-
12/24V GND
12/24V GND
USB
D- U5V
D+ GND
SPI
0.26 0.7 0.8
GND 0.9 +5V
I2C
0.1 0.0 GND +5V
TFT
RST RXO TXO GND NPWR
TH1 TH0 TB
0.23 AGND 0.24 AGND 0.25 AGND
MONI-SD
0.27 0.8 0.7 0.9 0.6
DATA2 MISO SCK MOSI SSEL
WIFI
3.3V NC NC 4.29
4.28 NC NC GND

SKR V1.4 32bit Controller Board - Technical Specifications:

Main Control Chip	*– 120MHz ARM Cortex-M3 LPC1769*
Input Voltage	*– 12V / 24V DC (Optional)*
Stepper Driver Compatibility	*– TMC2100 | TMC2130* *– TMC2208 | TMC2209 | TMC2225* *– TMC5160 | TMC5161* *– A4988 | DRV8825 | ST820 | LV8729* *– Also Supports External Drivers*
Integrated Extra Functions	*– Print Resume Functionality* *– Filament Break Detection* *– Automatic Shutdown After Print* *– Automatic Bed Levelling* *– BLTouch Capable* *– UART / SPI Driver Compatible*
Motor Interfaces	*– X | Y | Z^1/Z^2 | E0 | E1* *– Each Offers up to 256 Subdivisions* *– Z Axis Features Dual Output* *– Closed Loop Stepper Interface*
Heating Element Interfaces	*– HE0: Extruder 1 Terminal* *– HE1: Extruder 2 Terminal* *– HB: Heated Bed Terminal*
Thermistor Interfaces	*– TH0: Extruder 1 Port* *– TH1: Extruder 2 Port* *– TB: Heated Bed Port*
Display Interfaces	*– EXP1 + EXP2: LCD Display Ports* *– AUX-1: Port for TFT Display* *–* *Supports TFT28 | TFT35 | LCD2004 | LCD12864*
End Stop Ports	*– X- | X+* *– Y- | Y+* *– Z- | Z+*
Additional Interfaces	*– USB-B Port: Computer to Board Interface* *– TF Card Slot: Printing from Micro SD Card* *– CNC Fan Port: PWM Capable for Speed Control* *– 3 x Fan Ports: For Always-On Cooling Fans* *– 3-Pin LED Port: For RGB LED Strips & Neopixels* *– WiFi Port: For Dedicated ESP-01S WiFi Module*
Firmware Support	*– Marlin2.0 | Smoothieware*
Parts Included with the SKR V1.4	*– USB-B Cable*
Weight	*– ±160g*
Dimensions	*– 85 x 110mm*

Appendix b

Stepper Motor NEMA 17

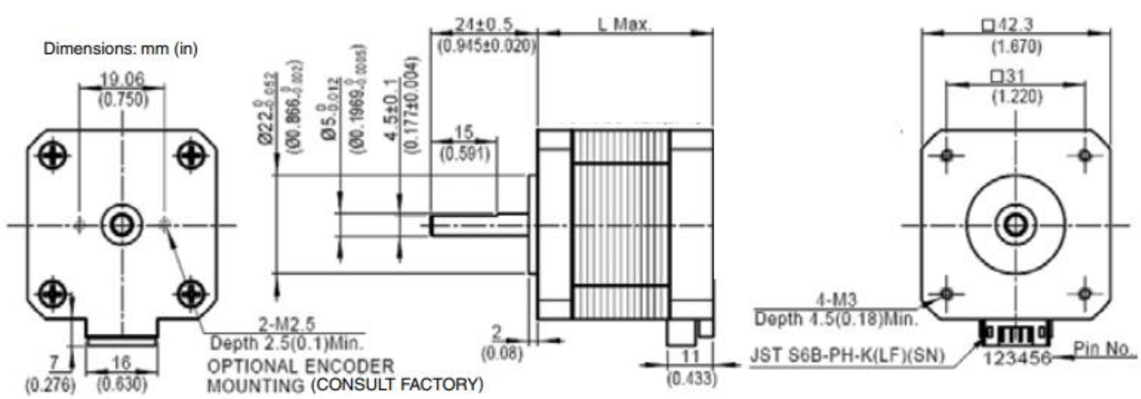
This document describes mechanical and electrical specifications for PBC Linear stepper motors; including standard, hollow, and extended shaft variations.

