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MECHANICAL ENGINEERING DEPARTMENT

Final Thesis

With a view to obtaining the Master's Diploma in Mechanical and Productive Manufacturing

Theme:

Design and build of 3D printer with a Conveyor belt system

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Acknowledgement

First and foremost, I extend my utmost gratitude to God for His guidance in every step of my learning journey and in completing this work.

To my mother and father, who raised me from a young age until I grew up and became a young adult, and to who I am today.

To everyone who taught us a letter and helped us, and to my supervisor Mr. Billel Lounici, who patiently oversaw my work.

To all whom this big heart and broad chest love.

To those who aspire to glory and follow its path.

Dedication:

As an expression of my deep gratitude,

I dedicate this work to my wonderful parents for every little and big thing they have done for me.

To my kind and generous grandmother, thank you from the depths of my heart.

To my siblings Zakaria, Assia, and Ayoub for their constant encouragement.

To the friends who accompanied me throughout the journey: Ayman, Hamza, Taqi, Fouad, Yassine, and Amine—you are all in my heart.

I dedicate this work to myself and to knowledge.

List of figures

Chapter I

Chapter II

Chapter III

Chapter IV

List of tables:

Chapter I

Chapter II

Chapter III

Contents

Abstract

In recent years, 3D printers have surged in popularity. Although 3D printing technology dates back to the 1980s, it is now regarded as one of the most significant technological breakthroughs of the 21st century. Various 3D printing processes have been developed over the years, with Fused Deposition Modeling (FDM) being one of the earliest and most popular. Despite its popularity, FDM still faces some challenges.

This study focuses on creating a cost-effective 3D printer that meets high specifications. By designing and building 3D printed parts, costs were minimized without compromising performance. The thesis also explores overcoming support structure issues by incorporating a fourth axis and addressing the challenge of printing larger objects. Our printer aims to be significantly more economical than current market alternatives while offering comparable performance.

Keywords: Additive Manufacturing, 3D Printing, Fused Deposition Modelling, Printing Objects, Design, conveyor belt of 3D Printer.

ملخص

في السنوات الأخيرة، أصبحت الطابعات ثلاثية الأبعاد شائعة جدًا .على الرغم من أن تكنولوجيا الطباعة ثلاثية الأبعاد تعود إلى الثمانينيات، إلا أنها تُعتبر الآن واحدة من أهم الإنجازات التكنولوجية في القرن الحادي والعشرين

(FDM) تم تطوير العديد من عمليات الطباعة ثلاثية الأبعاد على مر السنين، وكانت تقنية النمذجة بالترسيب المنصهر .تواجه بعض التحديات FDM واحدة من أولى التقنيات وأكثرها شعبية .على الرغم من شعبيتها، لا تزال تقنية

تركز هذه الدراسة على إنشاء طابعة ثلاثية الأبعاد فعالة من حيث التكلفة وتلبي المواصفات العالية .من خلال تصميم وبناء الأجزاء المطبوعة ثلاثية الأبعاد، تم تقليل التكاليف دون التضحية بالأداء .تناقش الأطروحة أيضًا إمكانية التغلب على مشكلات الهياكل الداعمة عن طريق إضافة محور رابع ومعالجة تحدي طباعة الأجسام الكبيرة.

تهدف طابعتنا إلى أن تكون أكثر اقتصادية بكثير من البدائل المتاحة في السوق بينما تقدم أداءً مماثلاً.

الكلمات المفتاحية :التصنيع بالإضافة، الطباعة ثلاثية الأبعاد، النمذجة بالترسيب المنصهر، طباعة الأجسام، التصميم، حزام النقل للطابعة ثلاثية الأبعاد.

Résumé

Ces dernières années, les imprimantes 3D ont gagné en popularité. Bien que la technologie d'impression 3D remonte aux années 1980, elle est désormais considérée comme l'une des percées technologiques les plus importantes du 21e siècle. Divers procédés d'impression 3D ont été développés au fil des ans, la modélisation par dépôt fondu (FDM) étant l'un des premiers et des plus populaires. Malgré sa popularité, le FDM présente encore certains défis.

Cette étude se concentre sur la création d'une imprimante 3D rentable répondant à des spécifications élevées. En concevant et en fabriquant des pièces imprimées en 3D, les coûts ont été minimisés sans compromettre les performances. La thèse explore également la possibilité de surmonter les problèmes de structures de support en ajoutant un quatrième axe et en abordant le défi de l'impression d'objets plus grands. Notre imprimante vise à être beaucoup plus économique que les alternatives sur le marché tout en offrant des performances comparables.

Mots-clés : Fabrication additive, Impression 3D, Modélisation par dépôt fondu, Impression d'objets, Conception, convoyeur de l'imprimante 3D.

General Introduction:

The origins of 3D printing date back to 1984 when Charles Hull developed stereolithography, enabling the creation of tangible 3D objects from digital data. Since then, 3D printing has become a key tool for prototyping across various engineering fields, including biomedical, aeronautical, and automotive applications. As the cost of 3D printers has decreased, the technology has also gained popularity among hobbyists.

3D printing is not expected to replace traditional manufacturing methods soon but is primarily used for creating testable prototypes quickly and efficiently. This single-step process allows intricate designs to be transformed from CAD models to physical prototypes within hours, facilitating rapid testing and iteration. Unlike traditional manufacturing, 3D printing offers more design freedom and generates less waste.

Despite being over 30 years old, the 3D printing industry has seen significant growth in the past decade, projected to reach $11 billion by 2022 with a 27% annual growth rate. However, current 3D printing technology has limitations, such as size constraints and the need for manual removal of parts, which can limit efficiency and increase the risk of damage.

To address these challenges, a new 3D printer design was developed that can print at 0 and 45 degrees on a moving conveyor belt. This innovation allows for the creation of larger parts, such as aircraft wings and prosthetics, and reduces the need for support materials by providing inherent stability in the printed layers. This approach expands the potential applications of 3D printing, enabling the production of more complex and sizable components.

Chapter I

Generality about 3D printing

1.1 Introduction:

In this chapter, we will focus on the 3D printer, offering a detailed examination and introduction to ensure readers gain a comprehensive understanding of it. We'll explore the innovation revolution and the most recent advancements it has experienced, highlight its key applications, and discuss how it has transformed into a machine that, far beyond mere factory necessity, is poised to revolutionize all industries and become a staple in every home.

1.2 Demystifying what a 3D printing is:

When people hear "printer," they typically envision the standard device found in homes or offices, designed for printing text and images onto paper in a two-dimensional (2D) format, utilizing length and width. However, a three-dimensional (3D) printer introduces an additional dimension: depth, transforming prints from mere flat representations into physical, usable objects that can be touched and interacted with (refer to Figure 1.1).

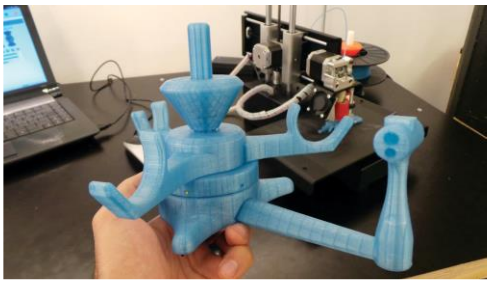


Figure 1.1 3D printed functional prototypes **Figure 1.2** 3D print of a spool holder

A 3D printer is an advanced manufacturing tool that builds real objects from 3D digital models through an additive process, layering material to form the final product. These printers can create a wide range of items, with the only limitation being the printer's size capacity. Complex objects can be crafted by printing individual parts and assembling them after printing., is illustrated in Figure 1.2.

Essentially, 3D printing transforms a digital blueprint into a tangible three-dimensional item by depositing material layer by layer, embodying a revolutionary approach to manufacturing [1].

1.3 3D Printing Through the Ages: Key History:

The fascinating world of 3D printing has a rich history that spans several decades, which dates back to 43's ago. Let’s take a journey through time to explore its origins and key milestones:

1.3.1 Early Beginnings (1980s):

In 1981, Dr. Hideo Kodama filed a patent for a rapid-prototyping process using photopolymers, marking a significant advancement in what is now known as 3D printing. This innovation built upon earlier concepts, such as the 'molecular spray' method described by Raymond F. Jones in a 1950 science fiction magazine, setting the stage for the development of additive manufacturing technologies

Figure 1.3 Dr. Hideo Kodama introduced rapid prototyping but couldn't finance it

1.3.2 The First Patents (1986):

In 1986, after Kodama's initial contributions, Chuck Hull was granted the first official patent for 3D printing technology. Hull, who worked for 3D Systems Corporation, had filed for a patent in 1984 for stereolithography (SLA), a process that uses 3D model data to produce physical objects. Kodama did not advance his patent application, leading Hull's patent to be acknowledged as the pioneering patent in 3D printing.

'Revolutionary'

Machine makes 3-D objects from drawings

By Kathleen Sullivan
American-Statesman Staff

Wedged into the corner of an unused photo lab at the University of Texas is an ungainly machine that can transform a computer drawing into a three-dimensional model at the touch of a button.

Sometime next year, the machine, which was developed by a UT graduate student, will make its way out of the lab and into the commercial arena. It will leave with the blessing of the UT Board of Regents, which Thursday gave an Austin company exclusive licensing rights to the "revolutionary" new technology embodied in the machine.

The licensing pact paves the way for the first transfer of technology from the University of Texas at Austin to a commercial venture.

The company that won the right to market the invention is Nova Automation Corp., whose principal shareholders are an Austin consulting engineer and Nova Graphics International Corp., an Austin-based computer graphics software firm.

The agreement represents a "hard fought" victory for UT's fledgling Center for Technology Development and Transfer, said Meg Wilson, coordinator of the center, which was given life during the last Texas Legislature and got

See Inventor, A11

Staff photo by Ralph Barrera

Associate Professor Joe Beaman shows some three-dimensional plastic models made by the 'selective laser centering' device developed by Carl Deckard, left.

Image courtesy of Carl Deckard and Joe Beaman

Figure 1.4 Carl Deckard and Joe Beaman inventing the first Selective Laser Sintering printer

Initial Commercialization (1987-1988): The inception of commercial 3D printing began with the introduction of the SLA-1 by 3D Systems Corporation in 1987, becoming available for purchase in 1988. During this period, Selective Laser Sintering (SLS) also emerged, patented by Carl Deckard, and was later acquired by Hull's company.

Technological Advancements: The development of 3D printing technologies continued, significantly influenced by Scott Crump of Stratasys Inc., building on the foundations laid by earlier innovations and broadening the technology's impact.

Introduction of FDM (1988-1992): Fusion Deposition Modeling (FDM) technology was developed in 1988, with Stratasys releasing the first FDM printer in 1992. This technology became a cornerstone for many modern 3D printers.

Broadening Applications: Over time, the use of 3D printing expanded beyond simple prototyping to include a wide array of materials, including metals and biological matter, showcasing the technology's versatility and potential for various industries.

Diversification of Materials (2006): A significant milestone was reached in 2006 when the company Object introduced a printer capable of using different types of materials, significantly broadening the creative and practical applications of 3D printing [2].

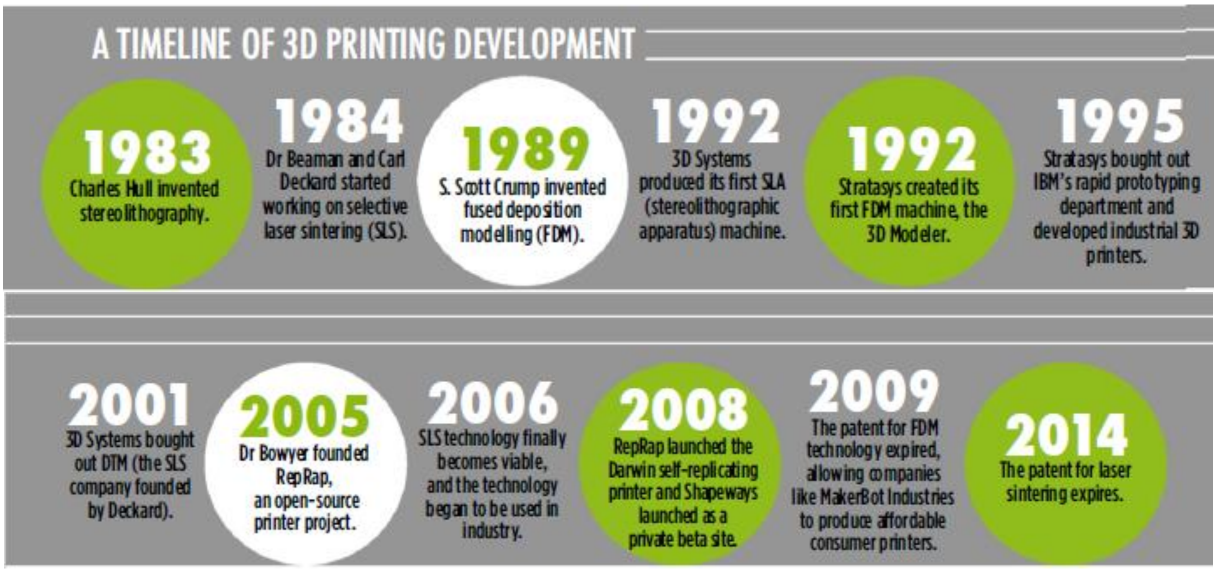


Figure 1.5: showing the historical sequence of the printer

1.4 3D printing technologies:

You might be curious about how 3D printing actually functions. Essentially, the process is an advanced progression from the 2D printing technologies many of us use at home or in the office 3D printing, an evolution of traditional 2D printing, constructs objects by layering materials based on a digital blueprint. Similar to how inkjet and laser printers deposit ink on paper, 3D printers create items by fusing materials in layers, a process also known as additive layer manufacturing (ALM) or additive manufacturing (AM). The initial step involves creating a digital model of the item via computer-aided design (CAD) software or 3D scanning of an existing object, followed by refinement with software tools. This model is then processed by slicing software, dividing it into thin cross-sections (typically around 0.1 mm thick). These sections are sent to the 3D printer, which prints them sequentially, gradually forming the three-dimensional object. [3].

1.4.1 Rapid Prototyping:

3D printing transforms digital models into physical objects by layering materials in a process known as additive manufacturing. Starting with a digital blueprint created via computer-aided design (CAD) software or 3D scanning, the design is sliced into thin layers, which are then printed successively to form the final object. This technology allows for rapid prototyping by integrating 3D CAD data, enabling easy modifications and streamlined prototype construction.

Models for printing must be geometrically valid, without flaws, to ensure accuracy. The combination of traditional machining techniques with modern printing technology marks a significant evolution in manufacturing, facilitating the creation of complex designs with efficiency. [4].

A sample of each category is displayed in Fig. The scaled data control model of a convertible roof system and the air-outlet nozzle of a passenger car is a functional prototype that supports the testing of the car’s climate control.

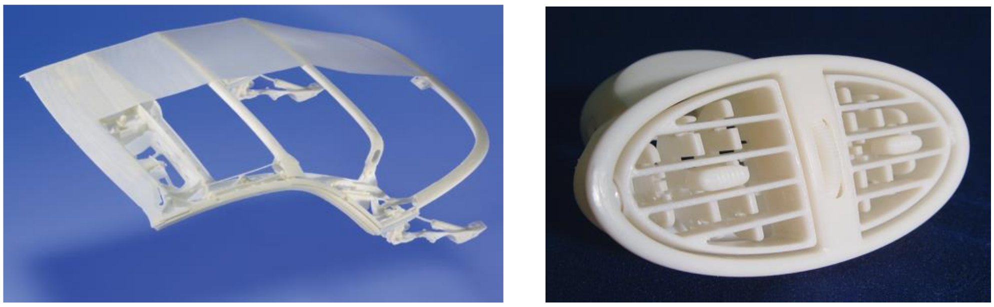


Figure 1.6: Rapid prototyping: concept model or solid image (left), laser sintering

As discussed, the devices utilized for creating prototypes through additive manufacturing are commonly known as prototypes, and more recently, as 3D printers. These machines are distinguished by several key features:

- Ease of use
- Quick setup and operation
- Affordable installation and operational costs
- Budget-friendly pricing
- Tolerance for manual intervention in the production process
- Employment of inexpensive and easy-to-maintain materials
- Less emphasis on overall productivity (excluding build time).

When the prototype creation extends beyond the scope of additive manufacturing, relying on a model produced additively as a base for further development, this extended process is termed indirect rapid prototyping or indirect prototyping. This approach doesn't introduce a new additive technique; instead, it encompasses a series of supplementary non-additive steps to enhance the initial additive process. [4].

1.4.2 What is additive manufacturing?

At its core, Additive Manufacturing (AM) is a set of technologies that fabricate items layer by layer, offering benefits like tooling elimination, complex design production, and cost-effective small runs. It supports a diverse range of materials and enables the creation of intricate structures previously unattainable with traditional methods. AM includes seven main process categories, facilitating customization and innovation in manufacturing from raw materials to finished products. [5].

1.4.2.1 Powder Bed Fusion: Powder Bed Fusion (PBF) is a group of 3D printing techniques, including DMLS, EBM, SLS, SLM, and SHS, that use lasers or electron beams to selectively fuse material powder layer by layer to create objects. The main difference among these techniques is the type of material they fuse, with DMLS using metal and SLS using plastic. EBM is unique in that it operates in a vacuum and is used specifically for metal products. [5].

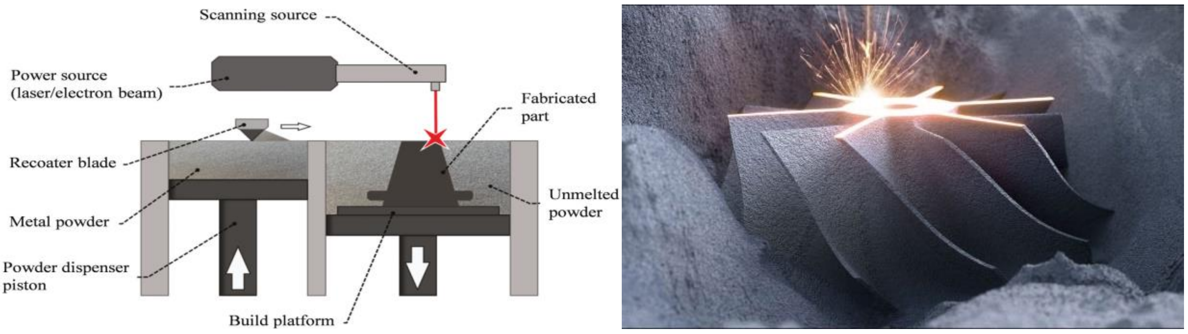
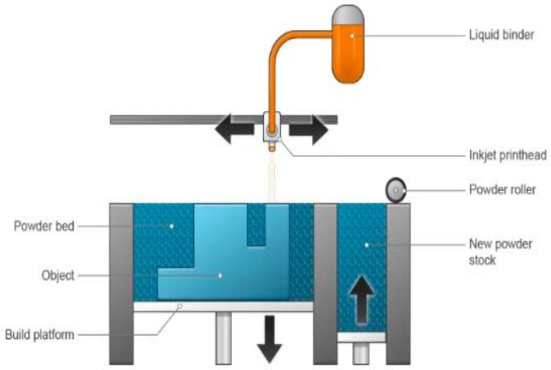


Figure 1.7 A schematic and rial of the Powder Bed Fusion (PBF) process

1.4.2.2 Binder jetting: Binder jetting technology uses a process similar to inkjet printing, where a binder is sprayed onto a powder bed (metal, glass, or ceramic) to build objects layer by layer. The printed items usually need post-processing and may be somewhat brittle, making the technique ideal for artistic applications. [5].



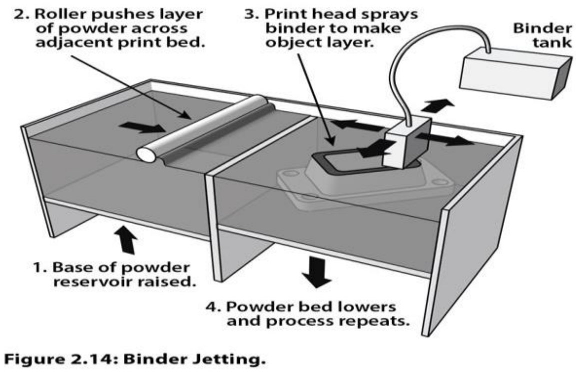


Figure 1.8 Schematic of Blinder jetting(2D) **Figure 1.9: Schematic of Blinder jetting(3D)**

Figure 1.10 binder jetting technology in Action.

1.4.2.3 Material Jetting: Material jetting creates objects by extruding material through a nozzle onto a build platform, using either Drop on Demand (DOD) or continuous flow, with thermal or piezoelectric techniques for material deposition. It often requires post-processing and is suitable for materials like liquid photopolymer and casting wax. This method is very precise and can print in multiple colors. It is used for prints that need high accuracy and a smooth finish [5].

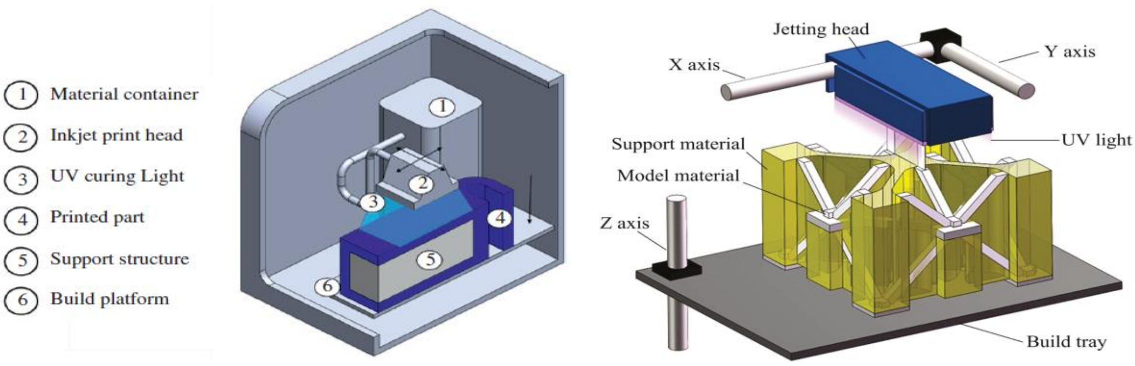


Figure 1.11: Schematic of material jetting technology.

1.4.2.4 Vat Photopolymerization: Vat photopolymerization involves using liquid photopolymer resins that are solidified through exposure to light (rather than heat), building objects layer by layer. This technique features different methods, including:

- Stereolithography (SL): Solidifies liquid resin in a vat using UV light, known for fine details and smooth finishes.
- Digital Light Processing (DLP): Projects UV light onto resin with mirrors, favored for its efficiency and detailed output. [6].

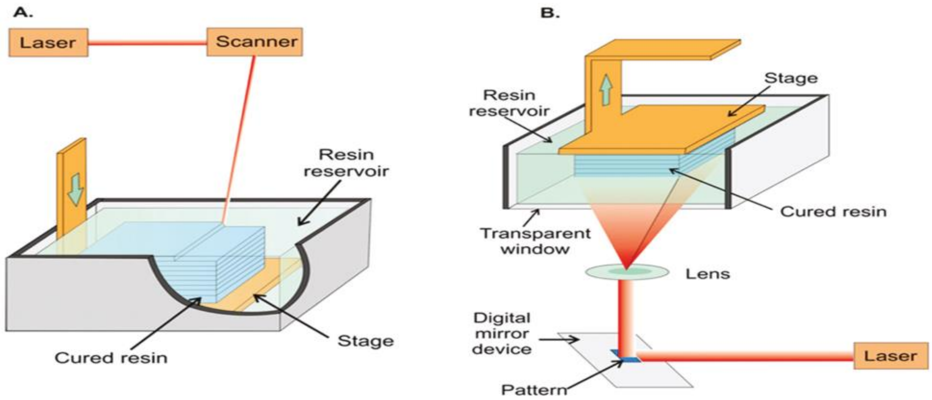


Figure 1.12: A schematic demonstrating two different types of VPP process (a) stereolithography (SLA), and (b) digital light projection (DLP).

1.4.2.5 Material Extrusion: This describes a widely used material extrusion is an Additive Manufacturing technique where melted material is extruded through a nozzle to build products layer by layer. It's cost-effective, uses materials from a spool, and works with various plastics like ABS, PLA, and TPU. Key to its success is maintaining consistent pressure and temperature. [7]..

This method uses a variety of materials, including plastics and plastics infused with additional materials; however, they can be weaker than other additive manufacturing methods.

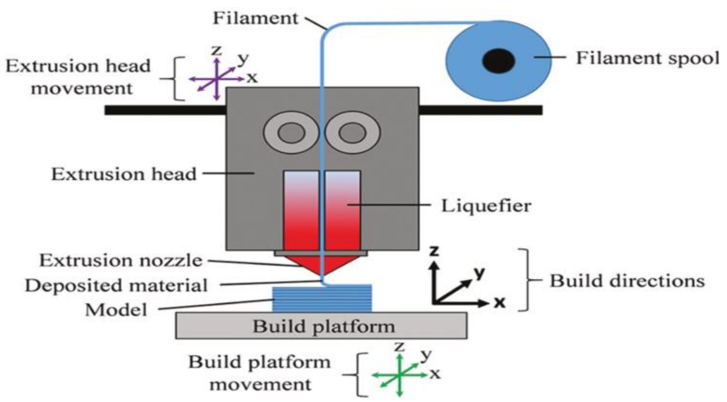


Figure 1.13: A schematic of the Material Extrusion (MEX) process, using a single filament of material

1.4.2.6 Directed Energy Deposition (DED):

Direct Metal Deposition (DMD) is an advanced additive manufacturing process used for repairing or augmenting parts, utilizing thermal energy (like lasers or electron beams) to melt materials such as metal powder or wire. It operates in controlled conditions, potentially under vacuum or heat, and can work on multiple axes for precise application. Variations include

- **Laser Engineered Net Shape (LENS):** which uses lasers to melt powdered material layer by layer.
- **Electron Beam Additive Manufacturing (EBAM):** which melts metal in a vacuum for high-quality metal part fabrication or repair.

