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Design Development Experimental Approach of Industrial Product Enhancement Prior To Fabrication with Stereo Lithography

P.N.S. Srinivas, [1] A.Rahul kumar[2]
[12]*Asst Prof (Department of mechanical engineering), Sri Vasavi institute of engineering & technology, JNTUK, INDIA*

Abstract: *As my research work is concerned with the optimization techniques by enhancing the rapid prototyping technique. In the manufacturing process of a particular product the in process parameters are going to qualitatively analyzed after the production process. This may lead to the various failures such as internal stresses, time dependent failures, cycling loading failures .to analyze these failures the losses incurred in the availability of skilled personals, inspection time , manufacturing& material cost. To overcome these failures one of the optimization technique is stereo lithography (Rapid prototyping) has been introduced.*

Keywords: *Rapid protyping, cyclic loading factors, material cost, inspection.*

I. Introduction

Rapid prototyping automates the fabrication of a prototype part from a three- dimensional (3D) CAD drawing. This physical model conveys more complete information about the product earlier in the development cycle. The turnaround time for a typical rapid prototype part can take a few days. Conventional prototyping may take weeks or even months, depending on the method used. Rapid prototyping can be quicker more cost effective means of building prototypes as opposed to conventional methods. Fabrication process fall into 3 categories: Subtractive, Additive and compressive. In a subtractive process a block of material is carved out to produce the desired shape. An additive process builds materials by joining particles or layers or raw materials. A compressive process forces a semi solid or liquid into desired shape, in which it is induces to harden or solidify. Most conventional prototypes fall into subtractive category.

These would include machining processes such as milling, turning, and grinding. Machining methods are difficult to use on parts with very small internal cavities or complex geometries. Compressive processes, also conventional, include casting and molding .The new rapid prototyping technologies are additive processes. They can be categorized by material: photopolymer, thermoplastic, and adhesives. Photopolymer systems start with a liquid resin, which is then solidified by discriminating exposure to a specific wavelength of light, Thermoplastic systems begin with a solid material, which is then melted and fuses upon cooling. The adhesive systems use a binder to connect the primary construction material. Rapid prototyping systems are capable of creating parts with small internal cavities and complex geometries. Also, the integration of rapid prototyping and compressive processes has resulted in the quicker generation of patterns from which moulds are made.

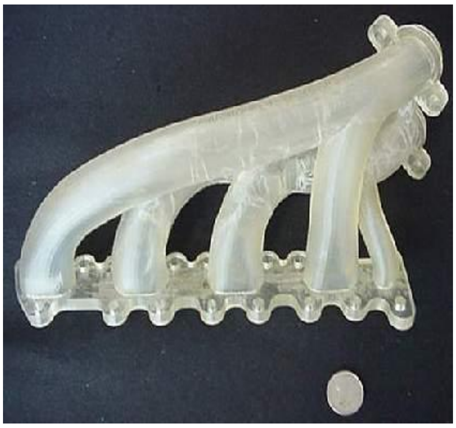


fig. Rapid Prototyped part

Rapid prototyping was commercially introduced in 1987 with the presentation of Stereo lithography. Several processes are now commercially available in the industry. They are as follows:

1. Stereo lithography
2. Selective Laser Sintering
3. Fused Deposition Modeling
4. Laminated Object Manufacturing
5. 3 D Inkjet Printing
6. Solid Ground Curing

Among these RP techniques Stereo lithography is most commonly and widely used.

II. The Basic Process

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

1. Create a CAD model of the design
2. Convert the CAD model to STL format
3. Slice the STL file into thin cross-sectional layers
4. Construct the model one layer atop another
5. Clean and finish the model

II.1.CAD Model Creation: First, the object to be built is modeled using a Computer-Aided Design (CAD) software package. Solid modelers, such as Pro/ENGINEER, tend to represent 3-D objects more accurately than wire-frame modelers such as AutoCAD, and will therefore yield better results. 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.

Fig.2 CAD Model

II.2.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." [6] 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. Since the .stl format is universal, this process is identical for all of the RP build techniques.