Standard shaft motor shown.

Phases	2
Steps/Revolution	200
Step Accuracy	±5%
Shaft Load	20,000 Hours at 1000 RPM
Axial	25 N (5.6 lbs.) Push
	65 N (15 lbs.) Pull
Radial	29 N (6.5 lbs.) At Flat Center
IP Rating	40
Approvals	RoHS
Operating Temp	-20° C to +40° C
Insulation Class	B, 130° C
Insulation Resistance	100 MegOhms

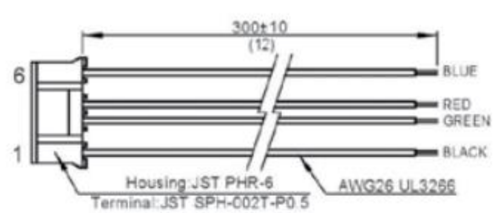
Description	Length	Mounted Rated Current	Mounted Holding Torque		Winding		Detent Torque		Rotor Inertia		Motor Weight	
					Ohms	mH						
(Stack)	"L" Max	Amps	Nm Typ.	oz-in Typ.	±10% @ 20°C	Typ.	mNm	oz-in	g cm2	oz-in2	kg	lbs
Single	39.8 mm (1.57 in)	2	0.48	68	1.04	2.2	15	2.1	57	0.31	0.28	0.62
Double	48.3 mm (1.90 in)	2	0.63	89	1.3	2.9	25	3.5	82	0.45	0.36	0.79
Triple	62.8 mm (2.47 in)	2	0.83	120	1.49	3.8	30	4.2	123	0.67	0.6	1.3

*All standard motors have plug connector. Consult factory for other options.



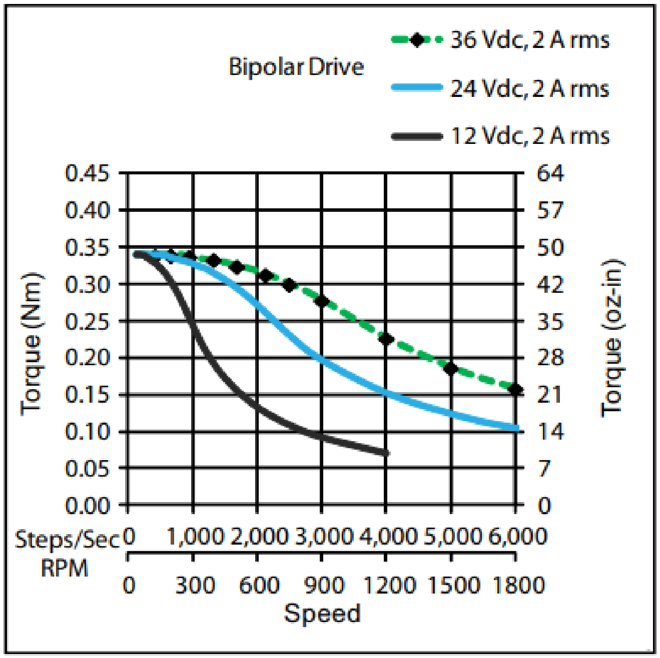
Standard shaft dimensions shown. All other dimensions apply to hollow and extended shaft options.

Dimensions: mm (in)
4 Lead Connector, PBC Part#6200490
(Consult factory for optional motor connectors)