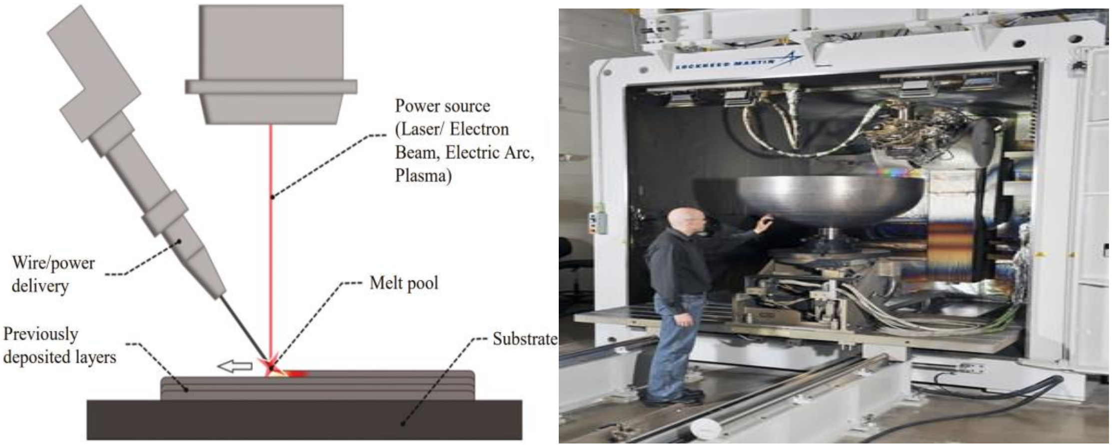


Figure 1.14 A schematic depicting a wire- fed DED process using a laser energy

Overall, DED stands out for its ability to extend the life of components and enhance product functionality through the addition of material, making it a valuable tool in maintenance, repair, and manufacturing settings. [8].

1.4.3 What are some types of 3D printers?

3D printers are diverse in size, technology, and material capabilities, catering to various applications in both industrial and personal contexts.

- ❖ **Industrial 3D printers**: offer wide-ranging sizes and functionalities for custom manufacturing, tailored for professional use. Conversely,
- ❖ **desktop or DIY 3D printers:** are compact, versatile, and widely used for business, artistic, and personal projects, with Fused Deposition Modeling (FDM) printers being notably popular in the DIY community for their accessibility and ease of use**.** [9].

1.4.4 Are their common desktop or DIY printers?

in the realm of desktop 3D printing, Fused Deposition Modeling (FDM) leads as the most prevalent technology, owing to its simplicity and effectiveness in printing with melted plastic filament layer by layer. However, the landscape is rapidly evolving with the rise of Digital Light Processing (DLP) and Stereolithography (SL) technologies, both finding increasing applications in home and professional settings, making them appealing for producing intricate items like small figurines and dental appliances.

❖ **Fused Deposition Modeling (FDM):** Dominating the DIY desktop printing market, FDM works by extruding melted plastic filament to construct an object layer by layer.

❖ **Stereolithography (SL):** SL, or SLA, is gaining traction in the high-end DIY market for its precise laser curing process, producing objects with smooth finishes, albeit with some limitations in speed and detail complexity.

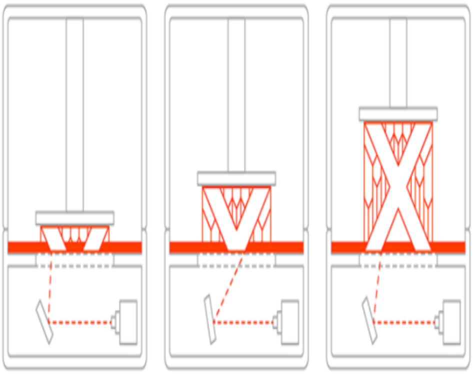


Figure 1.15 : SLA printer process

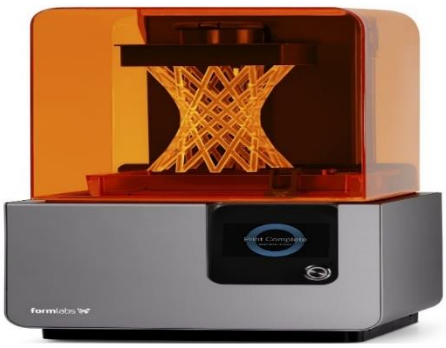


Figure 1.16: SLA printer

❖ **Digital Light Processing (DLP):** Another variant of vat photopolymerization, DLP might become a significant trend in the DIY community. stands out for its potential by curing resin layers quickly using a system of tiny mirrors, though its resolution is limited by mirror size.

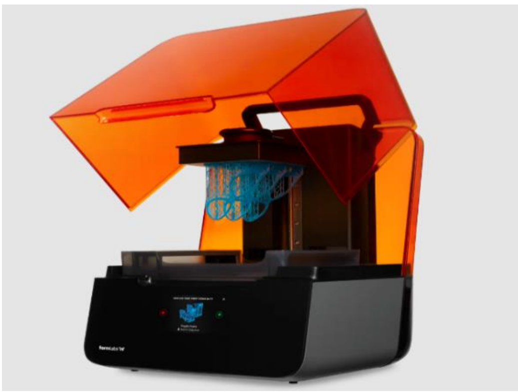


Figure 1.17: DLP 3D printer (lift) , (right)Surface finish in 3D SLA and DLP printing.

As these technologies become more refined and affordable, they promise to expand the possibilities of 3D printing for enthusiasts and professionals alike, fostering innovation and creativity in various applications. [9].

1.4.5 How does an FDM 3D printer work?

An FDM (Fused Deposition Modeling) 3D printer works similarly to a precision-controlled hot glue gun. It uses a nozzle to lay down material layer by layer, building an object. This technology can also take the form of a handheld 3D pen for artistic purposes, offering less precision but promoting creative expression. The FDM process includes:

a) Loading thermoplastic filament into the printer, melting it in the extruder.

b) Using a three-axis system, the extruder moves precisely in X, Y, and Z directions, extruding melted material that cools and solidifies into layers.

c) Adding a patterned infill within the object's outline to enhance strength and stability.

d) After one layer is complete, the process adjusts to add subsequent layers

e) This sequence repeats until the object is fully printed, allowing FDM printers to create complex 3D objects from digital models by accumulating material layers [9]..

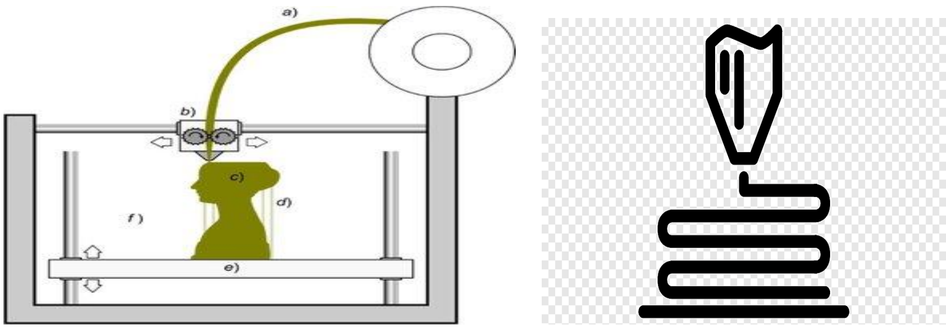


Figure 1.18: How does an FDM 3D printer work

1.4.6 Types of FDM 3D printers:

FDM 3D printers come in several distinct models and designs, each with its unique mechanisms and features:

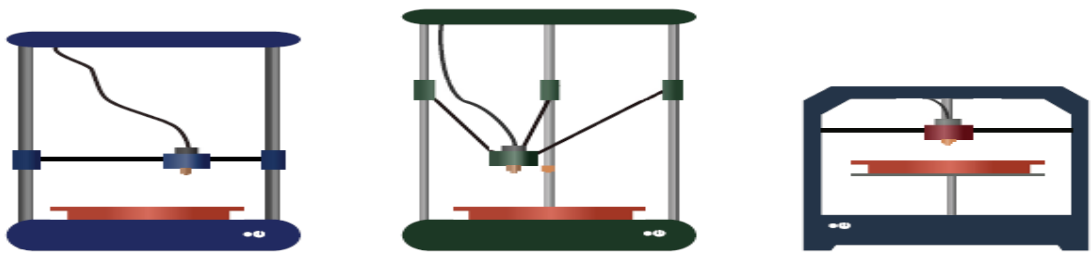


Figure 1.19: The most common FDM printers form left to right: polar printers, delta, and Cartesian.

a) **Freehand Pen**: This type functions more like a creative tool than a conventional printer, allowing direct manual control over the filament's placement in three dimensions.

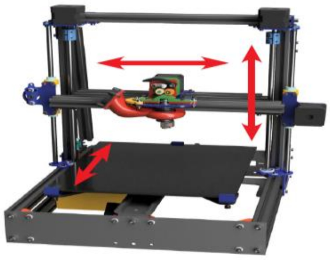


Figure 1.20 The most common Cartesian printer configurations.

b) **Cartesian:** Utilizes a coordinate system for movement along the X, Y, and Z axes, offering precise control and placement of the printed material in a defined, rectangular workspace.

c) **Delta**: Characterized by a trio of arms connected to a single print head, moving simultaneously to control the position of the extruder. This configuration is known for its speed and efficiency in taller print tasks.

d) **Polar**: Operates with a rotating build platform and a single moving arm that extends radially, offering a unique approach to object creation by varying the radius and angle instead of traditional Cartesian coordinates.

e) **Robotic Arm**: Mimics industrial robotic arms, offering a wide range of movement and the ability to print on different scales and angles, providing great flexibility in the printing process [9]..

1.4.7 3D Printing Applications:

The applications of 3D printing span a broad spectrum of industries, demonstrating the technology's versatility and potential to drive innovation, its impact is expected to expand, offering new possibilities for customization, efficiency, and sustainability in manufacturing and beyond, here is an overview of some of the most notable applications of 3D printing in various fields:

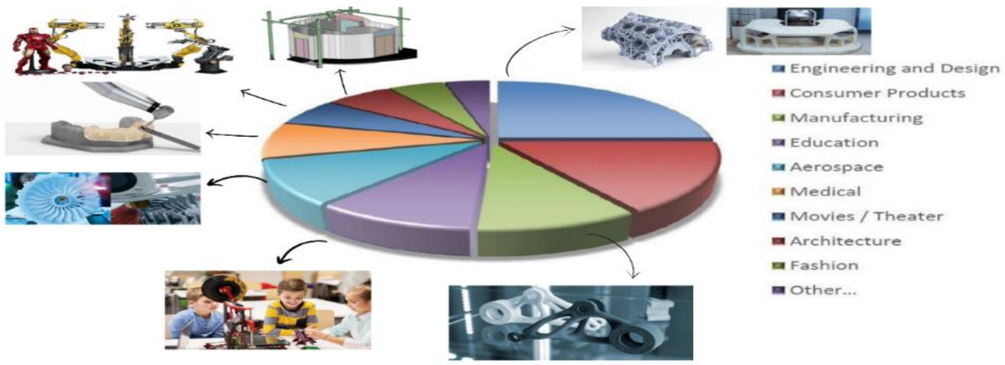


FIG1.21: The range of 3D printing usage according to disciplines.

1.4.8 Popular FDM 3D Printing Materials:

FDM 3D printing primarily uses materials like ABS and PLA, chosen for their versatility and user-friendliness. Advanced FDM printers can handle specialized materials tailored for specific needs, offering improvements in heat resistance, impact strength, chemical resilience, and rigidity.

MATERIAL	FEATURES	APPLICATIONS
ABS (acrylonitrile butadiene styrene)	Tough and durable Heat and impact resistant Requires a heated bed to print Requires ventilation	Functional prototypes
PLA (polylactic acid)	The easiest FDM materials to print Rigid, strong, but brittle Less resistant to heat and chemicals Biodegradable Odorless	Concept models Looks-like prototypes
PETG (polyethylene terephthalate glycol)	Compatible with lower printing temperatures for faster production Humidity and chemical resistant High transparency Can be food safe	Waterproof applications Snap-fit components
Nylon	Strong, durable, and lightweight Tough and partially flexible Heat and impact resistant Very complex to print on FDM	Functional prototypes Wear resistant parts
TPU (thermoplastic polyurethane)	Flexible and stretchable Impact resistant Excellent vibration dampening	Flexible prototypes
PVA (polyvinyl alcohol)	Soluble support material Dissolves in water	Support material
HIPS (high impact polystyrene)	Soluble support material most commonly used with ABS Dissolves in chemical limonene	Support material
Composites (carbon fiber, kevlar, fiberglass)	Rigid, strong, or extremely tough Compatibility limited to some expensive industrial FDM 3D printers	Functional prototypes Jigs, fixtures, and tooling

Table 2.1 Popular FDM 3D Printing Materials

1.5 Conclusion:

3D printing holds significant value in the industrial sector, enabling individuals or small entities to create high-quality models at an attractive price point, thus serving as an exemplary case study in educational contexts. It embodies a comprehensive real-world process initiated by computer-aided design, followed by data transfer to the printer's control board. The following chapter will delve into the essential tools required for designing a 3D printer.

Chapter II

Equipment and tools

2.1 Introduction:

In this chapter delves into the foundational elements that constitute the core of 3D printing technology—supplies, components, and materials. Here, we explore the diverse range of materials that can be used in 3D printing, including plastics, metals, and emerging composites. We also examine the key and analyse components of a 3D printer, such as the print bed (In our case we have a conveyor belt), extrusion nozzle, and filament spools, which are critical for the machine's operation and the quality of finished products.

2.2 Materials:

2.2.1 Filaments:

We talked about types in the first chapter, so - to avoid lengthiness - we will limit ourselves to one type, so the materials used in the FDM process are basically thermoplastic in the form of filament, and they are considered the lowest cost materials used in 3d printing**.**

Polylactic acid (PLA): PLA is a popular filament material in 3D printing, known for its environmental friendliness, ease of use, and stability during the printing of large models. The optimal nozzle temperature for printing with PLA is between 180-200°C, while the heated bed should be maintained at 60-70°C. [10]

Fig 2.1: PLA filament

Pros:

- Biosourced, biodegradable
- Odourless
- Can be post-processed with sanding paper and painted with acrylics
- Good UV resistance

Cons:

- low humidity resistance
- Can't be glued easily. [10]

2.2.2 Stepper motor:

Stepper motors are essential in 3D printers because they rotate in fixed increments, allowing for precise positioning without the need for a feedback loop. Their ability to move in distinct steps enables accurate control by simply counting these steps, crucial for the precision required in 3D printing. Additionally, stepper motors generate high torque compared to similar DC motors and do not require mechanical braking, making them perfect for applications where holding a position firmly is necessary. [11]

Fig 2.2: Stepper motor

- **The permanent magnet (PM)** stepper motor is compact and lightweight, making it ideal for applications where space and weight are limited. PM steppers also provide robust torque. On the other hand.

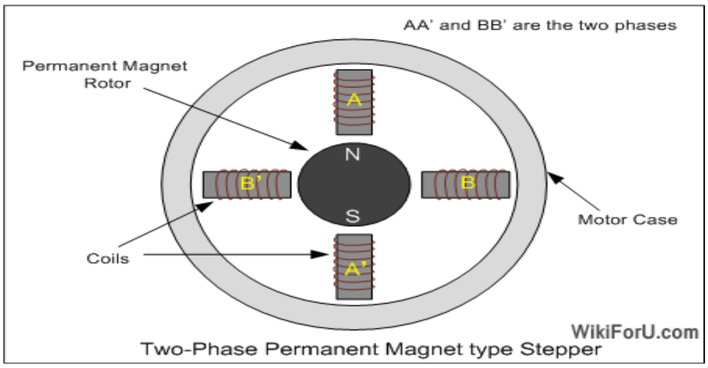


Fig2.3 : A Permanent Magnet Stepper Motor

- **The variable reluctance (VR)** stepper motor offers superior positioning resolution and precision but tends to have lower torque.

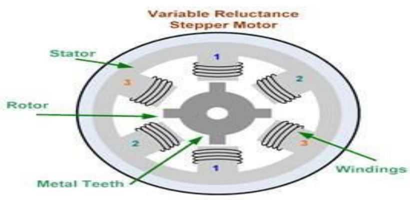


Fig 2.4 : A Variable Reluctance Stepper Motor

- **Hybrid stepper motors** merge the advantages of both PM and VR steppers, offering both high torque and excellent resolution and accuracy, making them the most commonly used type of stepper motor in various applications. [12]

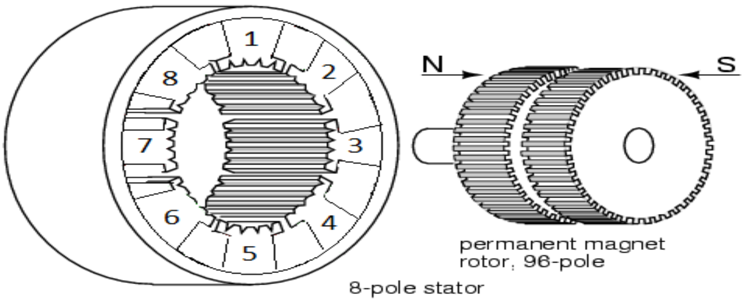


Fig 2.5: A Hybrid Stepper Motor

2.2.2.2 Characteristics of Stepper motors:

Stepper motors come in various shapes, sizes, styles, and with different features such as gear ratios, wiring configurations, step counts, and shaft designs. The choice of stepper motor for a specific application depends on these attributes.

- **Motor Size**: Stepper motors vary in size. For most 3D printers, especially simpler models that do not demand excessive force, a motor like the NEMA 17 is typically sufficient. It is popular in the 3D printing community for its quiet operation, durability, high performance, and reliability in maintaining step accuracy.

- **Step Count**: This refers to the number of steps the motor takes per full revolution, affecting the precision of movement and positioning. Common step counts include 24 and 200, with 200 steps per revolution translating to 1.8 degrees per step. Motors with a higher step count generally operate at lower speeds and have reduced torque compared to motors with a lower step count at the same speed.

- **Torque Rating**: This measures the motor's power output. Larger motors generally have a higher torque because they can generate more power.

  For 3D printing, a torque range of 40 to 55 N.cm is typically adequate, balancing the needs for speed and torque across different printer sizes, from those requiring minimal force to those needing substantial power. [12]

2.2.2.3 Advantages and disadvantages:

Advantages	disadvantages
The rotation angle of the motor is proportional to the input pulse.	More difficult to operate than DC motors
Existence of torque at standstill.	Relatively low speed and torque
Brushless motor	Mechanical resonance
Control of position, speed and synchronization of several motors (no need for feedback).	Torque decreasing rapidly as speed increases

Table 2.1 – Advantages and disadvantages of stepper motors

2.2.2.4 Motors NEMA 17:

NEMA is the abbreviation for “National Electrical Manufacturers Association” and comes from the U.S. association that represents the interests of the electrical engineering industry in the USA. And is one of the most commonly used motors in 3D printers

Fig 2.6 : Stepper motor NEMA 17

2.2.2.5 Characteristics of standard NEMA 17 type motors

200 steps per revolution (1.8 deg/step)

2 phases (bipolar)

4 wire cord

Voltage 2 V DC

Current 1.2 A

Phase resistance: 1.7 Ohm ± 10

Phase inductance: 4.5 mH ± 20

Holding torque: 0.4 N.m Min

Axle diameter: 5 mm / 0.188" (3/16")

Axle length: 22 mm

Motor body height: 40 mm

2.2.3 Frame :

A solid and sturdy structural frame is essential for many engineering projects, from 3D printer frames and translation axes to custom workbenches and machinery enclosures. T-slot aluminum is a material that offers high durability, maximum versatility, and a reasonable cost for custom structures and frames like these. T-slots are an unofficial standard for framing systems that consist of square or rectangular extruded aluminum lengths. They have a 'T' shaped slot along at least one of their sides. (look fig2.7)

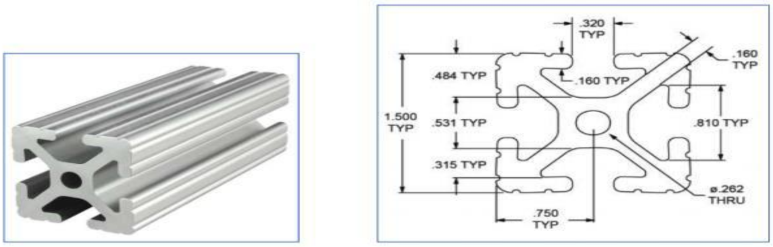


Fig 2.7: slot aluminum

These slots allow you to connect a wide range of hardware to the extrusion and adjust it as needed. They allow for an unprecedented level of customization and versatility for the designs and applications you can create. While there is no single unified standard for the manufacturing of these extrusions, there are some guidelines on the most popular profile sizes and slot shapes. It is easy to identify which components and profiles are compatible. [13]

Fig 2.8 : Aluminium Framing

2.2.4 Transmission:

2.2.4.1 Screw-Nut Systems:

The Nut-Screw Driven Linear Axis mechanism utilizes a nut and screw system to convert rotational motion into precise linear movement. This setup features a screw with a helical thread and a matching internally threaded nut. Rotating the screw causes it to move axially through the nut, resulting in linear motion along the screw's axis. The use of a ball-nut in this mechanism enhances accuracy and repeatability, making it ideal for handling high loads and speeds. Due to these characteristics, this solution is extensively employed in various fields such as machinery, automotive, robotics, and construction equipment. [14]

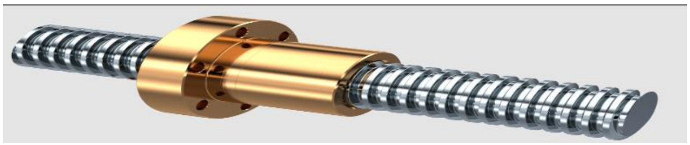


Fig 2.9: Screw-Nut Systems

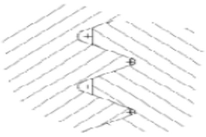
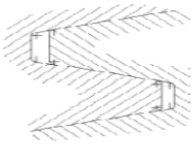
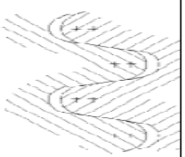
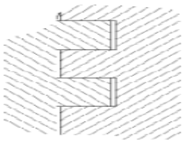
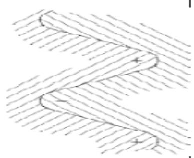
Trapezoidal Thread Screw(metric)	Trapezoidal Thread Screw	Round thread screw	Square screw	whiteworth thread gas thread
				
α=30	α=15			α =22.5
easy manufacture	fairly easy manufacturing	difficult manufacturin g	difficult manufacturing	difficult manufacturing
Mediocre efficiency	Good efficiency	Mediocre efficiency	Very good efficiency	Mediocre efficiency
Resistant	Resistant	shock-resistant	weakly resistant	Resistant
Use: organs Screw : assembly	Use : transformation of movement	Use: shock resistant cores	Use : transformation of movement non-standard	Use: racord, waterproofing, piping

Table 2- 2 Screw -Nut characteristics

Calculation of a transmission based on a screw-nut system:

The screw and nut system converts rotational motion into translational movement by coordinating the actions of both components.

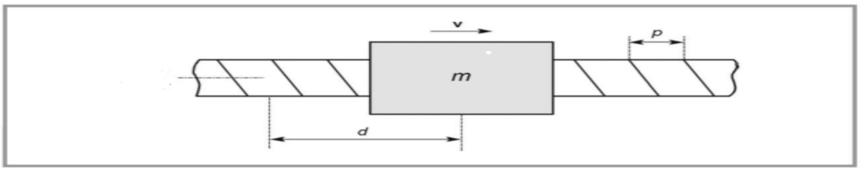


Fig 2.10: Screw-nut system

A load of mass (m) subjected to a resistive force (F_r) parallel to its displacement is attached to a nut moving on a pitch screw (P) fixed on the motor shaft. The slides, not shown on the figure, guide the load to impose the translation movement. The nut moves by one step for each turn of the screw. If the drive shaft turns by an angle (θ).

The power output (Ps) of a screw-nut system depends on the force of the load to be moved, the speed of movement and the efficiency of the system.

The power input (Pe) to a motor and its angular velocity (ω) of rotation. The constant C in this equation represents the motor's electrical torque, or the force that rotates the motor, which is supplied by the electrical power source. [15]

Here's some of the advantages and disadvantages of screw systems:

a) Advantages

-This mechanism makes it possible to exert significant forces and pressures.

-It's also allows fine adjustments

b) **Disadvantages**:

This mechanism generates a lot of friction.

Its fagility can lead to guidance problems.

The system is slow unless you have a significant screw step.

