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DESIGN AND DEVELOPMENT OF A FUSED DEPOSITION MODELLING RAPID PROTOTYPING MACHINE

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ABSTRACT

Rapid Prototyping is an additive manufacturing process by which a Three-Dimensional Model is made by various processes like SLA (Stereolithography), SLS (Selective Laser Sintering), LOM (Laminated Object Manufacturing), etc. A 3d printer which uses FDM (Fused deposition modelling) process is a 4-axis machine, in which 3 axes are x, y, z axis and fourth axis is the extruder, with which a filament comes out to form a layer. This paper emphasizes on design and development of a rapid prototyping machine which refers to a process of FDM (Fused Deposition Modelling), where a material like PLA (Polylactic acid), ABS (Acrylonitrile Butadiene Styrene), PC (Polycarbonate), etc., is heated to its melting point and is deposited layer by layer. Many such layers are fused to form the final 3d model.

Keywords: *SLA ,FDM*, *SLS*, *LOM*

1. INTRODUCTION

Rapid Prototyping is a process of taking a digital 3D model and turning that digital file into a physical object. Manufacturing facilities across the globe are using 3D printing as a way to reduce costs, save time, and produce better products. By no longer needing to outsource the prototyping of parts, companies are able to quickly iterate upon designs on the fly, oftentimes saving weeks of waiting for third parties to return molds or prototypes. From automobile manufacturers to electronics companies and anyone in between, 3D printing is an invaluable technology. Efficient and accurate production of prototypes or low-volume products can reduce the time to market and increase product versatility.

2.LITERATURE SURVEY

3D Printing was invented by Chuck Hull back in 1986 [1], it is an additive manufacturing technique in which digital 3D model is converted file into a physical object. Hull's invention concentrated solely on a fabrication process called Stereolithography (SLA). Since that time numerous other 3D printing technologies have been developed, such as Fused Deposition Modeling (FDM)/Fused Filament Fabrication (FFF), Selective Laser Sintering (SLS), PolyJetting and others, all of which rely on layer-by-layer fabrication and are based on a computer code fed to the printer.

While there are numerous technologies which can be used to 3D print an object, the majority of 3D printers one will find within a home or an office setting are based on the FDM/FFF or SLA processes, as these technologies are currently cheaper and easier to implement within a machine. We will go further into detail about these technologies and others a little bit later.

Methodology of 3D Printing

Figure 1.1 shows the process involved in 3D Printing. It involves following steps

1.Create 3D part using CAD.

2.Convert the file to .STL file type.

3.Slice it into G codes using slicing software.

4.Upload the program to printer

Figure 1.1: Process involved in 3D Printing

Once a 3D model is designed, the file (these usually have extensions such as 3MF, STL, OBJ, etc.) must be converted into G-code. G-code is a numerical control computer language used mainly for computer aided manufacturing (both subtractive and additive manufacturing). It is a language which tells a machine how to move. Programs such as Slic3r are required in order to convert 3D model files into G-code. Once the G-code is created it can be sent to the 3D printer, providing a blueprint as to what its next several thousand moves will consist of. These steps all add up to the complete fabrication of a physical object. There are other computer languages out there and perhaps many will eventually gain popularity, but for now G-code is by far the most important.

Various Techniques in 3D Printing

Various methods are there to create prototype. These methods are used based on the complexity of the design, the material used in the design, the purpose of the design, and the size of the design. They are as follows:

1. Stereo lithography - Stereo lithographic 3D printers (known as SLAs or stereo lithography apparatus) position a perforated platform just below the surface of a vat of liquid photo curable polymer [2]. A UV laser beam then traces the first slice of an object on the surface of this liquid, causing a very thin layer of photopolymer to harden. The perforated platform is then lowered very slightly and another slice is traced out and hardened by the laser. Another slice is then created, and then another, until a complete object has been printed and can be removed from the vat of photopolymer, drained of excess liquid, and cured.

2. *Fused Deposition Modeling (FDM)* – It is a process by which a machine deposits a filament (Thermoplastics or wax), on top or next to same material, in order to create a joint by heat or adhesion [3]. Here a hot thermoplastic is extruded from a temperature-controlled print head to produce fairly robust objects to a high degree of accuracy.

3. *Selective laser sintering (SLS)* - This builds objects by using a laser to selectively fuse together successive layers of a cocktail of powdered wax, ceramic, metal, nylon or one of a range of other materials.

