IMPLEMENTATION AND MANUFACTURING OF HUMANOID ROBOT ARM

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Abstract– The aim of this task is to contribute in the printing and implementing of a human size robot, Cooperating in this long going joint project to assemble the primary open source 3D printed life size robot. The goal was to manufacture and build this robot while figuring out how to print with 3D printers. 3D printing is an additive manufacturing method that can build objects directly from a computational model. Unlike traditional manufacturing methods such as milling and molding. 3D printing technology consists of a set of technologies operating on a similar principle of adding material in successive layers. Some common 3D printing technologies include FDM, SLA, SLS, DMLS, etc. But the most widely used and the type we used to build this project is a process known as Fused Deposition Modeling (FDM). All the downloadable parts from the official InMoov website were (211) parts only to build the upper body of the humanoid robot. But we only have built (81) parts from the total parts of the project to build only the right arm of the humanoid robot. It is essential that one considers some parameters though that you can specify in every software of a 3D printer, and that you need to be aware of in order to print the pieces correctly and be sure that they won't break down while the robot is functioning.

Keywords-- 3D Printing, additive manufacturing, design, humanoid robot arm, FDM printers.

I. INTRODUCTION

3D printing can create physical objects from a geometrical representation by successive addition of material [1]. It is capable of building complex geometries previously not possible to manufacture or to build. 3D printing technology has originated from the layer by layer fabrication technology of three -dimensional (3D) structures directly from computer-aided design (CAD) drawing [2]. The process is called printing as it is similar to regular printers apart from the fact that 3D printing occurs in three dimensions. This process known as additive manufacturing. As the name suggests, any product is manufactured by adding material. The material is added in the form of layers deposited in successive layers to build the complete product. So, Additive Manufacturing is the technology that builds 3D objects by successively adding layer of materials (plastic, metal, ceramic, bio-ink, concrete, etc.) one over the other in perfect geometry to ultimately create the solid object. As we said that the 3D printing technologies include different ways of building the object with different technologies, but the technology we used was the Fused Deposition Modelling (FDM). 3D printing technology increasingly used for the mass customization, production of any types of open source designs in the field of agriculture, in healthcare, automotive industry, and aerospace industries [3]. Depending on the application of the object being printed, we must determine the suitable material for the object. The material used in FDM 3D printing is called as a filament. Many types of filaments are available for 3D printing with varying properties like strength, density, flexibility, etc. The Inmoov humanoid robot arm was build by not only one type of material due to different conditions of every part in the arm. The material we used for the gears not the same as we used for the covers not the same we used for the bases. So, this humanoid robot arm was build by many types of materials with different properties due to every part's condition.

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II. TYPES OF 3D PRINTING TECHNOLOGIES

3D printing technology consists of a set of technologies operating on a similar principle of adding material in successive layers but in a different way of functioning. But The most common 3D printing technologies include SLA, SLS, DLP, FDM.

A. Stereolithography (SLA) technology

The main 3D printing technique that frequently used is photo-polymerization, which in general refers to the curing of photo-reactive polymers by using a laser, light or ultraviolet (UV) [4]. SLA printers excels at manufacturing parts with high levels of detail, smooth surface finishes, and tight tolerances. the quality surface finishes on SLA parts, not only look nice, but also will aid within the part's function testing the work of an assembly, as an example. It's wide used in the medical business and customary applications include anatomical models and microfluidics. and fig.1 explain how does it work.

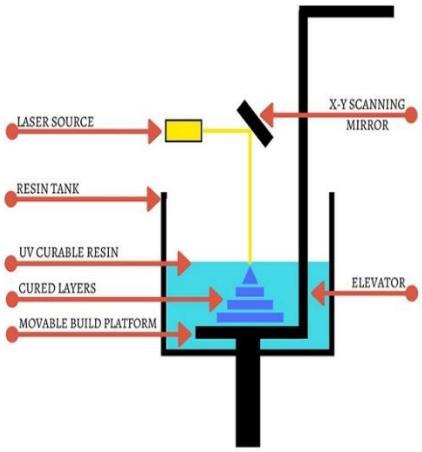

Fig.1 SLA 3D printer.

