Rapid Prototyping- A Holistic Review

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ABSTRACT:One of the critical factors in competitive technology is "time to market" along with foolproof design. This critical factor indicates the entire product design cycle from concept to product design to prototype to manufacturing process design to actual implementation. To have command over this critical factor Computer aided designing (CAD) and manufacturing (CAM) is taking hold as a mean of speeding the time to market for new product development. Recently rapid prototyping or additive manufacturing is the emerging field which fulfills this demand.This paper describes different methods of rapid prototyping and use of CAD techniques in RPT techniques to shorten the time to market and further for research and development of new products.

KEYWORDS: Rapid Prototyping Technology (RPT),CAD/CAM

I. INTRODUCTION

Rapid prototyping is the set of technologies that enables the manufacturing of physical models directly from three-dimensional models or virtual prototyping, through programs such as CAD, CAM, which are transferred to a computer responsible for its materialization. It uses data computer-aided-design (CAD) software or 3D object scanners to direct hardware to deposit material, layer upon layer, in precise geometric shapes. It was used for producing models and prototypes in late 1980s , but today with the advancement of technology it has a wide range of applications. It is called "third industrial revolution" because of its potential to change the manufacturing market.It delivers a perfect trifecta of improved performance, complex geometries and simplified fabrication.Low energy consumption; Little loss of material; High speed manufacturing; It can be used to make parts or products with complex geometries are few advantages of this technology. As a result, opportunities abound for those who actively embrace this technology. The advent of AM technologies as developing manufacturing technique presents a number of opportunities for the researchers in different fields.

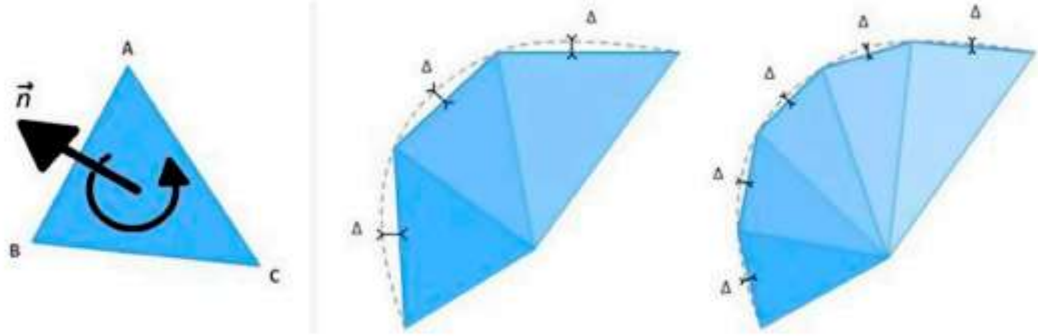
II. THE BASIC RAPID PROTOTYPE TECHNIQUES

Although several rapid prototyping techniques exist, all employ the same basic five-step process. The steps are as described follows.

1) Create a CAD model of the design: The object to be built is modeled using a Computer-Aided Design (CAD) software package. Solid modelers, such as Pro/ENGINEER, Solid Works, Inventor, and Catia tend to represent 3-D objects more accurately than wire-frame modelers such as AutoCAD, and will therefore yield better results. The various CAD packages use a number of different algorithms to represent solid objects. To establish consistency, the STL (Stereolithography, the first RP technique) format has been adopted as the standard of the rapid prototyping industry.

2) Convert the CAD model to STL format: The second step, is to convert the CAD file into STL format. This format represents a 3D surface as an assembly of planar triangles, "like the facets of a cut jewel." The file contains the coordinates of the vertices and the direction of the outward normal of each triangle. Because STL files use planar elements, they cannot represent curved surfaces exactly. Increasing the number of triangles improves the approximation, but at the cost of bigger file size. Large, complicated files require more time to pre-process and build, so the designer must balance accuracy with manageability to produce a useful STL file

3) Slice the STL file into thin cross-sectional layers: In the third step, a pre-processing program prepares the STL file to be built. Several programs are available, and most allow the user to adjust the size, location and orientation of the model. Build orientation is important for several reasons. First, properties of rapid prototypes vary from one coordinate direction to another. For example, prototypes are usually weaker and less accurate in the z (vertical) direction than in the x-y plane. In addition, part orientation partially determines the amount of time required to build the model. Placing the shortest dimension in the z direction reduces the number of layers, thereby shortening build time. The preprocessing software slices the STL model into a number of layers from 0.01 mm to 0.7 mm thick, depending on the build technique. The program may also generate an auxiliary structure to support the model during the build. Supports are useful for delicate features such as overhangs, internal cavities, and thin walled sections.