II.3.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 z 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 thin-walled sections. Each PR machine manufacturer supplies their own proprietary pre-processing software.

II.4.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.

II.5.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.

III. What Is Stereo Lithography?

SL is the most popular and widely is used rapid prototyping technology. It is a unique form of technology which allows for the translation of computer aided design drawing to3D solid objects within hours. In Stereo Lithography liquid plastic is solidified in precise patterns by laser beam resulting in solid epoxy realization of a 3D design. This ultraviolet laser beam is guided by CAD

Parts created using Stereo Lithography must be modeled through the use of CAD system, such as ANSYS, AUTOCAD, IDEAS; Pro.-Engineer etc. The CAD files are stored in STL format which defines the boundary surface of the object as mesh of interconnected triangle

Stereo Lithography process can be run in 3 modes:

1. Acces Mode.
2. Quick Cast
3. Solid Weave

The ACES mode produces crystal like transparency and exceptional strength at very high dimensional resolution. This mode of stereo lithography is perfect for parts that require exceptional visual quality such as lenses and optical components. Quick Cast is a SL mode creates quasi-hollow parts with a strong honey comb interior which is 80% hollow. From a quick cast prototype metal parts can be made 3-5 days. Solid weave boasts the quickest turnaround time of SLA modes without compromising on strength and precision. It is also most economical of three.

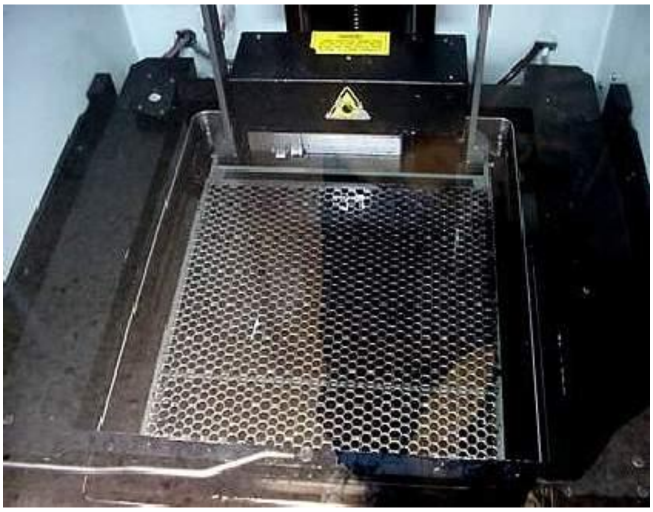
IV. Stereo Lithography Machine

Stereo lithography, also known as 3-D layering or 3-D printing, is accomplished using a special SLA machine containing a computer-controlled laser and a tank of light-curable plastic, or photopolymer

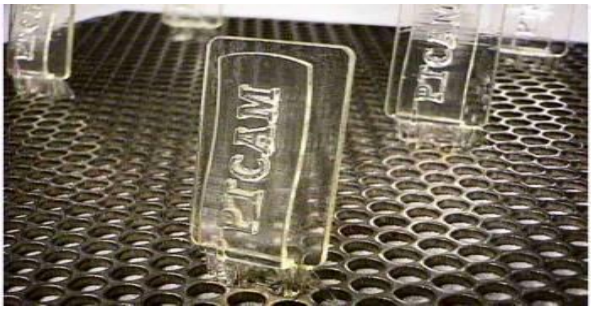
Stereo lithography machine

This machine has four important parts:

1. A tank filled with several gallons of liquid photopolymer. The photopolymer is a clear liquid plastic.
2. A perforated platform immersed in the tank. The platform moves up and down in the tank as the printing process proceeds
3. An ultraviolet laser
4. A computer that drives the laser and the platform