B. Selective Laser Sintering (SLS) technology

SLS is 3D printing technology that's functionally in fast speed, has high accuracy, and varies surface finish [5]. Selective laser sintering (SLS) melts along nylon-based powders into solid plastic. Since SLS parts are made of real thermoplastic material, they're durable, appropriate for practical testing, and might support living hinges and snap-fits. as compared Stereo-lithography (SLA) parts, parts are stronger, however have rougher surface finishes. SLS doesn't need support structures that the whole build platform are often utilized to nest multiple components into one build making it appropriate for half quantities above alternative 3D printing processes. several SLS parts are used to example styles that may someday be injection-molded. Fig.2 explain how does it work.

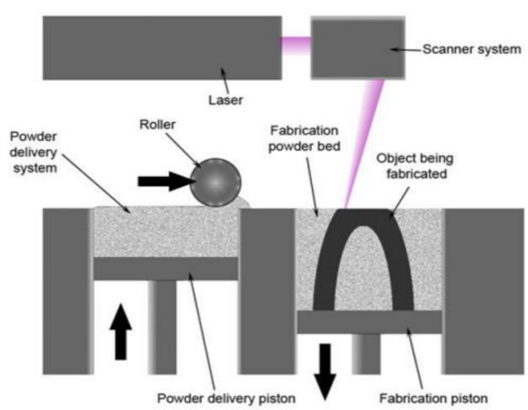

Fig.2 SLS 3D printer.

C. Digital Light Processing (DLP) technology

The main 3D printing technique that frequently used is the same technology of the SLA technology, photo-polymerization, which in general refers to the curing of photo-reactive polymers by using a laser, light or ultraviolet (UV) [6]. Digital light process is comparable to SLA therein it cures liquid resin using light. the first difference between the two technologies is that DLP uses a digital light projector screen whereas SLA uses a ultraviolet laser. this means DLP 3D printers will image a whole layer of the build all at once, leading to quicker build speeds. while oftentimes used for fast prototyping, the upper throughput of DLP printing makes it suitable for low-volume production runs of plastic parts. And fig.3 explain how does it work.

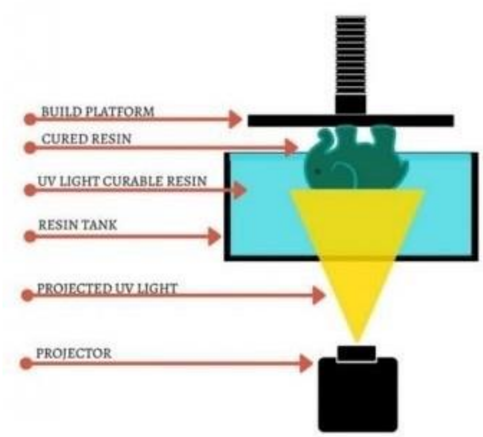

Fig.3 DLP 3D printer.

D. Fused Deposition Modeling (FDM) technology

Material extrusion-based 3D printing technology can be used to print multi-materials and multi-colour printing of plastics, food or living cells [7]. This process has been widely used and the costs are very low. Moreover, this process can build fully functional parts of product [8]. Fused deposition modeling (FDM) is a common desktop 3D printing technology for plastic parts. An FDM printer functions by extruding a plastic filament layer by layer onto the build platform bed. It's a cost effective and quick method for manufacturing physical models. There are some instances when FDM can be used for functional testing but the technology is limited due to parts having relatively rough surface finishes and lacking strength. And fig.4 explain how does it work.

