An-Najah National University

Faculty of Engineering and Information Technology
Mechanical and Electrical Engineering Department

Graduation Project 2

The Effect of Parameters on Three-Dimensional Printer

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Abstract:

This project Evolves around increasing the efficiency and accuracy of certain homemade 3D printers (DIY) and those 3D printers available in local market. (Market available printers) using open-source information available to obtain the needed data.

The main goal of this project is to provide simple guidelines to operate a 3d printer, using the hardware and the related software to enhance 3d printing operation using different type of filaments with different printing shapes arrangements.

Another goal also is to give helping hands by reaching out to local business to enable them to manufacture discrete products which are difficult to achieve using traditional manufacturing approaches at reasonable costs to accommodate high quality products.

This work’s first and foremost priority is to optimize certain 3D printing parameters such as Nozzle size, Filament size, Filament size, Filament (thermoplastics) polymer material melting temperature, Bed temperature, Printing speed, Printed layer thickness, Infill geometry and Infill density.

This project is expected to enhance 3D printing operation applications in local markets to meet the increasing demands on products of relatively small quantities and discrete items production. 3d printing goes in many fields of life such as engineering, medical, architecture, automotive, fashion and education.

In this part of world, 3D printers are hard to come up with or to buy due to their high prices and the tedious process of importing such machines here in Palestine. In this project, we try to reduce the errors and artifacts in homemade 3D printer at low costs. The machine worked with different types of thermoplastics; it was deal with many types of plastics depending on their chemical properties by controlling the heating and cooling timings to get the best results.

In the end, it turned out that the best printing angle is 45, speed is 50-80, filling angle is zero, and the filling percentage is 85%.

Chapter One: Introduction

1.1 Overview:

By layering material on top of each other, 3D printing may turn a geometrical representation into an actual thing. In recent years, the popularity of this 3D method has skyrocketed. Charles Hull [1] was the first to commercialize 3D printing processes in 1980.

3D printing is currently utilized to manufacture prosthetic heart pumps, jewelry collections, 3D printed corneas, PGA rocket engines, steel bridges in Amsterdam, and other things linked to the aviation and food industries. Speed, precision, and the capacity to generate highly customized, one-off models were the fundamental characteristics of 'additive manufacture' (AM), as opposed to subtractive manufacture (in which 3D things are created by starting cutting, carving, or drilling).There are various roadblocks to adoption, the most notable of which being the requirement that users be proficient in the use of rather complex computer modeling software. However, due to quick adoption in a few important areas, the use of 3D printing in industry is exploding.

1.2 Process technique of printing (FDM):

The FDM manufacturing technique is based on the simple principle of melting raw material and shaping it to create new shapes. The material is a filament that is wound into a roll, dragged by a driving wheel, and then heated to semiliquid in a temperature-controlled nozzle head. To generate layer-by-layer structural parts, the nozzle accurately extrudes and directs materials in an ultrathin layer after layer. The outlines of the layer given by the program, usually CAD, that has been placed into the FDM work system are followed [2,3]as shown in figure .

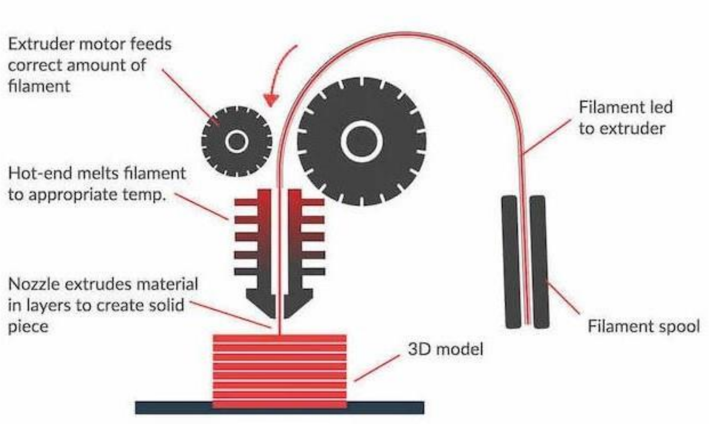

Figure 1: FDM manufacturing technique

Because FDM designs are made up of layers of thin filament, the thermo plasticity of the filament is critical. The thermo plasticity of the filament impacts its capacity to create bonding between layers during the printing process and then solidify at room temperature after printing. The mechanical qualities of the printed part are influenced by the layer thickness, width, and filament orientation, to name a few processing parameters. The complicated constraints of FDM have made filament material creation a difficult task [4].

Polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS) are the most well-known polymers employed in this approach (ABS). Other materials, such as (petg)and (tpu) are available in the country. We will use these four types in tests.

Here is a look at some different filaments in figure (2) below:

Figure 2: Types and colors of filament

1.3 Filament types

Polymer filament is classified into two types based on its composition: pure polymer filament and composite filament. Without adding additive solutions, the pure polymer filament is produced entirely of a polymer compound [5, 6, 7, 8, and 9]. Each form of pure polymer filament has its own unique mechanical properties and features [10]. Even so, the inherent features of pure polymers may not always be able to accommodate the mechanical properties required for some goods. This difficulty necessitates that academics and businesses continue to produce polymer filaments that are acceptable for commercial use. Adding additives to the filament composition is one of the ways to improve the mechanical qualities of a filament. The composite

Filament was created as a result of this procedure [11,12]. Some pure polymer filaments that arecommonly utilized in 3D printing and development procedures are employed in the following.

- **PLA**

PLA is one of the most cutting-edge materials that has been produced for a variety of applications. This type of polymer is biodegradable and thermoplastic. PLA has the potential to be used in medicinal applications due to its biocompatibility and lack of metabolic toxicity [13, 14]. This can be accomplished by converting it into a filament and then using the FDM method to treat it. "Lost PLA casting" is one of the more interesting things you can accomplish with PLA on a 3D printer. PLA is printed in the shape of an inner cavity and then enclosed with plaster-like materials in this technique. Because PLA has a lower melting temperature than the surrounding material, it is later burned out. As a result, there is a gap that can be filled (often with molten metal).

- **ABS**

ABS refers to a variety of acrylonitrile blends and copolymers, as well as butadiene-containing polymers and styrene. ABS was first launched in the 1950s as a more stringent alternative to SAN copolymers [15]. At the time, ABS was made up of a blend of SAN and nitrile rubber. Because nitrile is rubbery and SAN is glassy, this structure is amorphous, glassy, robust, and impact-resistant at room temperature. ABS has a complicated morphology, with variable compositions and additive effects, making it problematic in several ways. ABS, on the other hand, is a common material utilized in the FDM method's 3D printing process. However, the selection of other substances has its own set of drawbacks [16]. Researchers worked on a number of projects to improve the mechanical properties of ABS, one of which was to create an ABS composite filament reinforced with GO with a 2 wt percent GO content, which was manufactured using a solvent mixing process. The ABS material was successfully printed into a 3D model using this procedure. Adding GO to ABS increases its tensile strength and Young's modulus [17]. ABS is utilized in camera housings, protective housings, and packaging because it is very structurally strong. If you need a cheap, robust, stiff plastic that can withstand external impacts, ABS is a fantastic choice. Here is a look at ABS.