2.2.4.2 Pulleys-Belts Systems:

In a belt-driven transmission system, a flexible belt reinforced with high-tensile fibers forms a closed loop, connecting both ends of a carriage. A timing pulley, which is fitted within this loop, is driven by a motor. For effective coupling, the tooth profile of the timing pulley must match that of the timing belt. These components are available in various widths, tooth profiles, and pitches, which refer to the spacing between adjacent teeth [16]

Fig 2.11: Examples of simple Pulley-Belt systems

The table below describes types of pulley and belt systems, including timing belts, V-belts, flat belts, each system includes important specifications and characteristics such as belt type, profile, pitch and load capacity. This information allows users to choose the system that suits their specific needs.

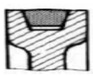
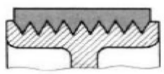
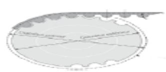
Type	Scheme	Features
FLAT BELTS		• Very silent • High speed transmission.
TRAPEZOIDAL BELTS	 	• High transmissible power (uses multiple throats) • Poly belts widely used in household appliances
TIMING BELTS		• Silent transmission without slipping • One of the two pulleys must have a flange so that the belt does not Pulleys

Table 2- 3 Pulley Belts Types

Calculation of a transmission by Belts

The belt is wrapped around the pulleys, and when one pulley is rotated, it causes the belt to move, which in turn causes the other pulley to rotate. This system is used to transmit power or motion from one shaft to another, with the pulleys serving to increase or decrease the speed or torque of the motion

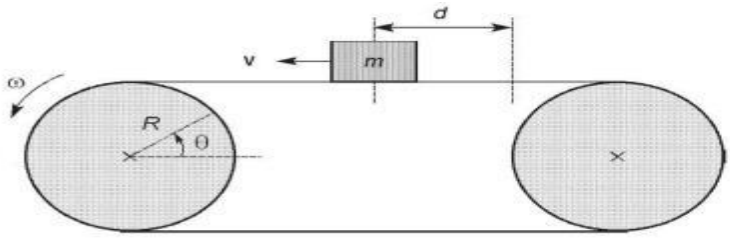


Fig 2.12 : transformation of motion by pulleys-belt system

In order to model the motion transformation of the pulleys-belt system of figure 2.12, we consider a mass load m which is subjected to a resistive force Fr. A pulley of radius R placed on the shaft of the motor drives a toothed belt attached to the load, when the motor turns an angle θ, The table 2.4 represents the advantages and disadvantages of belt-pulleys system.

Its offers a detailed comparison of the pros and cons of various pulley and belt systems, aiding engineers and designers in choosing the most appropriate option for their needs. It facilitates an informed decision-making process by evaluating factors like efficiency in power transmission, capacity for load, speed constraints, and maintenance requirements.

Advantages	Disadvantages
• Silent transmission • "High" transmission speeds (60 to 100 m/s for flat belts) • Large distance between pulleys possible	• Limited life • Low transmissible torque for flat straps • Initial belt tension required to ensure adhesion

Table 2. 4 Main advantages and disadvantages of belt system

2.2.5 Guiding System:

A guiding system allows a load to be moved along a linear path with high precision. Numerous technological solutions exist, their common objective is to offer a reduced mechanical clearance, maximum efficiency and long service life. There are many common terms associated are numerous: rail, guide, slider, etc... [17]

2.2.5.1 Roller Guide

A guide wheel is a type of wheel, typically used to guide or direct a moving object or material along a specific path or trajectory. Guide rollers (Fig. 2.13) are commonly found in a variety of industrial applications such as conveyor systems, printing presses and packaging equipment.

Fig 2.13: Roller Guide

2.2.6 Extruder:

An extruder, also known as a print head, is engineered to deposit layers of a print by pushing out melted plastic. Initially, a filament strand is fed into the extruder via a PTFE tube, starting off as a solid plastic at room temperature. It then passes through a heat sink designed to dissipate heat from the heat break and reduce the transition from solid to melted filament. A fan often mounted on the heat sink enhances cooling. The heat break itself is a narrow tube that helps prevent heat from traveling upwards to where the filament needs to stay solid.

In the heater block, typically made of aluminium for its heat conductivity, a small electric heater and a thermistor melt the material. This molten material is then extruded through the nozzle. Nozzles can vary in diameter, and many printers allow for their replacement to suit different printing needs. [18]

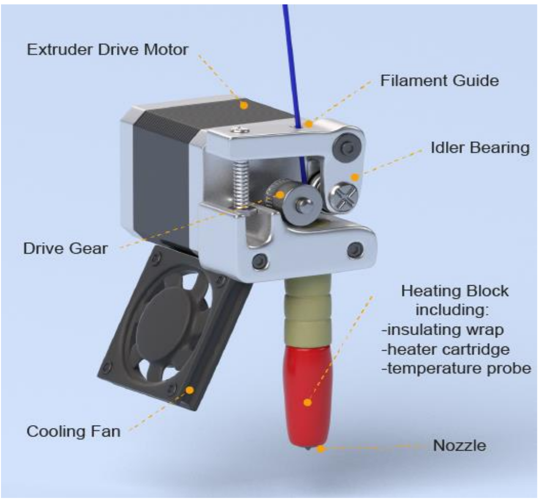


Fig 2.14 : Extruder of a 3D printer**.**

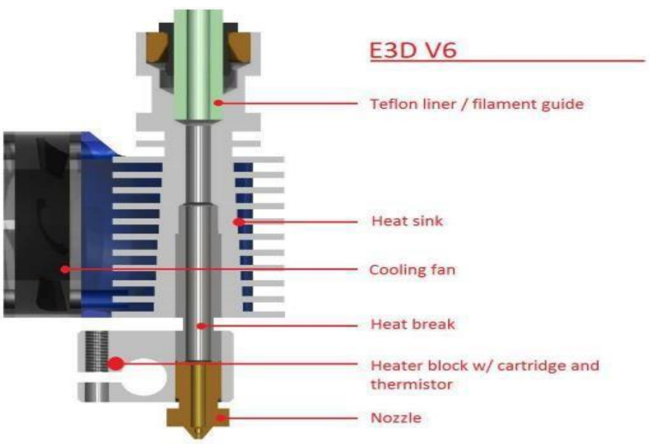


Fig 2.15 : Illustration of the extruder.

2.2.6.1 Direct Drive and Bowden Drives:

The primary types of filament drives are direct drives and Bowden drives, distinguished by the mechanism through which the filament is handled and transported. In direct drive systems, the cold end containing the filament drive is positioned directly above the hot end, moving together as one unit. The filament is fed straight from the spool through the cold end into the hot end[19]

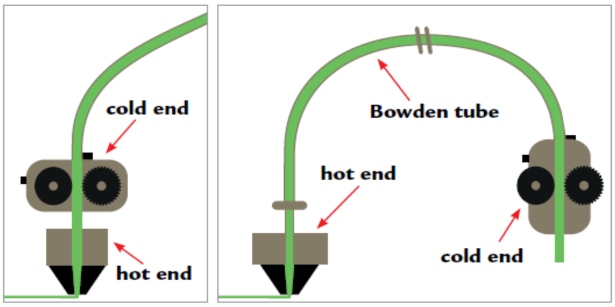


Fig 2.16 : Direct Drive vs. Bowden.

2.2.7 The Nozzle:

The nozzle is an essential component of the hot end and a critical element in a 3D printer, responsible for extruding melted filament onto the build platform. Desktop FDM 3D printers offer the flexibility to switch out nozzles to better meet specific printing needs. When choosing a nozzle, two key factors to consider are the material of the nozzle and its inner diameter, as these characteristics significantly influence printing performance. [20]

Today's nozzles are manufactured from various metals, chosen for their high thermal conductivity and the precision with which they can be crafted

2.2.7.1 Brass:

Brass is commonly used as the material for 3D printer nozzles due to its excellent heat conductivity and affordability, making it ideal for those new to 3D printing. However, being the softest among common nozzle materials, brass is susceptible to wear and can be easily damaged by any physical impact during the printing process. [20]

Characteristics:

- High thermal conductivity
- Corrosion-resistant
- Comparatively soft
- Low resistance to abrasion
- Maximum temperature capacity: 300 °C

2.2.7.2 Stainless steel:

Stainless steel is a tougher alternative to brass for 3D printer nozzles, offering higher abrasion resistance. This makes it suitable for long-term printing with filaments that contain hard particles, such as carbon fiber and metal, without risking erosion and a decline in printing performance. However, stainless steel nozzles do have poorer thermal conductivity compared to brass. [20]

Characteristics:

-Low thermal conductivity

-Corrosion-resistant

-High abrasion resistance

-Maximum temperature capacity: 500 °C

-Recommended for: Non-abrasive filaments and occasional use with abrasive materials such as NylonX, carbon fiber, glow-in-the-dark, metal-filled, wood-filled, and ceramic-filled filaments.

2.2.7.3Hardened steel:

Hardened steel nozzles represent a significant improvement for 3D printing, providing the durability needed for frequent printing with abrasive materials. These nozzles can last for years without needing replacement. However, they have a lower thermal conductivity than both brass and stainless steel, resulting in slower heating times. (20)

Characteristics:

- Low thermal conductivity
- Corrosion-resistant
- High hardness
- Maximum temperature capacity: 500 °C
- Ideal for: All types of materials, especially suitable for extensive use of abrasive materials.

Fig 2.17: Nozzles of different materials and sizes.

The inner bore diameter of a nozzle significantly impacts the precision and speed of 3D prints. Nozzles range from 0.1 mm to 1.0 mm in diameter, with smaller nozzles providing higher detail at slower speeds and larger nozzles enabling faster printing with less detail, ideal for rapid prototyping. The standard 0.4-mm nozzle offers a balanced compromise, suitable for most printing needs, as it allows for a maximum layer height of 0.32 mm, optimizing both speed and detail accuracy. [20]

Fig 2.18: Nozzles of different inner diameters**.**

2.2.8 Heated bed:

Heated bed or Heatbed is an important part of every modern 3D printer that should be compatible with as many materials as possible. The heated bed stops printed objects from bending, warping or detaching from the surface. [21] In our project, we replaced the warm bed with a conveyor belt, and we will have more clarification and more detail in the next chapter about the reason for the choice and its advantages

.

Fig 2.19: conveyor belt of 3d printer

2.2.9Arduino Board:

Arduino is an open-source programmable circuit board that includes a microcontroller, making it suitable for both simple and complex maker projects. Designed to sense and control physical objects, it can interact with various outputs like LEDs, motors, and displays in response to sensor inputs. Introduced in 2005 in Italy by Massimo Banzi, Arduino's flexibility and affordability have made it especially popular in the maker community and educational makerspaces for building interactive hardware projects. [22]

2.2.9.1 Types of Arduino Boards:

• Arduino Mega

• Arduino Uno

• Arduino Leonardo

• Arduino Red board

• Arduino lily pad. [22]

There are numerous open-source Arduino boards available, but we have chosen to focus on the Arduino Mega 2560 R3.

2.2.9.2 Arduino Mega 2560 R3:

The Arduino Mega 2560 is built around the ATmega2560 microcontroller and features 54 digital input/output pins, with 15 capable of PWM outputs. Additionally, it includes 16 analog inputs, 4 UARTs for serial communication, a 16 MHz crystal oscillator, USB connection, power jack, ICSP header, and a reset button. [23]

The ATmega2560 microcontroller chip acts as the central brain of the Arduino Mega board. Positioned prominently in the center, this large, black integrated circuit (IC) is the key component that controls the board's functions. It is mounted in a socket, allowing for removal if necessary. The ATmega2560 is a low-power, 8-bit CMOS microcontroller that uses the AVR enhanced RISC architecture. It is capable of executing complex instructions in just one clock cycle, achieving nearly 1 MIPS per MHz. This efficiency allows designers to balance power consumption with processing speed effectively. [23]

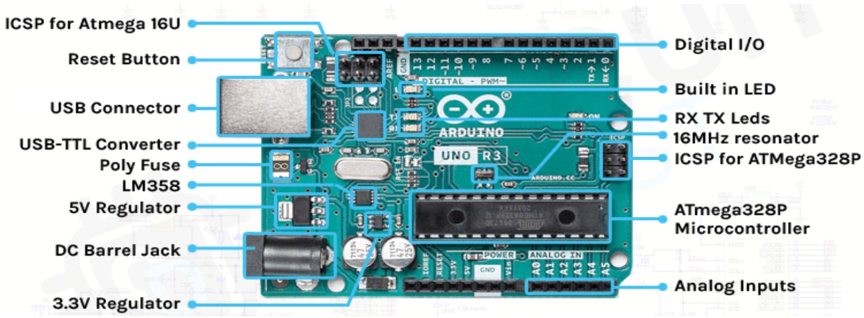


Fig 2.20: Arduino Board Components

2.2.10 Ramps 1.4 Arduino Mega 2560 Shield:

The RepRap Arduino Mega Polulu Shield, known as RAMPS, acts as an intermediary between the Arduino Mega controller and the electronic components of a RepRap 3D printer. The controller processes files that describe the object to be printed and converts this information into digital signals, such as activating specific pins. However, while the Arduino Mega can generate the necessary control signals, it lacks the power capacity to directly drive the printer's hardware. [23]

2.2.11 Endstop (Motion Sensors):

In 3D printing, each axis requires a reference point, known as the datum or home position, to guide its movements. At the beginning of each print job, the axes retreat until they reach these endstop points. These switches not only provide a reference for movement but also prevent the machine from exceeding its operational limits, which helps to avoid damage.

2.2.12 Mechanical Endstop:

The effectiveness of mechanical endstops in 3D printers depends on the switch quality, lever arm length (shorter arms increase precision), and the speed of carriage impact. High-quality, short-arm switches can achieve the necessary +/-0.01mm precision, while cheaper switches may be less reliable for precise Z-axis homing but are adequate for X and Y axis. Mechanical switches can be susceptible to electromagnetic interference, especially in two-wire setups where nearby PWM-controlled stepper or heater wires may cause disruptions. To minimize interference, it's recommended to route end-stop cables away from these sources and consider wire shielding or twisting. Three-wire switches, which provide a more stable signal, offer improved noise rejection. Although very cheap switches might fail prematurely, most are durable, supporting millions of cycles beyond a printer's typical lifespan, making them a cost-effective choice for straightforward setup and testing. [23]

We can monitor two other types in the market (**Optical Endstop**, **Magnetic Endstop)** but our work will focus on the first type

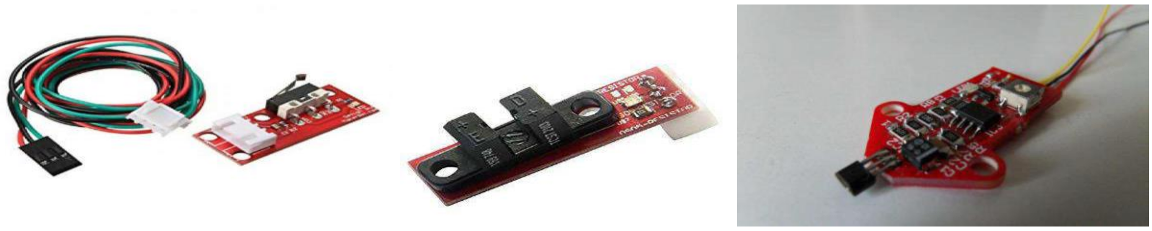


Fig 2.21: End-stop: a) Mechanical, b) Optical, c) Magnetic

2.2.15 Power Supply 12V:

12V power supplies, also known as 12VDC power supplies, are among the most widely used types today. They typically convert a 120VAC or 240VAC input into a 12VDC output using a mix of transformers, diodes, and transistors.

Fig 2.22: Power Supply 12V

2.3 Conclusion:

The aforementioned materials and equipment were essential for construction. A standard 3D printer can be significantly enhanced with various upgrades, providing better features and diverse applications. We employed this DIY method to simplify the process and reduce costs.

Chapter III

Sizing and study of 3d printer

3.1. Introduction:

Chapter 3 there will be discussion The specific concept that explored designing and building a 3D printer with a functioning conveyor belt system with an extruder that prints at an angle. The core aspect of these types of the 3D printing process is the print in series. this section will address an research about the available type of automation for 3D printing that is available on the market. In addition to detailing different companies that produced the current designs on the market.

3.2 Why a conveyor belt:

Since the inception of 3D printing, the predominant method has been to build layers from the bottom up, a technique utilized by the majority of printers. This approach is generally reliable and suitable for various applications, but it comes with certain restrictions. Specifically, the maximum size of a print is confined by the printer's build volume; it cannot surpass the printer's dimensions. For instance, printing elongated objects like airplane wings, large signs, or extended rods would require segmenting the item into pieces or using an unusually large printer.

However, angled printing offers a solution by enabling the extruder to print layers at a 45-degree angle while moving horizontally with each layer. This configuration allows the axis aligned with the conveyor belt to extend indefinitely, making it possible to print parts much longer than the printer itself. The primary challenge then becomes supporting the structure beyond the printer's length.

Another advantage related to the continuous printing capabilities of an angled printer is the ability to print parts in series. In most cases, standard 3D printers can only produce one part at a time, though they can print several small parts simultaneously as a single layer. Typically, these parts need to be manually removed, posing a risk of damage. Conversely, a conveyor belt printer allows for continuous printing. As parts are completed, they automatically move down the conveyor belt. The tension of the belt can peel the parts off, or an edge at the belt's end can facilitate their automatic removal. A bin placed at the end of the printer can collect these finished parts.

3.3. Why Angled Printing:

Printing from the ground up often necessitates the use of support material for designs that have overhanging features, as printing into thin air is not feasible. However, angled printing, which layers at a 45-degree angle, can reduce the reliance on support material by better accommodating certain types of overhangs compared to traditional vertical layering.

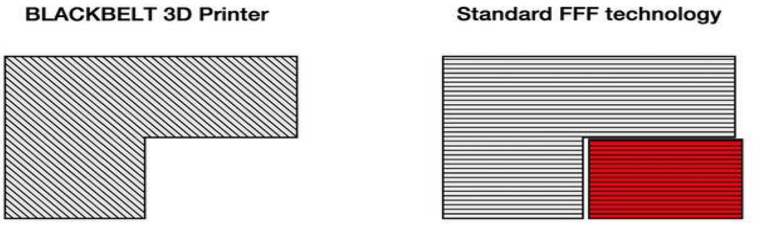


Fig3.1: Blackbelt Layering vs. Standard Layering

3.4 different type in the market:

In the following section, we will examine specific models that exemplify this technology These examples illustrate the diversity and innovation in 3D printing technology, particularly the integration of conveyor systems which extend the functional applications of printers beyond traditional confines. This enhancement facilitates not only the creation of uniquely large prints but also supports the efficient mass production of smaller items, broadening the impact of 3D printing across various sectors

3.4.1 Blackbelt 3D Printer

Blackbelt is an upstart 3D printing company from the Netherlands. The company’s mission is to bring fresh wind to the 3D printing landscape by coming up with designs that they hope will become the new standards of the 3D printing industry. They envision that soon, even if everyone does not own a 3D printer, they will have a 3D printed part in their home. As of 2017 their only product is the Blackbelt 3D printer, which underwent a successful Kickstarter Campaign and began shipping printers in October 2017[24]

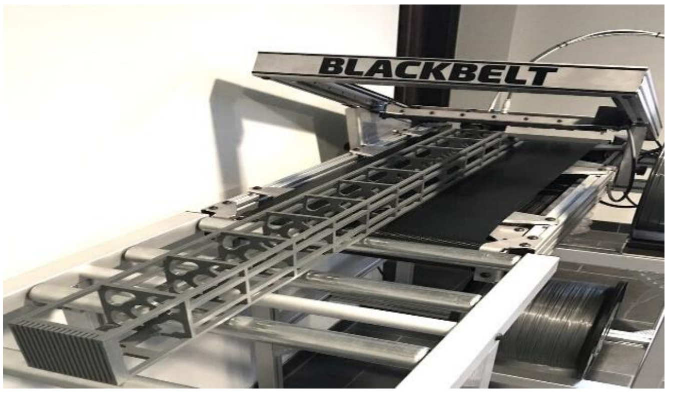


Fig 3.2: Blackbelt 3D Printer

3.4.2 Printrbot’s Printrbelt:

Printrbot is a 3D printer manufacturing company based out of California, USA. According to the company’s information page, their goal is to make the technology of 3D printing as accessible as possible. As of 2017, the company offers a variety of products, including six types of 3D printers—highlighted by the innovative Printrbelt—a CNC machine, 39 filaments, and 56 accessories. Their comprehensive range includes essential printing materials and spare parts. Committed to making 3D printing accessible, the company has priced certain models affordably for educational purposes, aiming to spark student interest in STEM through easy access to advanced technology. [25]

Fig 3.3 Printrbot's Printrbelt Design

3.4.3 Creality CR-30 3D PrintMill :

Developed through a collaborative effort between Creality and technology advocate Naomi Wu, the CR-30 integrates a conveyor belt that significantly enhances its operational flexibility. This model supports the continuous fabrication of extended objects and the simultaneous printing of multiple small-scale items, making it a versatile tool for both personal and commercial applications. [26]

Fig 3. 4 : Creality Design

3.5 Our design plan:

Our plan was based on the new angled printer concept, from which we maintained the general idea while altering its engineering, so to speak. This could offer better design options for people to explore. One of the design aspects I modified was the extruder head. As I mentioned, I kept the main shape, as it shares many characteristics with traditional printers. However, for the extruder head, I added the ability to rotate, giving it a 45° degree of freedom**.**

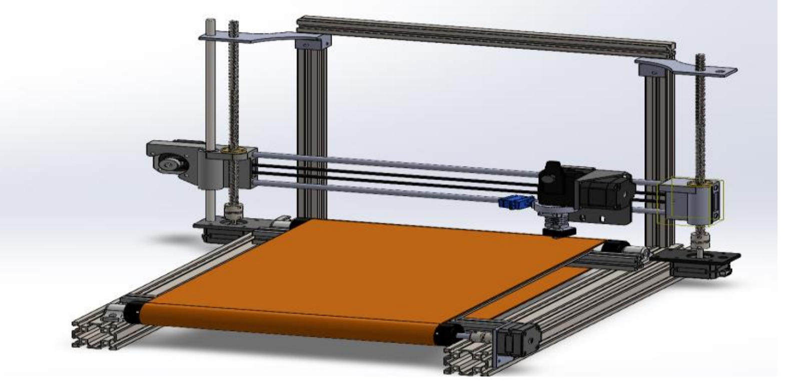


Fig 3.5 : showing our 3d printer design

For the sake of simplicity with our design and printer we chose the Y-axis to be the axis that the conveyor lies on. The X-axis is the axis upon which the extruder moves side to side and the Z-axis is the axis in which the conveyor moves up and down. To print multiple parts and print on an infinite axis the print surface must be constantly moving. A conveyor belt was determined to be the optimal way to achieve this function. The belt itself must be able to properly adhere to the PLA material used in the parts, while also being able to withstand the heat from the extruder hotend without melting. If the belt itself cannot meet these specifications, then an additional surface such as Kapton Tape or PEI sheets will be used.

3.5.1 workspace analysis:

The workspace of a 3D printer is defined as the area of 3D space that the printer can reach with its translational movements along each of the three axes. This is the work area where the printer can execute its programmed tasks and routes. The maximum position of the printer axes describes the boundaries of the area in which you are working. These boundaries surround the business envelope. The size of the working envelope determines the limits of access. These limits are set in the specifications of the printer we want to make. It contains four prismatic joints whose axes correspond to the Cartesian coordinate system. (See figure below). Specifications include the following pegs:

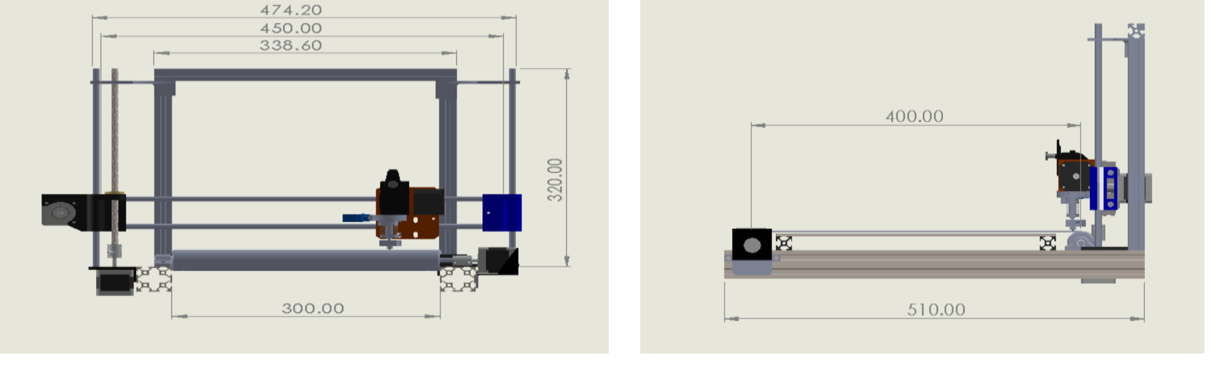


Fig 3.6: Workspace along XYZ

3.5.2 Functional analysis:

3.5.2.1 Feasibility study:

Questions	réponse
1) Who does the product serve?	operator
2) What does the product work on?	Filmant
3) For what purpose?	Continuos printing and larger

Tab3.1 : need-related question/answer spreadsheet

A beta-horn diagram, also known as a Haas diagram, is a visualization tool used in ordering theory and graph theory to represent partial orders. In the context of a conveyor belt 3D printer, it can be used to represent the manufacturing and printing stages of the additive manufacturing process. The diagram allows you to formalize the previous answers graphically, as shown in Figure (3.6)

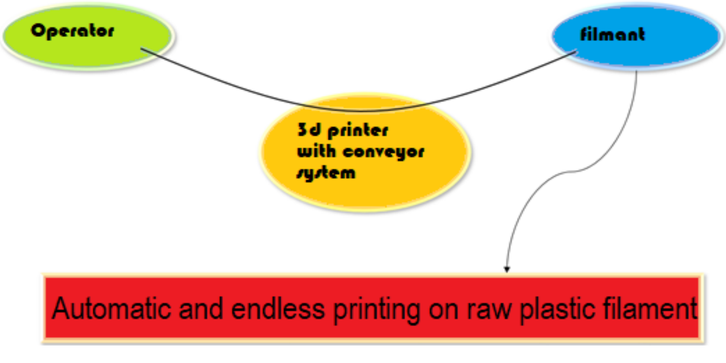


Fig 3.7: Beta horn diagram

3.5.2.2 External functional analysis:

Our analysis identified the key elements of the external context and service functions of the target product. These elements are illustrated in the octopus's diagram in Figure 3.7. The product's primary function is to enable the operator to automatically perform long-scale printing operations on raw plastic. Details of the various service functions are given in Table 3.1.

