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Rapid Prototyping Technology

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Abstract: *The term Rapid Prototyping (RP) refers to a class of technologies that can automatically construct physical models from Computer-Aided Design (CAD) data. The techniques are often collectively referred to as solid Free-Form Fabrication, Computer Automated Manufacturing, or Layered Manufacturing. A software package "slices" the CAD model into a number of thin (~0.1 mm) layers, which are then built up one a top another. Rapid prototyping is an "additive" process, combining layers of paper, wax, or plastic to create a solid object. RP's additive nature allows it to create objects with complicated internal features that cannot be manufactured by other methods.*
Keywords: *CAD, RPT, Laser Beam, FDM, SLS System.*

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I. INTRODUCTION

Rapid prototype or rapid prototyping is a relatively new term and in its simplest form, the process of creating prototypes quickly to visually and functionally evaluate an engineering product design. In an engineering product design context, a prototype is a preliminary version of the end-product and used to evaluate the design, test the technology or analyze the working principle which in turn provides product specification for a real working system. Prototypes are an integral part of engineering product design and more importantly in an overall new product development process. Rapid prototyping can be used at any stage of the product development cycle or for any component or sub-component and can be repeated numerous times along the new product design process.

1.1.1 Why is rapid prototyping important?

In this fast-moving modern-day consumer market, companies need to develop and introduce new products faster to remain competitive. Since faster product development and technology innovation are key to a company's success, rapid prototyping becomes the most important element of new product development. The following objectives are achieved through rapid prototyping.

- Faster new product development – Prototyping plays a vital role in the process of creating successful products because it speeds up the new product development process
- Early-stage design/concept validation of the form, fit, and function of the design
- Final stage product verification against the technical requirement and business objectives
- It allows functionality testing to test the objectives of the concept and to finalize the specification
- The prototype gives the end-user, client, customer, user participants hands-on user experience to get feedback

1.1.2 Methodology

Methodology of rapid prototyping: Although several Rapid Prototyping techniques exist, all employ the same basic five-step process. The steps are:
A. Create a CAD model of the design
B. Convert the CAD model in to STL format
C. Slice the STL file into thin cross-sectional layers
D. Construct the Prototype
E. Clean and finish the model
A. Cad Model Creation:
The object to be built is modeled using a Computer-Aided Design (CAD) software package. Using Solid modeling software's such as Inventor, Pro/ENGINEER etc, create 3-D. The designer can use a pre-existing

CAD file or may wish to create one expressly for prototyping purposes. This process is identical for all of the RP build techniques.

B. Conversion to STL Format:

The various CAD packages use a number of different algorithms to represent solid objects. To establish consistency, the STL (Stereo lithography, the first Rapid Prototyping technique) format has been adopted as the standard of the Rapid Prototyping industry. This format represents a Three-

Dimensional 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, since the STL format is universal, this process is identical for all of the RP build techniques.

C. Pre-Processing (Or) Slice the STL File:

The pre-processing software slices the STL model into a number of layers from 0.01 mm to 0.7 mm thick, depending on the Rapid Prototype technique used. 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.

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. Each RP machine manufacturer supplies their own proprietary pre-processing software.

D. Processing (Or) Layer by Layer Construction:

The fourth step is the actual construction of the part. Using one of several techniques, Rapid Prototyping machines build one layer at a time from polymers, paper, or powdered metal. Most machines are fairly autonomous, needing little human intervention.

E. Post Processing:

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. Prototypes may also require minor cleaning and surface treatment. Sanding, sealing, and painting the model will improve its appearance and durability.

II. RAPID PROTOTYPING TECHNIQUES

Most commercially available rapid prototyping machines use one of six techniques.