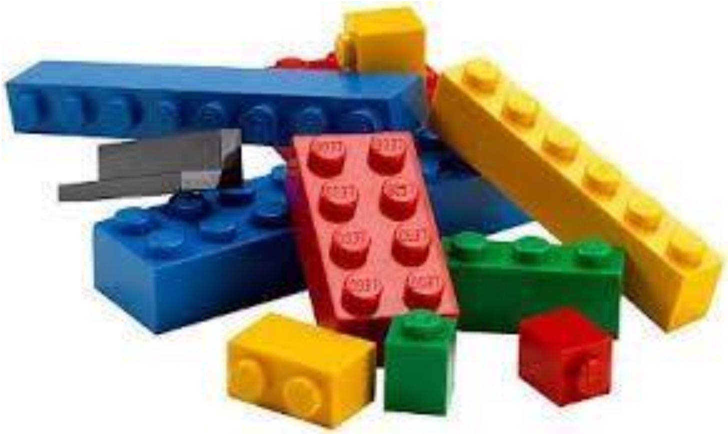

Figure 3: example for ABS use

- **TPU**

TPU material (thermoplastic polyurethane) is a flexible, abrasion-resistant thermoplastic. It's being employed in a variety of consumer and industrial manufacturing processes. It can become very soft in certain combinations, yet TPU material has a lot of advantages and qualities. TPU 3D printed items are tough and can resist temperatures up to 80 degrees Celsius. TPU filament resists abrasion, can tolerate impacts, and is chemically resistant. It's adaptable and may be found in a variety of sectors. TPU material comes in a variety of forms; however it may generally be divided into two categories. Polyether Polyurethane is the first name, and Polyester Polyurethane is the second. Both have distinct qualities that can be tailored to a specific requirement. Here is a look at TPU.

Figure 4: example for TPU use

- **PETG**

PETG is created from Polyethylene Terephthalate (PET), the same material used in plastic water bottles, but with some ethylene glycol replaced with CHDM (cyclo hexane di methanol) hence the letter "G" after PET, which stands for "glycol-modified." As a result, the filament is clearer, less brittle, and easier to extrude than PET. However, it has the unintended consequence of altering the recycling process. PET is readily recycled, but PETG is not; the slight variations between the two materials generate a pollutant in recycling facilities. Nonetheless, it's a great filament for printing objects that need to be robust, smooth, and shrink-resistant. PETG is especially popular since it is considered food-safe; nevertheless, you should read the fine print on every spool you purchase to be sure. Of course, it's not all good news: PETG isn't great at bridging due to its extreme stickiness, but it does have excellent layer adhesion. It's also more hygroscopic than PLA, which means that if left out, it'll be prone to both heavy stringing and air-moisture absorption. However, if you require a high-strength material and PLA or ABS are insufficient, normal PETG is an excellent choice. Here is a look at PETG.

Figure 5: example for PETG use

1.4 Significance of Work

The Main goal of this project is to provide simple guidelines to operate a 3d printer, using the hardware and the related software. Another goal also is to give helping hands by reaching out to local business to enable them to manufacture discrete products, which are difficult to achieve using traditional manufacturing.

Chapter two: Literature Review

2.1- 3D Printer between Past and Future

When was 3D printing invented?

Many industries have adopted 3D printing since its inception. The main advantages of “additive manufacturing” (AM) over subtractive manufacturing (where 3D objects are created by starting cutting, sculpting, or punching) were speed, accuracy, and the ability to create highly customized models all at once – for example, if you were a designer industrial refining of a prototype).

On August 8, 1984, Charles W 'Chuck' Hull was granted US Patent No. US4575330 for devices for the production of 3D objects by lithography. The 1 Chuck was, in essence, the world's first 3D printer.[18]

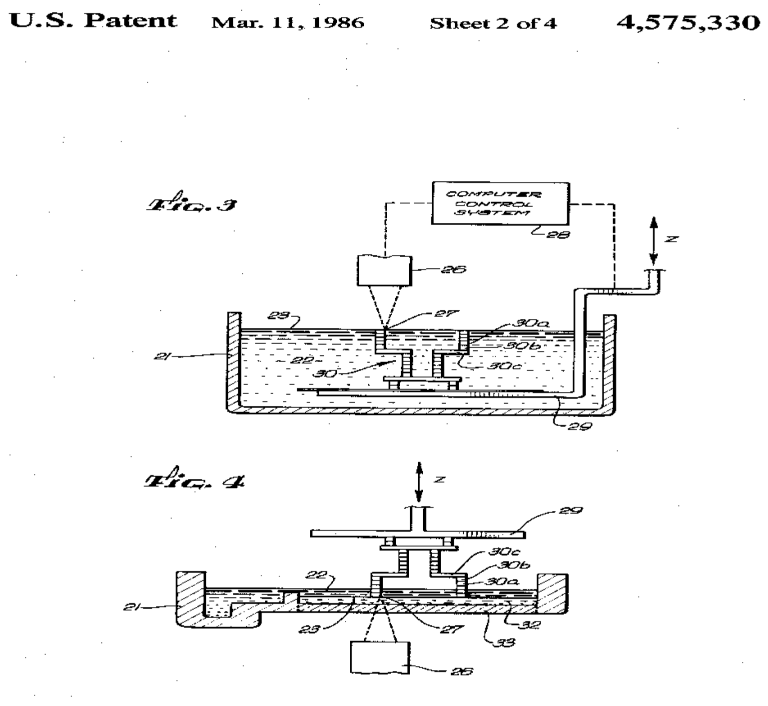

Figure 6: An image of the first 3D printer invented

The patent for Selective Laser Sintering (SLS) technology was filed in 1988 by Carl Deckard of the University of Texas. Using a laser, this technique fused powders instead of liquids.

Scott Crump also patented Fused Deposition Modeling (FDM) at the same period. FDM, also known as Fused Filament Fabrication, differs from SLS and SLA in that the filament is directly extruded from a heated nozzle rather than using light. FFF technology has since evolved into the most popular type of 3D printing available today.

With the development of the processes and technologies involved, more applications of AM were found, and more different technologies were found which led to the development and flourishing of the idea.

2.2 - Growth of 3D printer day by day

Many companies and startups started popping up and experimenting with different additive manufacturing techniques. As the process evolved and found more and more “additive manufacturing” applications AM, in 2006, the first commercially available SLS printer was launched, changing the game in terms of creating parts manufacturing. Industrial on demand.

CAD tools also became available at this time, allowing people to develop 3D models on their computers. This is one of the most important tools in the early stages of creating 3D printing.