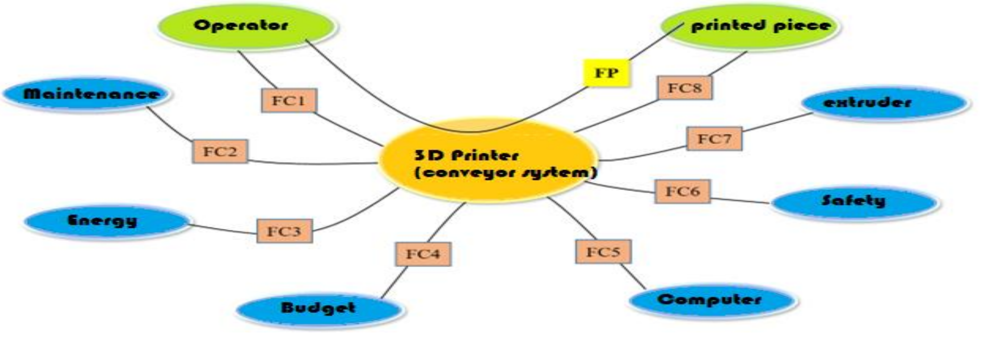


Fig 3.8: Octopus Diagram.

FP	Implementing printing operations on the moving bed in different sizes.
FC1	Be easy to use and move
FC2	Allow easy periodic maintenance
FC3	Adapting to the domestic electrical network
FC4	Reasonable price
FC5	Using CAD/CAM software for G-Code programming
FC6	Comply with safety standards
FC7	Heating the raw material to print the part
FC8	Subject to printing forces

Tab 3.2: service functions.

3.6 Study and calculation of the main machine components:

The goal of this section is to measure and validate the various functional components of our machine to ensure proper operation. We will discuss structural and power calculations. The components to be measured include:

- Trapezoidal screws
- Trapezoidal belts
- Bearings
- Conveyor belts

3.6.1 Mass Calculation:

Our 3d printer is composed of various components:

- Standardized Components: These include screws, nuts, bearings, and rails. Their weights and dimensions are listed in catalogs.

- Drive Motors: The weights are provided by suppliers on the product packaging or their websites.

- Custom-Designed Parts: These parts are specifically designed for our machine, with their weights estimated using SolidWorks CAD software, which factors in the dimensions and materials of each part.

After inputting the parts and defining their materials, SolidWorks allowed us to determine the masses of each piece. By considering the masses of all components, we were able to perform precise calculations to determine the resultant forces on each robot axis. The results are detailed in the following tables.

X-AXIS			
m_i	Piece Name	Number of pieces	Mass (g)
M1	Bearings	2	45.24
M2	Belt	1	10
M3	Pully	2	4
M4	Motor	1	222
M5	Scs8	2	30.26
M8	X mount	1	23.33
M9	Micro servo	1	8
M10	Bmg extruder	1	76
M11	extruder	1	67
M12	Head cup	1	8.49
		Total mass	494.32

Table 3- 3 X axis component weights

Z-AXIS			
m_i	Piece Name	Number of pieces	Mass (g)
M1	Rear corners	2	29.14
M2	t-slot frame	2	251.77
M3	Trapezoidal lead+nut	2	214.5
M4	Carriage R	1	40.73
M5	Carriage L	1	62.93
M6	Front corner	2	81.46
M7	Nema motor	3	129
M8	Linear shaft	1	62.74
		Total mass	872.27

Table 3- 4 Z axis component weights

Y-AXIS			
m_i	Piece Name	Number of pieces	Mass (g)
M1	Rear corners	2	29.14
M2	t-slot frame	2	954.60
M3	Roller shaft	2	66
M4	Tube holder	4	21.4
M5	bearing	3	30.26
M6	Tube mount	1	40.73
M7	Motor mount	1	62.93
M8	Nema motor	1	23.33
M9	Linear shaft	2	125.48
M10	Shaft mount	3	19.05
M11	Accoupling	1	15
M12	Belt	1	9
		Total mass	1397

Table 3- 5 Y axis component weights

3.7 Calculations of Forces, speed:

3.7.1 Calculations of Forces, speed and Transmission exerted on the X axis:

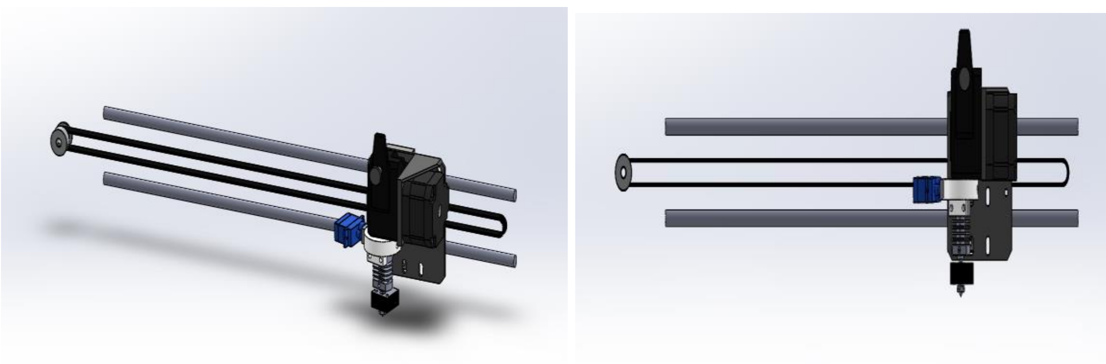


Fig 3.9*:* translation system along ***X***

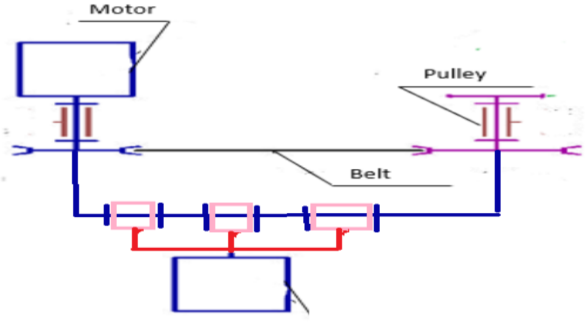


Fig 3. 10 kinematic schema along X

$FX = \frac{1}{2}(F1 + F2)$ (3.1) $with: m_i$=494.32g

$F1 = \Sigma m_i.g$ (3.2) F1 =494.32×0.001×9.81=4.84N

***F*2** Also changes given that it's a function of mass So :

$F2 = \Sigma m_i.\Upsilon$ (3.3)

$\Delta V = R \times \omega = 8 \times 314.15 = 2513.2 mm/s = 2.5132\ m/s$

$\Upsilon = \frac{\Delta V}{\Delta T} = \frac{2513.2}{0.1} = 25132 mm/s^2 = 25.132 m/s^2$

F2=494.32×0.001×25.132=12.42N

3.7.2 Motor Sizing:

It is important to understand the influence of 3 parameters:

1. Inertia: This corresponds to the resistance of an object to change in velocity.

2. Velocity

3. Torque: This is the most important factor in sizing a motor, as torque compensates for acceleration, load, and friction. [27]

Where:

- Pc: construction power.

$Pc = \frac{Q \times V}{K \times n}$ (3.4)

- n: overall efficiency,

- n = 0.75

We have set V = 7.5 m/min as the required maximum speed of the machine.

Q: the total mass of the elements

Q=∑Mi=494.32g

$K = \frac{60}{9.81}$ constant

$Pc = \frac{0.49432 \times 7.5 \times 9.81}{60 \times 0.75}$ = 0.80821w = 0.00080821kw

The information provided in the datasheet [27] indicates that the motor has a rated torque of 0.4 Nm at 600 rpm.

Power motor $P = 0.105 \times T(Nm) \times N(rpm) = 0.105 \times 0.4 \times 600 = 25.2w$ = 0.0252kw

3.7.3 Calculations on Trapezoidal Belts :

In order to make the best choice of belt with good performance to our machine, here we'll identify the type trapezoidal and to calculate we need to know certain data

Be for of that we need to choice F the Feed rate as 7500 mm\min as far as maximum , and build on it we can say ;

P= 2R π   so R= $\frac{p}{\pi 2}$ = 1193.66 with ryon of the motor we can say :

R= 1193.66 ⟶ 1 tr

r= 5 ⟶ 239 tr\min

Bellow we have the following data:

-$\boldsymbol{p}$:$engine\ pouwer$=0.0252 Kw
-$\boldsymbol{N_D}$:$motor\ rotational\ speed$=239 tr/min
-$\boldsymbol{D}$:$driven\ pulley\ diameter$=12.22mm
-$\boldsymbol{d}$:$driver\ puller\ parameter$=12$mm$

-The desired distance between the two pulleys is : C=476mm
- First, we calculate the operating engine Ps: Ps=$P.Ks$ (3.5)
The operating coefficient is known in the table (3.6).
We found: Ks=1.4 because the service life ranges from [16h; 24h] plus it is assumed that the device can be subjected to uniform transmission without jolts.
Ps= 0.0252×1.4= 0.03528Kw
We can conclude that he types of belt is A because the point with the coordinate (Ps,N_D)

3.7.4 Kinetic study

In this section we will study the kinetic part according to four criteria:
In order to determine the belt linear speed, belt center distance, belt length (Lp), and winding angle (θm),belt linear speed the following steps were performed.
by using this Formula [28]

$$V=r.\omega=\frac{\pi DND}{60} \quad (3.7)$$

$$V=\frac{3.14\times 12.22\times 239}{60}=1.52m/s$$

- Determination of belt length :

$$Lp=\mathrm{Lp}=2\mathrm{C}+1.57(\mathrm{D}+\mathrm{d})+\frac{(\mathrm{d}+\mathrm{D})2}{4\mathrm{C}} \quad (3.8)$$

So :

Lp=2 × 476 + 1.57(12.22 + 12) + $\frac{(12.22+12)2}{4\times 476}$= 990.33 mm

From the table (3.7) we get Lp=1000, and According to figure (3.11) we get KL = 0.98

the winding angle θm :

$$\theta_{m} = 180° - sin^{-1}\left(\frac{D-d}{2\times C}\right) = 180° \qquad (3.9)$$

And According to figure (3.16) we got $K\theta$=1

Basic belt power. From the table (3.7):

Pb= 1.48

Calculation of power rating Pa:

$$Pa = Pb\times KL\times K\theta \qquad (3.10)$$

Pa=1.48×1×0.98=1.45 kw

Determination the number of belts:

nb= $\frac{\text{Pa}}{\text{Pa}}$ =$\frac{1.48}{1.45}$≈1

In conclusion we need only one belt.

Bellow we have the tables and figures that helped us to reach our results :

	service léger 0 à 6 h/jour	service normal 6 à 16 h/jour	service dur 16 à 24 h/jour	service très dur en continu
transmission uniforme sans à-coups	1,0	1,2	1,4	1,6
transmission avec légers à-coups et chocs modérés	1,1	1,3	1,5	1,8
transmission avec à-coups et chocs élevés *	1,2	1,4	1,7	2,1

* avec des inversions de sens, des démarrages fréquents sous forts couples

Table 3.6 *Service Factor Value* K_s

Z	270, 295, 340, 380, 405*, 435, 465, 475*, 485, 505, 530*, 545, 570, 610, 625*, 635, 675, 700*, 710, 750, 780*, 790, 840, 895, 920*, 940, 1 000, 1 055, 1 080*, 1 095, 1 145, 1 205, 1 250, 1 330*, 1 420*, 1 540*...
A	415, 490, 541, 585, 620, 630*, 670, 700*, 719, 770, 790*, 820, 871, 890*, 933, 983, 990*, 1 049, 1 100*, 1 153, 1 201, 1 250*, 1 303, 1 353, 1 405, 1 430*, 1 455, 1 508, 1 550*, 1 608, 1 640*, 1 709, 1 750*, 1 858, 1 913, 1 940*, 2 013, 2 050*, 2 133, 2 200*, 2 273, 2 300*, 2 393, 2 480*, 2 533, 2 700*, 2 833, 3 183...
B	613, 655, 680, 729, 780, 830, 881, 930*, 980, 1 000*, 1 033, 1 083, 1 100*, 1 133, 1 185, 1 210*, 1 243, 1 318, 1 370*, 1 393, 1 465, 1 560*, 1 668, 1 760*, 1 872, 1 950*, 2 075, 2 180*, 2 283, 2 300*, 2 380, 2 480, 2 500*, 2 659, 2 700*, 2 870*, 3 200*, 3 393, 3 600*, 3 793, 4 060*, 4 430*, 4 820*, 5 043, 5 370*, 5 620, 6 070*, 6 585...
C	920, 1 075, 1 152, 1 312, 1 462, 1 505*, 1 662, 1 760*, 1 840, 1 950*, 2 094, 2 195*, 2 348, 2 420*, 2 500, 2 715*, 2 907, 2 880*, 3 080*, 3 312, 3 520*, 3 720, 3 964, 4 060*, 4 177, 4 278, 4 600*, 5 015, 5 380*, 5 662, 6 100*, 6 362, 6 815*, 7 035, 7 600*, 8 038, 8 444, 9 100*, 10 062, 10 700*...
D	2 576, 2 740*, 2 876, 3 100*, 3 226, 3 330*, 3 530, 3 730*, 4 080*, 4 386, 4 620*, 5 029, 5 400*, 5 676, 6 100*, 6 370, 6 840*, 7 126, 7 620*, 8 000, 8 405, 9 140*, 10 700*, 11 276, 12 200*, 13 700*, 15 200*...
E	4 660*, 5 040*, 5 105, 5 420*, 5 765, 6 100*, 6 505, 6 850*, 7 265, 7 650*, 8 055, 8 410, 8 790, 9 150*, 10 035, 11 230, 12 230*, 13 750*, 15 280*, 16 800*...

Séries étroites	SPZ	SPA	SPB	SPC	Lp (ISO 4184)
	630 à 3 550	800 à 4 500	1 250 à 8 000	2 000 à 12 500	**Lp (ISO 4184) :** 650, 710, 800, 900, 1 000, 1 120, 1 250, 1 400, 1 600, 1 800, 2 000, 2 240, 2 500, 2 800, 3 150, 3 500, 4 000, 4 500, 5 000, 5 600, 6 300, 7 100, 8 000, 9 000, 10 000, 11 200, 12 500

Table 3. 7 *Basic Length Of Trapezoidal Belts* ***Lp***

type courroie	diamètre primitif	vitesse linéaire V de la courroie (m/s)					type courroie	diamètre primitif	vitesse linéaire V de la courroie (m/s)				
		5	10	15	20	25			5	10	15	20	25
Z	50	0,45	0,72	0,85	–	–	C	180	3,92	6,10	7,33	8,32	–
	60	0,62	1,05	1,35	–	–		210	4,59	7,38	9,40	10,86	11,76
	70	0,73	1,29	1,70	1,94	–		240	4,99	8,31	10,82	12,75	14,14
	80	0,83	1,48	1,97	2,30	2,41		280	5,50	9,27	12,26	14,70	16,50
	90	0,90	1,61	2,18	2,58	2,76		320	5,83	9,96	13,34	16,10	18,29
	100	0,95	1,72	2,37	2,80	3,04		360	6,14	10,56	14,16	17,19	19,69
	110	1,00	1,82	2,48	2,99	3,27		430	6,55	11,25	15,32	18,68	21,43
A	85	1,25	2,04	2,66	3,01	–	D	290	8,92	13,44	15,95	16,80	–
	100	1,42	2,37	3,12	3,99	4,10		320	9,84	15,41	18,90	20,74	20,92
	115	1,55	2,64	3,52	4,21	4,73		360	10,94	17,50	22,07	24,96	26,19
	130	1,65	2,85	4,04	4,60	5,22		400	11,80	19,20	24,61	28,33	30,42
	150	1,75	3,03	4,10	4,80	5,72		460	12,78	21,18	27,55	32,29	34,37
	170	1,82	3,19	4,33	5,00	6,10		520	13,58	22,71	29,85	35,35	39,20
	190	1,87	3,30	4,54	5,55	6,39		580	14,16	23,96	31,64	37,76	42,80
B	120	2,11	3,23	4,23	4,80	–	E	440	10,97	18,85	24,69	28,33	29,44
	140	2,35	3,95	5,02	5,83	6,37		480	11,89	20,65	27,39	31,92	33,91
	160	2,57	4,03	5,61	6,63	7,37		520	12,62	22,15	29,63	34,95	37,68
	180	2,72	4,39	6,09	7,24	8,14		600	13,84	24,57	33,28	39,86	43,75
	200	2,81	4,81	6,42	7,71	8,75		700	14,94	27,26	36,66	44,28	49,35
	220	2,92	4,89	6,73	8,13	9,24		800	15,77	28,50	39,18	47,60	53,56
	250	3,01	5,06	6,89	8,64	8,85		950	16,82	30,40	42,00	51,40	59,13

Table 3- 8 Basic Power Of Trapezoidal Belts ***Pb [28]***

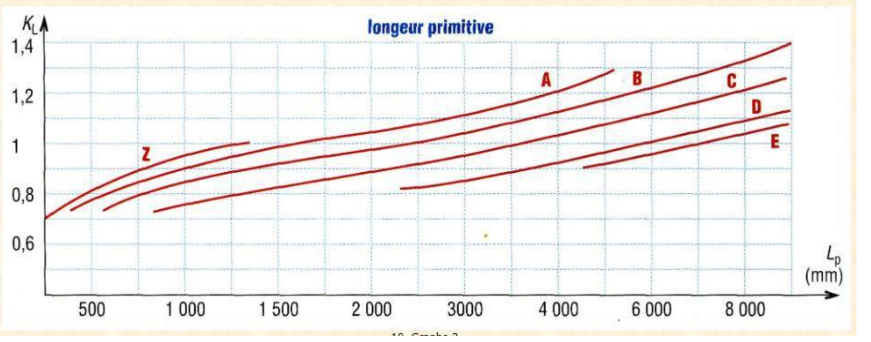


Fig 3- 11 Primary Length***[28]***

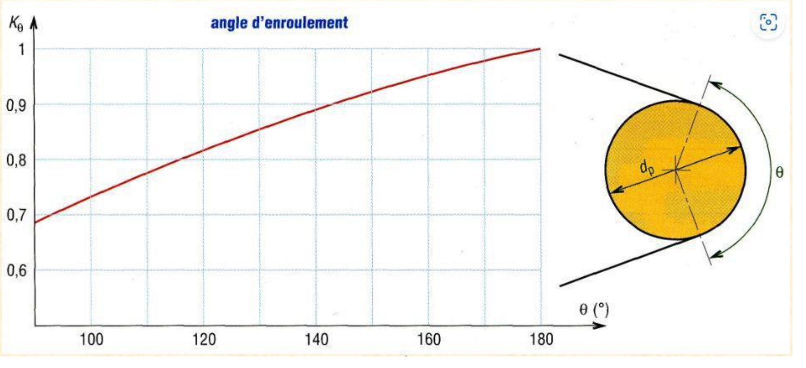


Fig 3- 12 Roll Angle***[28]***

3.7.5 Linear Rail Guide System Calculations

3.7.5.1 Bearing calculations

Bearings at the screw and belt bearings are dimensioned according to two criteria [29]:

- The dynamic load capacity. That is, $C\ bearing > C\ necessary$.
- The service Life.$L_h\ bearing > L_h\ necessary$

For this we will use the following formulas

$$C = \frac{f_z f_l P}{f_t f_n f_h} \qquad (3.11)$$

$\boldsymbol{fz}$: Additional coefficient for dynamic forces. We take $fz = 1$.

. f_h: Hardness coefficient. Consider $f_h = 1$.

. $\boldsymbol{f_t}$: Temperature coefficient. In our case $f_t = 1$

. $\boldsymbol{f_l}$: Coefficient of service life. We take $L_h\ necessary = 70000\ hours$

$$f_1 = \sqrt[3]{\frac{L_h\ necessary}{500}} \qquad (3.12)$$

$\boldsymbol{f}_n$: Coefficient of number of turns

$$\boldsymbol{f}_n = \sqrt[3]{\frac{100}{3N}} \qquad (3.13)$$

$$L_h = (\frac{C}{P})^k \times \frac{10^6}{60 \times N} \qquad (3.14)$$

$\boldsymbol{K}$=3 for Ball bearing

X-axis Bearing Sizing

The load carried by the bearing is divided by three because it is distributed over two guide rails and a trapezoidal Belt, $P = \frac{Fx}{3} = \frac{8.63}{3} = 2.87\ N$

- The result is $C = \frac{1.\times 5.19 \times 2.87}{1 \times 0.51 \times 1} = 29.2N$
- We chose the LM8UU Ball Bearing C dyn = 380N

So : $$L_h = (\frac{C}{P})^k \times \frac{10^6}{60 \times N} \qquad (3.15)$$

$$L_h = (\frac{380}{2.87})^3 \times \frac{10^6}{60 \times 239} = 161866117 \text{hours}$$

$L_h\ bearing = 161866117\ hours \gg L_h\ necessary = 70000\ hours$

3.7.6 Forces, speed exerted on the Y axis:

3.7.6.1 Calculations of Forces, speed:

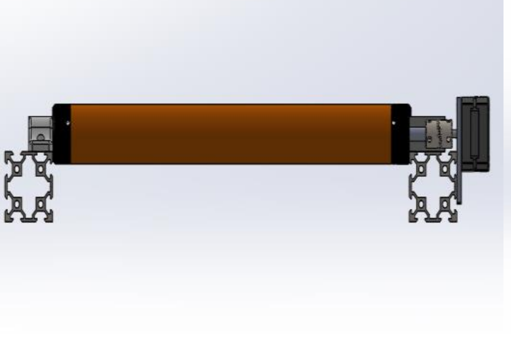
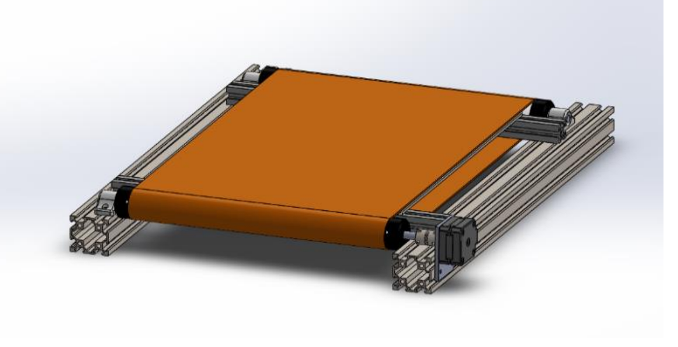



Fig3-13 translation and conception along Y system

$FX == \frac{1}{2}(F1 + F2) \qquad with\ m_i = 1397g$

$F1 = \Sigma m_i.g = 1397 \times 0.001 \times 9.81 = 13.7N$

$\boldsymbol{F2}$ Also changes given that it's a function of mass So :

$F2 = \Sigma m_i.\Upsilon$

$\Delta V = R \times \omega = 16 \times 314.15 = 5026.4 mm/s = 5.0264\ m/s$

$\Upsilon = \frac{\Delta V}{\Delta T} = \frac{5026.4}{0.1} = 50264 mm/s^2 = 50.2640 m/s^2$

F2=1397×0.001×50.2640=70.218N

3.7.6.2 Motor Sizing on Y

1. Befor of all we need to **Calculate Rotational Speed (RPM):**

- Steps per revolution = 200 steps.
- Step rate = 4000 steps/second.

