Rapid Prototyping: The Future of Manufacturing – An Overview

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Abstract— **The manufacturing process is witnessing a paradigm shift in the contemporary technology. New vistas of digital fabrication are proving revolutionary. This paper is a comprehensive overview of the additive manufacturing technology and its characteristic features. The fundamental process and the materials used are presented. Various forms of these manufacturing techniques offer wide range of advantages. The current applications and the futuristic view have also been discussed.**

Keywords— Additive manufacturing, Fused deposition modeling, Rapid prototyping, Solid Free Form manufacturing, Stereolithography, Three dimensional printing.

I. INTRODUCTION

Manufacturing process is broadly categorized into 2 groups: Additive and Subtractive. In additive process the manufacturing is by assembling particles or raw materials while in subtractive process, the desired shape is imprinted out of a block of material. Manufacturing by addition of small increments is an old idea and appears to be principle behind making of Egyptian pyramids. Rapid Prototyping is an additive manufacturing technique and is a type of computer-aided manufacturing (CAM).[1] The term Rapid Prototyping includes a range of new technologies that produce accurate parts directly from computer-aided designing (CAD) models in a short span of time without any need for human interface. It refers to automatic fabrication of mechanical models from the computer data and involves printing layer by layer. [2] The design from paper is transformed into CAD file and thence to the working model. [3]

Hideo Kodama invented the layered approach to stereolithography in 1970s by using ultraviolet light to cure photosensitive polymers. The term "Stereolithography" was coined in 1986 by Chuck Hull and_is a portmanteau of the Greek words "stereon" (solid), "lithos" (stone) and "graphy".

II. TYPES OF RAPID PROTOTYPING

Stereo Lithography Apparatus (SLA): It is an additive manufacturing process and forms 90% of all rapid prototyping. It is a Solid Free Form (SFF) fabrication technique. It utilizes a resin material. The ultraviolet laser beam is directed by Computer Aided Design data.

Selective Laser Sintering (SLS): It is an additive manufacturing process that uses CO2 laser to sinter compacted layer of fine heat fusible powder material to build the 3D model. The CO2 laser provides concentrated heated beam with high heat deflection temperatures. SLS applications include functional prototypes, high temperature components and snap fits with high accuracy.

Fused Deposition Modeling (FDM): It is an additive manufacturing process. It uses production grade thermoplastic material for the fabrication of prototypes and end-use products. FDM parts and prototypes are strong and able to withstand rigorous testing for form, fit, and function. These are dimensionally stable and do not absorb moisture. It is an option for conceptual models. It uses ABS plastic to produce models with precise feature details which lend themselves to be subjected to drilling, tapping and threading.

III. MATERIALS

Photopolymers are available for SLA Rapid Prototyping. Resins offer mechanical properties of durability and toughness. For thermoplastic applications, newer SLA resins provide heat deflection resistance up to 105°C as compared to traditional limits of 55°C. Ceramic-filled SLA resins deliver near-metal performance with higher stiffness and high temperature resistance. SLA resins are being developed to improve the performance of SLA parts regarding their mechanical and thermal performance and applications. An increasing number of materials that can be processed are becoming available with advancement in technology.

IV. PROCESS

Additive manufacturing by SLA starts with the 3D CAD data. The CAD files are converted to STL format which expresses the boundary surface of the model as mesh of connected triangles. The machine is capable of reading the digital data and utilizing it to produce physical object. The liquid materials react by solidifying when struck by a light source or high powered laser. The Laser is used for machining on the liquid UV curable photopolymer resin, incrementally building parts a layer at a time. Laser beam traces a part of the cross section pattern on surface of liquid resin. Then it is exposed to laser that cures the resin and adheres it to its layer below. Single layer thickness is typically of 0.05-0.15mm (0.002-0.006"). Resin filled blade sweep the part of cross section, recoating it with fresh material. Subsequent layer pattern is traced. Due to absorption, this reaction takes place only near the surface. Finally it is cleaned of excess resin by immersion in chemical bath.

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V. FABRICATION PROCEDURE

The additive manufacturing procedure starts with the fabrication of CAD model. Then the CAD file rapid prototyping translator transforms the CAD data in the tessellated SL format. The CAD model is sliced precisely in very thin sections horizontally. A support is used to ensure that the sweeper bar does not strike the platform and ensures removal of parts from the platform. The boundary surfaces of the object are delineated. The sweep period i.e. the number of sweeps of the recorder per layer is defined the z-wait i.e. the time that the system has to wait after recoating the successive layers are also specified. The data slices are in two x-y planes and the part is built in z direction.

The stereolithography built orientation is of two types namely bottom–up system and top-down setup. In bottom–up system scanning laser is the method of curing and in top-down setup digital laser projection is the method of illumination. In bottom–up system, the SL apparatus has a platform submerged just below the surface of a vat of photo-sensitive polymer. The UV laser traces the first layer of the resin stimulating its polymerization. The solidification starts at the borders and then progress to the internal parts. Then the platform sinks below the level of the liquid by the thickness of a layer and hence the hardened layer is covered with new layer of the liquid. The uniformity of the thickness of each layer is ensured by a sweeper bar that moves across the surface layer. Support is used for various parts of the model. The number and position of the supports follows the design of the prototype. The process of sweeping is repeated until the model is formed completely.