Open Source changed the game for 3D printing in 2005, allowing more individuals to use the technology. The Riprap Project, founded by Dr. Adrian Bowyer, was an open-source attempt to develop a 3D printer that could construct another 3D printer as well as other 3D printed things.

The first artificial leg was created in 2008, highlighting 3D printing and bringing this technology to millions of people around the world.

FDM was patented in the 1980s and then became public domain in 2009, changing the history of 3D printing and allowing for creativity. Prices of 3D printers began to fall as the technology became more accessible to new companies and competition, and 3D printing became more and more important.

2.3 - 3D printing nowadays

Although 3D printing began in the 1980s when Chuck Hull created and printed a little mug, printers have become less expensive to make in recent years, allowing them to be utilized in a surprising array of applications, including manufacturing, engineering, and even medicine.

- **Manufacturing:**

In a wide range of industries, 3D printing is changing the way we manufacture things. Costs have decreased as a result of advances in 3D printing technology, materials, and equipment, making their adoption in general manufacturing easier. Manufacturers may think in terms of short production runs and whole new components that would be impossible to build in a traditional manufacturing environment thanks to 3D printing. When it comes to 3D printing, manufacturers can also be strategic. McLaren Racing is an excellent illustration of how 3D printing is changing the automotive business; the steering wheels for their Formula 1 racing cars are created using 3D printing. The design process was substantially faster than typical design and production procedures since they could print a wheel and let drivers manipulate several prototypes and provide input. 3D printing is being used on the racetrack for the rapid development and manufacturing of new parts and tools that are believed to improve car performance.

Figure 7: an application on cars produced by 3D printer

- **Edible 3D printing:**

Who doesn't enjoy a good chocolate bar? One of the current applications of 3D printing is the creation of edible things such as chocolate. Chocolate is the ideal material for 3D printing since it hardens rapidly at room temperature, allowing chocolatiers to produce confections in any shape or form. This trend will only grow when more edible materials, such as ice cream, cookie dough, pizza, and even hamburger patties, are 3D printed. Edible 3D printing is becoming increasingly popular among professionals and individuals. 3D printing edible products is less time-consuming than traditional cooking, allows for more personalization and modification, and there is no limit to ingenuity.

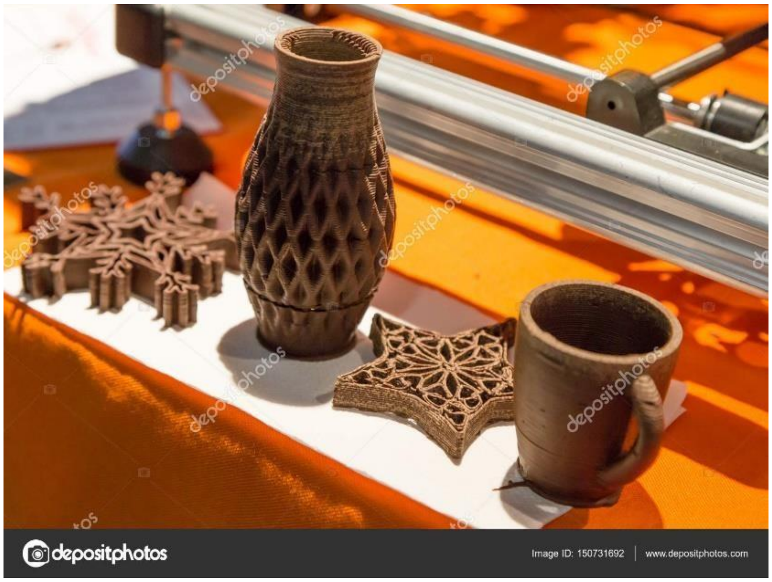

Figure 8: edible chocolate by 3D printer

- **Musical instruments:**

At Lund University in Sweden, the world witnessed the world's first live concert including fully 3D-printed instruments. Tools and hardware parts can be printed in complex shapes that would otherwise be impossible to achieve. To date, 3D printing has produced violins, flutes, keyboards, guitars, and drums. While the art of violin making hasn't changed much since the 17th century, 3D printing offers an alternative. Many 3D printed instruments are not only musically beautiful, but also technically stunning.

Figure 9: Musical instruments produced by 3D printer

- **Dresses:**

3D printing in the world of fashion? Yes, it’s the next 3D printing frontier! Nike already has the capability to create trainers using 3D printing, but now designers are relying on the technology to create amazing dresses that couldn’t be fabricated in any other way. With 3D printing, fashion fuses with technology and the normal fashion rules do not apply.

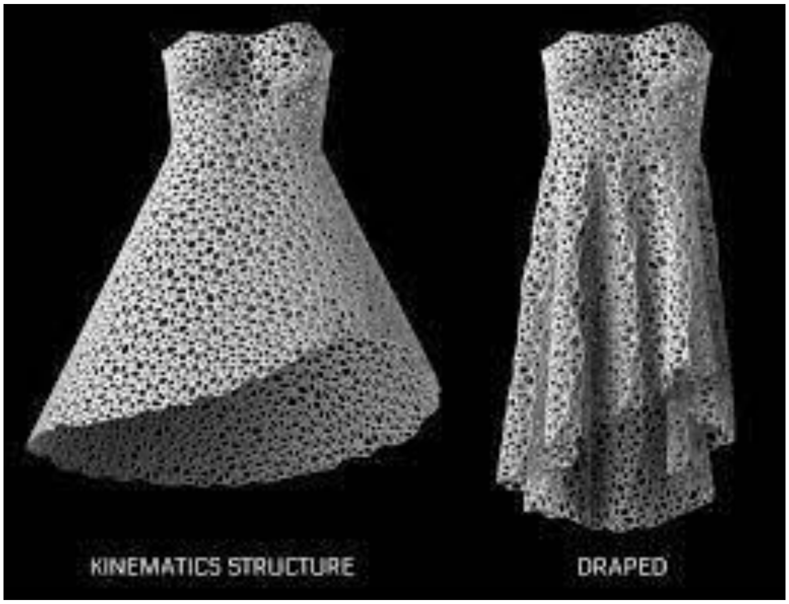

Figure 10: clothes (dresses) produced by 3D printer

- **Entire houses:**

For approximately $10,000, a 400-square-foot house was 3D printed in the Moscow suburbs in less than 24 hours. Other construction businesses have put this technique of 3D printing concrete to use in recent years, lowering the cost of building a 3D printed house. A futuristic office building in Dubai is the world's most advanced 3D printed structure. When emergency shelters are needed after natural or manufactured disasters, the rapidity of building for a 3D home is very desirable. Aside from the convenience, 3D printing houses provide limitless creative possibilities that were previously unavailable in traditional construction.

