# Rapid Prototyping: A Review

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**Abstract—** Rapid prototyping (RP) is one of the fastest developing manufacturing technologies in the world today. Rapid prototyping is a group of methods used to rapidly manufacture a scale model of a physical part or assembly using three-dimensional computer aided design (CAD), Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) data. Construction of the part or assembly is usually done using 3D printing technology. Rapid prototyping techniques are often referred to solid free, computer automated manufacturing, form fabrication. The need of the hour is to bring together globally this fraternity to collaborate with each other.

**Keywords**— Rapid prototyping, STL File, SLA, LOM, SLS, FDM, 3D Jet Printing.

**INTRODUCTION**

To compete in today's industry environment, companies must keep up with the leading technologies and processes and also push the boundaries and develop new and improved products and processes. Shortening the lead-time for introducing a new product to the market has always been important to maximize profits and competitiveness. Recent developments in Computer Aided Design (CAD) technologies have significantly reduced the overall design cycle. However, the manufacturing process of the production mold still relies on slow and expensive machining processes. The Manufacturing Industry is an area where time, efficiency and accuracy are the major driving forces behind innovation and research. The most competitive companies are those who continually reduce process times, increase efficiency and improve accuracy. Rapid Prototyping is an area that has and is continuing to reduce production time and increase efficiency and accuracy in developing and manufacturing prototypes compared to traditional prototype manufacture. The research development of Rapid Prototyping (RP) is to give the Rapid manufacturing the needed confidence to go on to customized/tailor made product.

Investment casting is a combination of science, experience and art. Prior to final design and pattern construction, it is important to select an investment casting foundry and initiate communications. Typically, each foundry will have unique capabilities, processes and requirements. In addition, pattern specifications will vary with the selection of the metal alloy and the geometry of the part. If producing patterns for the foundry, it is critical that the foundry reviews the design so that it can recommend necessary design modifications to produce the highest quality part. The foundry can also make recommendations that reduce cost, time and weight, while improving cast ability and product performance. Additionally, FDM research is ongoing, so new process guidelines may evolve.

The goal of this research is to formulate a generalized Mathematical Model for Optimum temperature & time with given multiple choices of various Shell thickness & RP Part volume and find the optimal Model equation in project for the manufactured any complicated shape regular & non regular in confidence level by using Design of experiment technique.

All the RP techniques employ the same basic five step process. The steps are as follows:

i. Create a CAD model of the design.
ii. Convert the CAD model in to STL format.
iii. Slice the STL model in to thin cross sectional layers.
iv. Construct the model one layer atop another.
v. Clean and finish the model.

## a) CAD Model Creation

First the object to be built is modeled using a Computer added (CAD) software package. A large number of software packages are available in the market like PRO/ENGINEER. These tend to represent 3-D models more accurately than the wireframe modelers such as AutoCAD and hence produce very good results. The designer can create a new file expressly for prototyping or may use the existing CAD file. The process is same for all 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 RP technique) format has been adopted as the standard of the rapid prototyping industry. The second step, therefore, is to convert the CAD file into STL format. 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, but at the cost of bigger files 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. Since the STL format is universal, this process is identical for all of the RP build techniques.

c) Slice the STL File

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 direction reduces the number of layers, thereby shortening build time. 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 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 thinwalled sections. Each PR machine manufacturer supplies their own proprietary pre-processing software.

d) Layer by Layer Construction

The fourth step is the actual construction of the part. Using one of several techniques (described in the next section) RP machines build one layer at a time from polymers, paper, or powdered metal. Most machines are fairly autonomous, needing little human intervention.

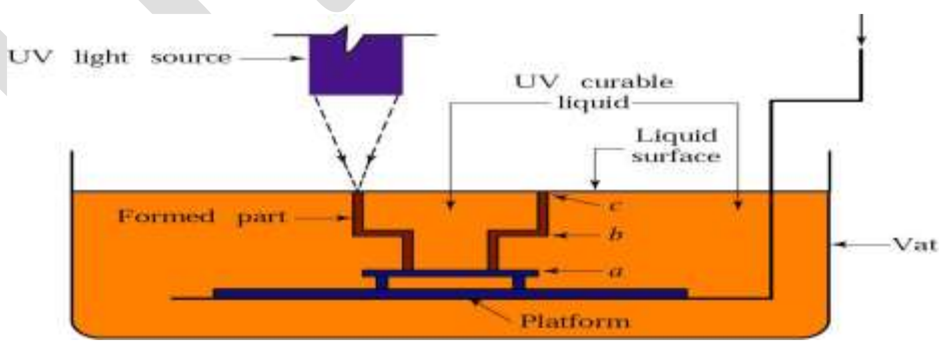
e) Clean and Finish

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/or painting the model will improve its appearance and durability.

