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Manufacturing of Components using Rapid Prototyping : A Review

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ABSTRACT

Now a day's 3D printing and their properties are becoming a notable topic in technological aspects. 3D printer is a device which convert any design into a product in real-life. 3D printing was discovered in the late 1970s or maybe early 1980s and it was the only technique of manufacturing process which do not include the usage of and tools, dies, fixtures, molds, etc. The name Rapid Prototyping (RP) or Additive Manufacturing itself expresses that it is the manufacturing of product with addition of material on top of the other. It saves time, cost & also reduces the material wastage. This paper mainly explains the FDM procedure of manufacturing & material used for 3D printing by FDM machine. This process is used in many different sectors like Automobile, Biomedical, Military, Agriculture, etc. There are many different methods of FDM 3D printing available in the market. In this paper the review is done on different processes, materials and type used for Rapid Prototyping. There are many different materials available for the use in Rapid Prototyping to acquire different types of properties in the product. The material could be thermoplastics, photopolymers, metal, and ceramics in the form of liquid, powder, resins, or filaments. The paper presents a review about Rapid Prototyping, different types of RP techniques, its benefits and limitations over traditional processes, different types of RP material its areas of applications and further advancements.

Keywords: - RP, 3D Printing, FDM

I. INTRODUCTION

Rapid prototyping is a revolutionary technique of manufacturing in the production industry. There was the crisis of machine tool in USA due to which this technique came into existence in the year 1980s. UAS was the dictator of tool industry in those days. It was difficult to design because of complex structure of the printer. In the initial stage of the machine development, they developed a procedure & working of prototype of a three-dimensional printer which was capable of printing object in 3D [1]. Rapid prototyping is a group of methods used to rapidly manufacture a model of a physical part or assembly using three-dimensional computer aided design (CAD), Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) data. The component is made by additive/layer by layer manufacturing, which is known as 3D printing [2]. This process can create very complex geometries which is not able to manufacture with conventional processes. Also, it helps to create object with less amount of time. In short, we can say that it is very efficient and time saving technology which is yet in development phase.

I. Need for Rapid Prototyping

There are many people who think about different brilliant techniques, but it is not enough to just think. We need to apply those virtual thoughts in a physical form. Now a days or in the future with the all-round growth in every industry, it is very essential to fabricate a prototype of the product for marketing it to the end users & all the types of distributors and the vendors for taking the opportunity & appreciable review of the product for making the product viable for its efficient use [3]. The process 'Additive Manufacturing' can prove it to be a dependent and efficient for mankind. The manufacturing technique can be certainly developed in its own domain to evolve over the years. By avoiding the techniques of producing a working system at the value of is failure of its structure and useless wasting of the material, it would be smarter to fabricate the product first which is general and cheaper prototype of the product to analyze the failure occurring in it and simulating the system which would lead to the feedback of the component. In fact, the prototype is not the end-user component. The prototype is only used to gather the useful data which is relevant to the component and modify it to fulfill the demands of the end-user with keeping the motive of the product same.

II. Review of Working & Types of FDM Machine

The Rapid Prototyping machine starts the production by collecting the data in terms of three-dimensional model with the help of Computer Aided Design (CAD), Image Acquisition or Scanning the model by different devices. A Data interface is used to translate the CAD model into a format called STL file format which is the only input understood by the 3D printers. The full form of STL is (Standard Triangular Language). The material used in the manufacturing of the product may be in the form of liquid, powder, filament, or resin which depends upon the Rapid Prototyping technique used to manufacturing the product.[4]. Fig 1 shows the schematic procedure of RP.

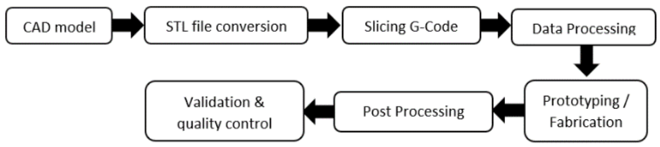

Fig. 1: Rapid Prototyping Process Flow Diagram

The STL file is then fed to the 3D printing software. In the software the file is passed through a slicing process which is used to translates the CAD model into the form of unstacks of two-dimensional cross section & stacks the cross-sectional layers of the build material which prints the model in layer-by-layer format after feeding the model to the 3D printer. The finished product is then passed through the post processing, after which the validation and quality control of the prototype is done. There are many different types of software available for the different companies of 3D printing machines designed especially for their own use. There are many different types of material available in the market. Different 3D printers use different types of material according to the desired output [5] [6].