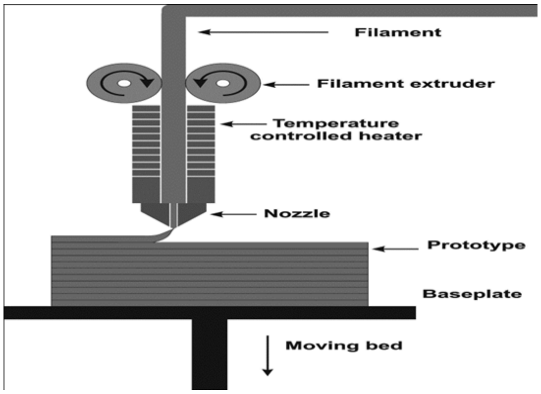

Fig.4 FDM 3D printer.

And this is the technology used to built our humanoid arm robot.

III. Materials Used for 3D Printing Technology in Manufacturing Industry

3D printing technology is capable to produce fully functional parts in a wide range of materials including ceramic, metallic, polymers and their combinations in form of hybrid, composites or functionally graded materials (FGMs) [9]. But the material used in the FDM technology called filament. The standard diameters for filaments are 1.75mm and 3mm. Many types of filaments are available for 3D printing with varying properties like strength, density, flexibility, etc. Most commonly used materials are Acrylonitrile Butadiene Styrene (ABS), Polylactic Acid (PLA), Polyethylene Terephthalate glycol-modified (Pet-G), Thermoplastic Polyurethane (TPU), etc.

TABLE I

MATERIALS PROPERTIES TABLE

	(TPU)	(ABS)	(PETG)	(PLA)
Impact Strength	High	High	High	Low
Durability	High	High	High	Low
Flexibility	Very High	Low	Low	Low
Chemical Resistance	Medium-high	High	High	Low
Water Resistance	Medium	Medium	High	Medium
Nozzle Extruder Temperature(^{o}C)	220-250	230-260	210-250	190-210
Closed Chamber	Not necessary	Recommended	Not necessary	Not necessary

Table I summarizes a wide variety of properties and characteristics for each material. We have also included a built-in comparison tool so that you can easily compare a selection of materials against one another. Based on this comparison, and based on every sing part of the humanoid robot, the whole arm was built with PLA material as shown in fig. 5, but any transmission parts built with PETG material due to its efficient properties as shown in table I and what it looks like shown in fig. 6.

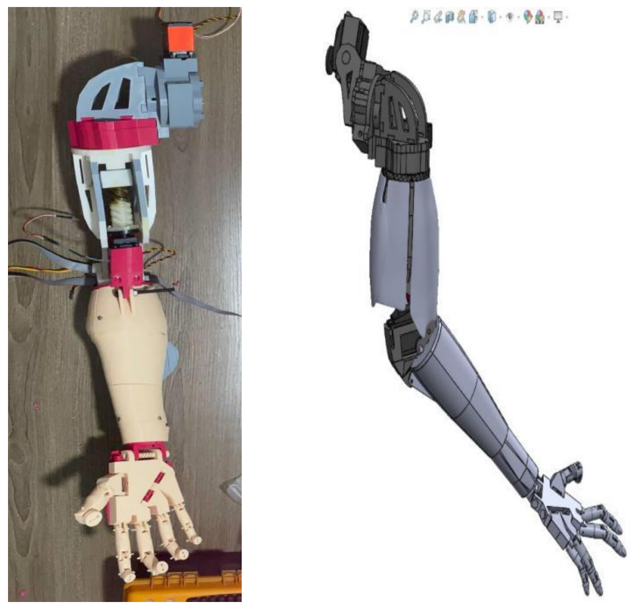

Fig.5 The humanoid robot arm.