Figure 11: building 3D printed concrete house

- **Print body parts:**

The application of 3D printing in healthcare and medical is one of the most spectacular real-world instances of the technology. 3D printing will alter medicine and humanity's future, from bone structures that may be implanted in the human body to organs, heart, and liver tissue. These aren't just models; in many situations, these are fully functional bodily parts. Northwestern University's medical school even 3D printed ovaries for mice, allowing infertile mice to birth healthy pups**.**

Figure 12: body part (ear) produced by 3D printer

2.4-What Is the Future of 3D Printing?

While 3D printing may not dominate the entire manufacturing industry yet, analysts expect that there will be a significant amount of growth until it captures most of the market due to its high accuracy and somewhat lower cost compared to other technologies, we can see today that 3Dprinting is revolutionizing large sectors such as automotive, architecture or medical. But to what extent can this technology improve?

In the medical field, 3D Bio printing has become a huge topic in fact, 3D bio printing has a wide range of uses. The many benefits of this technology are clearly visible. It has the ability to regenerate human tissues for burn patients. It is also a technique for producing human organs for transplantation. Today, we can see that there are not enough donors, and bio printing can be a great, fast and life-saving solution. Various tissue structures, such as kidney tissue and skin tissue, can be created using 3D bio printing technology.

1D printing is also developing in a field for architecture, and may increase in the coming years. Faster construction, lower project costs, and reduced material waste are just a few of the advantages of this technology for the construction industry.

The overall impact of 3D printing on the manufacturing business is impossible to anticipate. However, based on what's already happened in the business and what analysts predict will happen in the coming years, it's safe to argue that 3D printing hasn't yet reached its full potential.

Chapter Three: Methodology

3.1- Material and Methods

In this research, because it permits the manufacture of 3D objects directly from computer-aided design tools, fused deposition modeling (FDM), or three-dimensional (3D) printing, is becoming more common. Several criteria influence the quality of 3D parts, and they must be fine-tuned to achieve a high-quality end output. The current research focuses on altering numerous parameters like layer height, raster angle, extruder temperature, printing speed, and Percentage infill to improve the precision of products created by FDM. A variety of materials were used for this study.

3.2- Materials used

This study will use four types of filaments:

1) The Poly-L-lactic Acid (PLA) wire. The diameter of this PLA filament is 1.75mm. It has a density of 1.25 g/cm^3. The PLA has a melting temperature between 180◦C-220◦Cand a glass transition temperature between 60-65◦C [19] and it friendly environmental.
2) The Polyethylene Terephthalate Glycol (PETG) wire. The diameter of this PLA filament is 1.75mm. It has a density of 1.27 g/cm^3 .The PETG has a melting temperature between 230-250° C and a glass transition temperature between 60-80◦C .
3) The Acrylonitrile butadiene styrene (ABS) wire. The diameter of this PLA filament is 1.75mm. It has a density of 1.03 g/cm^3 .The ABS has a melting temperature between 230-250° C and a glass transition temperature between 80°-100°C and it has bad smell and gas emissions.
4) The Thermoplastic Polyurethane (TPU) wire. The diameter of this PLA filament is 1.75mm. The TPU has a melting temperature between 220-250° C and a glass transition temperature between 50°-60°C.

The 3D printer was assembled made by older students **as in figure (13) below**. The Marlin firmware open-source software and the Simplify 3D slicing software were used to generate G-code files and to command and control the 3D printer for the fabrication of the desired parts.

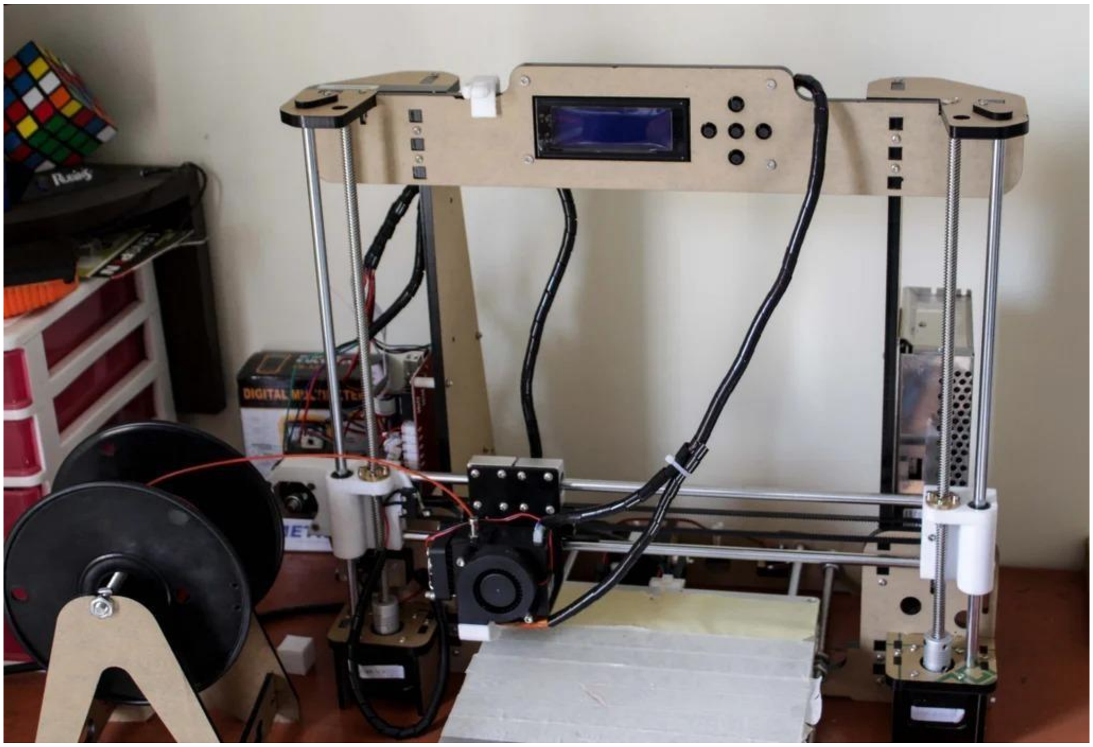

Figure 13: The 3D printer was made by older students

3.3- Methods:

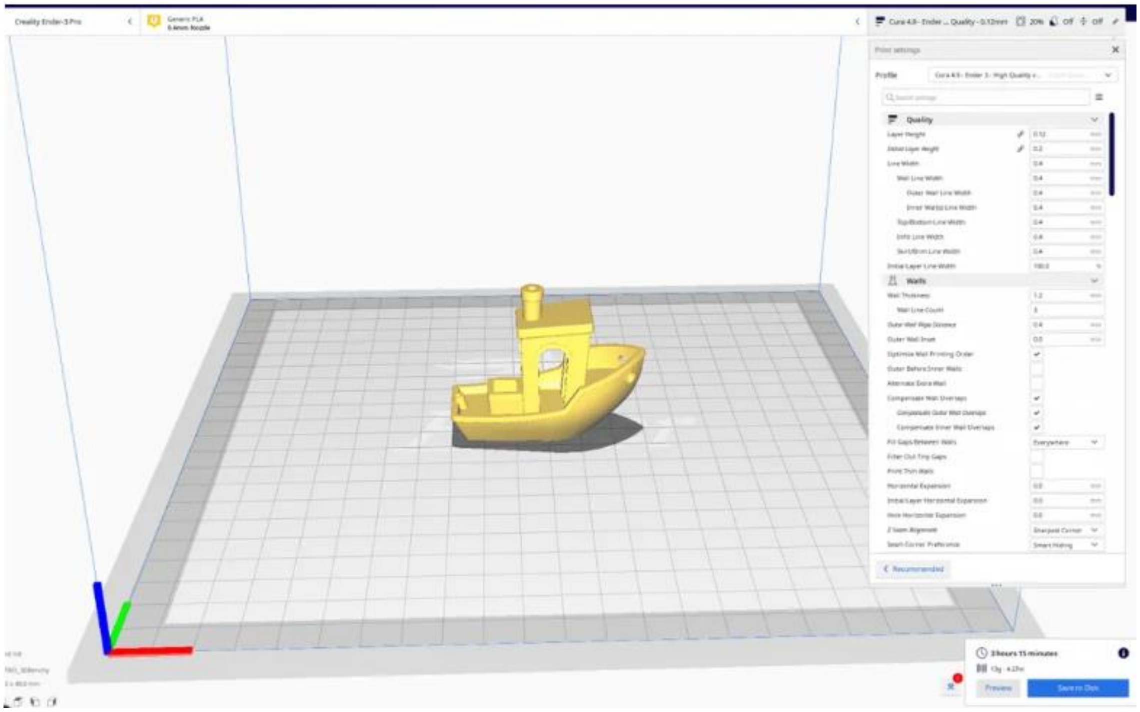

Figure 14: simple shape in Ultimaker Cura works ready to print

At first, the sample is drawn using Geometry and Figure (CAD) used Ultimaker Cura as shown in the **figure (14)** or we bring a ready-made design from the Internet, we convert the drawing to G-code format and prepare it for uploading to the printer, then the file uploaded to a printer and then the printing process begins, the printing process is repeated, focus is placed on one of the variables (bed temperature, printing speed, nozzle temperature, and extrusion speed) for each Type of filament, in order to reach the best settings for each type of filament and solutions to some potential problems for beginners to obtain a high-quality product. All experiments will be recorded with the output in the form of tables to facilitate understanding and comparison between the different types of filaments.

Despite the significant advantages of this technology over injection molding and machining (subtractive) technologies, it nevertheless faces a number of difficulties. These challenges arise primarily as a result of the layer-by-layer construction approach that distinguishes 3D printing systems. The deposited material (individual material raster's) cools and binds with the surrounding material as it solidifies. **Figure (15) below** shows the bonding of material raster's from the same layer and nearby layers, which is caused by the melted material's thermal energy diffusion.

Heating and rapid cooling cycles of the deposited material cause non-uniform thermal gradients, which contribute to stress build-up in certain conditions. Part distortions and dimensional inaccuracies emerge in 3D printed parts as a result of this process. **Figure (16) below** depicts a rectangular ABS 3D printed beam that has warped as a result of stress build-up. Because of the dimensional inaccuracy, the part was rejected.

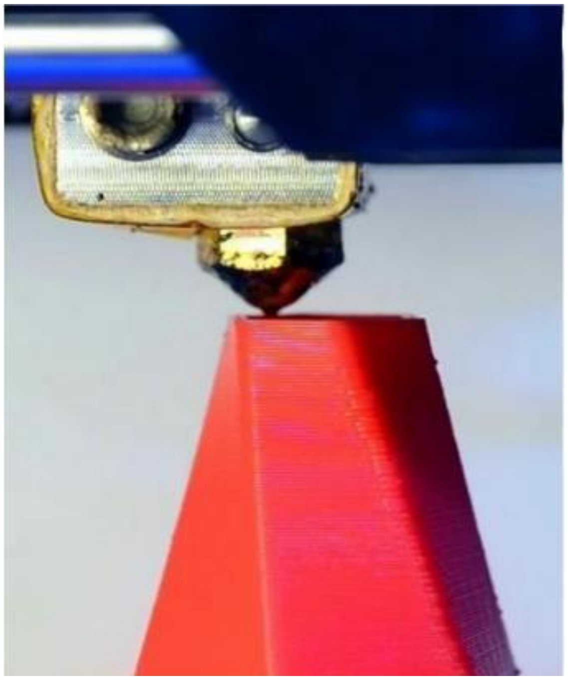

Figure 15: Material deposition in FFF 3D printing

Figure 16: Warping of 3D printed part due to stress build-up

Chapter Four: Results

In 3D printing, there are many variables that can have an impact on the durability of a printed product. Among the variables to be studied is layer height, temperature, filling density, filling angle, printing angle and printing speed.

Experiments with more than one type of filament are planned for PLA, The project was not completed due to time constraints, and we ended up printing a group of shapes from one type of filament (PLA) with changing the angle of printing and changing the height of the layer and preparing them to be sent to Hisham Hijjawi College to conduct a tensile and torque test.

The effect of layer height

3D printing, the layer height refers to the thickness of each layer of material that is laid down during the printing process. The layer height can have a significant impact on the quality and appearance of the final printed product.

Generally, using a smaller layer height will result in a higher quality print with smoother surfaces and more detailed features. However, this comes at the cost of longer print times and potentially higher material usage. On the other hand, using a larger layer height can significantly reduce print times, but the resulting print may have a rougher surface finish and less detailed features.

It's important to choose the right layer height for your project based on the desired balance between print quality and speed. For example, if you are printing a highly detailed model with fine features, you will likely want to use a smaller layer height to ensure that those features are accurately reproduced. On the other hand, if you are printing a large object with fewer details, you may be able to use a larger layer height without sacrificing too much in terms of quality.

In general, it's a good idea to experiment with different layer heights to find the one that works best for your specific printing needs.
The layer height in 3D printing can have an impact on the stress that the printed product can withstand. In general, using a smaller layer height will result in a stronger and more durable print. This is because smaller layer heights create a higher density of material, which makes the print more resistant to deformation and breakage.

If the height of the layer is the same as the diameter of the nozzle, the shape of the extruded filament will be perfectly circular. As the height of the layer decreases, due to the constant diameter of the nozzle, the extruded filament is flattened, thus creating a larger area of contact with the subsequent layer. Also, decreasing the height of the layers involves increasing their number to achieve the same dimensions of the printed object. However, it's important to note that the layer height is just one factor that can affect the strength and durability of a 3D printed object. There are other factors that can also play a role, including the type of material used, the printing temperature, and the design of the object itself.