Fuse Deposition Molding (FDM): - There are different types of 3D printing technologies which we can think of. But Fused deposition Modeling (FDM) is a Rapid Prototyping technique which is a most commonly used for making prototypes and useful components in the industries. In this type of technique, the material used is a thermoplastic filament which is heated to about 200 to 250 degree C, which converts the material into liquified form & extrude the material on the printing tray layer by layer from a tip of the extruder to create a 3D object. The material is in the form of threads or filament. When the model is of complex and hanging structure, supports are provided to the respective positions which can be easily removed from its place

This filament is then melted into the extruder nozzle & the molten material is then extruded on the hot bed. The printing method is a computerized process which converts the STL file of the model into the three-dimensional coordinates x, y & z. The nozzle extrudes the material on horizontal plane constructing the cross section of an object on the bed. The layer is then cooled & hardened after extrusion. After a layer is processed, the hot bed is vertically lowered to a thickness equal to one layer thickness, so cycle continuous the process for the successive layer. After the final product is designed and chipped from the hot bed, it is sent for the post processing. In post processing the scaffoldings material is removed from the object. FDM technique is a slower process as compared to other techniques like SLA & SLS. There are 2 possibilities of movement in the FDM machine. In the first possibility the extruder moves in x, y plane & the bed moves in the z plane. In the second possibility the bed is steady & the extruder moves in x, y & z plane [7] [8].

FDM 3D printing techniques

1. **Cartesian FDM 3D printers: -**

Cartesian 3D printers as shown in fig 2 are the type of FDM 3D printers which are commonly found in the market. This technique basically uses the Cartesian coordinate system in mathematics, it uses orthogonal axis- x, y & z to determine the perfect position & orientation of the printing head. Depending on the model and manufacturer of the printer, the print platen of this machine will oversee the Z axis, allowing the extruder to be positioned on the X and Y axes, so that it can move in four directions.

Two well-known brands in the Fused Deposition Modeling market that use Cartesian technology for their FDM 3D printers are Ultimaker and MakerBot. The main advantage of these solutions is that they are generally inexpensive and are sold as kits to be assembled by the user.

Fig. 2: Cartesian FDM 3D printers

2. **Polar FDM 3D printers: -**

Polar 3D printers do not depend upon the x, y & z coordinate positioning. Polar 3D printing use angle and length positioning. Instead of using square grid it uses circular grid to describe the points which is not determined by X, Y and Z axes, but by angle and length. This implies that the circular plate rotates at the same time, with the extruder moving up & down. This method particularly prints only spiral objects, such as traffic cones, Plant vase, etc. The fig 3 shows the polar 3D printer The main advantage of Polar FDM 3D printers is they only have two engines, whereas Cartesian printers need at least three. In the long term, the polar printer has greater energy efficiency and can make larger objects while using less space. However, polar printers have an inconsistent accuracy; as they rotate in a circle, there is much more accuracy in the center than in the outer area.

Fig. 3: Polar FDM 3D printers

3. Delta FDM 3D printers: -

These printers are being seen more and more on the FDM 3D printing market. They operate with Cartesian coordinates. As shown in the Fig 4, this method involves a circular printing plate that is combined with an extruder that is fixed at three triangular points (hence the name 'Delta'). Each of the three points then moves up and down and left and right, thereby determining the position and direction of the print head. Therefore, the manufacturing limits of these machines are defined solely by the diameter of the base and the height of the arms. Delta printers, with a fixed print tray, were designed to speed up the printing process. Another advantage of Delta printers is that they can be resized, without affecting quality. However, they can prove more difficult to calibrate.[9]

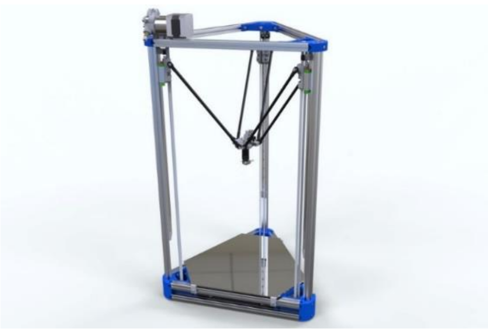

Fig. 4: Delta FDM 3D printers

Robotic Arm & Hybrid FDM 3D printing: -

Robotic Arm is the most essential component in the manufacturing industry. Fig 5 & 6 shows the physical structure of this process. It is mostly used in Assembling components on industrial production lines, especially in large automotive plants. Now 3D printing has started to incorporate the robotic arms into their production units, mostly for manufacturing of the 3D printed homes and buildings, this technology remains in the development stage. Robotic arms are primarily used in the assembly of parts. Hybrid manufacturing is a 3D printing process in which the combination of both additive (3D printing) and subtractive (CNC machining, milling) methods brought in a single solution. This machine allows the easy exchange of tools for different type of work. In the case of FDM 3D printers that incorporate subtractive heads, which mostly have Cartesian structure. However, there are other cases, such as the Kraken project, which depend upon a robotic arm which is capable to extrude material, but which also includes subtractive methods, for creating a hybrid manufacturing project. We know that the machine which incorporates both the techniques has a much larger price tag, although the benefits can be far greater as it expands the capabilities of part creation.