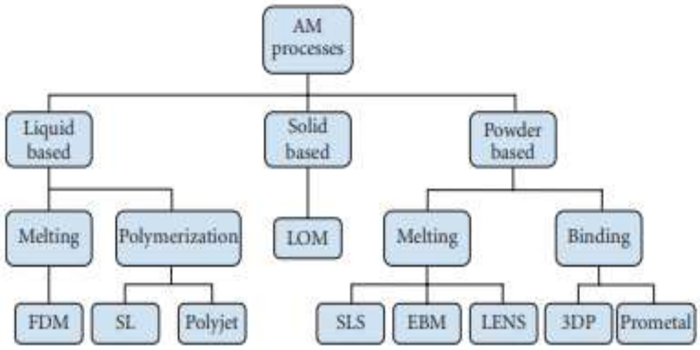


4) Construct the model one layer atop another: The fourth step is the actual construction of the part. Using one of several techniques , RP machines build one layer at a time from polymers, paper, or powdered metal. Most machines are fairly autonomous, needing little human intervention. The final step is post-processing. This involves removing the prototype from the machine and detaching any supports. Some photosensitive materials need to be fully cured before use.

5) Clean and finish the model: Prototypes may also require minor cleaning and surface treatment. Sanding, sealing, and/or painting the model will improve its appearance and durability.

III. **METHODS USED FOR PROTOTYPING:**

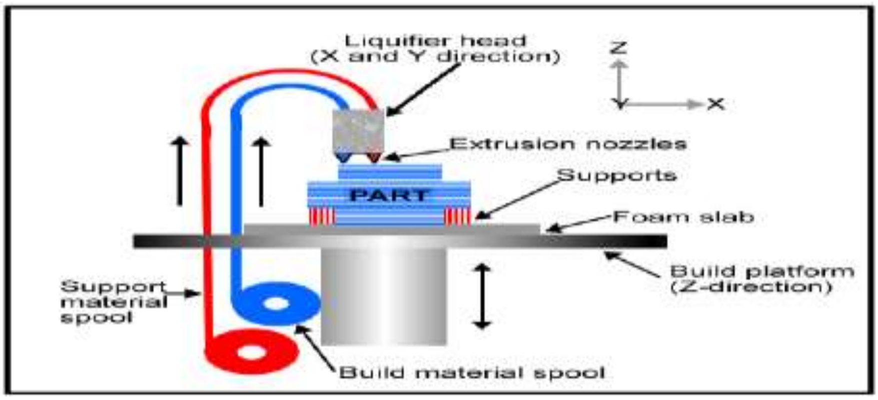
The rapid prototype processes are used to recognize the data format based on a 3D CAD model, which is digitally processed by specialized machines. It is possible to print metals and ceramics but not all commonly used manufacturing materials. Materials for rapid prototyping are still limited. The criterion used is to classify these processes into liquid base, solid based, and powder based. The processes included in this review are considered the most relevant in the past, and promising for the future of the industry.



I.LIQUID BASED:

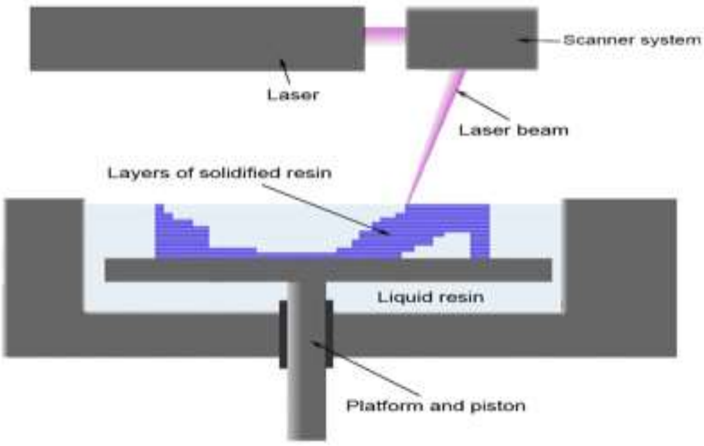
1.Fused Deposition Modeling (FDM)

It is an additive manufacturing process in which a thin filament of plastic feeds a machine where a print head melts it and extrude it in a thickness typically of 0.25 mm. Materials used in this process are polycarbonate (PC), acrylonitrile butadiene styrene (ABS), polyphenylsulfone (PPSF), PC-ABS blends, and PC-ISO, which is a medical grade PC. The main advantages of this process are that no chemical post-processing required, no resins to cure, less expensive machine, and materials resulting in a more cost effective process. The disadvantages are that the resolution on the z axis is low compared to other additive manufacturing process (0.25 mm), so if a smooth surface is needed a finishing process is required and it is a slow process sometimes taking days to build large complex parts. To save time some models permit two modes; a fully dense mode and a sparse mode that save time but obviously reducing the mechanical properties.