$N = \frac{\text{Step Rate}}{\text{Steps per Revolution}} \times 60N = \frac{4000\ \text{steps/sec}}{200\text{steps}\backslash\text{rev}} \times 60N =$ N=20rev/sec×60

N=1200 RPM = 1200 tr\min

Now we move to

-Calculate Linear Speed:

$$V = \frac{D \times \pi \times N}{60} \qquad (3.16)$$

With Diameter (D) = 32 mm = 0.032 meters

$$V = \frac{0.032 \times \pi \times 1200}{60}$$

V≈2.01m/s

-angular speed;

$$\omega = \frac{2\pi \times N}{60} \qquad (3.17)$$

$$\omega = \frac{2\pi \times 1200}{60}$$

ω≈125.66rad/s

$Pc = \frac{Q \times V}{K \times n} = Pc = \frac{1.397 \times 2.01 \times 9.81}{60 \times 0.75}$ = 0.612w = 0.000612kw

Power motor $P = 0.105 \times T(Nm) \times N(rpm) = 0.105 \times 0.5 \times 1200 = 63w$ =0.063kw

$p_s = K_s \times P = 1.6 \times 0.063 = 0.10\ kw$

-Belt Length Calculation

For an endless belt, the total belt length can be calculated using the formula:

$$L = 2 \times C + \pi(d_1 + d_2) + \frac{(d_2 - d_1)^2}{4 \times C}$$

$$L = 2 \times 400 + \pi(32 + 32) + \frac{(32 - 32)^2}{4 \times 400}$$

L=1001.06 mm

- **Calculating Load Capacity**
  1. **Determine the Printed Object's Weight**:

- Estimate the average weight of the printed objects. For example, if the average small print weighs 400 grams (0.4 kg), you need to consider the total weight of all objects on the belt at any given time.
  2. **Calculate the Belt Load Capacity**:
- If the belt has a load capacity of 50 kg/m and is 0.3 meters wide, it can support: Total Load Capacity=Belt Width×Load Capacity per Meter
- Total Load Capacity=0.4 m×2 kg/m=0.8 kg
  3. **Check the Material Distribution**:
- Ensure the weight of all printed objects within a certain length does not exceed this capacity. For example, if you print twenty objects each weighing 0.1 kg, and they are distributed evenly over a meter of belt length, the total weight would be:

Total Weight=20×0.1kg=2kg

3.7.7 Forces, speed exerted on the Z axis:

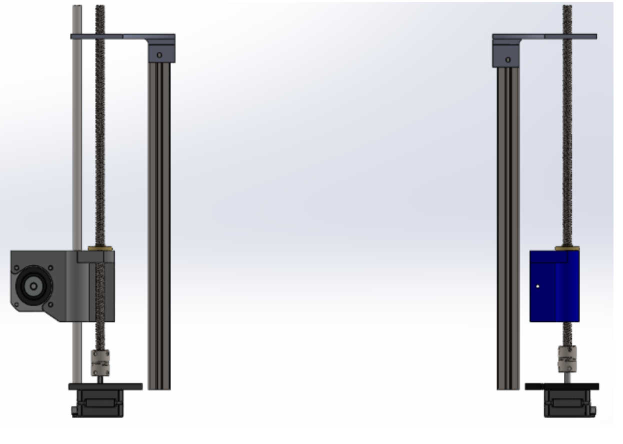


Fig 3- 14 2D conception along Y

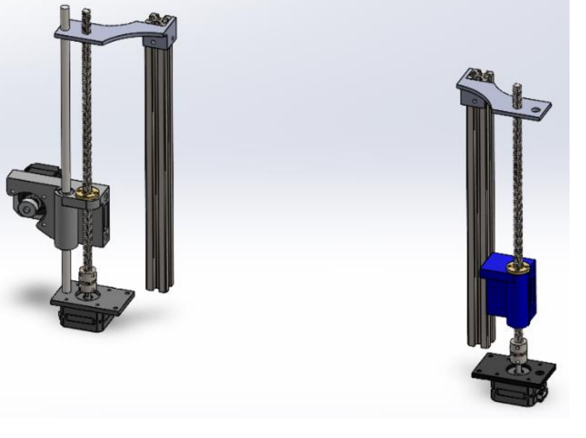


Fig3-15 translation system along Y

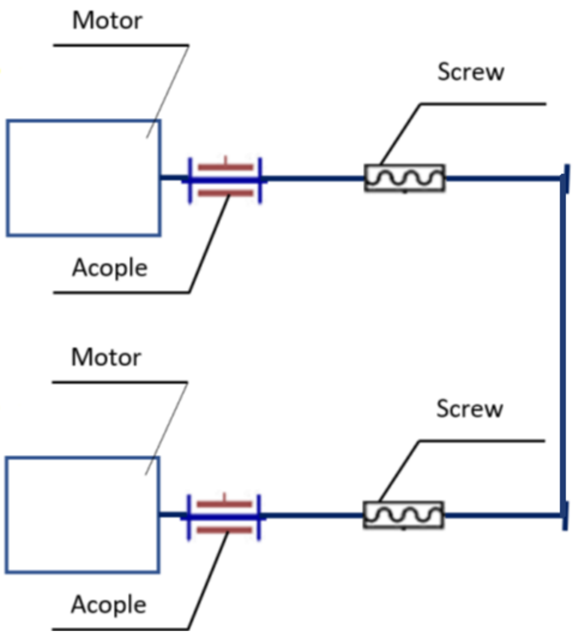


Fig 3.16 kinematic schema along Z

The load F along Z is purely axial and, in addition to the weight of the components(F_1), inertia forces due to acceleration and deceleration (F_2). with the condition that the total forces will be divided on three, as this is supported by the two linear guides and the trapezoidal screw. This gives:

$FZ == \frac{1}{3}(F_1 + F_2)$ $\quad$ *with* m_i=872.27g

With : $F_1=\Sigma m_i.g$

And : $F_2=\Sigma m_i.\Upsilon$

g: gravity

i : components weights

$F_1=\Sigma m_i.g=872.27\times0.001\times9.81=8.55N$

F2 Also changes given that it's a function of mass

So : $F_2=\Sigma m_i.\Upsilon$

Υ: Acceleration. is given by:

$\Upsilon=\frac{\Delta V}{\Delta T}$

$\Delta V=\frac{P}{2\pi}\times\omega=314.15=99.99mm/s=0.099m/s$

Let's take **Δ= 0.1s**, which is a fairly short response time. We get:

$\Upsilon=\frac{\Delta V}{\Delta T}=\frac{0.099}{0.1}=999.97mm/s^2=0.99m/s^2$

So : $F_2=\Sigma m_i.\Upsilon$, $F_2=872.27\times0.001\times0.99=0.86N$

$FZ == \frac{1}{3}(F_1 + F_2) = 3.13N$

3.8 Transmission system calculation:

3.8.1 Calculations on trapezoidal screws:

The trapezoidal screw/nut pair has long been used to transform rotary motion into linear motion in a wide range of applications. rotary motion into linear motion. The total power (P_t) transmitted by the screw to the nut is transformed into power (P_u). The ratio $\frac{P_u}{P_t}$ =η defines the system's efficiency, which depends on the coefficient of friction between the contact surfaces of the screw, nut and thread helix angle.

This is sliding friction. Part of the power is therefore transformed into heat with each movement. It is possible to parameterize this sliding friction to evaluate the proper functioning of the assembly. The criteria is to limit the contact surface pressure on the thread side, to enable smooth sliding between the two surfaces.

We also limit the product $.V_{st}$ (P= contact surface pressure . and V_{st} = friction velocity over the average thread diameter) to limit the power lost in the form of heat. as heat. This keeps the temperature of the surfaces in contact in check. This limitation is important because if we use bronze nuts, it's important not to " damage " the lubricant, where as if we use self-lubricating polyamide nuts , which require no extra oil or grease, the temperature must be controlled. the permissible values of the product $P .V_{st}$ are reduced. [30]

3.8.2 Calculation of contact surface pressure "P_s“

The contact surface pressure "p" is calculated using the following formula [30]*:*

$P=\frac{F}{At}$ (3.18)

F : Axial force [N].

At : Total bearing surface between screw teeth and nut teeth. in the plane perpendicular to the axis. [mm2].

In our case we can get At from the software SolidWorks (2022). At=101mm²

3.8.3 Calculation of sliding speed « V_{st}»

The sliding speed can be calculated using one of the following formulas [30]:

- if we have already defined the number of revolutions per minute of the screw

$V_{st} = \frac{N\, p_{as}}{1000 \sin\alpha}$ (3.19)

N= number of screw revolutions per minute.

p_{as} = thread pitch [mm]

α = thread helix angle

- if we have already defined the transfer speed of the nut:

$V_{st} = \frac{V_{tr}}{\sin\alpha}$ (3.20)

Vst = sliding speed on average diameter. [m/min]

Vtr = transfer speed [m/min].

NOTE: Screw rotation in revolutions per minute and nut transfer speed are linked by the following formula [30]:

$N = \frac{1000\ Vtr}{p_{as}}$ (3.21)

In our case, we set the number of screw revolutions per minute to 3000 rpm, so we use the equation (4.4) for bronze nuts (which is our case), the product $p\ .vst$ is used to draw the graph shown in figuree where three zones are highlighted, each characterized under certain conditions of use, between sliding speed and pressure.

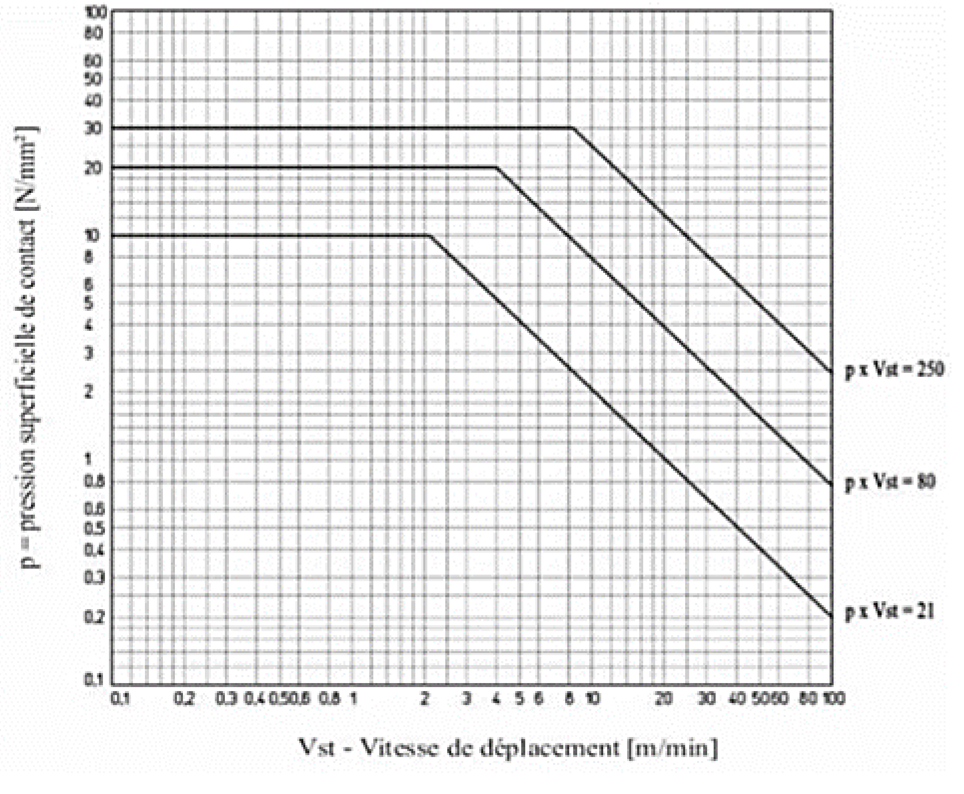


Fig 3. 17 Bronze sliding condition [30]

Load type	*f i*
Constant loads with controlled acc/dec ramps	*From 1 to 0,5*
Constant loads with rip starts and stops	*From 0,5 to 0,33*
Highly variable loads and speeds	*From 0,33 to 0,25*
Shock and vibration loads	*From 0,25 to 0,17*

Table 3.8. Safety coefficients with respect to inertial forces [30]

3.8.4 Z-axis component calculations:

Forces, speed and pressure exerted on the Z-axis:

the contact surface pressure is

$P=\frac{F}{At}$ =0.030 N/mm^2

helix angle:

$\alpha=\tan^{-}1\frac{p_{as}}{\pi D}$ =4.549

The sliding speed is:

$V_{st}=\frac{11.5\times2}{1000\times\sin 4.549}$ =0.29 m/min

Now let's calculate the product by using Formula

$P.V_{st}.fi$=0.030×0.29×0.7=6.09$MPa.m/min$

In conclusion, according to the Figure (3.14), the screw operates in zone A. Operating conditions are ideal.

Z-axis Bearing Sizing

The load carried by the bearing is divided by three because it is distributed over two guide rails and a trapezoidal screw.

Knowing that , $P=\frac{FZ}{3}=\frac{13.3}{3}=4.43\ N$

- The result is $C=\frac{1.\times5.19\times2.87}{1\times1.42\times1}=16.19N$
- We chose the LM8UU Ball Bearing C dyn = 380N

So : $L_h=(\frac{C}{P})^k\times\frac{10^6}{60\times N}$

$$L_h = \left(\frac{380}{4.43}\right)^3 \times \frac{10^6}{60 \times 11.5} = 884438536 \text{hours}$$

$L_h\ bearing = 884438536\ hours \gg L_h\ necessary = 70000\ hours$

3.8 Conclusion:

This chapter offers a comprehensive framework for sizing a 3D printer with a conveyor system, covering key aspects such as transmission systems, motor selection, studies, and guidance system evaluation. The insights gained from this process are reflected in the design and construction of a well-optimized 3D printer that can perform its intended tasks effectively and efficiently.

Chapter IV

Assembly and programming

4.1 introduction:

This chapter will focus on the assembly and enhancement of the electrical and mechanical components of our machine. We have naturally gravitated towards open-source solutions that are widely adopted in the machine-building community. Specifically, we will use Marlin firmware on an Arduino with a CNC shield. As with any project, we faced challenges with some of our initial choices, and we will discuss these obstacles along with their solutions in due course.

4.2 Structure Assembly:

4.2.1 Outer frame:

The frame of the 3D printer is designed using aluminium extrusion rails known as V-slots. We chose extruded aluminium due to its superior strength-to-weight ratio compared to steel, making it robust enough for most structural design applications. Additionally, it is affordable and easy to work with.

Fig4.1 CAD frame of 3D printer

Fig 4.2 The frame in reality

As mentioned in the previous chapters, we used 20x20 and 40x40 aluminium frames, securing each piece to the other.

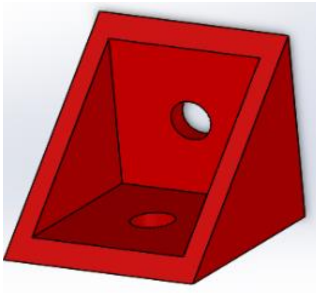


Fig 4.3: Printed angle bracket

After going to the manufacturing workshop, we cut the aluminium columns, then using a bracket corner to fix the frame, we glued four of them together, and we had to drill a hole in the fifth column to fix it with a screw, and this gave the frame better cohesion between the two columns.

4.2.2 X-axis assembly:

- Linear Rods:

Commonly made from steel and chrome-plated for enhanced hardness, linear rods come in various lengths and diameters. For the design of this printer, we used rods with an 8mm diameter

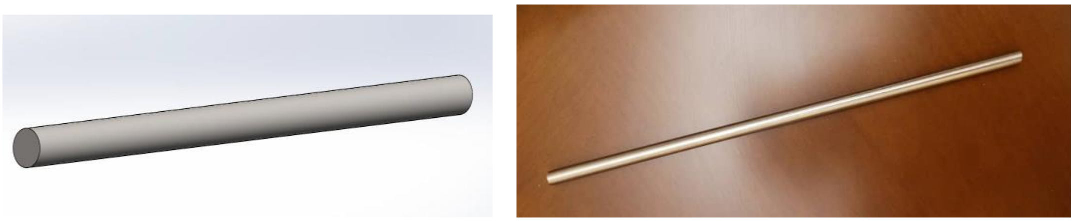


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Fig4.4: 8mm linear rod

- **Stepper Motor:**

To provide thread movement for the extruder assembled with the feeder all assembled in a support plate, we used a NEMA 17 “1704HS168A” stepper motor.

To convert the rotational movement of the motor into linear motion for the x-axis, we used a GT2 timing belt with a pitch of 2mm and of 6mm width and a GT2 timing pulley with 2mm pitch, 6mm width, 20 tooth and a 5mm bore diameter to match the size of the stepper motor shaft. As for the pulley, we printed it for more profit and economy in construction.

Fig 4.5:(L) GT2 timing Belt and GT2 timing pulley, (R) printed pully

As the picture below shows the installation on the support plate.

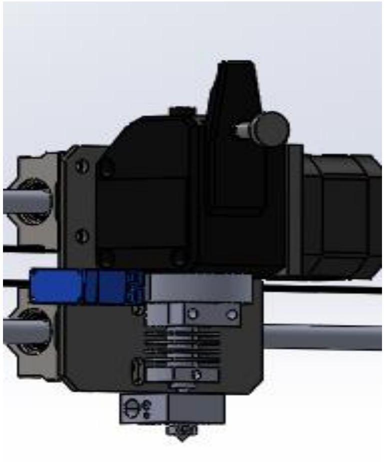


Fig 4.6: support plate assembly

For the linear rod, it passes inside a roller, which facilitates the process of moving on the X-axis.

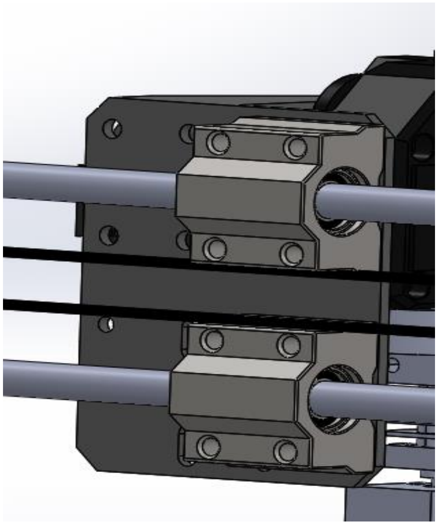


Fig 4.7: Linear ball bearing

Printed items also include the x mount, Among the printed items is the holder and more details will follow on how to print.

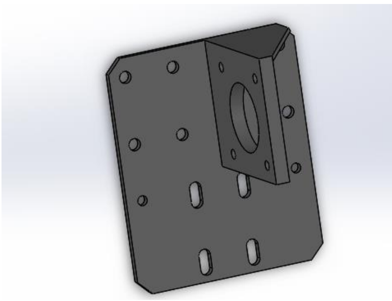
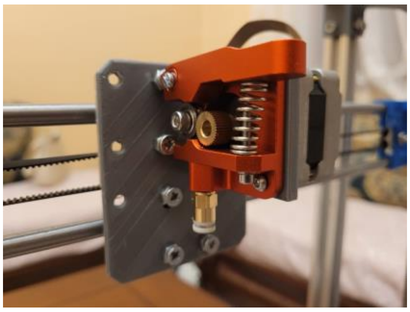



Fig 4.8: X mount holder

- **Extruder assembly:**

Everything starts from the feeder, through the extruder cap, all the way to the nozzle. The idea behind that cap was to install it with a small servo to give the extruder a fourth degree of freedom and allow it to move 45 degrees.

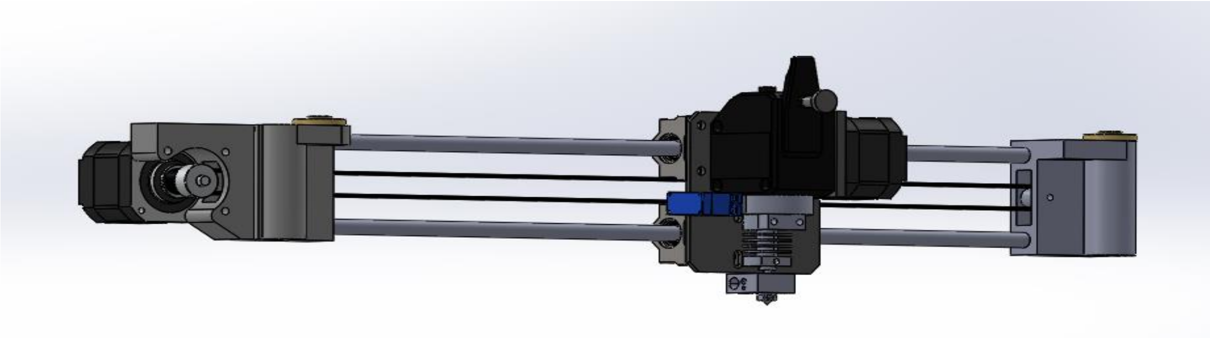
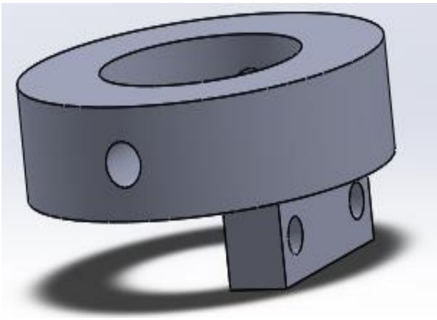


Fig 4.9: Assembly of the X-axis + Extruder assembly



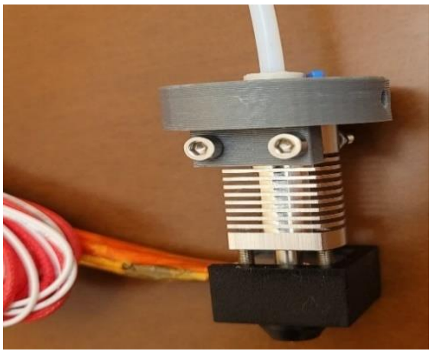
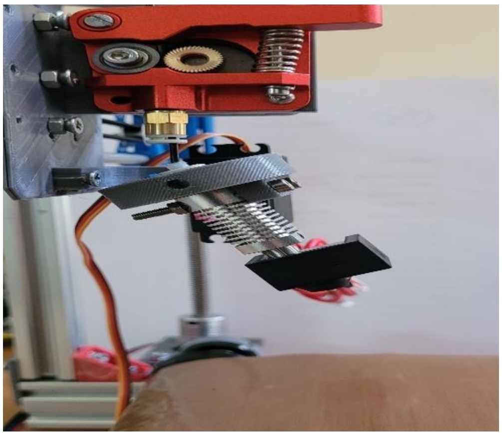


Fig 4 .10: Extruder Hat

This Extruder Hat allows us to mount a micro motor with a plastic arm, the idea of which is to add a degree of freedom and a 4th axis to the printer, which in turn rotates the extruder 45 degrees.



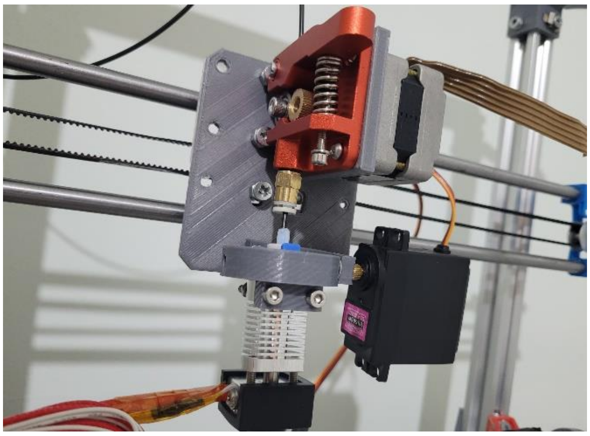
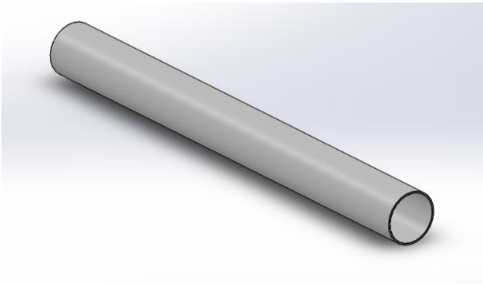


Fig 4.11 : rotates the extruder 45 degrees.

4.2.3 Y-axis assembly:

This axis is based on the moving of the conveyor. If we bring a cylinder tube with a length of 285 mm and a diameter of 32 mm, it enters the tube holder with a diameter of 33 mm and we drill an 8 mm hole in it to insert the cylinder shaft directly to the roller, which in turn will convert the linear motion to a rotary motion.



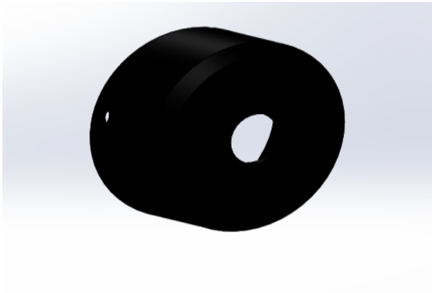


Fig 4.12: cylinder tube with holder

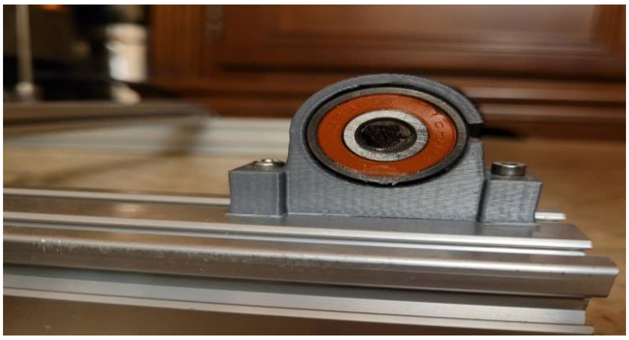


Fig4.13: Mount Bearing

Fig 4.14: The assembly

Of course, the Nema motor responsible for the movement of the axis, we assemble it with a plate and We use couplings to transfer torque from a stepper motor to a connecting pin. The diameter of the motor shaft is 5mm and the diameter of the connecting pin is 8mm, so we chose a coupling of 5mm*8mm.