In addition, the specific stress that a 3D printed object can withstand will depend on the application and the conditions it will be subjected to. For example, a print that is designed to hold a small amount of weight may be able to withstand much higher stress if it is only subjected to static loads, rather than dynamic loads.
Overall, it's important to consider all of these factors when determining the suitability of 3D printed object for a given application. If you need an object to withstand high pressure, it's generally a good idea to use a smaller layer height and a stronger, more durable material, and to carefully consider the design of the object to ensure that it can withstand the required loads.[20]

The following samples on figure (17) that has printed by varying the layer thickness and printing speed:

Figure 17: 3d samples that produced by 3d printer

Speed effect:

Printing speed refers to the speed at which the printer moves and deposits material as it builds the object, the printing speed can have an impact on the quality and appearance of the printed product.

In general, using a faster printing speed can result in a rougher surface finish and less detailed features, as the printer has less time to lay down each layer of material. This can also lead to warping or other distortions in the print, as the material may not have enough time to cool and solidify before the next layer is applied.

On the other hand, using a slower printing speed can result in a higher quality print with a smoother surface finish and more detailed features. However, this comes at the cost of longer print times.

The researches indicate that the strength of samples decreases with increasing speed. In the range of 50-80 mm/s, the strength of the specimens remained at a similar level; however, above 80 mm/s, it decreased significantly.

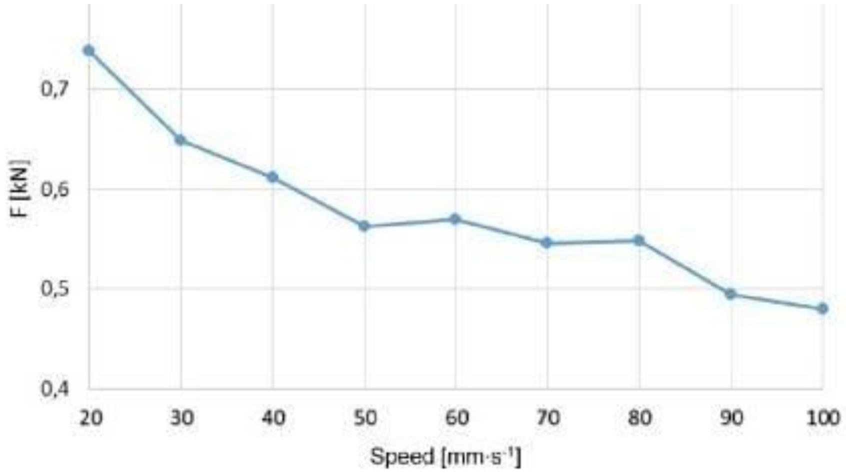

Figure 18: Graph of the mean value of the breaking force as a function of the printing speed

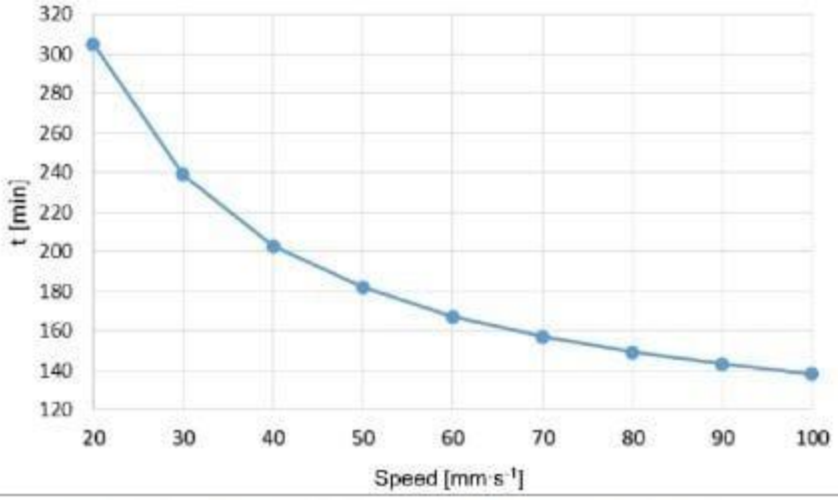

Figure 19: Printing time of the five specimens as a function of printing speed

From the above figures(18,19), it can be concluded that in the case of the BIG Builder DUAL FEED printer by Builder 3D Printers HQ and PLA, the optimal print speed ranges between 30 and 60 mm·s-1, due to the low value of the coefficient of variation. Based on the author's experience in working with the aforementioned printer, it appears that the polyoptimal printing speed is 60 mm·s-1, due to its durability and printing time. At higher speeds, defects appear in the printed models due to the occurring wear of Teflon tubes in the print head, and the resulting insufficient quantity of the supplied material. This is the result of an increasing resistance of the filament passing through the head. [21]

It's important to choose the right printing speed for your project based on the desired balance between print quality and speed. For example, if you are printing a highly detailed model with fine features, you may want to use a slower printing speed to ensure that those features are accurately reproduced. On the other hand, if you are printing a large object with fewer details, you may be able to use a faster printing speed without sacrificing too much in terms of quality.

Printing Temperature effect:

Printing Temperature refers to the temperature at which the printer extrudes the material as it builds the object. The printing temperature can have an impact on the quality and appearance of the printed product.

Higher printing temperatures provide enough fluidity and reduce the adhesion of melting PLA, which increases the dynamic speed of material and causes energy transfer into the deposited layer. When the adhesion between layers increases, the intensity of PLA is also enhanced [22]. The rate of change in tensile strength increases with the decrease in printing temperature because the lower printing temperature causes the incomplete melting of the material, which reduces the layer-to-layer adhesion and exhibits brittleness and can result in a more rigid and less fluid extrusion of the material, which can lead to a rougher surface finish and more imperfections in the print. However, using a lower printing temperature can also reduce the risk of warping or other distortions, as the material has more time to cool and solidify before the next layer is applied.

It's important to choose the right printing temperature for your project based on the desired balance between print quality and stability. In general, it's a good idea to start with the recommended printing temperature for the specific material you are using, and then make adjustments as needed based on your specific printing needs.

Printing filling effect

In 3D printing, infill refers to the internal structure of the printed object, which is created by filling the interior of the object with a pattern of material. The infill can have an impact, on the strength and durability of the printed product, as well as its weight and material usage.

There are two main factors that can affect the infill of a 3D printed object: infill angle and infill density.

Infill angle effect

Infill angle refers to the orientation of the infill pattern relative to the surface of the object.

