A comprehensive review of 3D printing and their process parameters

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***Abstract*: 3D printing is currently the most advance manufacturing technique that is used to make desirable products. This method enables the manufacturers to customize the product and also to develop complex products according to their requirements. 3D printing technology permits the fabrication of physical objects based on the 3D CAD model through the layer-by-layer deposition of the material. It uses Magnetic Resonance Image (MRI), Computed Tomography (CT), and 3D scanning images, and these data are converted into surface tessellation language (STL) files for fabrication. Here in this work, a comprehensive review of 3D printing was carried out to identify the major aspects of 3D printing and also identify the parameters which directly affect the properties of 3D printed components.**

***Keywords*: 3D printing, review, performance parameters, methods, origin**

1. Introduction

3D printing is called desktop fabrication. It is a rapid prototyping process whereby a real object can be created from a 3D design. A 3D printer machine uses a CAD model for rapid prototyping process. 3D printing is called as desktop fabrication which is a process of prototyping where by a structure is synthesized from its 3d model. The 3d design is stored in as a STL format and after that forwarded to the 3D printer. It can use a wide range of materials such as ABS, PLA, and composites as well.3D printing is one kind of rapidly developing and cost optimized form which is used for rapid prototyping. The 3D printer prints the CAD design layer by layer forming a# real object. 3D printing process is derived from inkjet desktop printers in which multiple deposit jets and the printing material layer by layer derived from the CAD 3D data.3D printing is diversifying and accelerating our life, letting various qualities of products to be synthesized easier and faster [2]. Three-dimensional (3D) printing has the ability to impact the transmission of information in ways similar to the influence of such earlier technologies as photocopying. This identifies sources of information on 3D printing, its technology, required software and applications. Along 3D printing, companies are able to extract and innovate new ideologies and various design replications with no time or tool expense. 3D printing possibly challenges mass production processes in future. 3D printing influences many industries, such as automotive, architecture, education, medical, business and consumer industries [3].

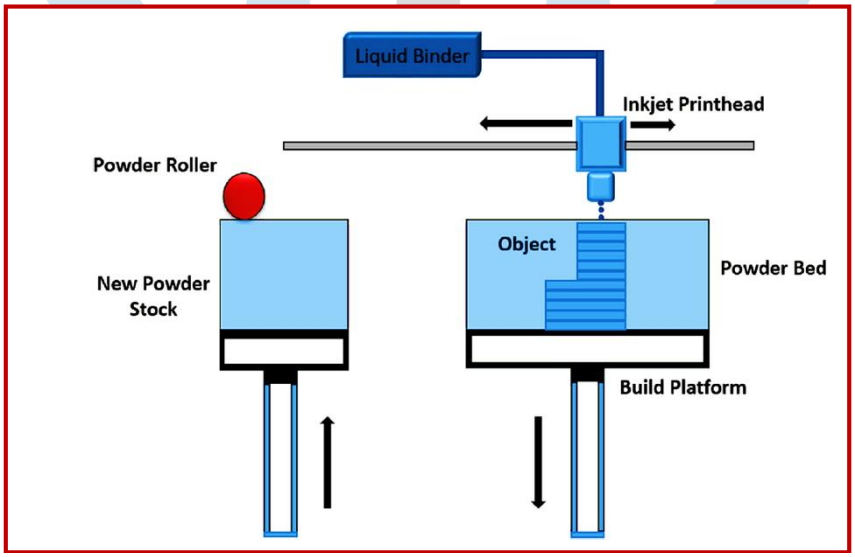

Fig. 1 Additive Manufacturing with 3-D Printing

Manufacturing activities particular date back to 5000 to 4000 BC as per the historian. The manufacturing activities mostly based oriented to wood works earthenware and metal works. After that in the 2500 BC, some sculptures were produced by earthenware, glass beads, wax casting and pieces of jewellery. Steel production has been recorded during the 600 to 800 AD, sand casting of cast iron during 800 to 1200 AD. Manufacturing development in ancient India start since 3000 BC and example of a casting of particular that age 11 cm bronze dancing girl found at Mohen jo Daro. In 2000 BC found iron bowls, daggers, nails, arrows, hooks, and pillars in Delhi area (Hopkinson 2006). In 500 AD during those days cast crucible steel was first produced. After that since 1750 AD all machine tools run by the power of steam engine which developed by western countries. The steam engine gives growth of production and supply chain availability of goods all over the world. After that during 1920 to 1940 mostly develop automation, die casting, wax methods, die casting required engineering manufacturing took place. 1940 to 1960 during that period computer enter in the market, ceramic molds, nodular irons, semiconductors were widely available in the manufacturing market. At last, 1990 to till date

nanotechnology, micro manufacturing, automation, robotics manufacturing and additive manufacturing are the most successful manufacturing process adopted by the Indian manufacturer. There are several positive reviews of additive technologies which most suitable for all sectors. Recently, Government under The Atal Innovation mission is a flagship initiative of the prime minister of India set up by NITI Ayog to promote innovation and entrepreneurship across the country. NITI Ayog has announced.