4. ***Multi-jet modeling (MJM)*** - This again builds up objects from successive layers of powder, with an inkjet-like print head used to spray on a binder solution that glues only the required granules together. The V-Flash printer, manufactured by Canon, is low-cost 3D printer. It's known to build layers with a light-curable film.

5. ***Inkjet 3D printing*** **-** It creates the model one layer at a time by spreading a layer of powder (plaster, or resins) and inkjet printing binder in the cross-section of the part. It is the most widely used 3-D Printing technology these days and the reasons beyond that are stated below. This technology is the only one that Allows for the printing of full color prototypes. Unlike stereo lithography, inkjet 3D printing is optimized for speed, low cost, and ease-of-use. No toxic chemicals like those used in stereo lithography are required. Minimal post printing finish work is needed; one needs only to use the printer itself to blow off surrounding powder after the printing process. Allows overhangs and excess powder can be easily removed with an air blower.

Applications of 3D Printing

While initially 3D printing was primarily a technology for prototyping, this is quickly changing. Now numerous manufacturers are producing end-use components and entire products via additive manufacturing. From the aerospace industry, to medical modeling and implantation, to prototyping of all kinds, 3D printing is being used by virtually every major industry on the planet in one way or another.

3D printed models of human organs have been a frequent tool for surgeons over the last two to three years, as they provide a more intricate view of the issues at hand. Instead of relying on 2D and 3D images on a computer screen or a printout, surgeons can actually touch and feel physical replicas of the patient's organs, bone structures, or whatever else they are about to work on.

Additionally, there is research underway by many companies to 3D print partial human organs such as the liver and kidney [4]. Over the next decade, it's very possible that we will be 3D printing entire human organs for transplantation. Customized open source prosthetic limb fabrication is another important area 3D printing is excelling.

Because of the unique geometries offered by additive manufacturing, militaries around the world, as well as agencies such as NASA and the ESA, along with numerous aircraft manufacturers are turning to 3D printing in order to reduce the overall weight of their aircraft. Complex geometries and new materials offer superior strength with less mass, potentially saving organizations like NASA boatloads of fuel, and thus money, during the launching of spacecraft or rockets out of our atmosphere [5]. At the same time, companies like Boeing and Airbus are using 3D printing to reduce the weight of their aircraft, allowing them to cut fuel costs for each flight.

FDM

Fused Deposition Modelling (FDM) is an additive manufacturing process, in this process, thermoplastics in the form of filament is passed through a heating element which melts the filament and thrusts thorough a small nozzle [6]. The nozzle moves in three dimensions laying down the melted plastic layer by layer in the required shape resulting in realization of final physical object.

Objects created with an FDM printer start out as computer-aided design (CAD) files. Before an object can be printed, its CAD file must be converted to a format that a 3D printer can understand, usually .STL format.

FDM printers use two kinds of materials, a modeling material, which constitutes the finished object, and a support material, which acts as a scaffolding to support the object as it's being printed.

During printing, these materials take the form of plastic threads, or filaments, which are unwound from a coil and fed through an extrusion nozzle. The nozzle melts the filaments and extrudes them onto a base, sometimes called a build platform or table. Both the nozzle and the base are controlled by a computer that translates the dimensions of an object into X, Y and Z coordinates for the nozzle and base to follow during printing.

In a typical FDM system, the extrusion nozzle moves over the build platform horizontally and vertically, "drawing" a cross section of an object onto the platform. This thin layer of plastic cools and hardens, immediately binding to the layer beneath it. Once a layer is completed, the base is lowered — usually by about one-sixteenth of an inch — to make room for the next layer of plastic.

Printing time depends on the size of the object being manufactured. Small objects — just a few cubic inches — and tall, thin objects print quickly, while larger, more geometrically complex objects take longer to print. Compared to other 3D printing methods, such as stereolithography (SLA) or selective laser sintering (SLS), FDM is a fairly slow process.

Once an object comes off the FDM printer, its support materials are removed either by soaking the object in a water and detergent solution or, in the case of thermoplastic supports, snapping the support material off by hand. Objects may also be sanded, milled, painted or plated to improve their function and appearance.