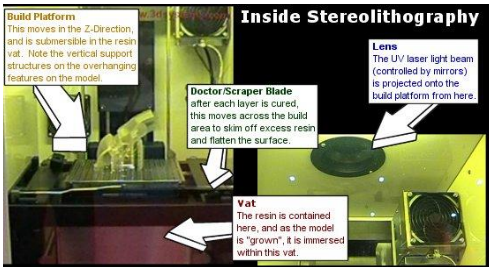


The platform in the tank of photopolymer at the beginning



The platform at the end of a print run, shown here with several identical objects

INSIDE OF SLA MACHINE



Object curing machines

V. The Stereo Lithography Process

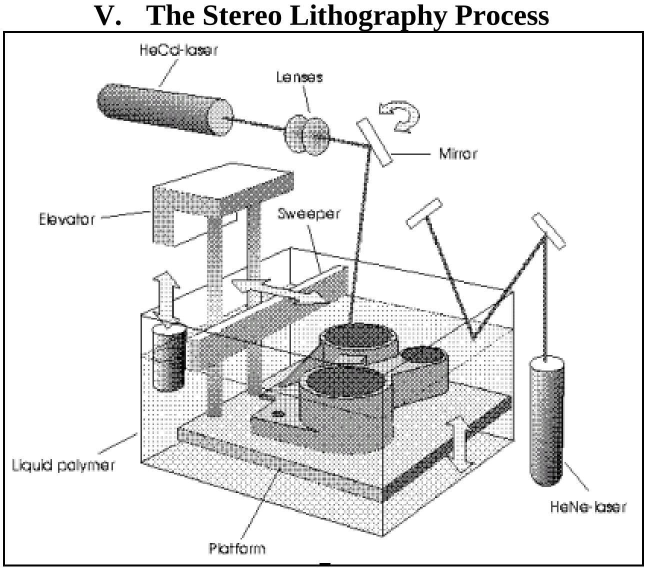
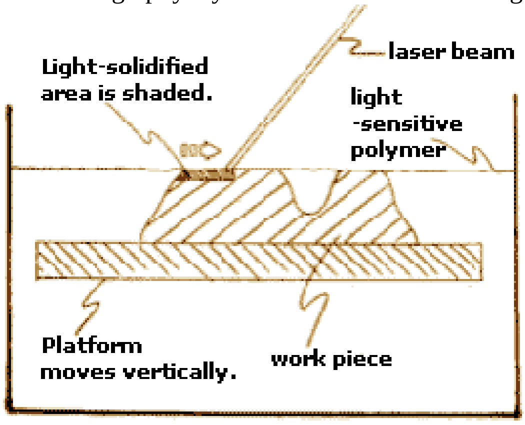


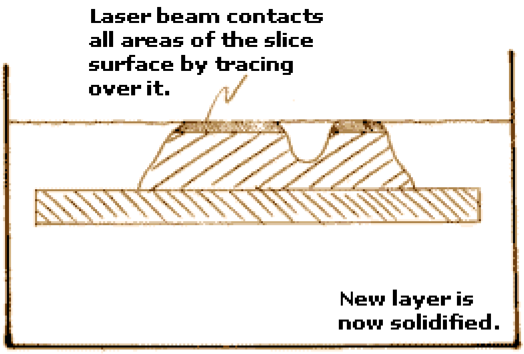
Fig 3: Schematic diagram of stereo lithography.

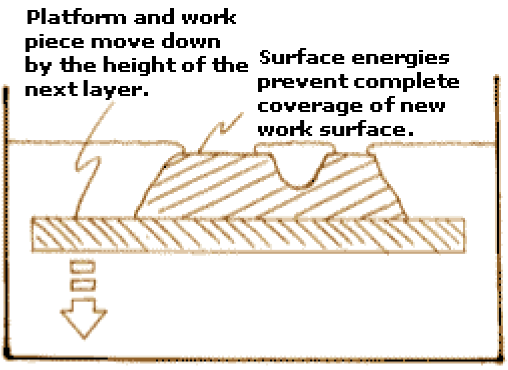
The basic Stereo lithography process consists of the following steps:

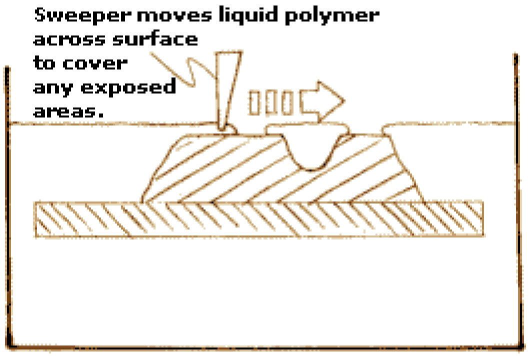
- A 3-D model of an object is created in a CAD program.
- Special computer software "cuts" the CAD model file into thin layers typically five to 10 layers per millimeter of part thickness.
- The 3-D printer's ultraviolet laser "paints" one of the layers, exposing the top surface of the liquid plastic in the tank and hardening it. The photopolymer is sensitive to ultraviolet light, so wherever the laser touches the photopolymer, the polymer hardens.
- The platform drops down into the tank a fraction of a millimeter, and then the laser "paints" the next layer on top of the previous layer.
- This process repeats, layer by layer, until the 3-dimensional plastic model is complete.
- Depending upon the size and number of objects being created, the laser might take a minute or two for each layer. A typical run might take six to 12 hours. Runs over several days are possible for large objects. The maximum size for the machine is an object 10 inches (25 cm) in each of three dimensions ... 10 x 10 x 10.
- When the process is complete, the SLA machine raises the platform with the completed 3-D object. If the finished object is small, several can be produced at the same time, sitting next to each other on the tray.
- Once the run is complete, the finished objects are rinsed with solvent to remove all uncured plastic and then "baked" in an ultraviolet oven that thoroughly cures the plastic

The sequence of steps for producing Stereo lithography layer is shown in the following figures;





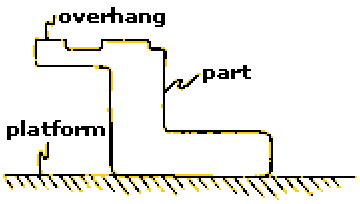


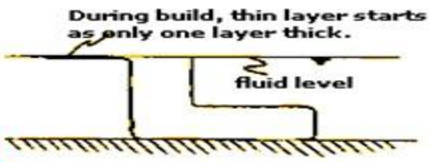


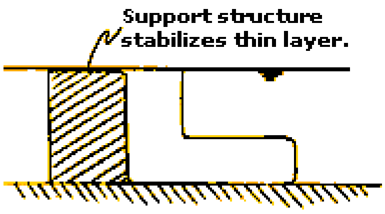
COMPLETED PART

Uncured resin is removed and the model is post-cured to fully cure the resin. Because of the layered process, the model has a surface composed of stair steps. Sanding can remove the stair steps for a cosmetic finish. Model build orientation is important for stair stepping and builds time. In general, orienting the long axis of the model vertically takes longer but has minimal stair steps. Orienting the long axis horizontally shortens build time but magnifies the stair steps. For aesthetic purposes, the model can be primed and painted.

During fabrication, 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 three figures show why supports are necessary:

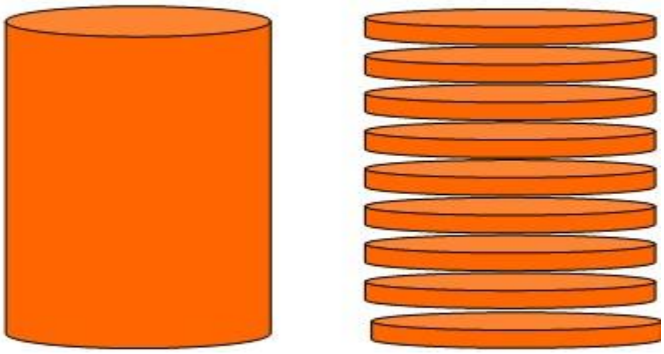






VI. Stl (Stereo Lithography) Files

The .STL file format has become SLA industry's standard CAD export format and is required to interact with stereo lithography machines. This format approximates the surfaces of a solid model with small triangles and was designed to give the proper amount of model detail required to operate the Stereo Lithography machines. Virtually all of today's modern CAD software programs are capable of producing an STL file. For the user, the process is often as simple as selecting File, Save As, STL.