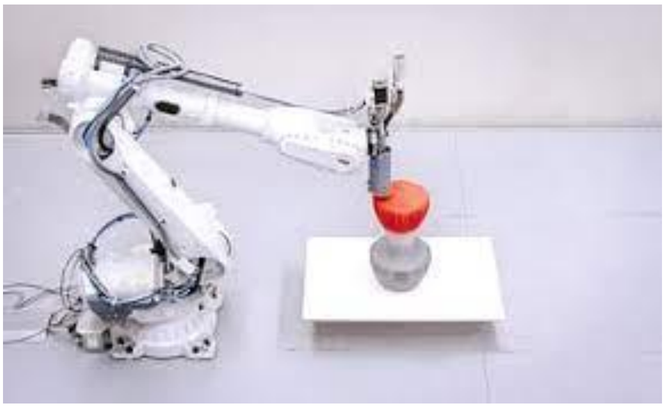

Fig. 5: Robotic Arm & Hybrid FDM 3D printing

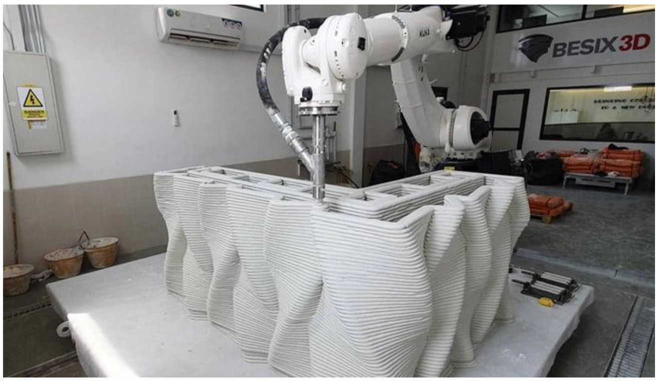

Fig. 6: Robotic Arm & Hybrid FDM 3D printing

II. Materials used in RP

Materials used in FDM 3D printing are as follows: -

1) Standard Plastics: -These are used for non-critical applications.

- Polylactic acid (PLA): -

PLA is a type of polyester made from fermented plant starch from corn, cassava, maize, sugarcane or sugar beet pulp. PLA is generally, the material used in FDM (Fused Deposition Molding) 3D printers. The main properties of the PLA material are that, (1) It is rigid, strong but brittle in nature which means it can brake easily. at the same time, (2) The material has less resistant to heat & chemicals which means that it can melt in higher temperatures, (3) It is a biodegradable material with no odor of any kind.

- Acrylonitrile Butadiene Styrene (ABS): -

ABS is generally, the material used in FDM (Fused Deposition Molding) 3D printers. ABS or Acrylonitrile butadiene styrene is a common thermoplastic polymer typically used for injection molding applications. This engineering plastic is popular due to its low production cost and the ease with which the material is machined by plastic manufacturers. Better yet, its natural benefits of affordability and machinability do not hinder the ABS material's desired properties.

2) Engineering Plastics: -These are used for structural purpose applications.

- Thermoplastic Elastomer (TPE)

TPE material are flexible materials which can be transformed in to desired structure. It is a rubber like material that can be processed like Plastic

- Nylons: -

Nylon 11 (polyamide) is a strong and tough engineering-grade SLS thermoplastic. Parts produced with this material show a high elongation at break, elasticity and high impact resistance. Nylon filament offers great toughness and flexibility. Many nylon copolymers also exist which modify the strength and rigidity of the material to meet application requirements.

3) Advanced Plastics: -These are used for mechanical, thermal & chemical high strength applications

- PEEK: -

It is one of the top-notch materials present in the market. It is one of the costliest material. It is a colorless, organic thermoplastic polymer that achieves some of the best results out of all thermoplastics worldwide. It is part of the polyaryletherketone (PAEK) family.

Table 1: Material Properties & Selection Criterion

Material	PLA	ABS	Nylon	PEEK
Properties	Tough, Strong, Biodegradable	Impact Resistance, Structural Strength and Stiffness, Chemical Resistance, Excellent High and Low Temperature Performance, Great Electrical Insulation Properties,	Tough and partially Flexible, very high impact resistance, offers good ductility	Harsh chemical Resistance, very low Moisture uptake, good fire performance, excellent mechanical strength, good dimensional stability

		Easy to Paint and Glue		
Temperature	Temperature to melt the material is between 190-220°C	Temperature to melt the material is between 220-250°C	Temperature to melt the material is between 240-290°C	Temperature to melt the material is between 370-410°C
Cost	Low Cost	Low Cost	Expensive	Higher Cost
Odor	Produces dangerous fumes during 3D printing	No fumes are produced	Nearly odorless	Produces dangerous fumes during 3D printing
Print rate	45 – 60 mm/s	45 – 60 mm/s	25-50 mm/s	Up to 50 mm/s

III. CONCLUSION

This paper reviews the details regarding the different Rapid Prototyping procedures & techniques to know the deep insights of product manufacturing. Also, stating the different types of material used and their significance of RP in product manufacturing. Advantages of 3D printing are endless therefore it is most preferable technology in complex shaped geometry of product. Rapid Prototyping is going to change the future of manufacturing industries in upcoming decades. This paper provides an overview of RP technology in brief and emphasizes on their ability to shorten the product design and development process. For certain applications, particularly metals, machining will continue to be a useful manufacturing process. Rapid prototyping will not make machining obsolete, but rather complement it. At last, we can conclude that, in the upcoming days Rapid Prototyping will change the entire traditional manufacturing techniques & make the output efficient and durable.

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