Design of 3D Printing

The figure 2 shows the rendered view of CAD model of the mechanism for movement in all directions [3]. The 3 – Dimensional motion is achieved by synchronization of movements in X, Y and Z directions. The Extruder nozzle is the main part of the printer in which the plastic which is in the form of filament melts and prints on a heated bed. The goal of the mechanism is to make sure that this extruder nozzle will be able to print anywhere inside the predetermined print volume. This mechanism uses 4 stepper motors, one for X – axis movement (Lateral movement or Left – Right movement), two for Y – axis movement (to and fro movement) and one for Z – axis movement (Vertical movement). This mechanism uses single motor to control 4 lead screws to which the print bed is connected for the movement in Z – direction. The lead screws are driven by the motor which in turn moves the bed in vertical direction. For the movement in Y – axis direction, two separate motors are used to move two separate carriages. Two motors have been used here because the print volume is large, there will be disruption in movement if only a single motor is used. For smaller print volumes, single motor may be sufficient. For the movement is X – axis direction a single motor is used which is mounted onto the carriage that moves in Y – axis direction. The detailed working and design of the mechanism in respective directions are explained in further sections. This mechanism is designed for precision, the stepper motors used is having resolution of 0.36^o, i.e., 1000 steps per revolution which provides high precision, the mechanism used for movement in Z – axis provides precision, ease of control and easy synchronization.

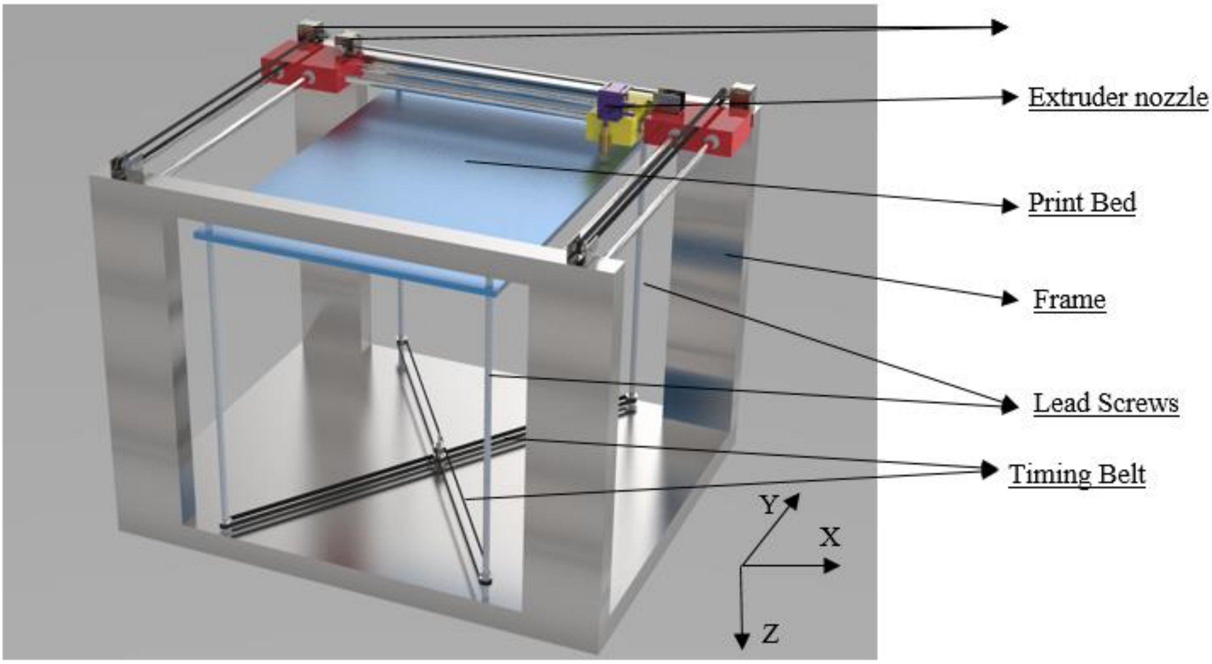

Figure 1.2: CAD model of the Printer

3.FEA ANALYSIS OF 3D PRINTER

FEA analysis forms a very important procedure in developing a new machine. FEA software can easy to use and has a tremendous amount of power to calculate stress and displacement for the complex shapes and sizes which is difficult to be calculated in the mechanical theory. FEA can be used for variety of analysis, from static to dynamic analysis, from modal to heat transfer, etc.

The Analysis of the x axis rod is as given in the table 1.

