Need for the compression in product development

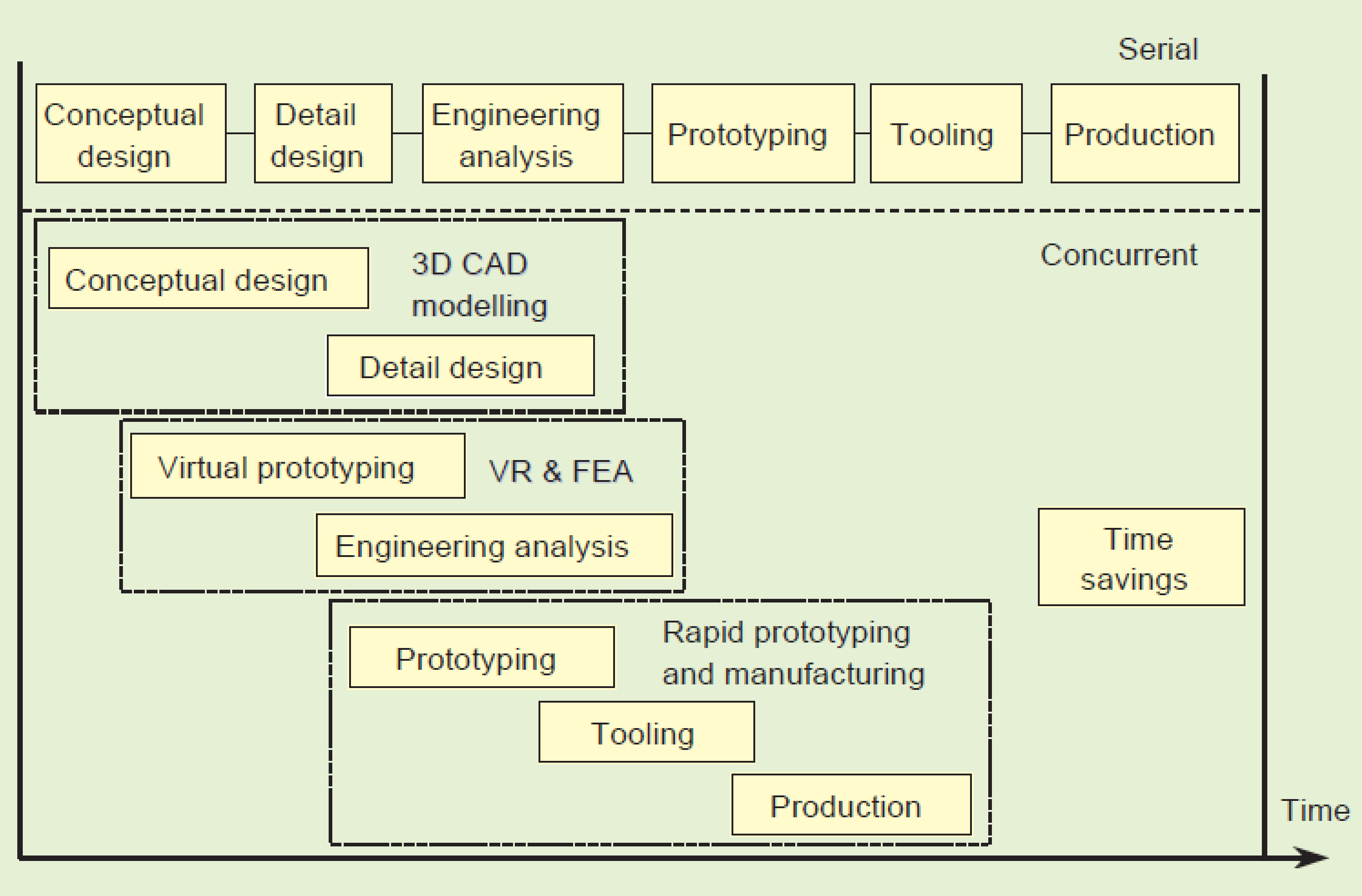


Figure 1 Time compression engineering

Need for the compression in the product development

- • To increase effective communication.
- • To decrease development time.
- • To decrease costly mistakes.
- • To minimize sustaining engineering changes.
- • To extend product life time by adding necessary features & eliminating redundant features early in the design.