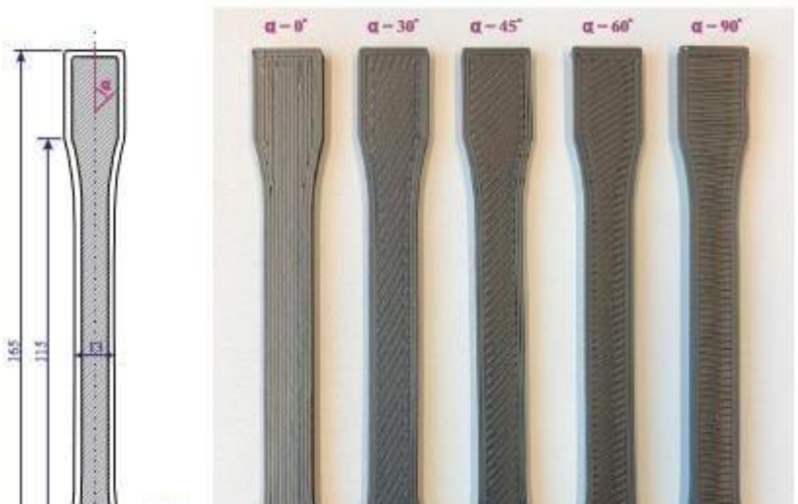

Figure 20: The geometric model and 3D-printed specimens with different raster orientations (Dim .in mm)

Using a different infill angle can affect the strength and appearance of the print, as well as the amount of material that is used. For example, using an infill angle that is perpendicular to the surface of the object can result in a stronger print, but it may also use more material. On the other hand, using an infill angle that is diagonal to the surface of the object can result in a weaker print, but it may use less material. [23]

The results confirmed that 0◦ specimens and 90◦ specimens showed highest and lowest strength, respectively.

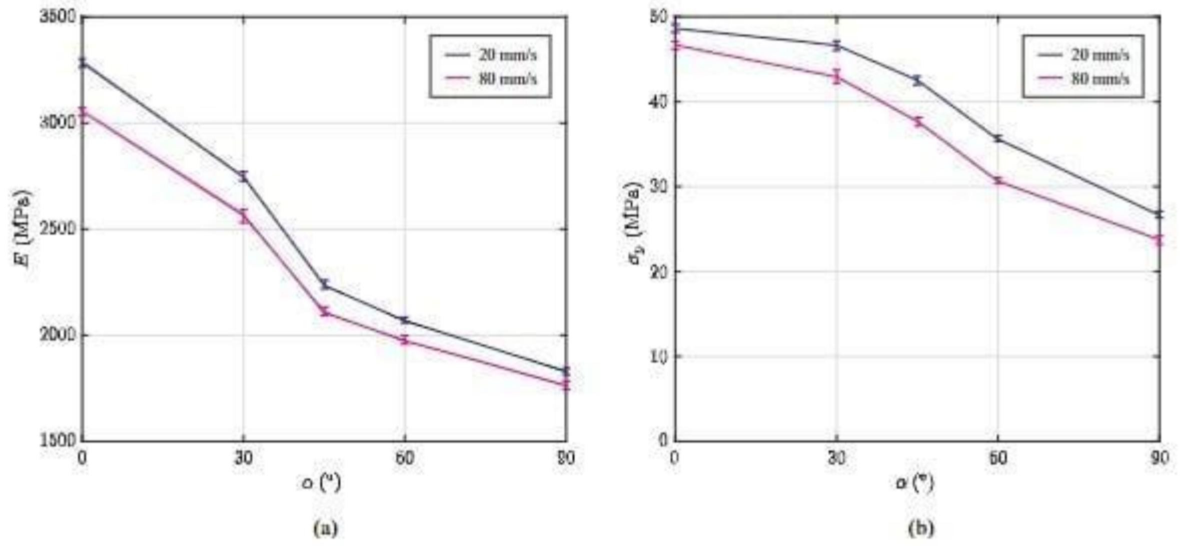

Figure 21: Dependency of (a) elastic modulus, and (b) tensile strength on the raster angle for examined 3D-printed specimens

(Figure 22-a) shows the relationship between the orientation of the fill lines and the elastic edge in the samples printed under different speeds.

(Figure 22-b) shows the relationship between the direction of the packing lines and the stress on the product. This problem occurred for all samples printed at different printing speeds.

Infill density effect

Infill density refers to the amount of material used to fill the interior of the print. Using a higher infill density can result in a stronger and more durable print, but it can also increase the print time and material usage. On the other hand, using a lower infill density can reduce the print time and material usage, but the resulting print may be less strong and durable.

According to experimental analysis of specimens put through the Izod impact test, the energy absorption is at its highest at 85% infill density for each infill pattern. Results showed that the fracture resistance of specimens was a mutual function of induced stress and crack propagation at the notch area during the impact test and the dynamics of impact failure outlined by mechanics of laminate composite.

As the proportion of infill density increased, the results originally indicated an increased tendency in the energy absorption of impacts; however, the trend decreased after 85% of the infill volume, as shown in **(Figure 23)**. Since the element of stress intensity and fracture propagation, as well as indirectly influencing the force, are greatly influenced by the microstructure of the printed specimen. [24]

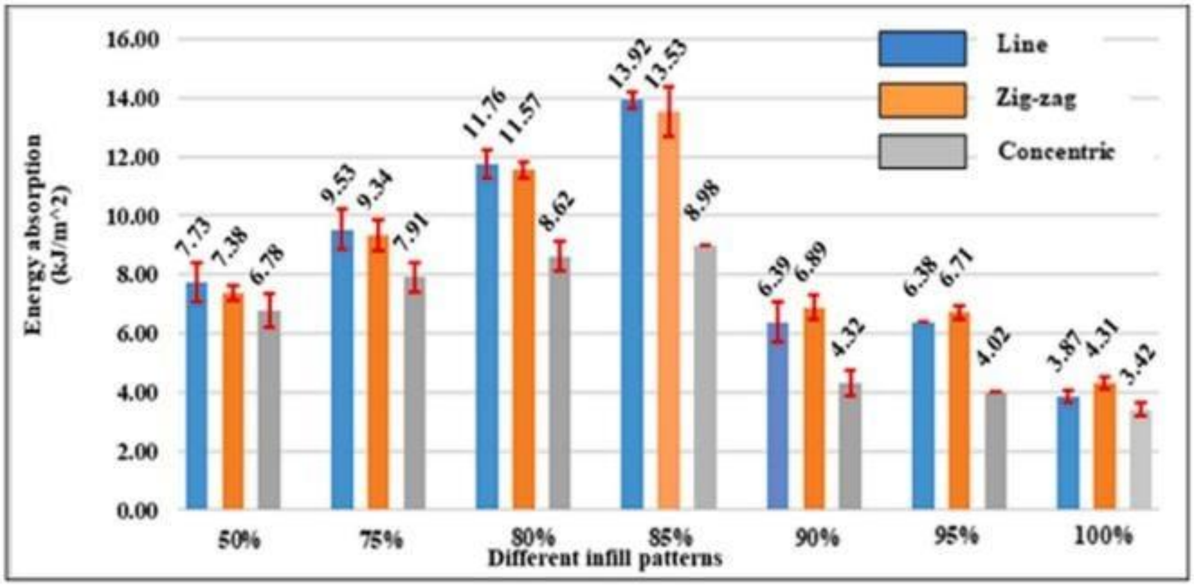

Figure 22: impact energy absorption at combination of different infill density and patterns

Printing angle

Printing angle refers to the orientation of the print bed or build plate relative to the printer's nozzle, and using a different printing angle can affect the stability of the print.