A. Stereolithography
B. Selective Laser Sintering
C. Laminated Object Manufacturing
D. Fused Deposition Modeling
E. Solid Ground Curing
F. Three-Dimensional Printing

2.1.1. **Stereolithography**:

Stereolithography (SLA) is the first Rapid Prototyping process founded in 1986.A vat of photosensitive resin contains a vertically-moving platform. The part under construction is supported by the platform that moves downward by a layer thickness (typically about 0.1 mm / 0.004 inches) for each layer. A laser beam traces out the shape of each layer and hardens the photosensitive resin. For aesthetic purposes, the model can be painted.

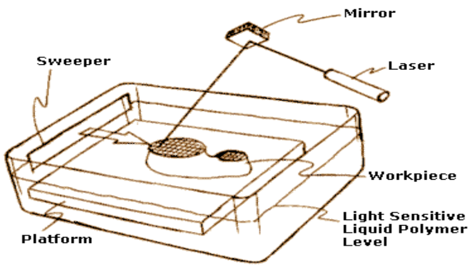


Figure:1 Stereolithography (SLA) System

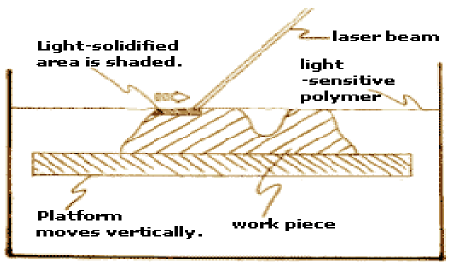


Figure: 2 Step (1)

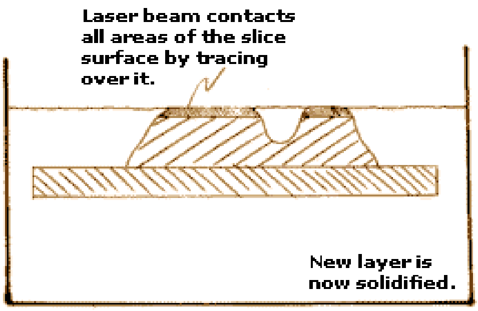


Figure: 3 Step (2)

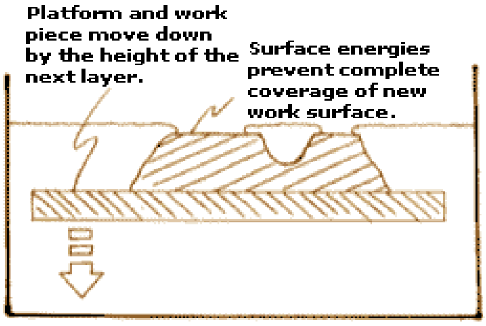


Figure: 4 Step (3)

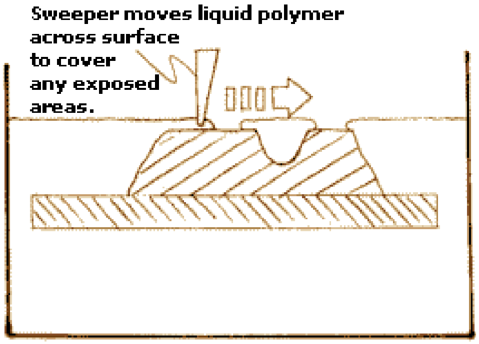


Figure: 5 Step 4)

Figure: 4 Step (5)

If extremities of the part become too weak, it may be necessary to use supports to prop up the model. The supports can be generated by the program that creates the slices, and the supports are only used for fabrication.

The following figure shows why supports are necessary:

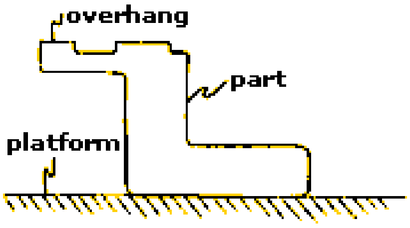


Figure: 5 Supports

2.1.2 Laminated Object Manufacturing

The figure below shows the general arrangement of a Laminated Object Manufacturing.