The six RP techniques available are as follows:

• Stereo Lithography (SLA).

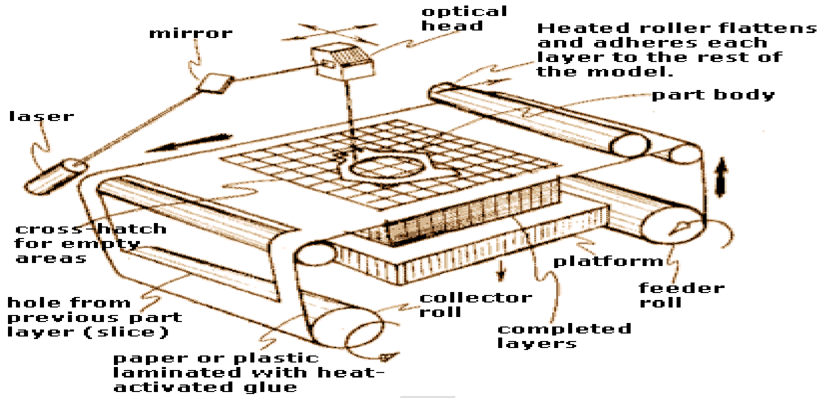
SLA RP technology has three main parts: a vat filled with ultraviolet (UV) curable photopolymer, a perforated build tray, and an UV laser. Due to the absorption and scattering of beam, the reaction only takes place near the surface and voxels of solid polymeric resin are formed. A SL machine consists of a build platform (substrate), which is mounted in a vat of resin and a UV Helium-Cadmium or Argon ion laser. A slice layer is cured on to the build tray with the UV laser. The pattern of the slice layer is “painted” with the UV laser with the control of the scanner system. Once the layer is cured, the tray lowers by a slice layer thickness allowing for uncured photopolymer covering the previously cured slice.




In new SL systems, a blade spreads resin on the part as the blade traverses the vat. This ensures smoother surface and reduced recoating time.

• Laminated Object Manufacture (LOM):-

The figure below shows the general arrangement of a Laminated Object Manufacturing (LOM™, registered trademark by Helisys of Torrance, California, USA) cell:




Material is usually a paper sheet laminated with adhesive on one side, but plastic and metal laminates are appearing.

1. Layer fabrication starts with sheet being adhered to substrate with the heated roller.
2. The laser then traces out the outline of the layer.
3. Non-part areas are cross-hatched to facilitate removal of waste material.
4. 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.
5. Once new material is in position, the platform moves back up to one layer below its previous position.
6. The process can now be repeated.

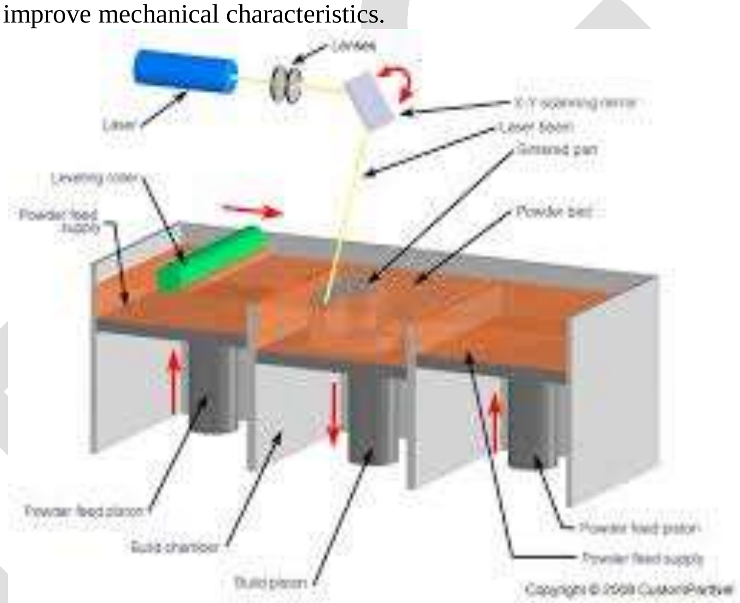
The excess material supports overhangs and other weak areas of the part during fabrication. The cross-hatching facilitates removal of the excess material. Once completed, the part has a wood-like texture composed of the paper layers. Moisture can be absorbed by the paper, which tends to expand and compromise the dimensional stability. Therefore, most models are sealed with a paint or lacquer to block moisture ingress.