The printing angle has a significant effect on the microstructural, mechanical, and surface properties of the product printed in a 3D printer.

The best results in terms of microstructural, mechanical, and surface properties are typically obtained at a printing angle of 45 degrees.

The following samples that printed by varying the Printing angle:

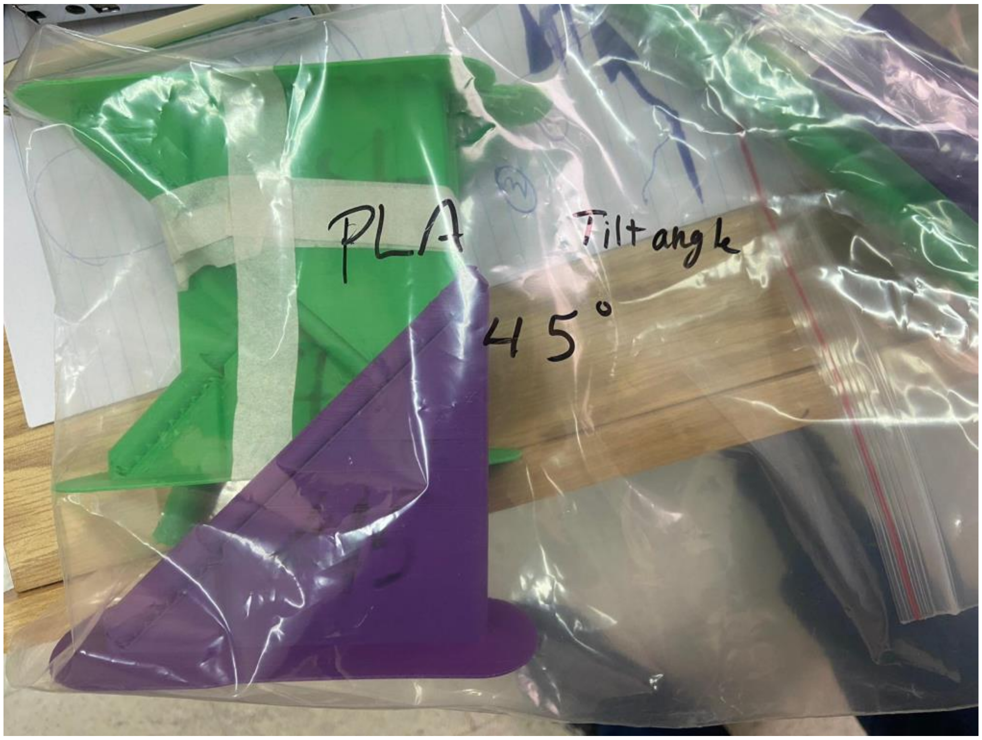

Figure 23: samples that printed by varying the Printing angle

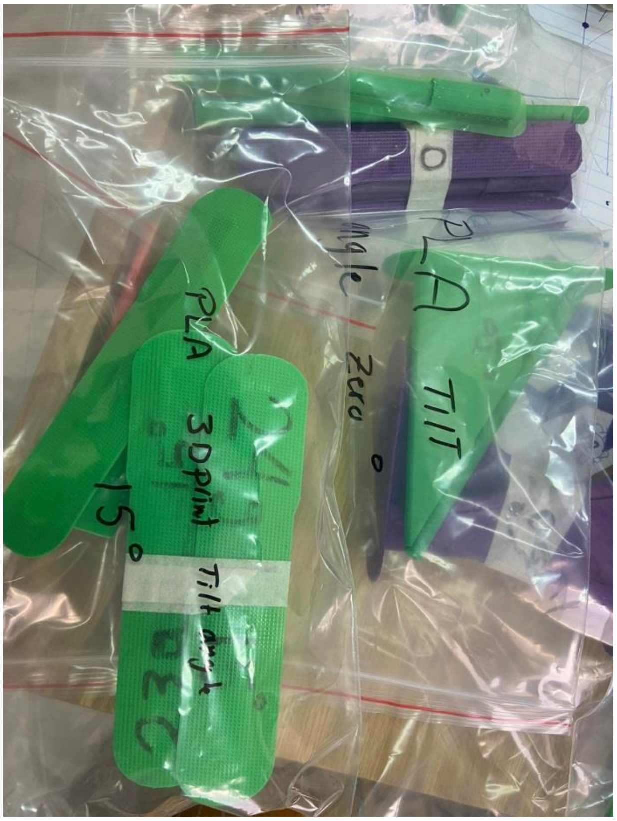

Figure 24: samples that printed by varying the Printing angle

Chapter Five: Conclusion & Recommendation

5.1 Conclusion & Recommendations:

Given the above, it is important to consider the application of the printed product when selecting appropriate variables in a 3D printer, as different applications may require different levels of strength, durability, and accuracy.

For example, if you are printing a functional part that will be subject to high stresses or impacts, you may want to use a stronger and more durable material, as well as a smaller layer height and higher fill density to increase the strength of the print. On the other hand, if you are printing an object that will be used primarily for decorative purposes, you may be able to use a softer, less durable material, and you may be able to use a greater layer height and lower density for padding without sacrificing much in terms of strength and durability.

In addition, it is important to consider the specific requirements of the application when setting other variables in the printer, such as print temperature and speed. For example, if you are printing an object that requires fine, detailed features, you may want to use a slower print speed to ensure that those features are accurately reproduced. On the other hand, if you are printing a large object with less detail, you may be able to use a faster print speed without sacrificing much in terms of quality.

In general, it is important to carefully consider the application of the printed product when selecting the appropriate variables in a 3D printer in order to achieve the required balance between strength, durability, and quality.

However, this technology did not come without flaws. To run effectively and get the intended results, FFF 3D printers require a significant amount of human experience. The advancement of 3D printing technology has resulted in the simplicity of the printing preparation process, but an awareness of process parameter contribution is still required to get an acceptable final printing output.

The presence of layer height, infill percentage, printing speed, shell thickness, printing temperature, retraction, and supports all help to achieve desired printing results. The importance of each parameter is explored, and a process parameter setting range is recommended to meet various requirements such as reduced 3D printing time, enhanced part strength, and improved surface quality. A simple part design was chosen to be manufactured in a homemade low-cost desktop 3D printer in order to show the probable part quality variations induced by varied process parameter settings. The part was printed several times, each time with various process parameter values.

Challenges

While working on this project, we faced many challenges, the most important of which are:

1. Closing barriers and disrupting students' access to the university to work on the project.
2. The printer takes a long time to produce each sample.
3. Learning on the printer took a lot of time and resulted in many damaged samples.

Chapter Six: Reference

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