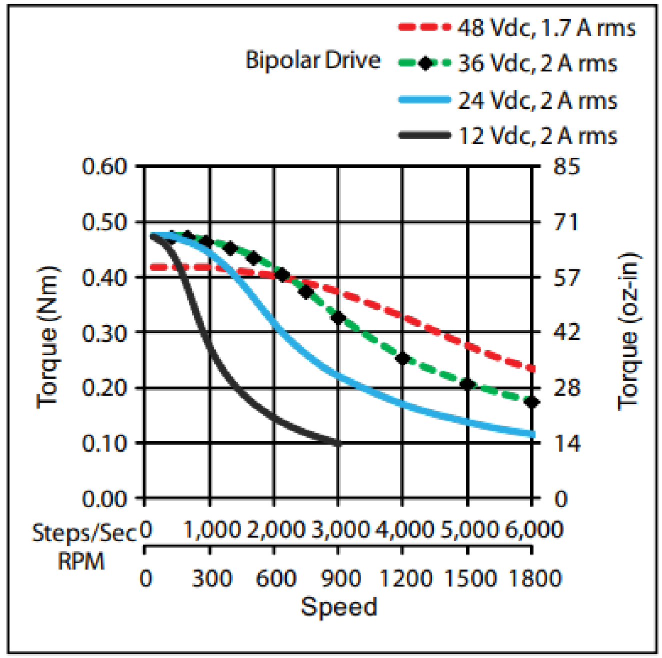


NEMA 17 **Stepper Motor**

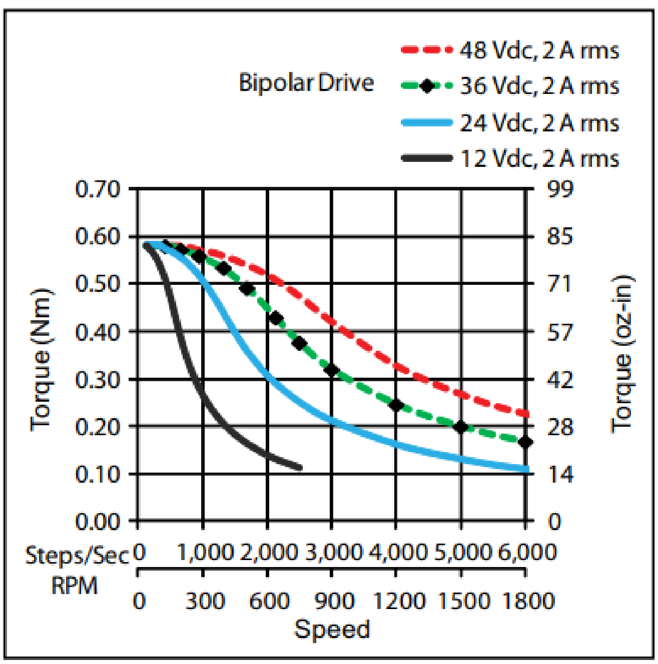
*Performance curves apply to continuous duty cycles.
Consult factory for intermittent cycles or other voltages.