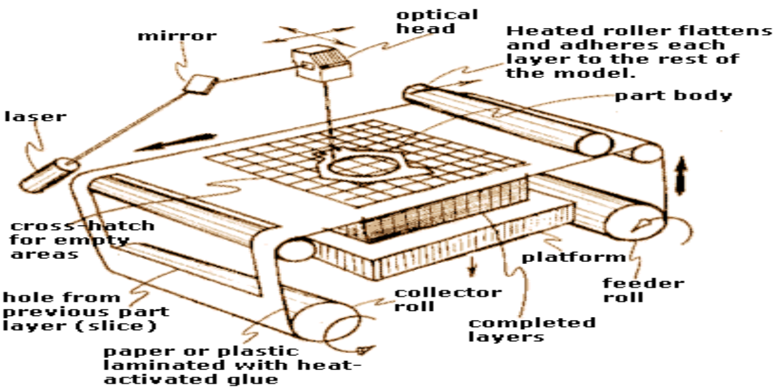


Figure: 6 Laminated Object Manufacturing

Material is usually a paper sheet laminated with adhesive on one side, but plastic and metal laminates are appearing. Layer fabrication starts with sheet being adhered to substrate with the heated roller. The laser then traces out the outline of the layer. Non-part areas are cross-hatched to facilitate removal of waste material. Once the laser cutting is complete, the platform moves down and out of the way so that fresh sheet material can be rolled into position. New material is in position, the platform moves back up to one layer below its previous position. If the process repeated, finally we will get solid model.

2.1.3 Selective Laser Sintering

Selective laser sintering was patented in 1989. The technique uses a laser beam to selectively fuse powdered materials, such as nylon, elastomer, and metal, into a solid object. Parts are built upon a platform which sits just below the surface in a bin of the heat-fusable powder. A laser traces the pattern of the first layer, sintering it together. The platform is lowered by the height of the next layer and powder is reapplied. This process continues until the part is complete. Excess powder in each layer helps to support the part during the build.

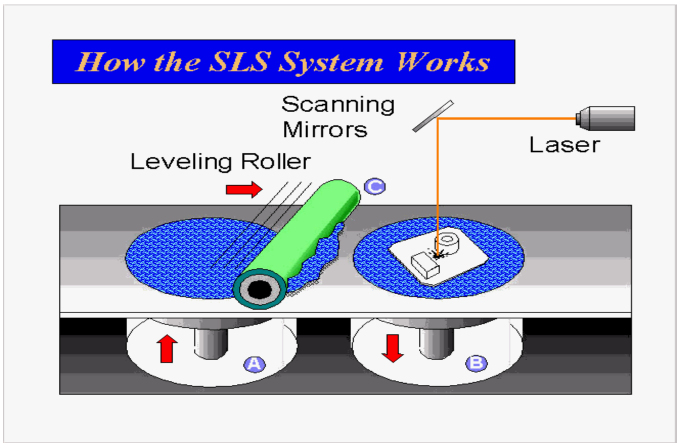


Figure: 7 Schematic diagram of selective laser sintering

2.1.4 Fused Deposition Modeling (FDM)

The FDM process was developed in 1988. The fundamental process involves heating a filament of thermoplastic polymer and squeezing it out like toothpaste from a tube to form the RP layers. The materials include polyester, ABS, elastomers, and investment casting wax. The overall arrangement is illustrated below:

In this technique, filaments of heated thermoplastic are extruded from a tip that moves in the x-y plane. The controlled extrusion head deposits very thin beads of material onto the build platform to form the first layer. The platform is maintained at a lower temperature, so that the thermoplastic quickly hardens. After the platform lowers, the extrusion head deposits a second layer upon the first. Supports are built along the way, fastened to the part either with a second, weaker material or with a perforated junction.