INTRODUCTION TO RAPID PROTOTYPING

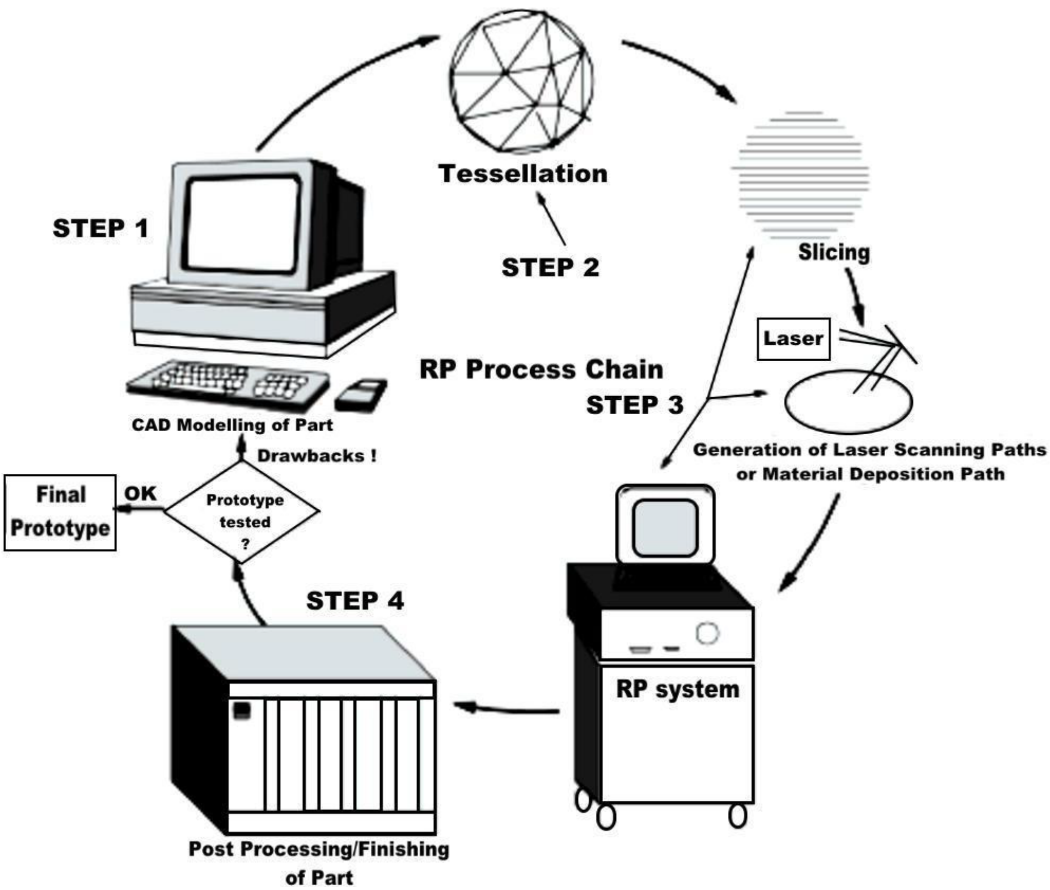
One of the important steps prior to the production of a functional product is building of a physical prototype. Prototype is a working model created in order to test various aspects of a design, illustrate ideas or features and gather early user feed-back. Traditional prototyping is typically done in a machine shop where most of parts are machined on lathes and milling machines. This is a subtractive process, beginning with a solid piece of stock and the machinist carefully removes the material until the desired geometry is achieved. For complex part geometries, this is an exhaustive, time consuming, and expensive process. A host of new shaping techniques, usually put under the title **Rapid Prototyping**, are being developed as an alternative to subtractive processes. These methods are unique in that they add and bond materials in layers to form objects. These systems are also known by the names **additive fabrication, three dimensional printing, solid freeform fabrication (SFF), layered manufacturing** etc. These additive technologies offer significant advantages in many applications compared to classical subtractive fabrication methods like formation of an object with any geometric complexity or intricacy without the need for elaborate machine setup or final assembly in very short time. This has resulted in their wide use by engineers as a way to reduce time to market in manufacturing, to better understand and communicate product designs, and to make rapid tooling to manufacture those products. Surgeons, architects, artists and individuals from many other disciplines also routinely use this technology.