Table 1: Result of the X-axis results

Name	Minimum	Maximum
Volume	599955 mm^3	
Mass	2.60815 kg	
Von Mises Stress	0.000433376 MPa	6.64818 MPa
Displacement	0 mm	0.0693607 mm
Safety Factor	15 ul	15 ul
X Displacement	-0.00920428 mm	0.00844204 mm
Y Displacement	-0.0022751 mm	0.00227577 mm
Z Displacement	-0.00000000000000053207 mm	0.0688433 mm
Equivalent Strain	0.000000040949 ul	0.0000347935 ul

Stress: The figure 1.3 shows the reaction force and the stress acting in the rods, the reaction forces are acting near the constraints given where the maximum stress is developed near the fixed region and near the place where the load is acting from the carriage. The maximum stress and the minimum stress developed is given in the table 1.1.

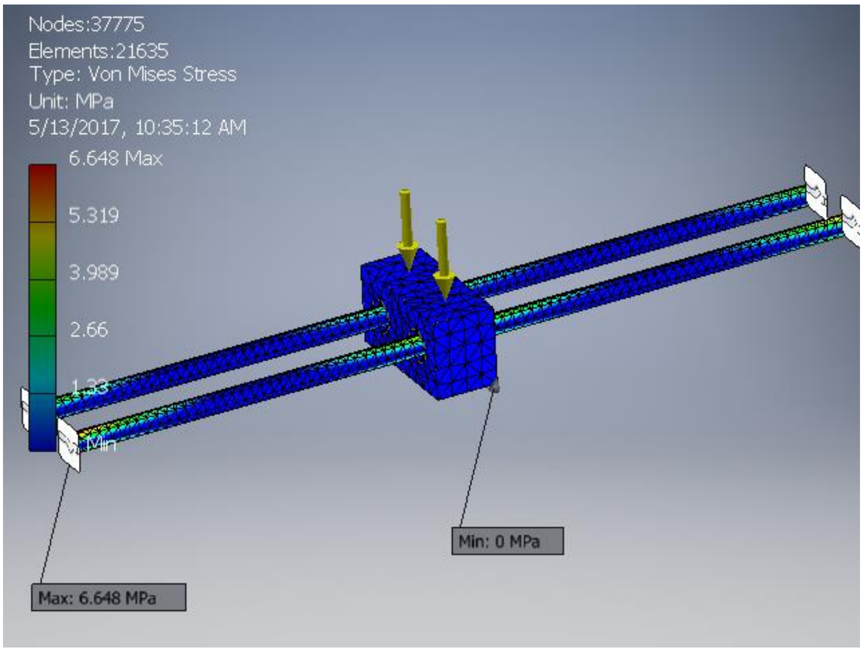

Figure 1.3: Von-Mises Stress for x-axis

Displacement: For a successful design, the displacement has to be minimum, the rod has been selected in such a way that the displacement has to be minimum. Thus the rod is selected as per the Theoretical calculation and then Analyzed. In figure 1.4, the maximum displacement is near the carriage where the load of 30N is acting on it. The rods selected for the x axis is able to withstand the load and thus the material and diameter can be selected as per analysis done.