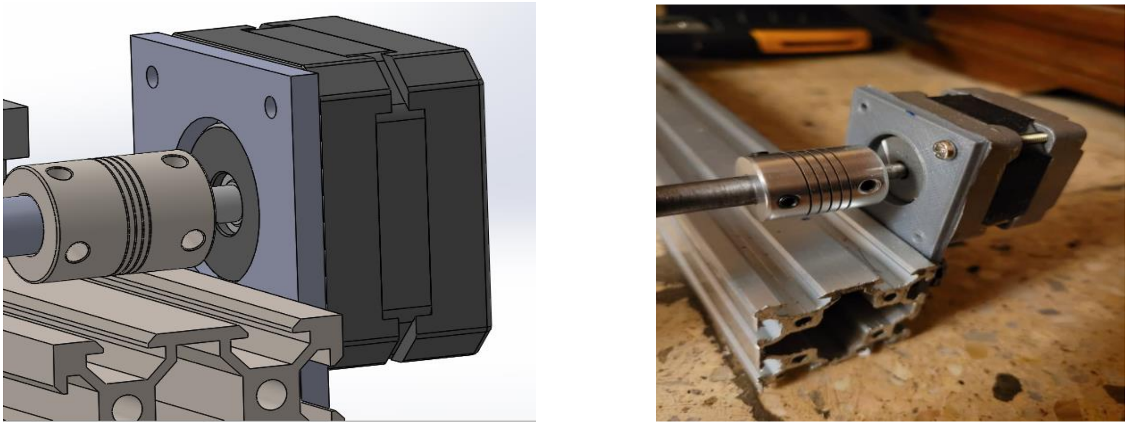


Fig 4.15: The motor assembly with a coupler and plat

We placed an aluminium column between the two bases for good sealing and to avoid excessive movement glued with angle bracket.

Fig 4.16: An aluminium column

- **Z-axis assembly:**

The Z axis will be responsible for the rise and fall of the X axis, so we must make sure that it is well secured from the top and bottom, so we printed the upper and lower corners.

Fig 4.17*:* Assembly of the Z-axis

Fig4. 18: upper and lower corners

The way the X-axis will move is by inserting the linear shaft into the Carriage that we also printed, which in turn will rise and fall by means of a motor, so the X-axis will necessarily move.

Problem and solution:

When we came to print the Carriage, we faced an obstacle, which is a problem that many engineers in the industrial sector face and which must be taken into consideration, which is the problem of time. When we uploaded the part to the Cura program, it showed us that it would take 13 hours and 2 minutes. This is a lot of time for a university student, as it is not possible to spend a whole day waiting for one part, and it is impossible to leave the lab and leave it unattended to avoid an accident. In addition, we asked if there was anyone outside the university who could assign the task and provide us with the service, but the result was unexpected. The price of the product will be as follows: **Printing hours x 400 = final price**.

Whichmeans:**13.2x400=5280DA**.

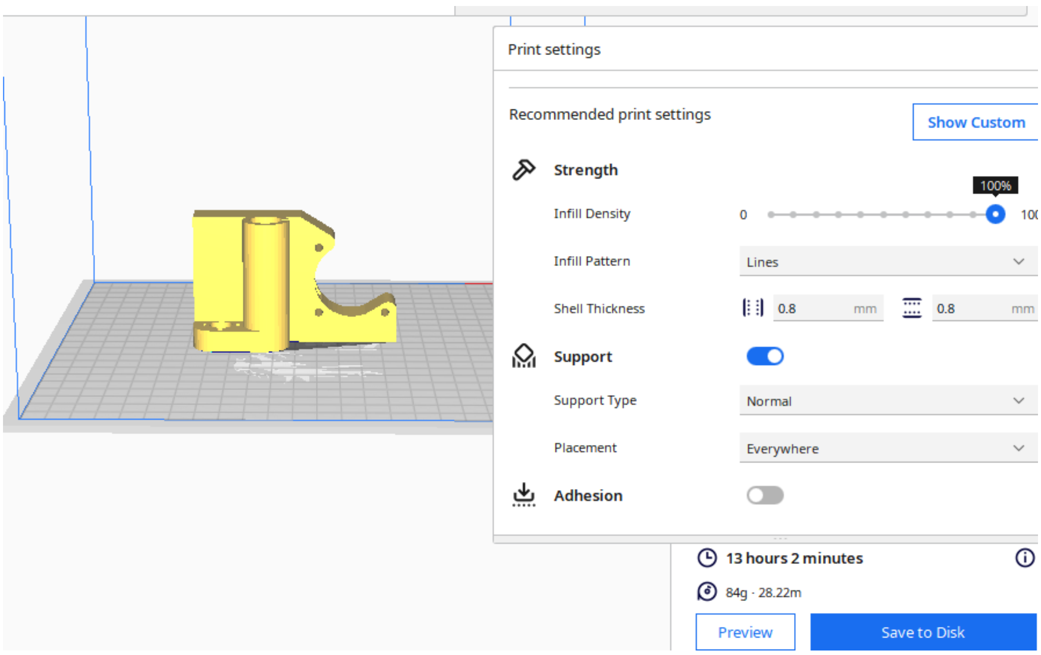


Fig.4.19: Piece from cura showing the time

So we had to think outside the box and use some engineering tricks. We loaded the piece onto SolidWorks and then divided the piece into three pieces like this:

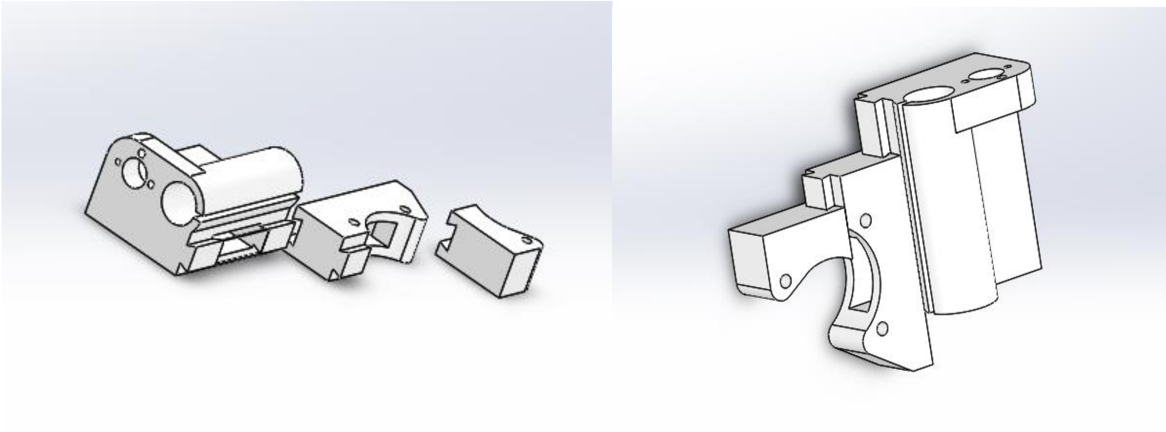


Fig 4.20: The piece is divided in solid.

Then print each piece separately. Fortunately, the lab has two printers, which made it easy for us. Each piece was printed in parallel, and it did not take more than about 5 hours.

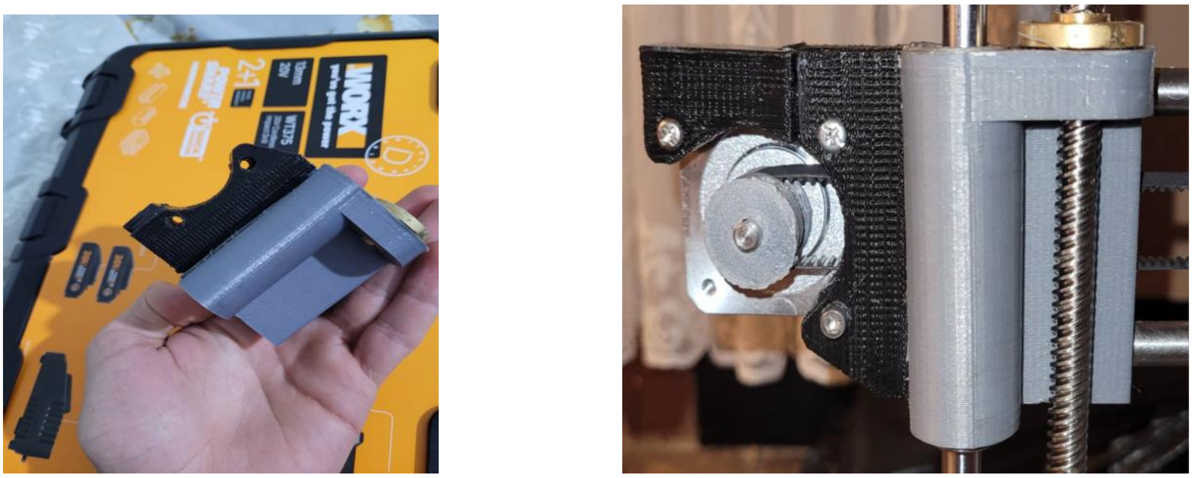


Fig4.21 : Final rustle

- ***Lead screw:***

To move the X-axis up and down the Z-axis, a Lead screw is used. The used lead screw diameter is 8mm, a 2mm pitch and 8mm lead

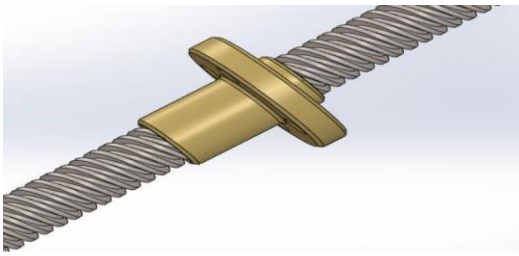


Fig 4.22: 8mm Lead screw and a brass nut.

The guide system was a linear shaft.

Another Problem and solution:

Our initial thinking and design were to build the Z-axis based on two linear shafts and a screw. This ultimately results in a curve with a defective degree of inclination as shown in the Fig.

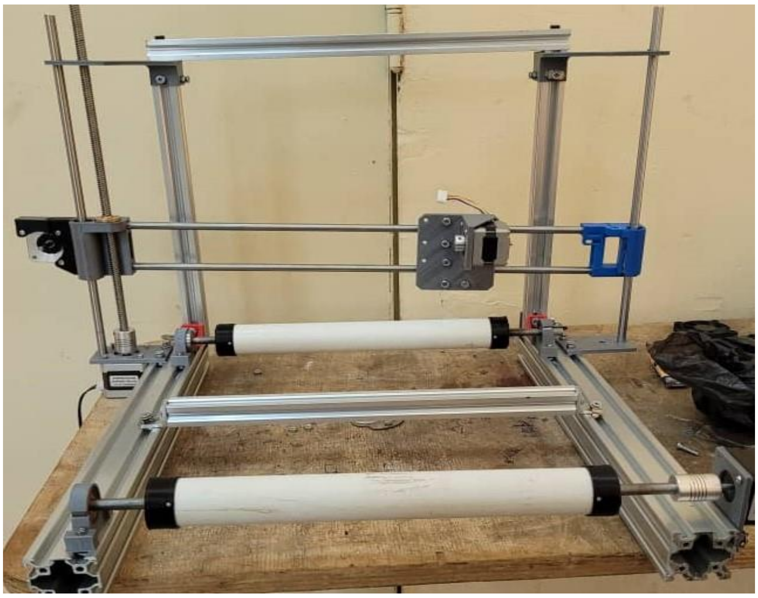


Fig4.23: Error appears on the right side

To solve this problem, we replaced the linear shaft with another screw. We kept the rolling, so we saw that this motion system would create a similarity between it and the ball screw system, which has a high level of mechanical efficiency. Ball bearings create a smooth sliding surface for the screw, thus reducing friction and thus increasing the life of the ball screw.

Fig4.24: The image shows the error is corrected.

4.2.4 Final shape of the machine:

After assembling each axis to get our final structure as you can see in the next figure:

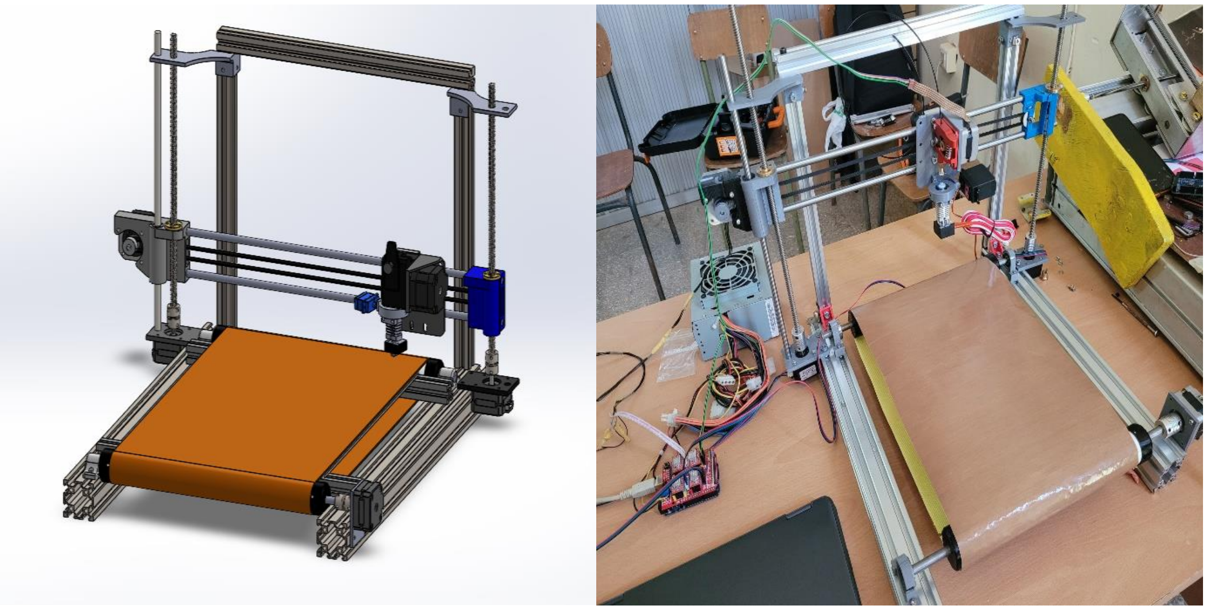


Fig 4.25: Final shape of the machine

4.4 CAD and Slicing Software:

In the rapid prototyping section, our process begins with a product idea, which we then develop into a sketch. This sketch is converted into a computer-aided design (CAD) for 3D printing. Figure 4-24 illustrates the fundamental steps of transforming an idea into a 3D-printed object.

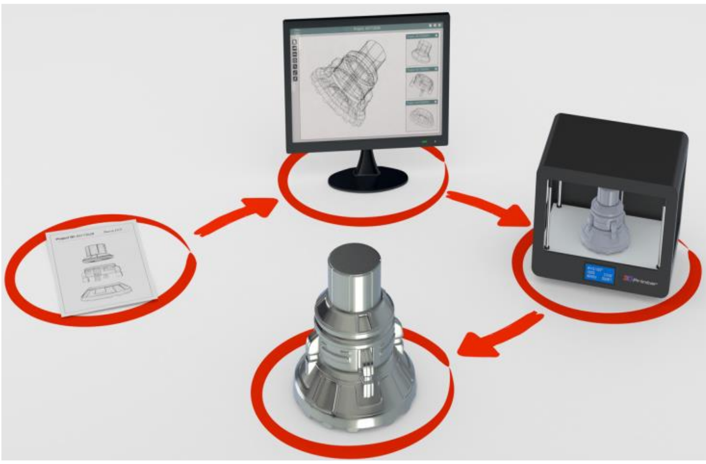


Fig 4.26: The workflow from idea to finished 3D print

As you can see going clockwise from the left: 2D drawing, CAD file generation, 3D printed prototype, final piece.

Today, there is a wide variety of 3D modelling applications available, ranging from simple and user-friendly to more complex ones. We have opted for SolidWorks, a program that enables us to create models and export them as STL files.

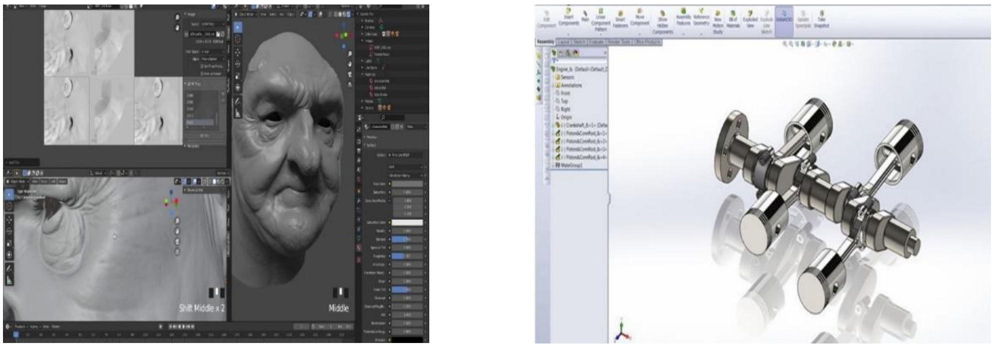


Fig 4.27: some CAD interface (blender\SolidWorks)

4.4.1 Cura slicing:

Cura is a popular slicing software developed by Ultimaker, used for 3D printing. It converts 3D models into instructions for 3D printers. Here are some key features and functions of Cura software:

Slicing: Cura slices a 3D model into layers and generates the corresponding G-code, which is the language 3D printers understand.

User-Friendly Interface: It provides an intuitive and easy-to-navigate interface, making it accessible to both beginners and experienced users.

Customizable Settings: Users can customize a wide range of settings, including layer height, print speed, temperature, and support structures, to optimize prints for different 3D printers and materials.

Pre-Configured Profiles: Cura comes with pre-configured profiles for various 3D printers and materials, simplifying the setup process.

Support for Multiple File Formats: It supports various file formats like STL, OBJ, and 3MF, which are common in 3D modeling.

Fig 4.28: cura interface

Cura is widely used in both hobbyist and professional 3D printing due to its robust features and ease of use.

4.4.2 how to print:

Now we take a practical example so that the reader of this note can understand the most important steps for printing 3D parts.

For example, we take this piece (the extruder cap) and draw a drawing on the solid with the appropriate dimensions for it.

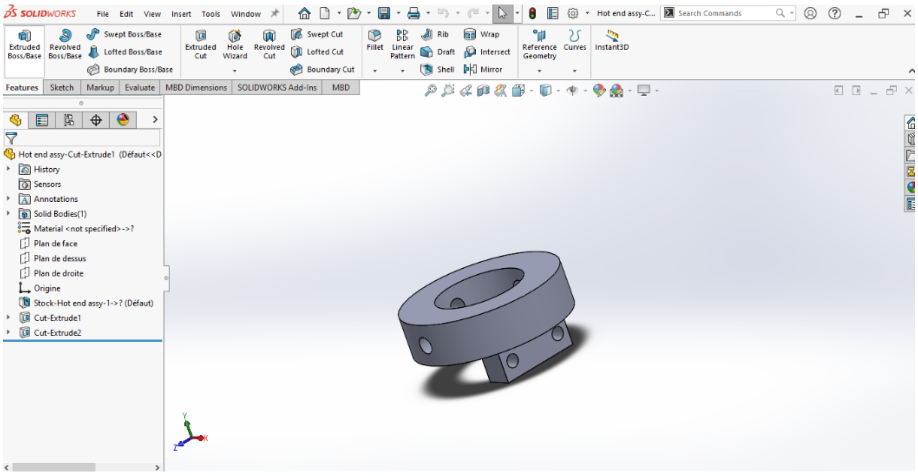


Fig4.29: The piece drawn on SolidWorks

Then we click on the Save as: icon and specify the stl format

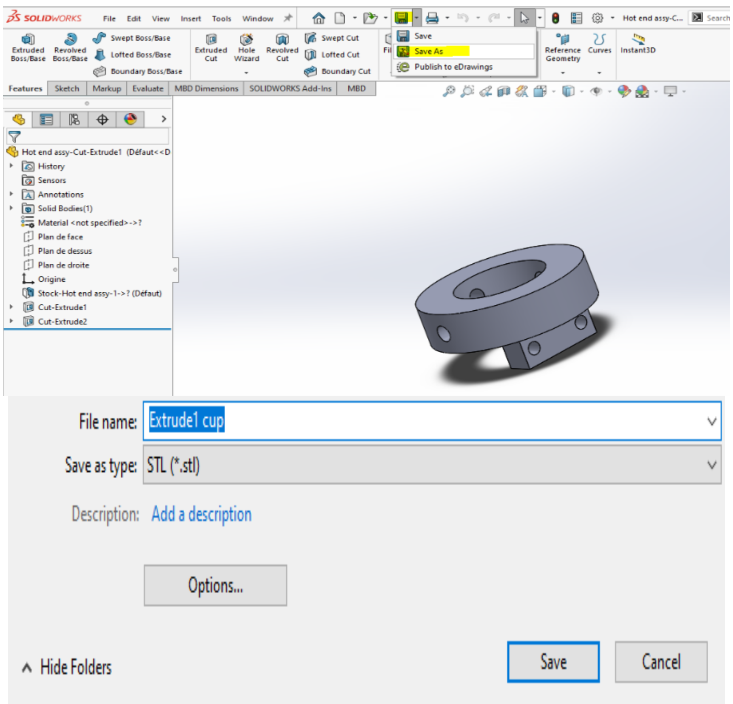


Fig 4.30: save as STL

Then we open the Cura program after downloading it from the official website and downloading it is completely free.

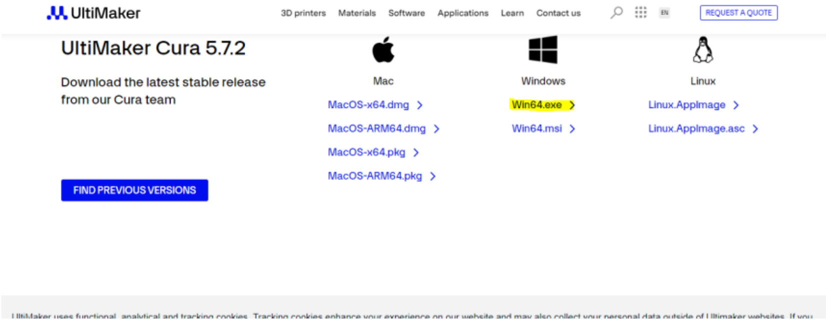


Fig 4.31 download cura programme

The first thing we do after opening the program is to add the printer that we will work on. We choose this instruction: ultimaker printers.

Then we search for creality 3d and find out the type of creality ender 3 pro.

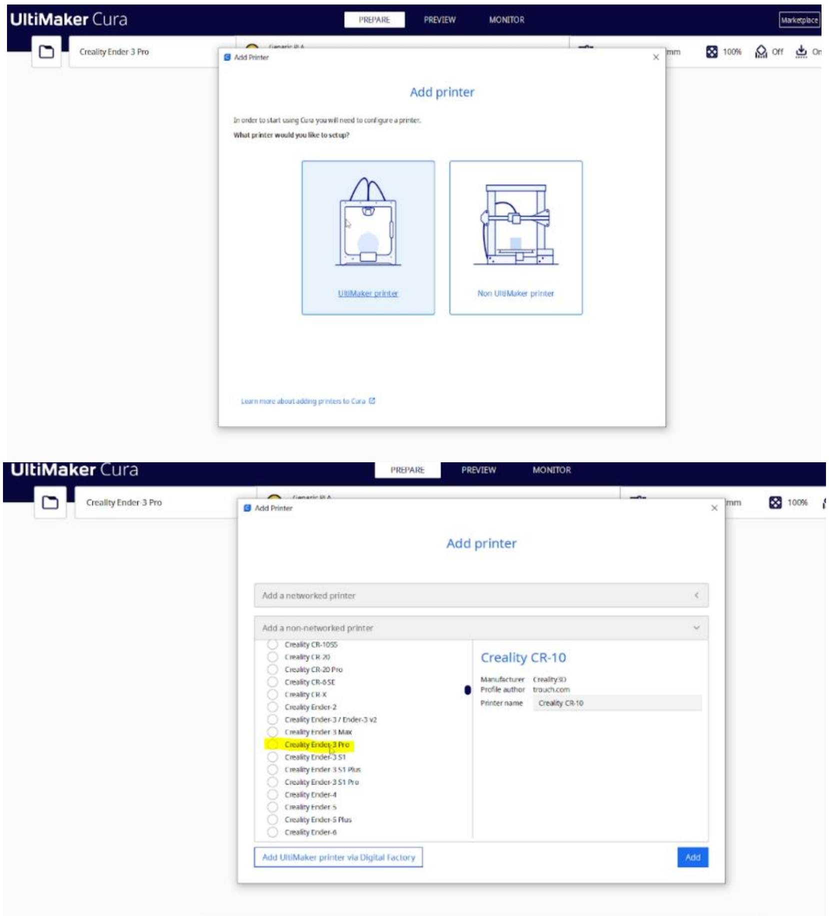


Fig 4.32 : chois our Machin

This interface gives us on the right the control of the printing settings, and on the left the orientation and positioning of the piece.