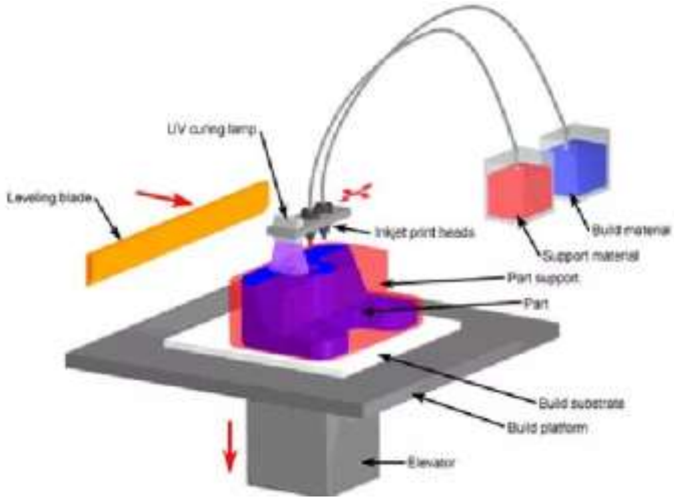
2.Stereo lithography

Patented in 1986, Stereolithography started the rapid prototyping revolution. The technique builds three dimensional models from liquid photosensitive polymers that solidify when exposed to ultraviolet light. The model is built upon a platform situated just below the surface in a vat of liquid epoxy or acrylate resin. A low-power highly focused UV laser traces out the first layer, solidifying the model's cross section while leaving excess areas liquid. Next, an elevator incrementally lowers the platform into the liquid polymer. A sweeper re-coats the solidified layer with liquid, and the laser traces the second layer atop the first. This process is repeated until the prototype is complete. Afterwards, the solid part is removed from the vat and rinsed clean of excess liquid. Supports are broken off and the model is then placed in an ultraviolet oven for complete curing.Because it was the first technique, StereoLithography is regarded as a benchmark by which other technologies are judged. Fig. 4 Shows the Stereolithography process.



3. Polyjet

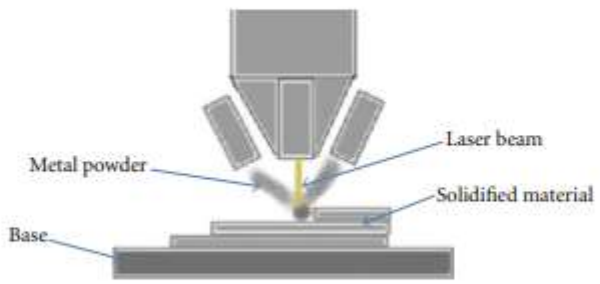
This is an additive manufacturing process that uses inkjet technologies to manufacture physical models. The inkjet head moves in the x and y axes depositing a photopolymer which is cured by ultraviolet lamps after each layer is finished. The layer thickness achieved in this process is 16 µm, so the produced parts have a high resolution. However, the parts produced by this process are weaker than others like stereolithography and selective laser sintering. A gel-type polymer is used for supporting the overhang features and after the process is finished this material is water jetted. With this process, parts of multiple colors can be built.