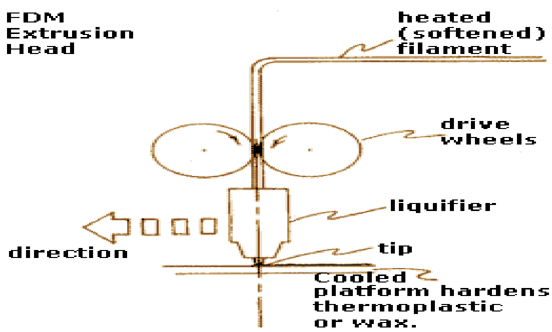


Figure: 8 Fused Deposition Model

2.1.5 Solid Ground Curing (SGC)

The SGC process uses photosensitive resin hardened in layers as with the Stereolithography (SLA) process.

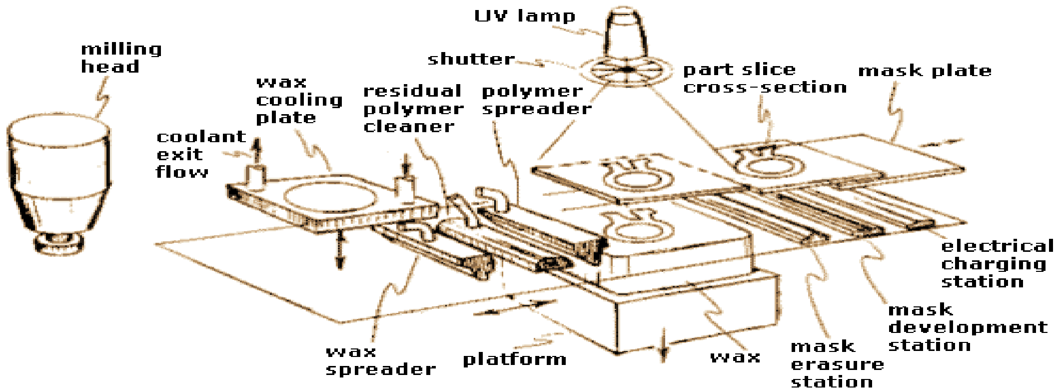


Figure: 9 Solid Ground Curing

The steps in the process are as follows.
At the beginning of a layer creation step, the flat work surface is sprayed with photosensitive resin, as shown below:

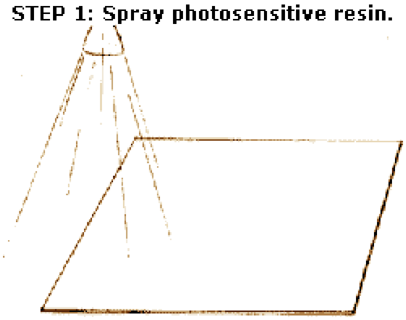


Figure: 10 Step (1)

Figure: 11 Step (2)

For each layer, a photo mask is produced using Cubital's proprietary ionographic printing technique, as illustrated as step 2 onwards.

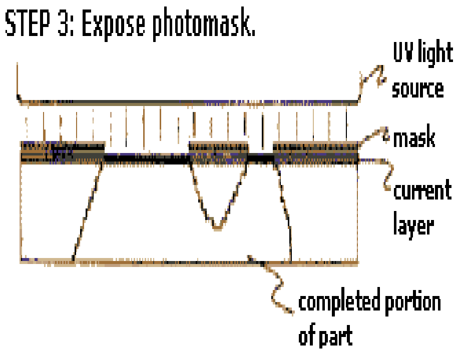


Figure: 12 Step (3)

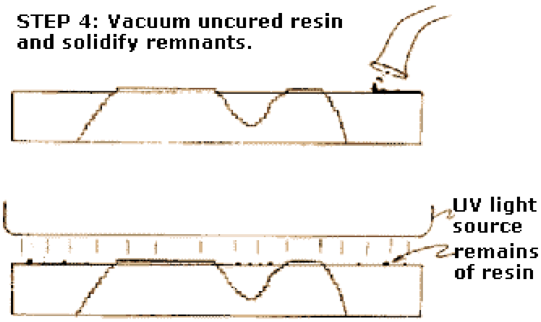
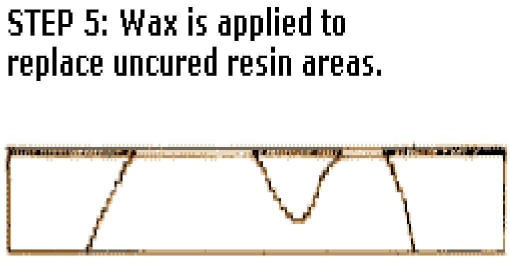