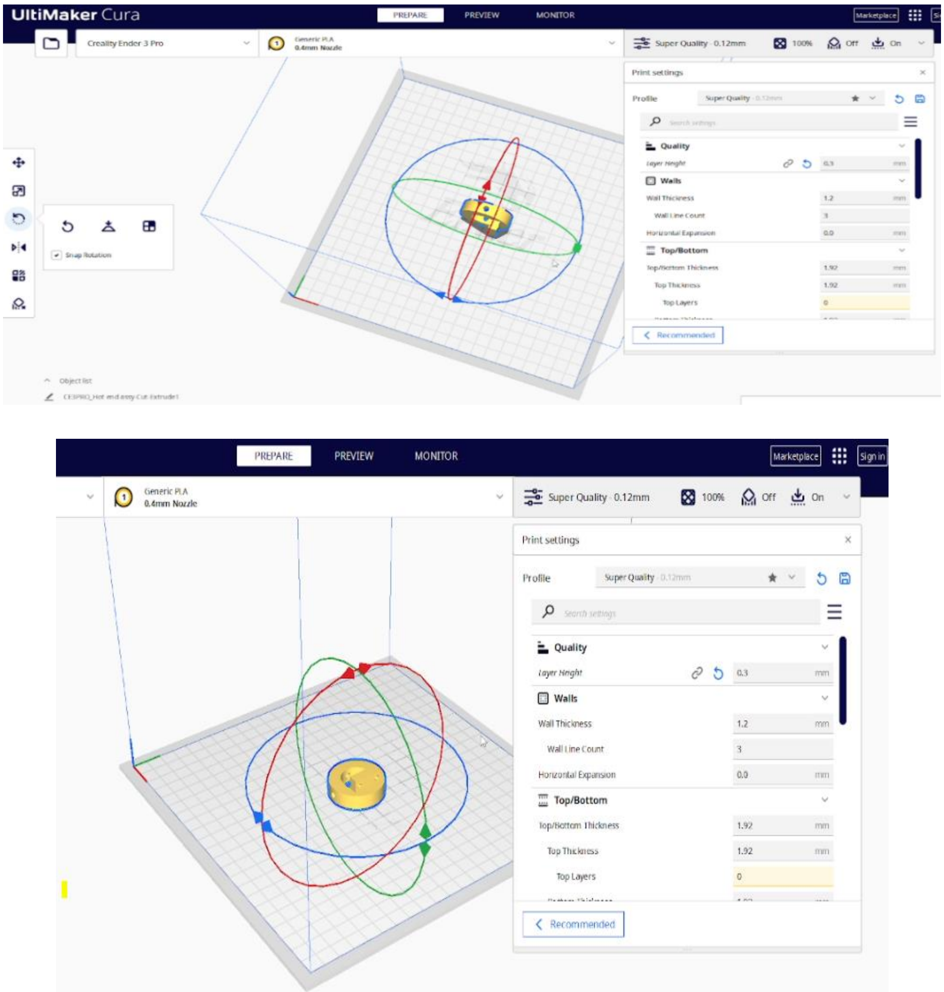


Fig 4.33: cura interface

You must go to the infill box and mark infill density, which means the internal fullness of the piece, in some cases 80, 100, and 25 depending on the piece, and then choose the type of fullness, and lines is an option that is more appropriate for all pieces.

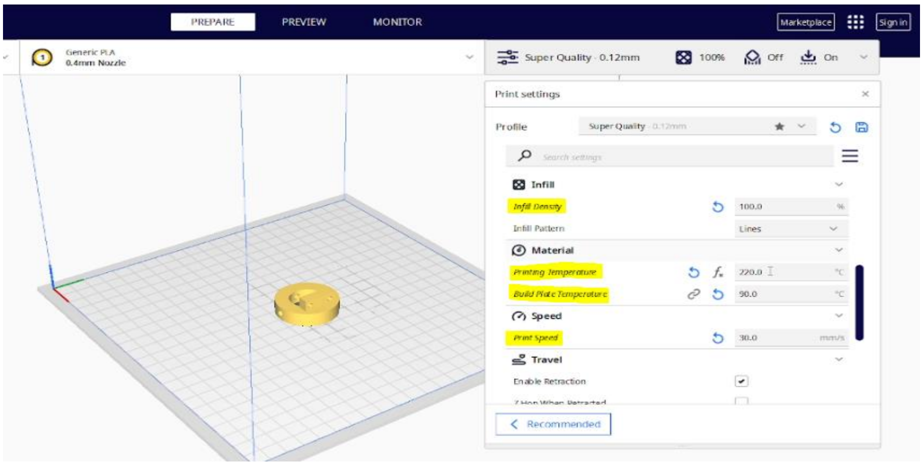


Fig 4.34: Adjust settings

Then we go to material. You have to take the material you are printing with into consideration. In our case, we were printing with PLA, so we choose 220 for the plastic and 90 for the bed.

Also, the speed of printing, which will be reflected in the quality of printing. The lower the speed, the more beautiful the overall piece will be, In our case, we did not know the option of supports because we do not need them, as they depend on each piece and its complexity.

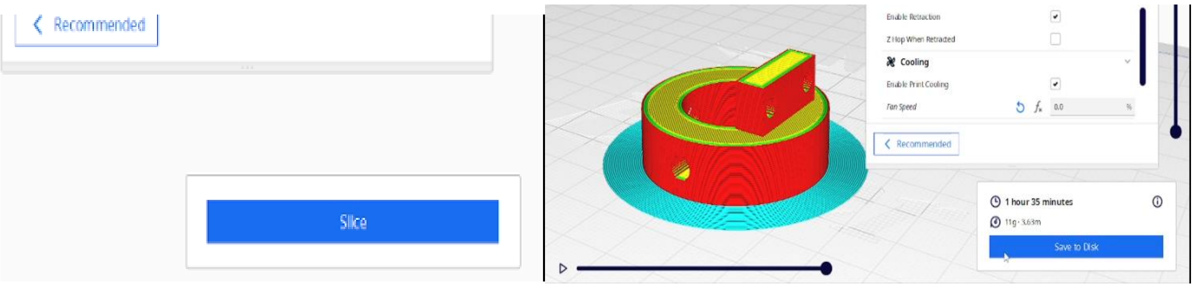


Fig 4.35 : slice and save

In the end, we click on slice. It shows you the time it will take and the weight after we click save to disk and save the work in G code format.

Then the printing step begins. We withdraw the TF card and insert it into the computer to download the code, then we insert it again into the printer.

We go to the LED screen and choose print from TF card, and we know the part code according to what was previously named. We show the printer until it is ready in terms of the temperature of the extruder and bed, then it will start.

The screen will show you the percentage of printing, the amount of time consumed, and the temperature.

After the time specified for you in the program, your piece will be completed.

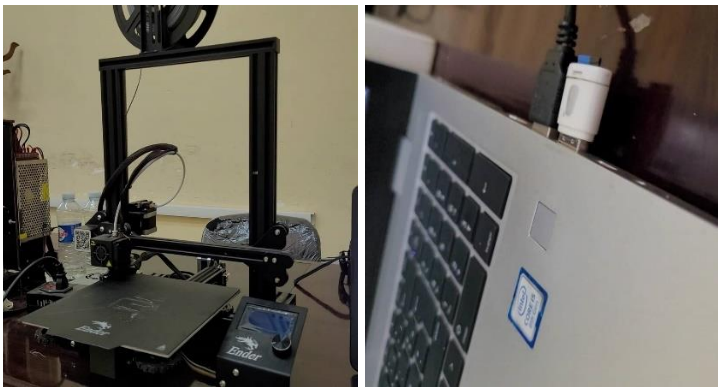


Fig 4.36 : connect the machine with pc

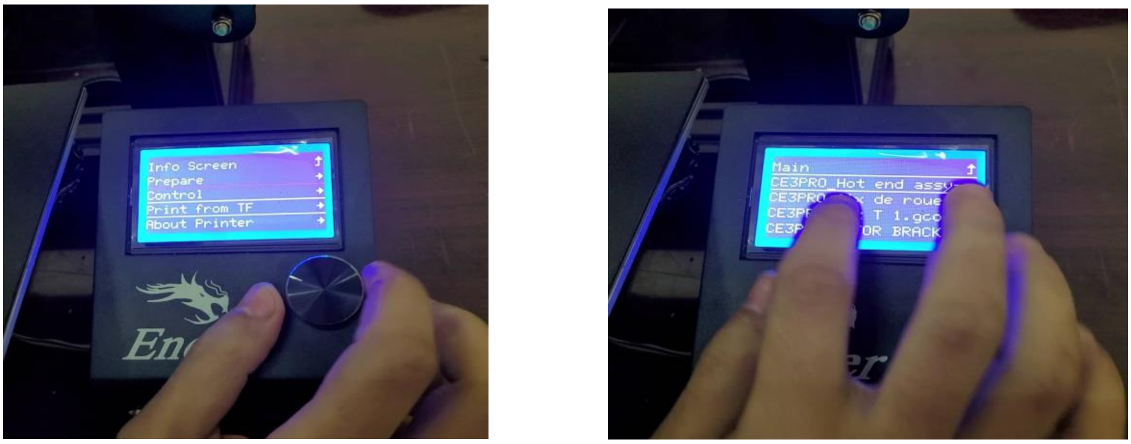


Fig 4.37: Select the part, then set the bed and extruder temperature.

Fig 4.38: The image shows the piece during and after the printing process.

4.5 Configuring Marline and controlling the machine with Arduino:

The 3dprinter is piloted using G-code instruction sequences. Marlin firmware is an open-source firmware used to control 3D printers, CNC machines, and other similar devices. It is widely adopted in the 3D printing community due to its flexibility, extensive features, and active development The marline uses G-code as input, and outputs motion control via the Arduino It's easier to understand when you look at Figure 4:

Fig 4.39: G-code communication to CNC machine

4.5.1 How to install MARLIN:

First, Arduino IDE must be installed in the Laptop then we can download the marlin from the website for free. be Shure to Download the latest stable release as a ZIP file and extract it to a known location on your computer.

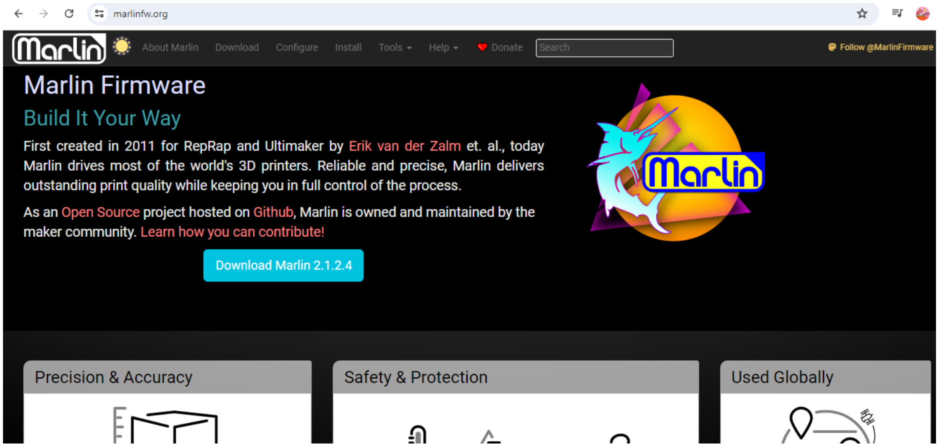


Fig 4.40: marlin download

Open the Arduino IDE.

Go to Sketch > Include Library > Manage Libraries.

Search for and install the following libraries:

-U8glib

-LiquidCrystal

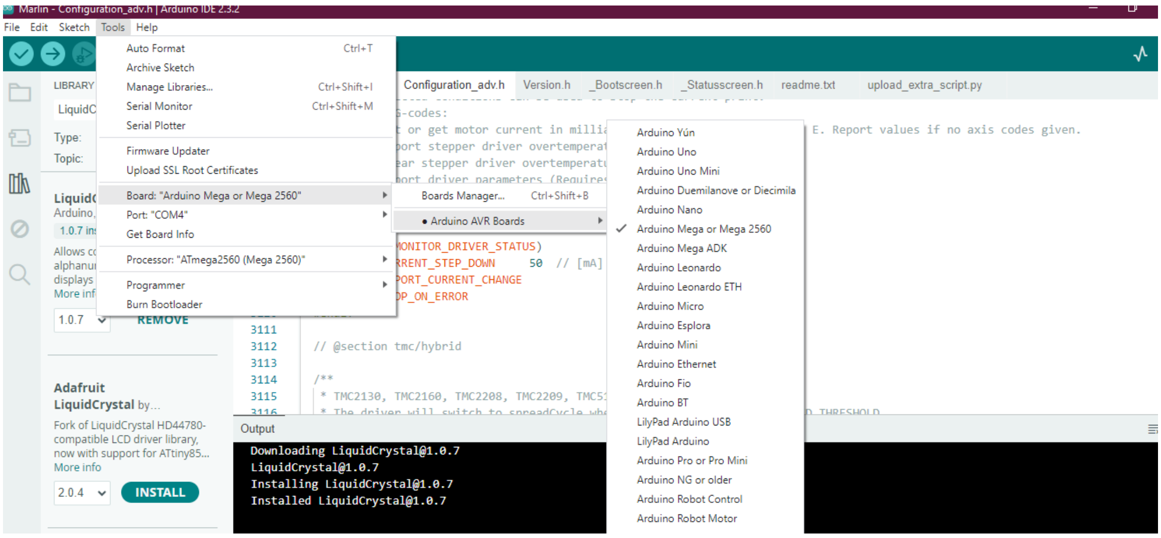


Fig 4.41: Arduino interface

In the Marlin folder, there is a file named Marlin.ino. Open this file with the Arduino IDE. It will open several tabs, including the Configuration.h and Configuration_adv.h files you edited earlier, In the Arduino IDE, go to Tools > Board and select Arduino Mega 2560 or Mega ADK. Go to Tools > Port and select the COM port that corresponds to your Arduino board.

Click the Verify button (checkmark icon) to compile the firmware. This process checks for any errors in your configuration. If the compilation is successful, click the Upload button (right arrow icon) to upload the firmware to your Arduino board.

4.5.2 repetier-host:

Repetier-Host is a free and versatile 3D printing software that serves as a host for controlling 3D printers. It provides a user-friendly interface for slicing models, managing prints, and sending commands to the 3D printer.

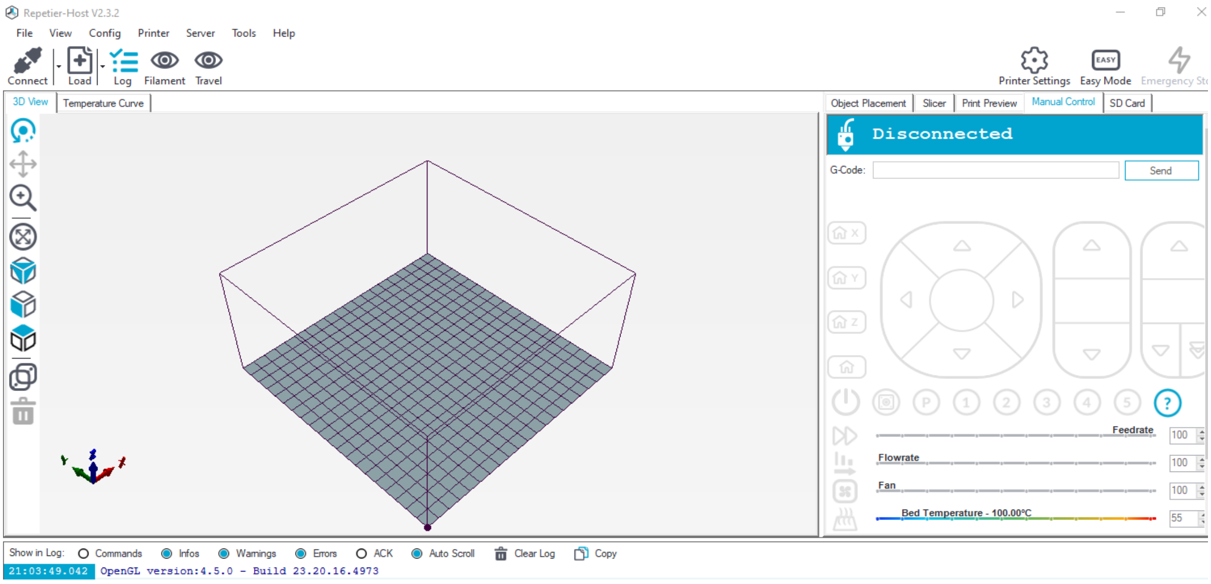


Fig 4.42: repetier-host interface

However, in order to send the G-code to the Arduino an interface or a controller software that tell the Arduino what to do. In matter fact there is so many interfaces to work with but we will stick on it.

4.6 Electronic equipment's:

4.6.1 Assembly of the Parts:

The electronics parts as mentioned before in chapter 2 are assembled as in the following figure:

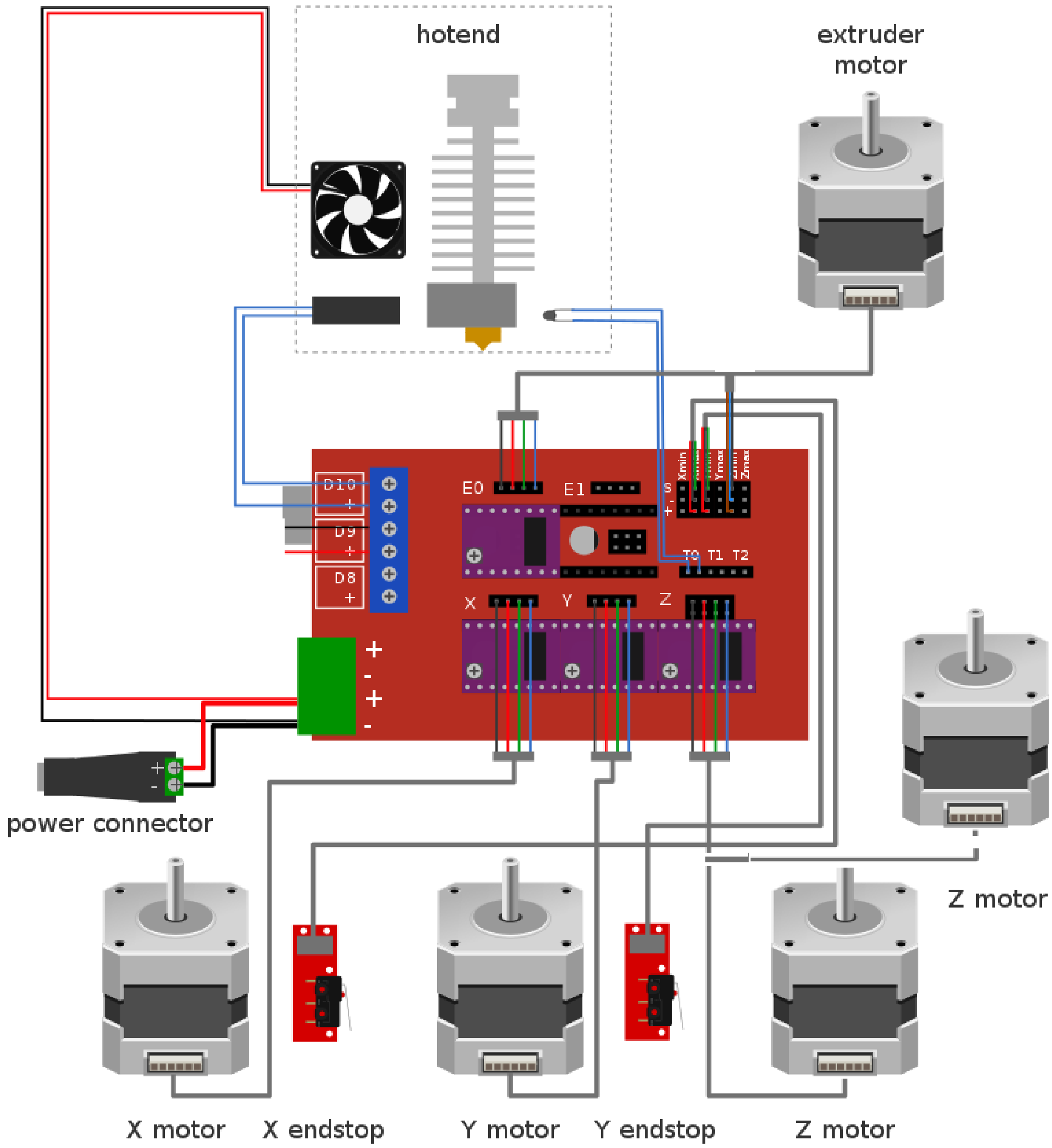


Fig 4.43 : Wiring diagrams for electrical components

Unfortunately for us, we relized too late that the board was broken, so we had to head to the cnc shield.

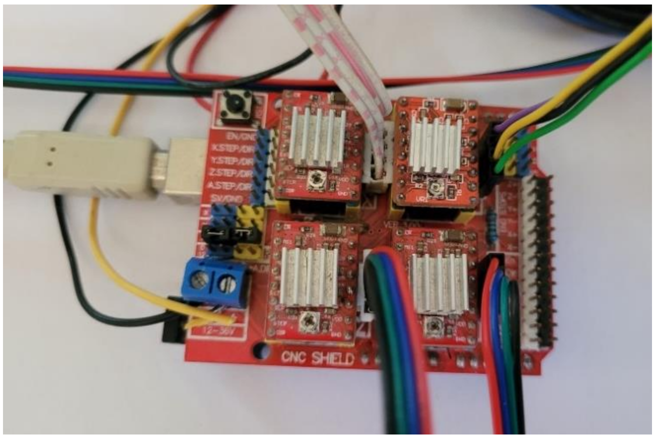


Fig4.44 Motors cables assembly in Arduino

After installing the drivers, we must measure the current and adjust it as the fig 4.36:

Fig4.45: measure the current

Finally, the machine was created as follows, with the capabilities and capacities we have available:

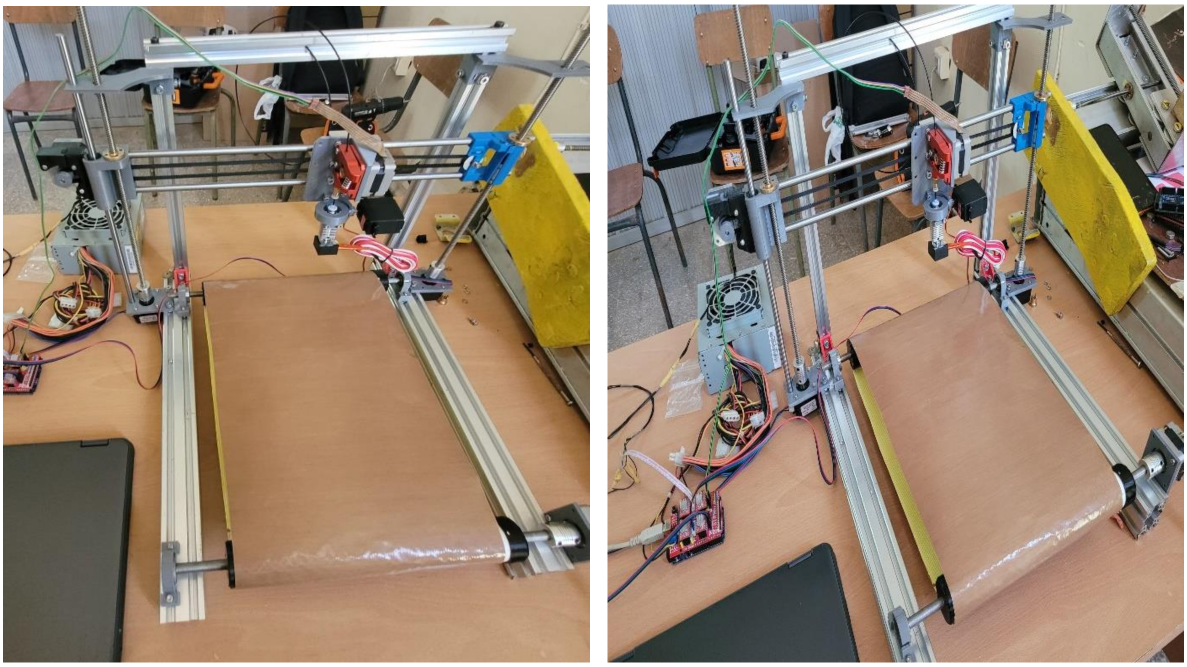


Fig4.46: The final form of the machine

4.7 Conclusion:

In this chapter, we introduced the key electrical components used in our project and detailed their wiring. We also described the computer part of the machine. Furthermore, we successfully controlled the stepper motors by uploading Marlin firmware onto the Arduino, facilitated by operations performed using Repetier-Host

General Conclusion:

At the end of this project, we successfully created a stable system for the printer. Our design choices for critical components, such as the drive shafts and belt deck, were justified by using Solidworks for design validation. The build process involved fabricating many parts to precise specifications and 3D printing numerous components. Although the machine did not fully function due to issues with the Arduino board, the build results confirmed the reliability of our processes.

We identified the reasons why some components performed below our design specifications and developed potential solutions for future implementation. Additionally, we made several suggestions to address the issues that hindered some of our proof-of-concept designs. Similar to our efforts, companies like Blackbelt and Printrbot required many years of prototyping and ideation before achieving functional prototypes. We developed a proof-of-concept prototype with a vast array of components and subsystems that operated within our design specifications, laying the groundwork for future improvements and refinements.