II.SOLID BASED:-

1. Laminated Object Manufacturing (LOM)

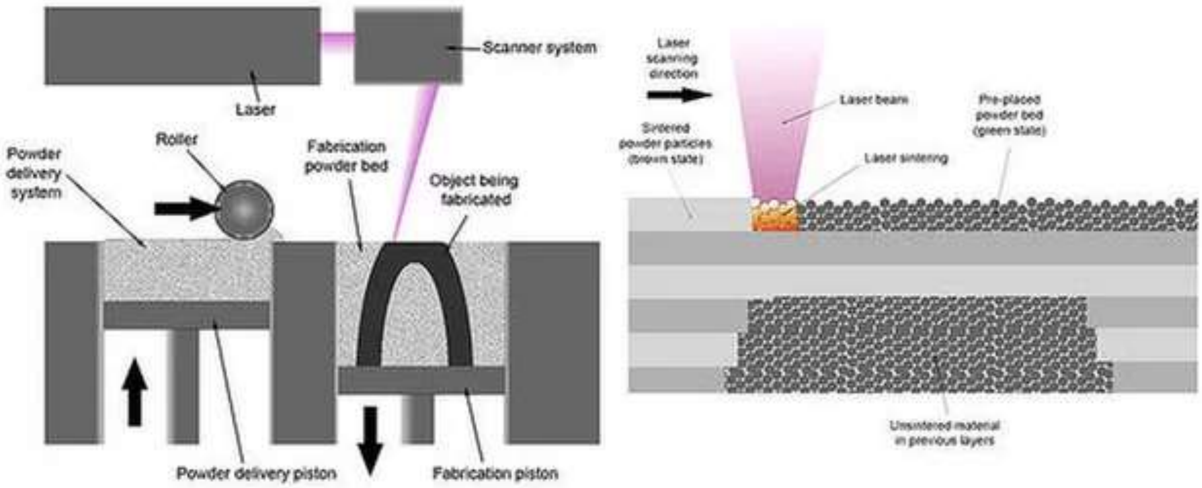
It is developed by Helisys of Torrance, CA, layers of adhesive-coated sheet material are bonded together to form a prototype. The original material consists of paper laminated with heat activated glue and rolled up on spools. A feeder/collector mechanism advances the sheet over the build platform, where a base has been constructed from paper and double-sided foam tape. Next, a heated roller applies pressure to bond the paper to the base. A focused laser cuts the outline of the first layer into the paper and then cross-hatches the excess area (the negative space in the prototype). Cross-hatching breaks up the extra material, making it easier to remove during post-processing. During the build, the excess material provides excellent support for overhangs and thin walled sections. After the first layer is cutting is completed, the platform lowers out of the way and fresh material is advanced. The platform rises to slightly below the previous height, the roller bonds the second layer to the first, and the laser cuts the second layer. This process is repeated as needed to build the part, which will have a wood-like texture. Because the models are made of paper, they must be sealed and finished with paint or varnish to prevent moisture damage.



III.POWDER BASED:-

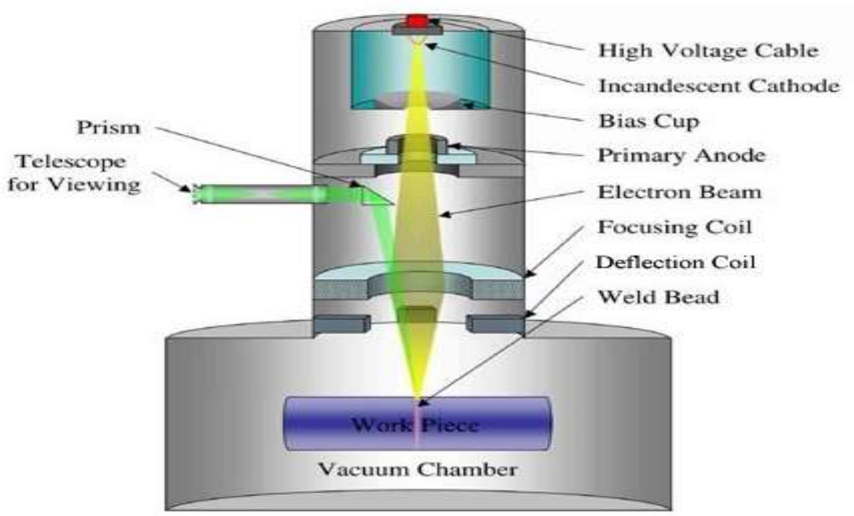
1. SLS (Selective laser sintering) / SLM (Selective laser melting) of metal powders:

This is a three-dimensional printing process in which a powder is sintered or fuses by the application of a carbon dioxide laser beam. The chamber is heated to almost the melting point of the material. The laser fused the powder at a specific location for each layer specified by the design. The particles lie loosely in a bed, which is controlled by a piston, that is lowered the same amount of the layer thickness each time a layer is finished. This process offers a great variety of materials that could be used: plastics, metals, combination of metals, combinations of metals and polymers, and combinations of metals and ceramics. Examples of the polymers that could be used are acrylic styrene and polyamide (nylon), which show almost the same mechanical properties as the injected parts. It is also possible to use composites or reinforced polymers, that is, polyamide with fiberglass. They also could be reinforced with metals like copper. For metals, a binder is necessary. This could be a polymer binder, which will be later removed by Support material nozzle Support material Base Build material nozzle Build material Figure 8: Fused deposition modeling. heating or a mix of metals with very different melting point. Parts of alumina with high strength can be built with polyvinyl alcohol, which is an organic binder. The main advantages of this technology are the wide range of materials that can be used. Unused powder can be recycled. The disadvantages are that the accuracy is limited by the size of particles of the material, oxidation needs to be avoided by executing the process in an inert gas atmosphere and for the process to occur at constant temperature near the melting point. This process is also called direct metal laser sintering.