Figure: 13 Step (4)

After the layer is cured, all uncured resin is vacuumed for recycling, leaving the hardened areas intact. The cured layer is passed beneath a strong linear UV lamp to fully cure it and to solidify any remnant particles, as illustrated below:

In the fifth step, wax replaces the cavities left by vacuuming the liquid resin. The wax is hardened by cooling to provide continuous, solid support for the model as it is fabricated. Extra supports are not needed.



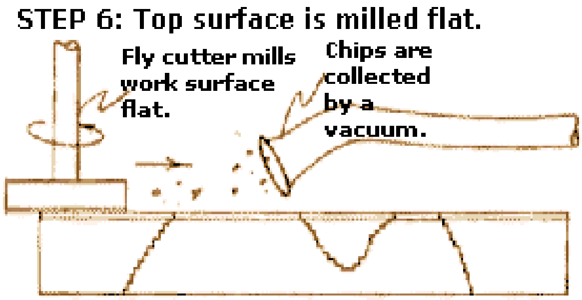


Figure: 14 Step (5) **Figure: 15 Step (6)**

In the final step before the next layer, the wax/resin surface is milled flat to an accurate, reliable finish for the next layer

Figure: 16 Step (7)

2.1.6 Three-Dimensional Printing

It is another technique based on the Inkjet printing process. It comes from the printer and plotter industry where the technique involves shooting tiny droplets of ink on paper to produce graphic images. RP ink jet techniques utilize ink jet technology to shoot droplets of liquid-to-solid compound and form a layer of an RP model.

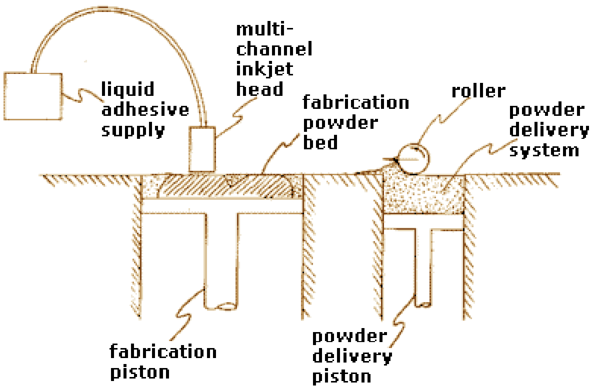


Figure: 17 Three Dimensional Printing

III. APPLICATIONS OF RAPID PROTOTYPING

Rapid prototyping is widely used in the automotive, aerospace, medical, and consumer products industries. Although the possible applications are virtually limitless, nearly all fall into one of the following categories,

A. Prototyping

B. Rapid Tooling

RP parts are used as patterns for making molds and dies. RP models can be indirectly used in a number of manufacturing processes such as, Vacuum Casting, Sand Casting, Investment Casting and Injection molding.

C. Rapid Manufacturing

IV CONCLUSION

Future development is improved accuracy and surface finish. Today’s commercially available machines are accurate to ~0.08 millimeters in the x-y plane, but less in the z (vertical) direction. Improvements in laser optics and motor control should increase accuracy in all three directions.

The introduction of non-polymeric materials, including metals, ceramics, and composites, represents another much anticipated development. These materials would allow RP users to produce functional parts. Today's plastic prototypes work well for visualization and fit tests, but they are often too weak for function testing. More rugged materials would yield prototypes that could be subjected to actual service conditions
Another important development is increased size capacity
One future application is Distance Manufacturing on Demand, a combination of RP and the Internet that will allow designers to remotely submit designs for immediate manufacture.

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