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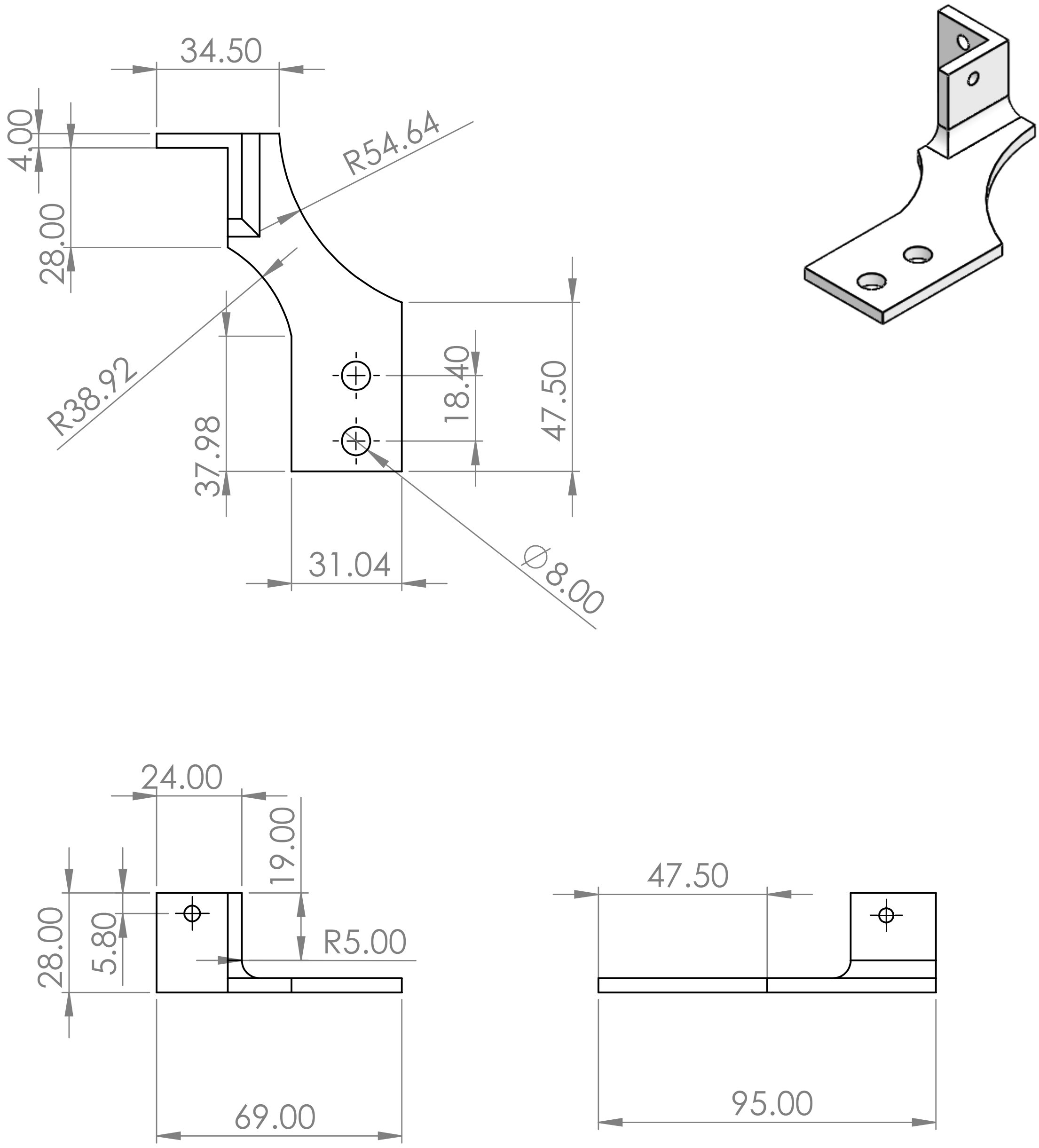
Annex



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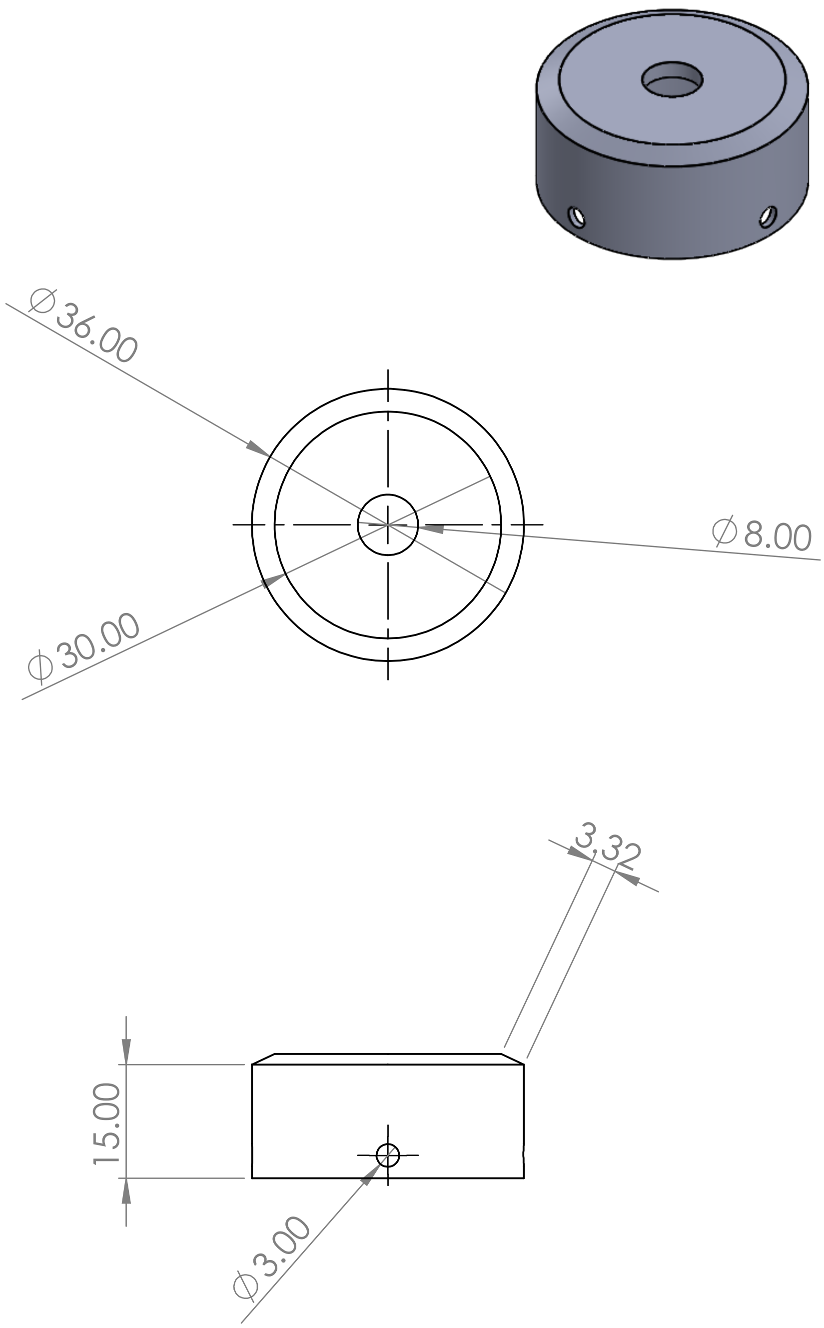

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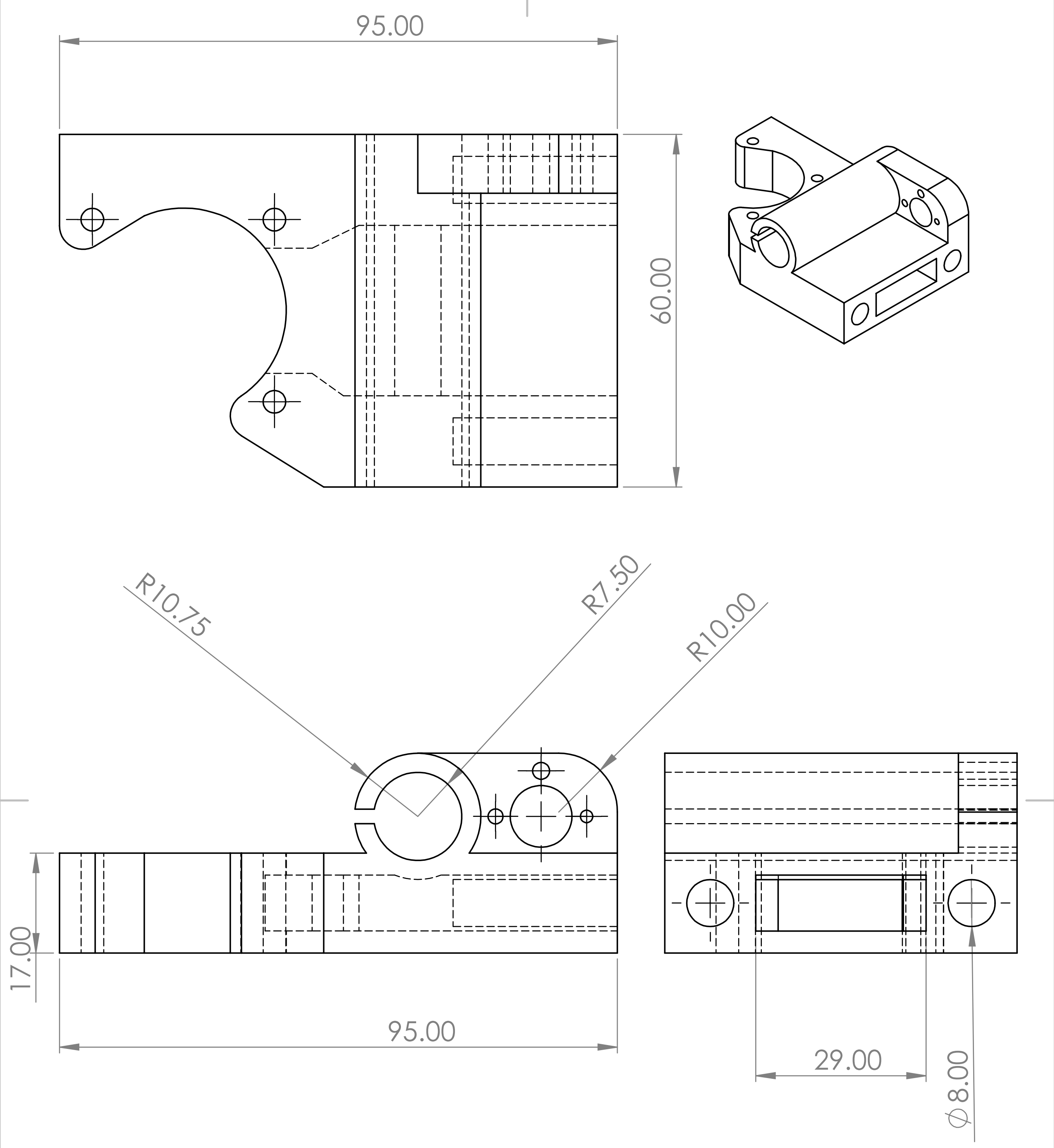
FORMAT : A4			



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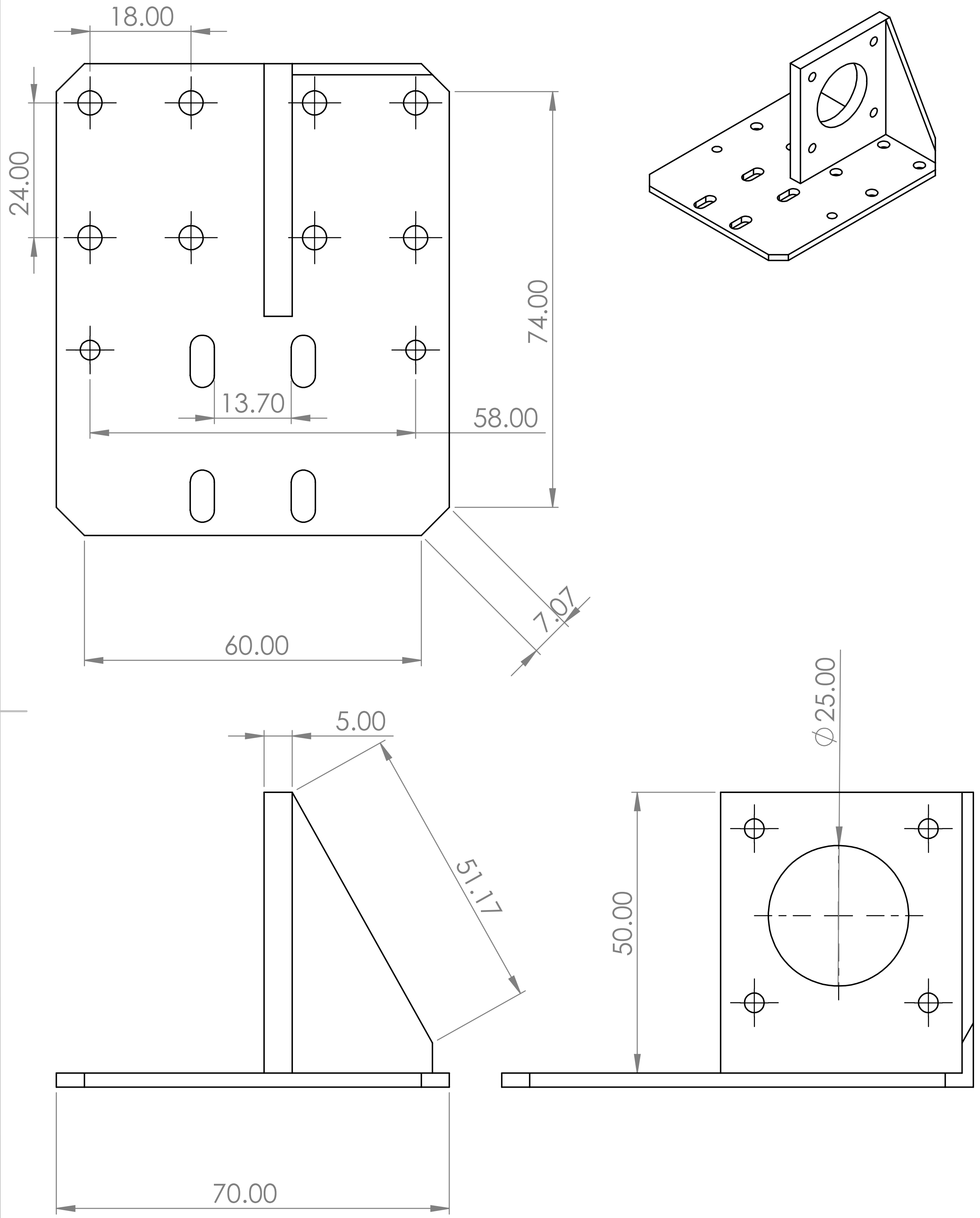

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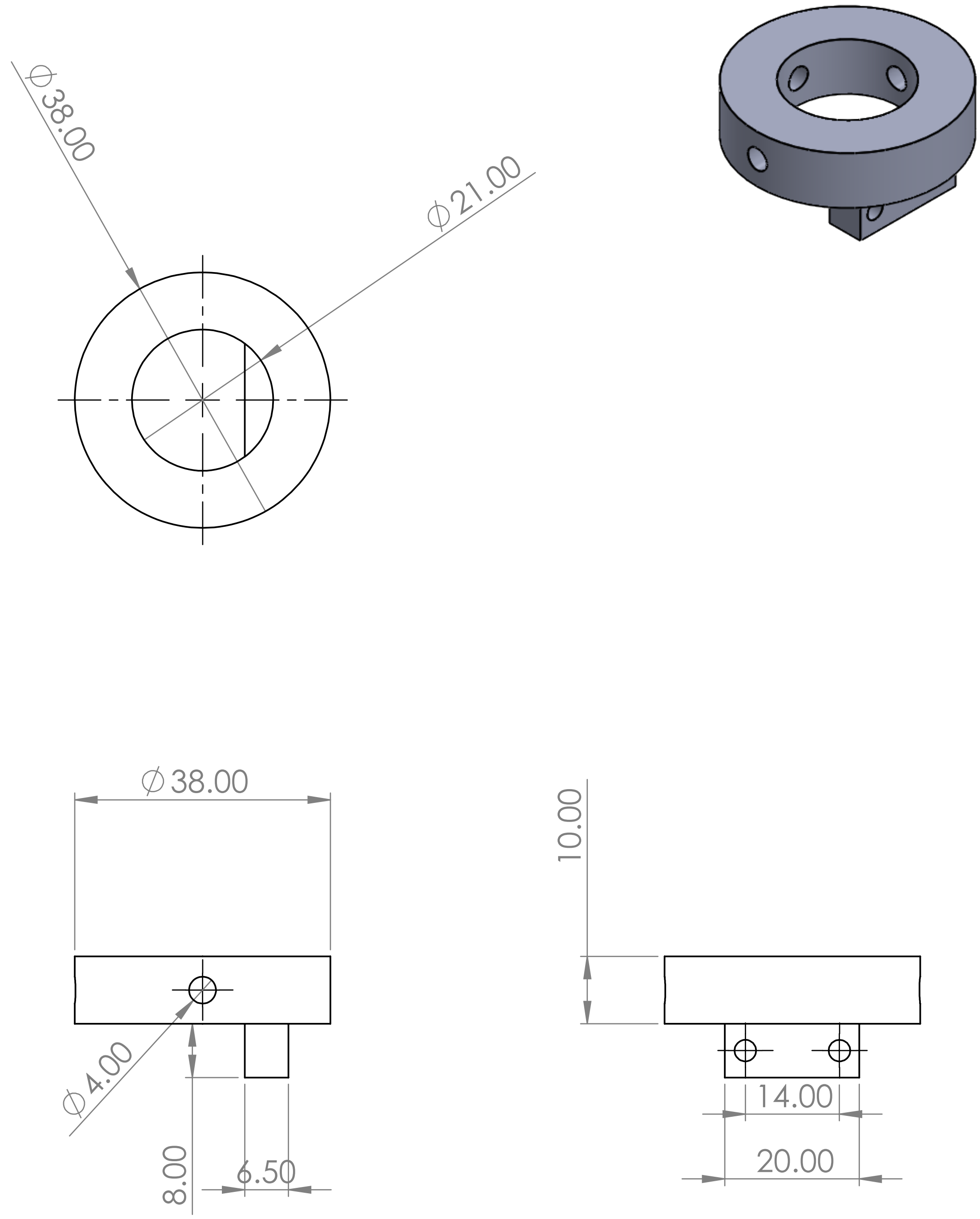

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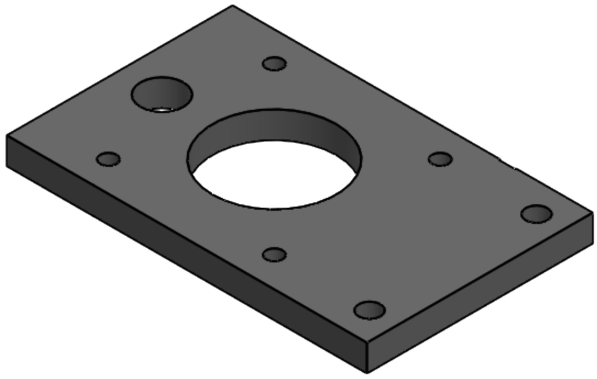

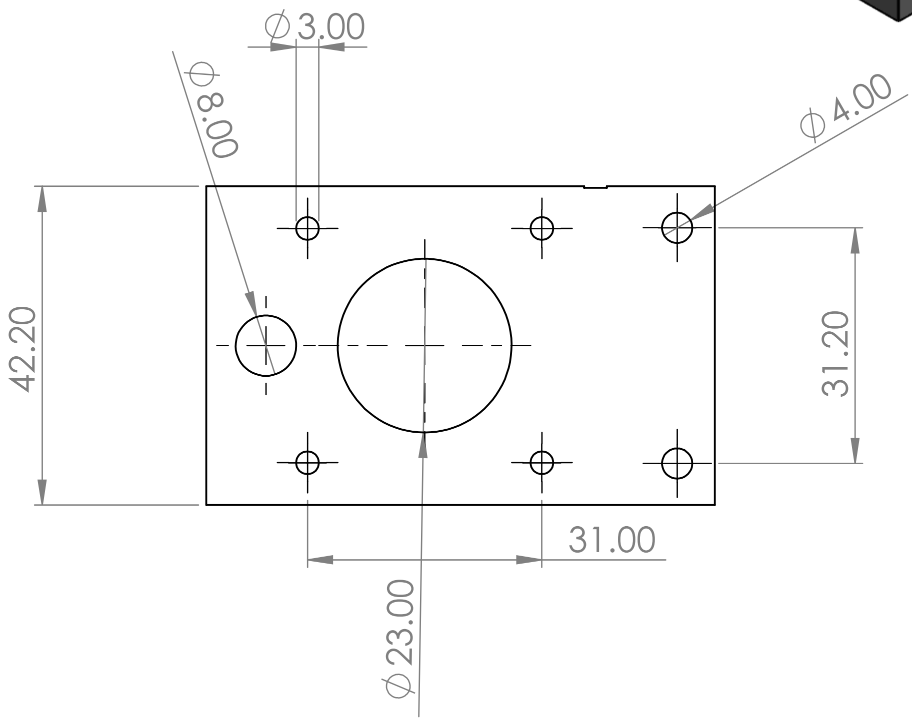

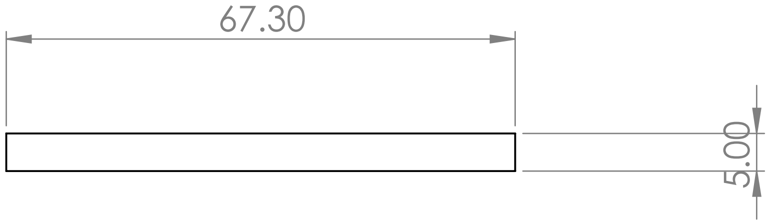

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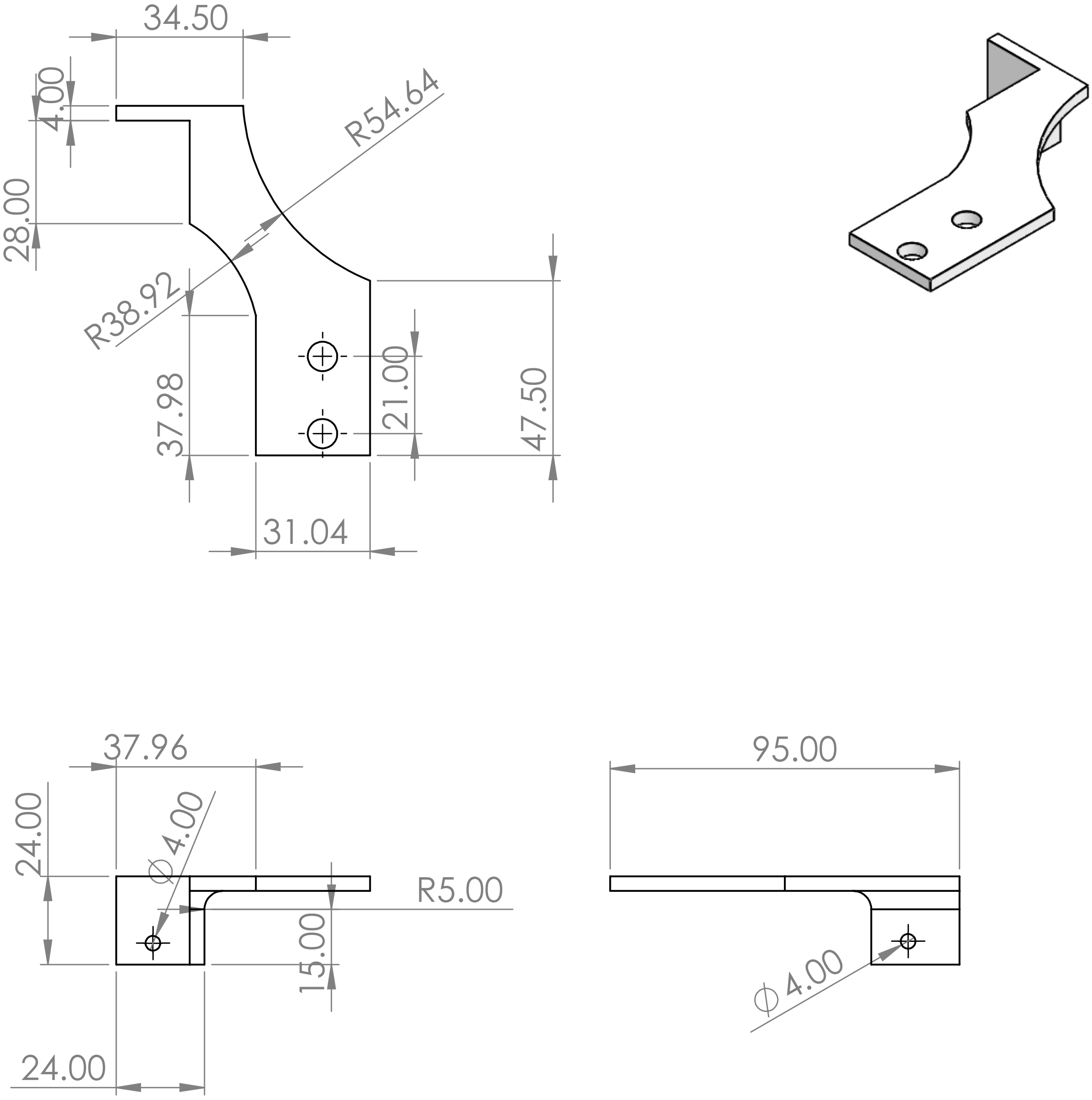

scale 1:2	FMP - MASTER	USDB1	MATERIAL:PLA
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