Single Stack



Double Stack



Triple Stack

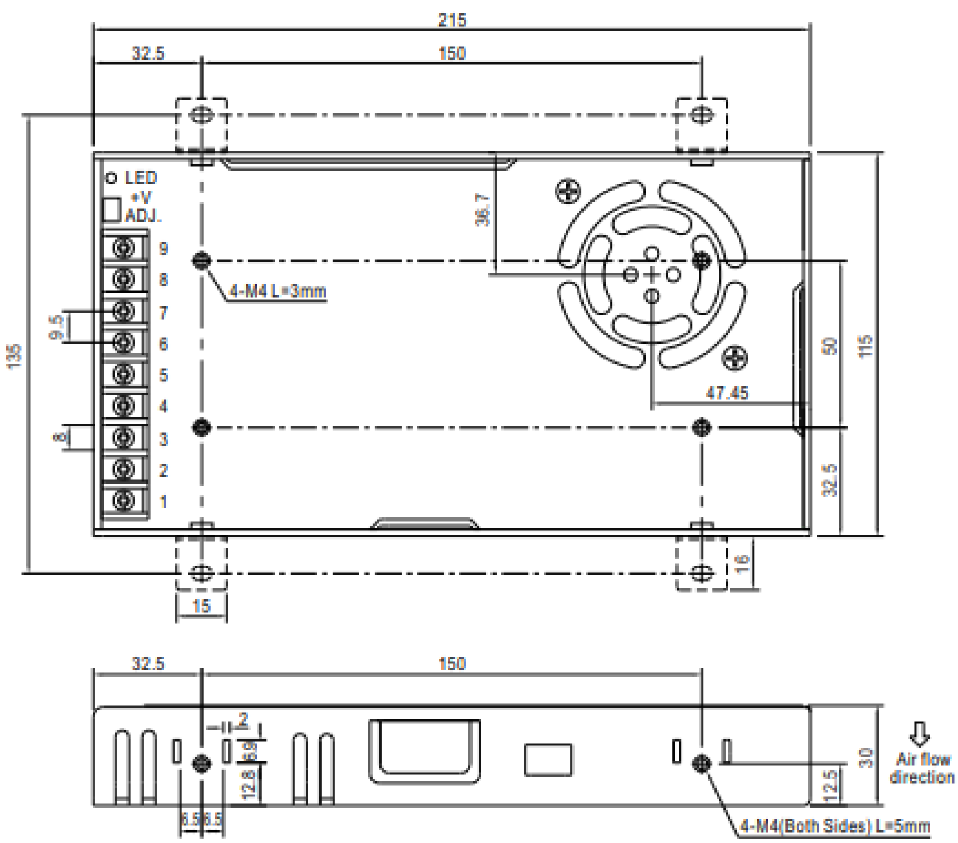
Appendix c

MEAN WELL

350W Single Output Switching Power Supply **LRS-350 series**

Mechanical Specification

Case No.207A Unit:mm



Terminal Pin No. Assignment :

Pin No.	Assignment	Pin No.	Assignment
1	AC/L	4~6	DC OUTPUT -V
2	AC/N	7~9	DC OUTPUT +V
3	FG ⏚		

Installation Manual

Please refer to : http://www.meanwell.com/manual.html

MEAN WELL 350W Single Output Switching Power Supply **LRS-350 series**

SPECIFICATION

MODEL		LRS-350-3.3	LRS-350-4.2	LRS-350-5	LRS-350-12	LRS-350-15	LRS-350-24	LRS-350-36	LRS-350-48
OUTPUT	DC VOLTAGE	3.3V	4.2V	5V	12V	15V	24V	36V	48V
	RATED CURRENT	60A	60A	60A	29A	23.2A	14.6A	9.7A	7.3A
	CURRENT RANGE	0 ~ 60A	0 ~ 60A	0 ~ 60A	0 ~ 29A	0 ~ 23.2A	0 ~ 14.6A	0 ~ 9.7A	0 ~ 7.3A
	RATED POWER	198W	252W	300W	348W	348W	350.4W	349.2W	350.4W
	RIPPLE & NOISE (max.) Note.2	150mVp-p	150mVp-p	150mVp-p	150mVp-p	150mVp-p	150mVp-p	200mVp-p	200mVp-p
	VOLTAGE ADJ. RANGE	2.97 ~ 3.6V	3.6 ~ 4.4V	4.5 ~ 5.5V	10.2 ~ 13.8V	13.5 ~ 18V	21.6 ~ 28.8V	32.4 ~ 39.6V	43.2 ~ 52.8V
	VOLTAGE TOLERANCE Note.3	±4.0%	±4.0%	±3.0%	±1.5%	±1.0%	±1.0%	±1.0%	±1.0%
	LINE REGULATION Note.4	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%
	LOAD REGULATION Note.5	±2.5%	±2.5%	±2.0%	±1.0%	±0.5%	±0.5%	±0.5%	±0.5%
	SETUP, RISE TIME	1300ms, 50ms/230VAC 1300ms,50ms/115VAC at full load							
	HOLD UP TIME (Typ.)	16ms/230VAC 12ms/115VAC at full load							
INPUT	VOLTAGE RANGE	90 ~ 132VAC / 180 ~ 264VAC by switch 240 ~ 370VDC (switch on 230VAC)							
	FREQUENCY RANGE	47 ~ 63Hz							
	EFFICIENCY (Typ.)	79.5%	81.5%	83.5%	85%	86%	88%	88.5%	89%
	AC CURRENT (Typ.)	6.8A/115VAC 3.4A/230VAC							
	INRUSH CURRENT (Typ.)	60A/115VAC 60A/230VAC							
	LEAKAGE CURRENT	<2mA / 240VAC							
PROTECTION	OVER LOAD	110 ~ 140% rated output power							
		3.3~36V Hiccup mode, recovers automatically after fault condition is removed. 48V Shut down and latch off o/p voltage, re-power on to recover.							
	OVER VOLTAGE	3.8 ~ 4.45V	4.6 ~ 5.4V	5.75 ~ 6.75V	13.8 ~ 16.2V	18 ~ 21V	28.8 ~ 33.6V	41.4 ~ 46.8V	55.2 ~ 64.8V
		3.3~36V Hiccup mode, recovers automatically after fault condition is removed. 48V Shut down and latch off o/p voltage, re-power on to recover.							
	OVER TEMPERATURE	3.3~36V Hiccup mode, recovers automatically after fault condition is removed. 48V Shut down and latch off o/p voltage, re-power on to recover.							
FUNCTION	FAN ON/OFF CONTROL (Typ.)	RTH3≧50℃ FAN ON, ≦40℃ FAN OFF							
ENVIRONMENT	WORKING TEMP.	-25 ~ +70℃ (Refer to "Derating Curve")							
	WORKING HUMIDITY	20 ~ 90% RH non-condensing							
	STORAGE TEMP., HUMIDITY	-40 ~ +85℃, 10 ~ 95% RH							
	TEMP. COEFFICIENT	±0.03%/℃ (0 ~ 50℃)							
	VIBRATION	10 ~ 500Hz, 5G 10min./1cycle, 60min. each along X, Y, Z axes							
	OVER VOLTAGE CATEGORY	III: According to EN61558, EN50178, EN60664-1, EN62477-1; altitude up to 2000 meters							
SAFETY	SAFETY STANDARDS	IEC/UL 62368-1,BSMI CNS15598-1,EAC TP TC 004,KC62368-1(for LRS-350-12/24 only),GB 4943.1, BIS IS13252(Part1): 2010/IEC 60950-1: 2005(NOTE 11),BS EN/EN61558-1, BS EN61558-2-16 Designed by AS/NZS 61558.1/2.16, AS/NZS 62368.1,BS EN/EN62368-1,							
	WITHSTAND VOLTAGE	I/P-O/P:3.75KVAC I/P-FG:2KVAC O/P-FG:0.5KVAC							
	ISOLATION RESISTANCE	I/P-O/P, I/P-FG, O/P-FG:100M Ohms/500VDC / 25℃/ 70% RH							
	EMC EMISSION	Compliance to BSMI CNS15936, EAC TP TC 020,KS C 9832, KS C 9835(for LRS-350-12/24 only)							
	EMC IMMUNITY	Compliance to BS EN/EN55035, EAC TP TC 020,KS C 9832, KS C 9835(for LRS-350-12/24 only)							
OTHERS	MTBF	2099.9K hrs min. Telcordia SR-332 (Bellcore) ; 328.6Khrs min. MIL-HDBK-217F (25℃)							
	DIMENSION	215*115*30mm (L*W*H)							
	PACKING	0.76Kg; 15pcs/12.4Kg/0.67CUFT							