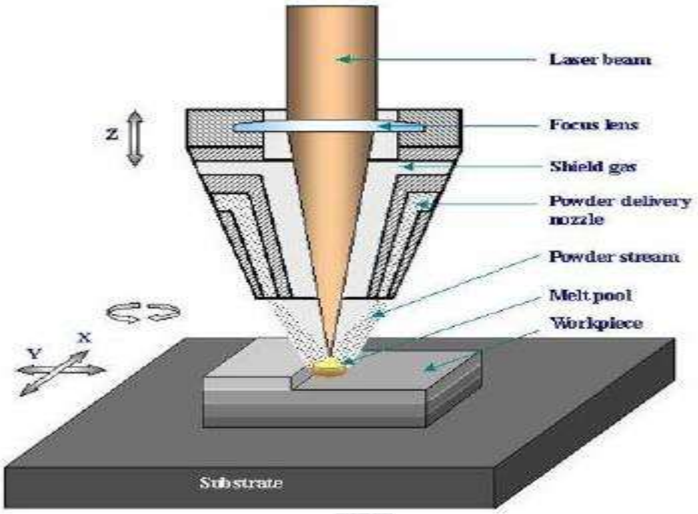
2.Electron Beam Melting

A process similar to SLS is electron beam melting (EBM). This process is relatively new but is growing rapidly. In this process, what melts the powder is an electron laser beam powered by a high voltage, typically 30 to 60 KV. The process takes place in a high vacuum chamber to avoid oxidation issues because it is intended for building metal parts. Other than this, the process is very similar to SLS. EBM also can process a high variety of prealloyed metals. One of the future uses of this process is the manufacturing in outer space [33, 34], since it is all done in a high vacuum chamber.



2.Laser Engineered Net Shaping

In this additive manufacturing process, a part is built by melting metal powder that is injected into a specific location. It becomes molten with the use of a high-powered laser beam. The material solidifies when it is cooled down. The process occurs in a closed chamber with an argon atmosphere. This process permits the use of a high variety of metals and combination of them like stainless steel, nickel based alloys, titanium-6 aluminium-4 vanadium, tooling steel, copper alloys, and so forth. Alumina can be used too. This process is also used to repair parts that by other processes will be impossible or more expensive to do. One problem in this process could be the residual stresses by uneven heating and cooling processes that can be significant in high precision processes like turbine blades repair



3.Printing three-dimensional (3D Printing).

Parts are built upon a platform situated in a bin full of powder material. A 3-D printing head selectively "prints" binder to fuse the powder together in the desired areas. Unbound powder remains to support the part. The platform is lowered, more powder added and leveled, and the process repeated. When finished, the green part is sintered and then removed from the unbound powder. 3-D Printing used to produce ceramic molds and cores for investment casting, also to make powder metal tools and products. After each layer, a cutting tool mills the top surface to uniform height. This yields extremely good accuracy, allowing the machines to be used in the jewelry industry. 3D Systems has also developed a 3-D printing based system.

4.Prometal

It is a three-dimensional printing process to build injection tools and dies. This is a powder-based process in which stainless steel is used. The printing process occurs when a liquid binder is spurt out in jets to steel powder. The powder is located in a powder bed that is controlled by build pistons that lowers the bed when each layer is finished and a feed piston that supply the material for each layer. After finishing, the residual powder must be removed. When building a mold no postprocessing is required. If a functional part is being built, sintering, infiltration, and finishing processes are required. In the sintering process, the part is heated to 350◦F for 24 hour hardening the binder fusing with the steel in a 60% porous specimen. In the infiltration process, the piece is infused with bronze powder when they are heated together to more than 2000◦F in an alloy of 60% stainless steel and 40% bronze. The same process, but with different sintering temperatures and times, has been used with other materials like a tungsten carbide powder sintered with a zirconium copper alloy for the manufacturing of rocket nozzles; these parts have better properties than CNC machined parts of the same material.

III.**CONCLUSION**

In this paper article is discussed the early versions of additive manufacturing for making fast prototypes that was initiated by the necessity of speeding the process in model development and shortening the time between product development and market placement. Additive manufacturing processes take the information from a CAD file that is later converted to an STL file. In this process, the drawing made in the CAD software is approximated by triangles and sliced containing the information of each layer that is going to be printed. There is also a discussion of the relevant additive manufacturing processes and their applications and a review of how the parts are made using these additive manufacturing processes. The continuous and increasing growth experienced since the early days and the successful results up to date, there is optimism that additive manufacturing has a significant place in the future of manufacturing.

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