2. Additive manufacturing process

The control instructions for rapid prototyping and additive manufacturing most commonly involves the following steps:

2.1 Geometric modelling: Creating a model of the component in a CAD system. Solid modelling is preferable due to its complete and explicit mathematical representation of the geometry. Solid modelling also manages to distinguish the interior from the exterior which is the most important issue during this step.

2.2 Tessellation of geometric model: The CAD model is converted into the tessellation format STL which is the standard tessellation format today. The surface in the CAD model is converted into a surface made of triangles arranged to distinguish the interior from the exterior in the model.

2.3 Slicing of the model into layers: The STL file is sliced into parallel horizontal layers closely packed to each other. In rapid prototyping and additive manufacturing, the horizontal layers are formed in the x-y plane while the layering occurs in the z direction. Each layer is subsequently added by the additive manufacturing system resulting in a physical model.

3D printing process can be described and defined in the following steps:

2.4 CAD Model Creation: Initially, the item to be 3D printed is designed utilizing a Computer-Aided Design (CAD) software. Solid modelers, for example, CATIA, and SOLID WORKS have a tendency to represent 3-D objects more precisely than wire-frame modelers, for example, AutoCAD. This procedure is comparative for the majority of the Rapid Prototyping building methods [6].

2.4.1 Conversion to STL Format: The different CAD models use different methods to present solid parts. To have consistency, the stereo lithography format has been followed as the standard of the 3D printing industry.

2.4.2 Slice the STL File: A preprocessing computer program is done which readies the STL format going to be built. Numerous programs are there, which permit the user to tweak the model. The preprocessing program cuts the Stereo lithography model into numerous layers from 0.01 mm to 0.7 mm thickness, in view of the building method. The program likewise makes an auxiliary structure to help the model amidst of building. Sophisticated structures are bound to use auxiliary support [7].

2.4.3 Layer by Layer Construction*:* The fourth step is the actual construction of the part. Using one of various techniques RP machines build one layer at a time from polymers, or powdered metal.

3. Existing Research Works

Since many decades researchers are optimizing the different process parameters and also evolving different additive manufacturing process. Some of the recent work carried out in this field were mentioned here. **Mwema et.al [2020]** In this chapter, an overview of the basic principles of fused deposition modelling, commonly known as 3D printing technology, is presented. The chapter begins by introducing the holistic concept of additive manufacturing and its scientific principle as the technology for the modern and future industry. Then, the science of 3D printing is described. The applications of FDM in various fields are also highlighted with a focus on an interesting role the 3D printing technology is playing in the fight against Covid-19 pandemic. **Wu et.al [2020]** had compared with the traditional material reduction manufacturing, additive manufacturing technology is a great change, which brings new opportunities for the production models. Fused Deposition Molding (FDM) equipment is one of the most widely used to additive manufacturing equipment. The nozzle system is the core component of FDM technology. Its performance directly affects the product forming accuracy and efficiency. **Moetazedian et.al (2019)** In this study, the importance of the testing environment for correct assessment of tensile strength of polylactiacid (PLA) is investigated. A novel design of tensile specimen was developed to test the anisotropic mechanical properties of additively manufactured specimens. The effects of three environmental factors were considered: physiological temperature (37°C), hydration (specimens stored in solution for 48 hours) and in-aqua testing (specimens submerged in solution). **Maamoun et.al (2018)** The current study investigates the influence of selective laser melting (SLM) process parameters on the quality of parts fabricated from different Al alloys. A design of experiment (DOE) was used to analyze relative density, porosity, surface roughness, and dimensional accuracy according to the interaction effect between the SLM process parameters. The results show a range of energy densities and SLM process parameters for AlSi10Mg and Al6061 alloys needed to achieve “optimum” values for each performance characteristic.