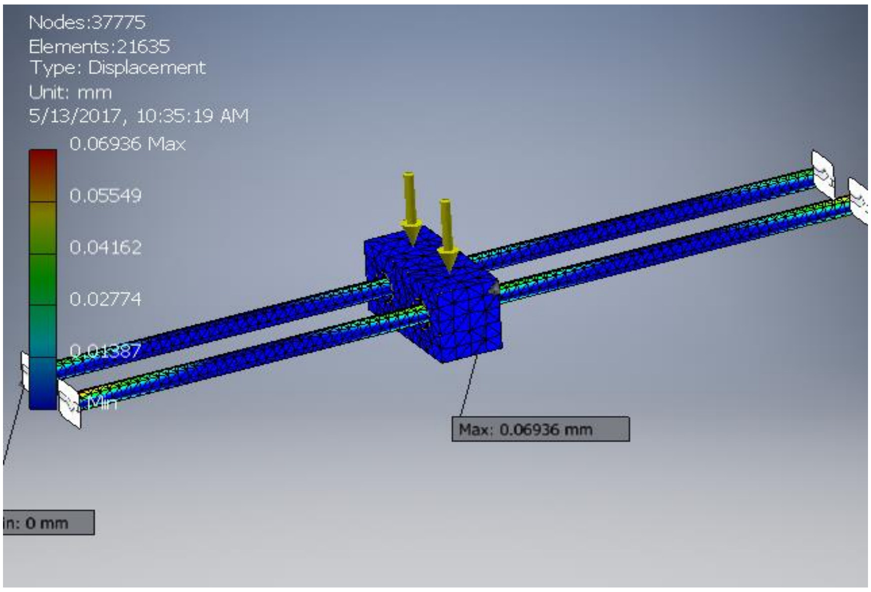

Figure 1.4: Displacement pattern for x-axis rods

Strain: The Hooke's law stated that stress is directly proportional to strain, in the figure 5, the Strain is as low as 3.479 x e^{-05}. This low strain value allows us to select a suitable diameter for the rod and to select the material for the rod.

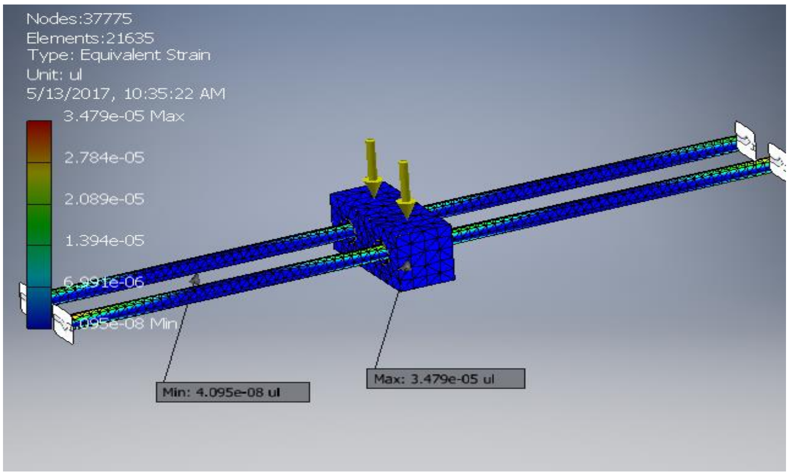

Figure 1.5: Strain for x-axis rods

Since the displacement and the stress is minimum for the selected material which can be used for the development of the machine.

4. CONCLUSION

This mechanism is designed for precision. Using a single motor for vertical movement makes Bed leveling easy and the bed movement can be monitored with resolution in microns. In some mechanisms, the extruder nozzle is made to move in Z – axis direction and bed is made to move in Y – axis direction, these mechanisms face problem of distortion of printed object while printing at high rates due to rapid movement of bed in Y – axis direction. Using the mechanism explained in this paper, large volumes can be printed easily along with higher rates of printing without any distortion, the control of the mechanism becomes easy because of less number of motors used and good synchronization can be achieved. The stepper motors used is having resolution of 0.36^o, i.e., 1000 steps per revolution which provides high precision and accuracy.

REFERENCES

[1] Bak, D. (2003). Rapid prototyping or rapid production? 3D printing processes move industry towards the latter. *Assembly Automation*, 340-345. doi:10.1108/01445150310501190

[2] Jacobs, P.F., Rapid Prototyping & Manufacturing, Fundamentals of Stereolithography, Society of Manufacturing Engineers, 1992, Chapter 1: 11–18

[3] Dr. Rajashekar Patil, Deepak D, Dharshan Gowda S, Krishna Kashyap C S, Mohammed Murtaza, Prashanth S N, Harsha N and Bharath V G, Economical 3d – Printer by Adopting FDM Technique, International Journal of Mechanical Engineering and Technology, 8(4), 2017, pp. 442-447. http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=8&IType=4

[4] Schubert C, van Langeveld MC, Donoso LA Innovations in 3D printing: a 3D overview from optics to organs *British Journal of Ophthalmology* Published Online First: 28 November 2013. doi: 10.1136/bjophthalmol-2013-304446

[5] Bethany C. Gross, J. L. (2014). Evaluation of 3D Printing and Its Potential Impact on Biotechnology and the Chemical Sciences. *Analytical Chemistry*, 3240 – 3253.

[6] Prof. Deepa yagnik, Fused Deposition Modeling – A Rapid Prototyping technique for Product Cycle Time Reduction cost effectively in Aerospace Applications, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, PP 62-68