Definition: Rapid prototyping is basically a additive manufacturing process used to quickly fabricate a model of a part using 3-D CAM data.

It can also be defined as layer by layer fabrication of 3D physical models directly from CAD.

Methodology of Rapid Prototyping:

RP in its basic form can be described as the production of three dimensional (3D) parts from computer aided design (CAD) data in a decreased time scale. The basic methodology of all RP process can be summarized as shown in following figure.



Rapid prototyping process chain

- Construct a CAD model.
- Convert it to STL format.
- RP machine processes .STL file by creating sliced layers of model.
- First layer of model is created.
- Model is then lowered by thickness of next layer.
- Process is repeated until completion of model

- The model & any supports are removed.
- Surface of the model is then finished and cleaned.

(1) Development of a CAD model

The process begins with the generation CAD model of the desired object which can be done by one of the following ways;

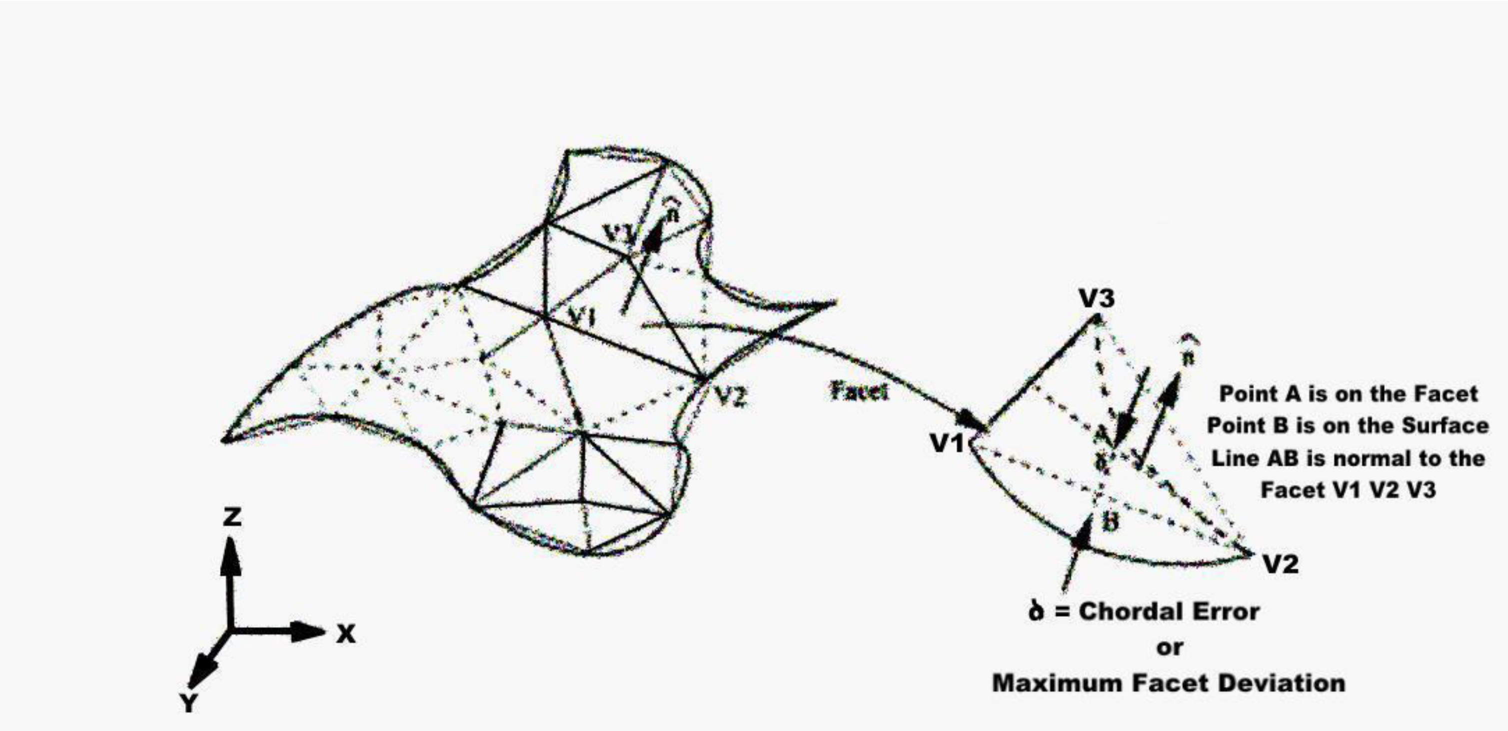
- • Conversion of an existing two dimensional (2D) drawing
- • Importing scanned point data into a CAD package