Baturynska et.al (2018) This paper presents review of three methods that are used to control and manage quality of parts produced by PPBF AM process. Review showed that statistical analysis as well as machine learning requires big amount of data to be more accurate. In contradiction, mathematical modeling requires deep knowledge on both process and material physics. Proposed conceptual framework provides an idea of how these challenges can be avoided. **Stewart et.al [2018]** it has done analysis on fused deposition modeling using poly lactic acid as material, which reveals minute details of one among the various branches of 3D printing. To eliminate the part-to-part variation and to control the process parameter it is very important to study the temperature gradient of the material so produced in the liquefier. **Han et al. [2017]** it has conducted an over fill and under fill analysis in order to achieve high quality functional part using a deposition planning method. This method was based on algorithm involving grouping

and mapping. In this analysis five properties which are important in fused deposition process been identified. **Gosselin et.al [2016]** had studied one innovative method academic and research teams have been working on is to utilize concrete as a 3D printed material to develop structural elements and whole buildings. Three research teams have made considerable progress on this research objective. Firstly, there is the team Contour Crafting led by Dr. Behrokh Khoshnevis and University of Southern California. Secondly, there is The Freeform Construction team from Loughborough University with Hyundai Engineering and Construction. Lastly, there is the XTreeE team in conjunction with Sam Universitey. **Putzmeister et.al [2016]** had revealed some applications of shotcrete are dependent on formwork while concrete 3D printing does not depend on formwork. A combination of digital design and robotic technology is applied in the process of 3D printing but this is not applied in shotcrete. However, there are different shotcrete robots currently utilized in the costruction industry. Examples of the shotecrete robots include the RPJ-X shotcrete robot and SPM 307 robotic nozzle manipulator. **Malaeb et.al (2015)** have also performed research on determining the optimum mix for 3D printing concrete. Their optimum mix for strength, buildability, flowability, and extrudability consisted of fine aggregates (160g), cement (125g), sands (80g), and a water to cement ratio of 0.39. The accelerator and retarder added were 1 mL and 0.625 mL, respectively. The compressive strength for the mix was 42 MPa (6,100 psi). The 3D printing machine used to print the concrete comprised of a motion control system, a pumping mechanism, a tank for the concrete, and a 2 cm (1 in) printing nozzle.

Brittney et.al [2015] in her article on the 3Dprint.com website indicate that Winsun has 3D printed a six-story apartment building (see Figure 2.4) and an entire villa (see Figure 2.5), in China. The 3D printer used measured 20 ft. in height, 132 ft. in length and 33 ft. in width. The Winsun team CAD modeled the building and transferred it to the 3D printer. The 3D printer was then able to accurately construct the structural elements using a patented and undisclosed ink formula.

Eddie et.al [2015] highlighted that the world's first 3D printed hotel villa (Figure 2.6) was completed in 2015 in the Philippines. Lewis Yakich, a Californian Engineer, and Andrey Rudenko, a 3D printer designer, teamed up to 3D print the first operational commercial building. The building is about 34.5 feet by 41 feet and 10 feet high. The villa (building) had 2 bedrooms and was an addition to the Lewis Grand Hotel in the Philippines. It took about 100 hours to print, however the duration of the project was much longer due to testing, installation of plumbing, electrical wiring and reinforcing bars.

Fig. 2 Construction of the 3D Printed Villa (Eddie, 2015)

Scott et.al [2015] indicated that Oak Ridge National Laboratory (ORNL) combined clean energy technologies into a 3D printed building and vehicle (Figure 2.7). Its technology showed a new approach to energy use, storage, and consumption. It also demonstrated additive manufacturing's rapid prototyping potential. Large scale 3D printers were used to build the vehicle and the house. **Duffy et.al [2015]** highlighted in her article how a Dutch company, MX3D, plans to build the first 3D printed steel footbridge. The bridge will span about 49 feet over a canal in Amsterdam and will be 3D printed from start to finish without any prefabricated parts. **Goldberg et.al [2014]** in her article indicated that the pioneer of the open-source wave was Dr. Adrian Bowyer. Dr. Bowyer developed the first replicating printer. This led to the first commercial 3D printer to be in the market, the SLS machine. The commercialization of 3D printers enabled individuals to print models of their choice.

4. Conclusion

The development of 3D printing is the most innovative technique to fulfill the current manufacturing requirement. With this method, one can make the complex product very comfortably without the wastage of ram materials. This method also makes a great impact on the medical sector and provided the tool for bone implant and tissue generation. 3D printing making people day to day life easier and the main thing is more effectively.

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