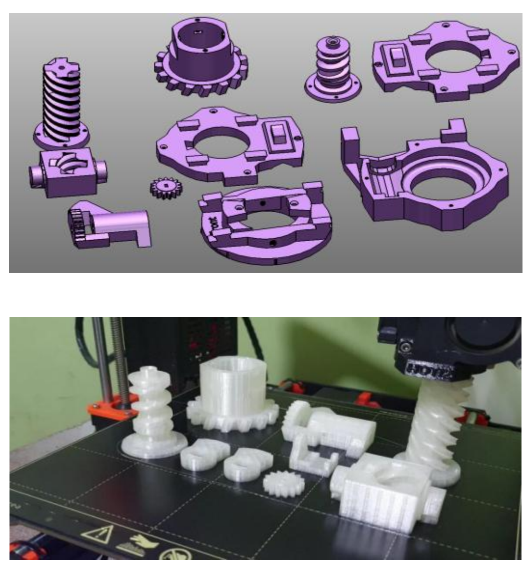

Fig.6 Gears printed with PETG material

IV. 3D printed parts

There are some parameters though that you can specify in every software of a 3D printer, and that you need to be aware of in order to print the pieces correctly, and be sure that they won't break down while the robot is functioning.

- Infill.
- Support.
- Brim..
- Raft.
- Skirt.

For example this part from the right arm in the (forearm)

In fig. 7, a part from the arm that we would explain on it the function of every parameter.

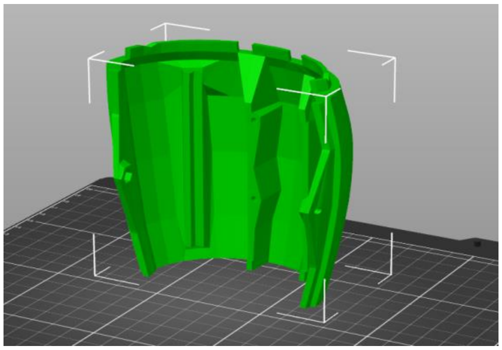

Fig.7 Part from the forearm cover.

By applying The parameter (skirt) on :

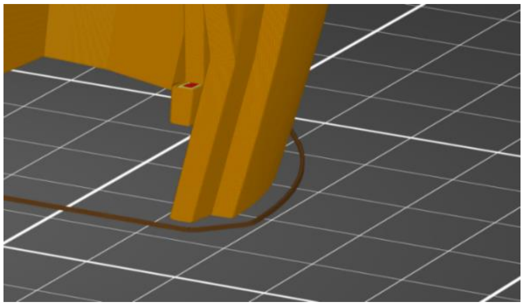

Fig.8 Skirt parameter.

A skirt is an outline that surrounds your part but does not touch the part as shown in fig. 8. The skirt is extruded on the print bed before starting to print your model. Skirts serve a useful purpose because they help prime your extruder and establish a smooth flow of filament. Observing the skirt also allows you to detect and adjust any leveling or adhesion issues before the actual model begins printing.

By applying the parameter (brim) on :

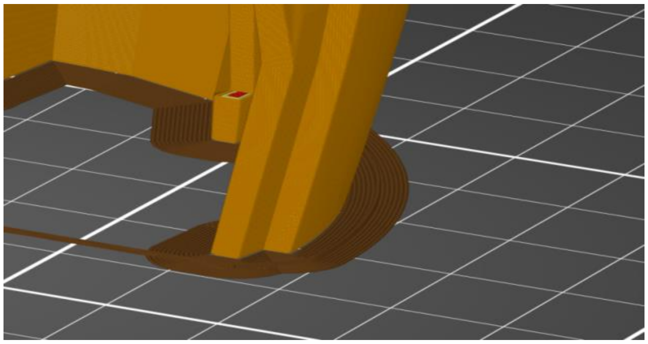

Fig.9 Brim parameter.