The LOM™ developer continues to improve the process with sheets of stronger materials such as plastic and metal. Now available are sheets of powder metal (bound with adhesive) that can produce a "green" part. The part is then heat treated to sinter the material to its final state.

• Selective Laser Sintering (SLS)

Selective Laser Sintering (SLS) is the rapid prototyping technology of choice for a range of functional prototype applications, including those with snap fits, living hinges and other mechanical joints. The ability of SLS to produce several pieces at one time also makes the process a good choice for Direct Digital Manufacturing (DDM) of products requiring strength and heat resistance.

Thermoplastic powder is spread by a roller over the surface of a build cylinder. The piston in the cylinder moves down one object layer thickness to accommodate the new layer of powder. A piston moves upward incrementally to supply a measured quantity of powder for each layer. A laser beam is traced over the surface of this tightly compacted powder to selectively melt and weld the grains together to form a layer of the object. The fabrication chamber is maintained at a temperature just below the melting point of the powder so that the laser elevates the temperature slightly to cause sintering - the grains are not entirely melted, just their outer surfaces - which greatly speeds up the process. The process is repeated, layer by layer, until the entire object is formed. After the object is fully formed, the piston is raised. Excess powder is simply brushed away and final manual finishing may be carried out. No supports are required with this method since overhangs and undercuts are supported by the solid powder bed. It takes a considerable cool-down time before the part can be removed from the machine. Large parts with thin sections may require as much as two days of cooling. SLS offers the key advantage of making large sized functional parts in essentially final materials. However, the system is mechanically more complex than stereolithography and most other technologies. A variety of thermoplastic materials such as nylon, glass filled nylon, and polystyrene are available. Surface finishes and accuracy are not as good as with stereolithography, but material properties can be quite close to those of the intrinsic materials. The method has also been extended to provide direct fabrication of metal and ceramic objects and tools. Since the objects are sintered they are porous. It may be necessary to infiltrate the part, especially metals, with another material to improve mechanical characteristics.




• Fused deposition Modeling (FDM)