NOTE

1. All parameters NOT specially mentioned are measured at 230VAC input, rated load and 25℃ of ambient temperature.
2. Ripple & noise are measured at 20MHz of bandwidth by using a 12" twisted pair-wire terminated with a 0.1uf & 47uf parallel capacitor.
3. Tolerance : includes set up tolerance, line regulation and load regulation.
4. Line regulation is measured from low line to high line at rated load.
5. Load regulation is measured from 0% to 100% rated load.
6. Length of set up time is measured at cold first start. Turning ON/OFF the power supply very quickly may lead to increase of the set up time.
7. The 150% peak load capability is built in for up to 1 second for 12~48V.LRS-350 will enter hiccup mode if the peak load is delivered for over 1 second and will recover once it resumes to the rated current level(115VAC/230VAC).
8. The ambient temperature derating of 5℃/1000m is needed for operating altitude greater than 2000m(6500ft).
9. This power supply does not meet the harmonic current requirements outlined by BS EN/EN61000-3-2. Please do not use this power supply under the following conditions:
   a) the end-devices is used within the European Union, and
   b) the end-devices is connected to public mains supply with 220Vac or greater rated nominal voltage, and
   c) the power supply is:
      - installed in end-devices with average or continuous input power greater than 75W, or
      - belong to part of a lighting system

   Exception:
   Power supplies used within the following end-devices do not need to fulfill BS EN/EN61000-3-2
   a) professional equipment with a total rated input power greater than 1000W;
   b) symmetrically controlled heating elements with a rated power less than or equal to 200W
10. RCM is on voluntary basis and meets relevant IEC or AS/NZS standards complying with AS/NZS 4417.1.
11. Some model may not have the BIS logo, please contact your MEAN WELL sales for more information.

※ Product Liability Disclaimer : For detailed information, please refer to https://www.meanwell.com/serviceDisclaimer.aspx

File Name:LRS-350-SPEC 2024-05-16