A Brim is a special type of skirt that is actually attached to the edges of your model as shown in fig. 9. Typically, the brim is printed with a increased number of outlines to create a large ring around your part, similar to the brim of a hat. Brims are often used to hold down the edges of your part, which can prevent warping and help with bed adhesion. The Brim may be a preferred option to the raft (which also helps with adhesion), as the brim can typically be printed much faster and uses far less filament. Once the print is complete, the thin brim can be separated from the solid model and discarded.
By applying the parameter (raft) on :

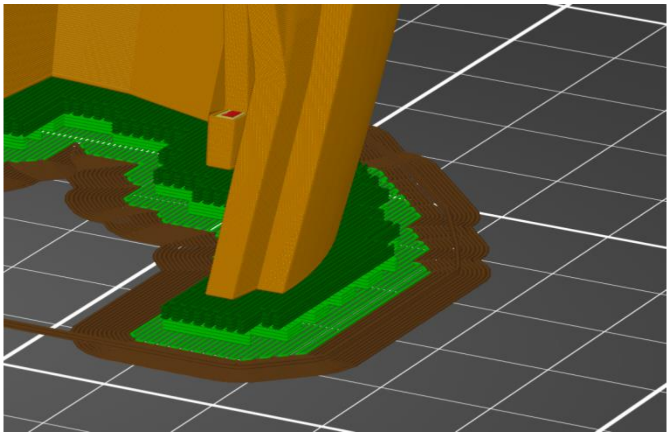

Fig.10 Raft parameter.

A Raft is a horizontal latticework of filament that is located underneath your part as shown in fig 10. Your 3D printed part will be printed on top of this raft, instead of directly on the build platform surface. Rafts are primarily used with ABS to help with warping and

bed adhesion, but they can also be used to help stabilize models with small footprints, or to create a strong foundation on which to build the upper layers of your part. The raft included in Simplify3D has been optimized over years of testing on hundreds of different machines to ensure easy separation and a high-quality surface finish on the bottom of your part. Once the print is complete, the raft effortlessly peels away from the print and can be discarded.
By applying the parameter (support) on :

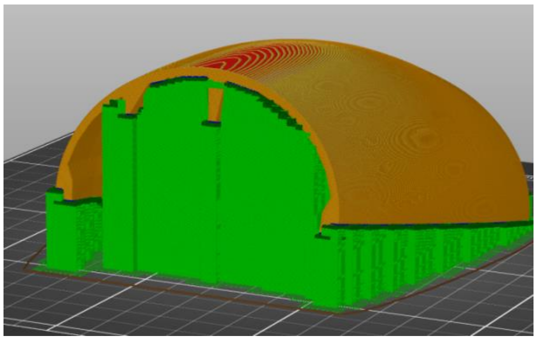

Fig.11 Support parameter.

Used with almost all 3D printing technologies, support structures help to ensure the printability of a part during the 3D printing process as shown in fig. 11. Supports can help to prevent part deformation, secure a part to the printing bed and ensure that parts are attached to the main body of the printed part.

V. Infill parameter

Infill density is the “fullness” of the inside of a part as shown in fig. 12. In slicers, this is usually defined as a percentage between 0 and 100, with 0% making a part hollow and 100%, completely solid. As you can imagine, this greatly impacts a part’s weight: The fuller the interior of a part, the heavier it is.

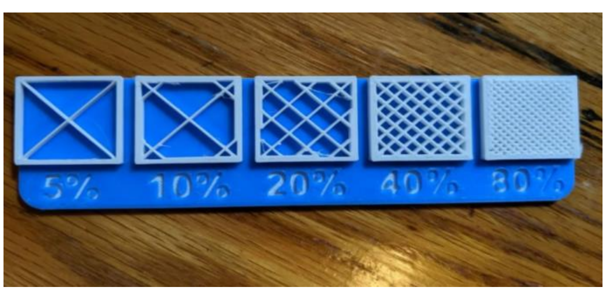

Fig.12 Infill density.

VI. Conclusion

3D printing technology starts to have their own benefits in the manufacturing industries, it offers many benefits to the engineers, companies and designers. Thus, this paper is to overview the types of 3D printing technologies and the type used to print the humanoid robot arm, different materials used print different parts in the robot arm, and the different parameters of 3D printing technology for printing any design or any part.

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