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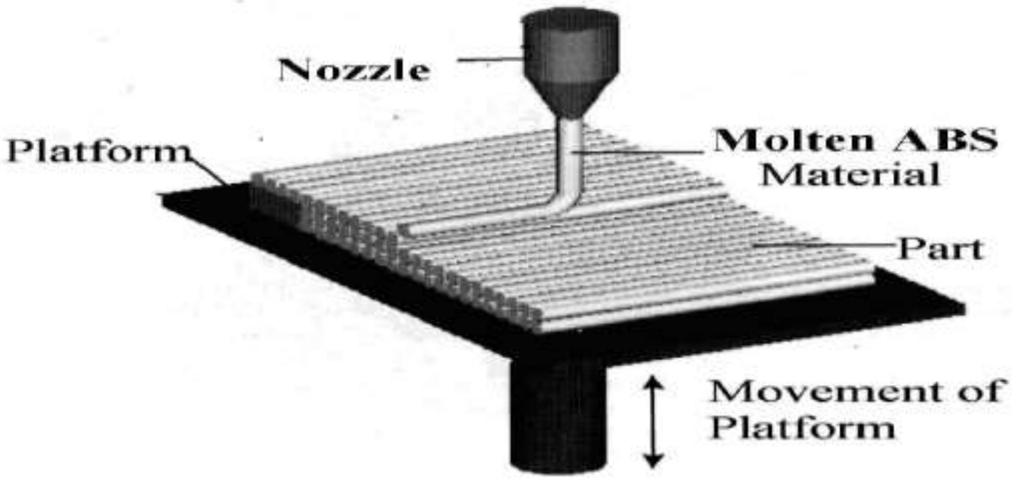
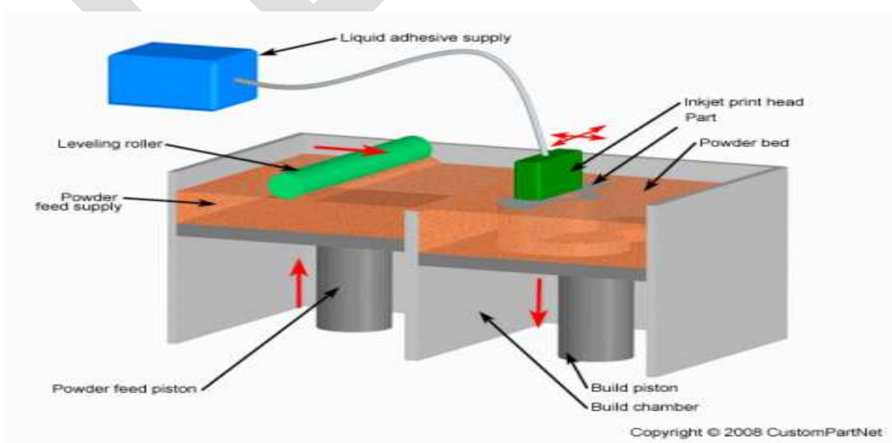
In Fused Deposition Modeling (FDM) process a movable (x-y movement) nozzle on to a substrate deposits thread of molten polymeric material. The build material is heated slightly above (approximately 0.5 C) its melting temperature so that it solidifies within a very short time (approximately 0.1 s) after extrusion and cold-welds to the previous layer as shown in figure. Various important factors need to be considered and are steady nozzle and material extrusion rates, addition of support structures for overhanging features and speed of the nozzle head, which affects the slice thickness. More recent FDM systems include two nozzles, one for part material and other for support material. The support material is relatively of poor quality and can be broken easily once the complete part is deposited and is removed from substrate. In more recent FDM technology, water-soluble support structure material is used. Support structure can be deposited with lesser density as compared to part density by providing air gaps between two consecutive roads.




• 3D Ink Jet Printing

Three Dimensional Printing (3DP) technology was developed at the Massachusetts Institute of Technology and licensed to several corporations. The process is similar to the Selective Laser Sintering (SLS) process, but instead of using a laser to sinter the material, an ink-jet printing head deposits a liquid adhesive that binds the material. Material options, which include metal or ceramic powders, are somewhat limited but are inexpensive relative to other additive processes. 3D Printing offers the advantage of fast build speeds, typically 2-4 layers per minute. However, the accuracy, surface finish, and part strength are not quite as good as some other additive processes. 3D Printing is typically used for the rapid prototyping of conceptual models (limited functional testing is possible).

The 3D printing process begins with the powder supply being raised by a piston and a leveling roller distributing a thin layer of powder to the top of the build chamber. A multi-channel ink-jet print head then deposits a liquid adhesive to targeted regions of the powder bed. These regions of powder are bonded together by the adhesive and form one layer of the part. The remaining free standing powder supports the part during the build. After a layer is built, the build platform is lowered and a new layer of powder added, leveled, and the printing repeated. After the part is completed, the loose supporting powder can be brushed away and the part removed. 3D printed parts are typically infiltrated with a sealant to improve strength and surface finish.



## CONCLUSION

This paper provides an overview of RP technology in brief and emphasizes on their ability to shorten the product design and development process. Classification of RP processes and details of few important processes is given. The description of various stages of data preparation and model building has been presented. An attempt has been made to include some important factors to be considered before starting part deposition for proper utilization of potentials of RP processes. Finally, the rise of rapid prototyping has spurred progress in traditional subtractive methods as well. Advances in computerized path planning, numeric control, and machine dynamics are increasing the speed and accuracy of machining. Modern CNC machining centers can have spindle speeds of up to 100,000 RPM, with correspondingly fast feed rates. Such high material removal rates translate into short build times. 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.

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