In top-down approach the build platform is dipped into the resin from above and the light is projected on a transparent plate from underneath. As the illuminated surface is always smooth, hence recoating of the structure is not required. Also, as the surface is not exposed to the environment, the oxygen inhibition is prevented.

After the completion of layers addition, the supports are removed manually. The final curing of the object is done. The excess resin is drained out or removed using solvents. The final step in the manufacturing is the finishing that is carried out by painting coats. The custom finishing is achieved by chrome plating, surface coatings, Laser etching, vapor deposition, dip coatings and color matching.

VI. APPLICATIONS

Rapid Prototyping substantially decreases time for development of patterns, molds and prototypes. The prototypes are strong enough to be machined and are possible in a variety of shapes, colors, textures and finishes. Hence it finds plethora of applications in mechanical and scientific field. Industry specific applications apply macro scale additive manufacturing. The resins are the most commonly used materials. However, polymer–ceramic composite objects can also be fabricated.

In medical applications, the Digital Imaging and Communication in Medicine (DICOM) data is translated into Stereolithography (STL) files, which are then read and built by 3D Printers.[4] The scientific applications in medical field are brought through segmentation and mesh generation for 3D printing. The DICOM data of Computed Tomography, Magnetic Resonance Imaging, Ultra Sono Graphy software is utilized. For features smaller than conventional sialolithography, two proton polymerization is used such as application of stereolithography in preparing porous structures for production of tissue engineering scaffold. [5,6]

VII. DISCUSSION

The manufacturing entails either additive or subtractive process. The difference in manufacturing in these two techniques lies in the material used, the processing protocols and their accuracy. The additive manufacturing process can produce large models with surface variations and accuracy, whereas the subtractive manufacturing process produces homogeneous models with more accuracy. Additive manufacturing can build those geometries that are not feasible by subtractive manufacturing techniques. [3] The precision of additive technology depends upon the thickness of the layer and width of the curing beam. The thickness of the layer should be less and curing beam should be narrower for better accuracy. However, more number of layers and narrow diameter of the curing beam prolongs the fabrication time.

Durable and resistant materials are available as material selection is the key in the manufacturing process. The resin is the most commonly used material that is polymerized in two ways, either by Digital Light Processing (DLP) or by the Laser i.e. Stereolithography (SLA). There are certain constraints associated with the process of stereolithography. Though it is a time saving procedure but being a sensitive procedure, some steps are time-consuming especially support removal.

Rapid prototyping has revolutionized the engineering and science. The 3D solution is increasing and holds promise for intricate forming capabilities. There are many interesting trends in the ongoing developments in this field. Currently there is no standard 3D printing process for medical research. The demand for RP models in the medical field are on rise. The variety of newer and usual applications of rapid prototyping continues to grow. However, the development of new materials and technology will further define the role of rapid prototyping. 3D engineered biomimetic scaffolds to promote bone tissue growth and differentiation is an emerging technology to develop bone tissue. [7] The additive manufacturing technologies are capable of producing complex heterogeneous architectures for the fabrication of functional materials.

VIII. CONCLUSION

Additive manufacturing can be useful in multiple diverse manufacturing industries. Stereolithography technology is still in its emergent stage and is a promising option to be a foremost technology in the manufacturing industry. As the understanding of the additive manufacturing technology

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advances, it is expected that its applications will continue to grow with time. Advancements in the current technology are expected to open the newer vistas including possibility of manufacturing the living organisms. Inclusion of new functionalities to the advanced materials would revolutionize the manufacturing industry. [8] This path breaking evolution appears to hold the possibility of manufacturing living organism.

REFERENCES

[1] Hirt L, Reiser A, Spolenak R, Zambelli T. Additive Manufacturing of Metal Structures at the Micrometer Scale. Adv Mater. 2017;29(17):1-30.
[2] Skoog SA, Goering PL, Narayan RJ. Stereolithography in tissue engineering. J Mater Sci Mater Med. 2014;25(3):845-56.
[3] Ferry PW Melchels, Jan Feijen, Dirk Grijpma. A review on stereolithography and its applications in biomedical engineering. Biomaterials 2010;31:6121-30.
[4] Pucci JU, Christophe BR, Sisti JA, Connolly ES Jr. Three-dimensional printing: technologies, applications, and limitations in neurosurgery. Biotechnol Adv. 2017;35(5):521-9.
[5] Brunello G, Sivolella S, Meneghello R, Ferroni L, Gardin C, Piattelli A et.al. Powder-based 3D printing for bone tissue engineering. Biotechnol Adv. 2016;34(5):740-53.
[6] Lee KW, Wang SF, Fox BC, Ritman EL, Yaszemski MJ, Lu LC. Poly(propylene fumarate) bone tissue engineering scaffold fabrication using stereolithography: effect of resin formulations and laser parameters. Biomacromolecules 2007;8:1077-84.
[7] Marro A, Bandukwala T, Mak W. Three-Dimensional Printing and Medical Imaging: A Review of the Methods and Applications. Curr Probl Diagn Radiol. 2016;45(1):2-9.
[8] Studart AR. Additive manufacturing of biologically-inspired materials. Chem Soc Rev. 2016;21;45(2):359-76.

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