VII. Sla Accuracy

SLA**Y** parts may be built using normal or "high" resolution. Normal resolution is typically defined as SLA parts build using a .010" or larger laser beam diameter and .004" or greater layer thickness. Building parts in this manner results in the most cost-effective build, but may not catch all of the tiny features of small parts or tools. Normal resolution SLA can manufacture parts with tolerances of +/- .005 to .006 inches. This is the standard resolution available at most suppliers.

High resolution is defined as an SLA part builds using a .003" - .004" diameter laser beam and/or a layer thickness less than .004". Building parts with the smaller laser beam diameter results in parts with sharp corners and the thinnest possible walls. Thin layers reduce the cleanup required to smooth out contours or to polish tooling masters. High resolution SLA can manufacture parts with tolerances of +/- .002 to .003 inches. This build style results in the most accurate, highest quality parts available in the industry, but it is also slower and more expensive than normal resolution.

VIII. Sla Materials

A number of excellent photopolymer materials are now available for SLA rapid prototyping. Each material has unique properties which can be used to simulate more traditional metals or plastics for rapid prototypes. Some SLA resins mimic traditional engineering plastics such as PBT or ABS, with toughness and durability that make the resulting SLA parts suitable for mechanical testing and evaluation. Other SLA resins have properties similar to polypropylene, with fine features and details that can provide accurate test parts. If higher temperatures are needed, new SLA resins provide heat deflection resistance up to 220°F (105°C) as compared to traditional limits of 130°F (55°C). And, for near-metal performance, ceramic-filled SLA resins can be used to make parts with superior stiffness and high temperature resistance. The high stiffness also provides mechanical foundation for structural Nickel plating the resulting parts have a composite structure with mechanical and thermal performance approaching that of metal. New SLA resins are constantly being developed and refined to extend the mechanical and thermal performance of SLA parts.

Material	Appearance	Viscosity(cps)	Density(gm/cm^3)
DSM SOMOS R 1020	Optically clear	130 cps at 30^{0}c	1.12 gm/cm3 at 25^{0}c
DSM SOMOS R 9120	Transparent amber	450 cps at 30^0 c	1.13 gm/cm^3 at 25^{0}c
CIBATOOL R SL 5195	Clear	180 cps at 30^{0}c	1.16 g/cm^3 at 25^0 c

IX. Application of Sla Technology

- Aesthetical and conceptual models–It is used to produce models that are eye-catching and complex. This is because it can convert CAD exactly into 3-D coordinates.
- Parts requiring detail and accuracy–The resolution of laser used can be increased to sufficiently high levels. Also layer thickness can be varied. So we can make more accurate models.
- Master patterns for casting–Using this technology, master castings for processes like vacuum casting, investment casting, sand casting, injection molding.

X. Benefits of Sla

- Crisp and highly detailed pieces
- Speed of delivery(usually 2 to 3 days)
- Tolerance with .005 inch/inch
- Saves money
- Time saving
- Test product
- Locates error
- Improves design
- Sells product
- Rapid manufacturing

XI. Problems with Rapid Prototyping

The model is composed of several layers. When slant edges and curves are involved, no finishing is obtained. Instead a stair-case like appearance is the result. Also the parts involved are subjected to shrinkage and distortion.

Limited variety of materials in Rapid Prototyping Mechanical performance of the fabricated parts is limited by the materials used in the Rapid Prototyping process.

XII. Conclusion

Stereo Lithography saves time, money, allows speedy delivery and helps in improving design. Stereo Lithography can be applied to almost any industry including oil refining, petrochemical, power and marine industries. It is also the most effective and economical of all Rapid Prototyping techniques. It is still a technology in its growing stages and will prove to be a major technology in the future.

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