- • Creating a new part in CAD in various solid modeling packages
- • Altering an existing CAD model

RP has traditionally been associated with solid rather than surface modelling but the more recent trends for organic shapes in product design is increasing the need for free flowing surfaces generated better in surface modelling.

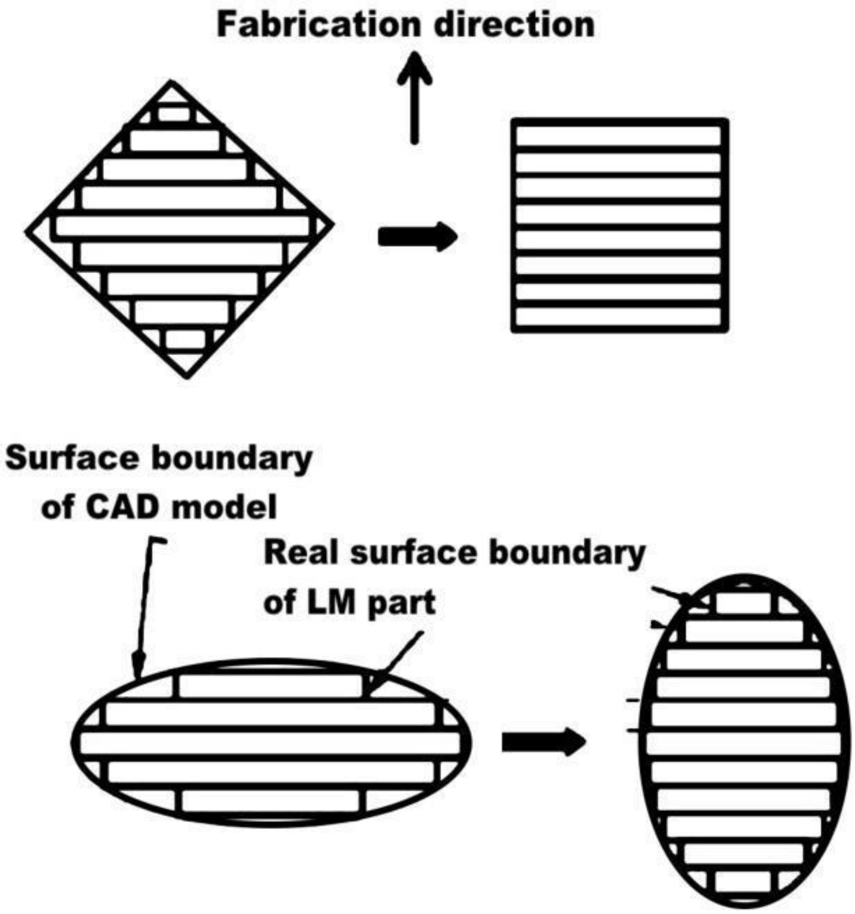
(2) Generation of Standard triangulation language (STL) file

The developed 3D CAD model is tessellated and converted into STL files that are required for RP processes. Tessellation is piecewise approximation of surfaces of 3D CAD model using series of triangles. Size of triangles depends on the chordal error or maximum fact deviation. For better approximation of surface and smaller chordal error, small size triangle are used which increase the STL file size. This tessellated CAD data generally carry defects like gaps, overlaps, degenerate facets etc which may necessitate the repair software. These defects are shown in figure below. The STL file connects the surface of the model in an array of triangles and consists of the X, Y and Z coordinates of the three vertices of each surface triangle, as well as an index that describes the orientation of the surface normal.



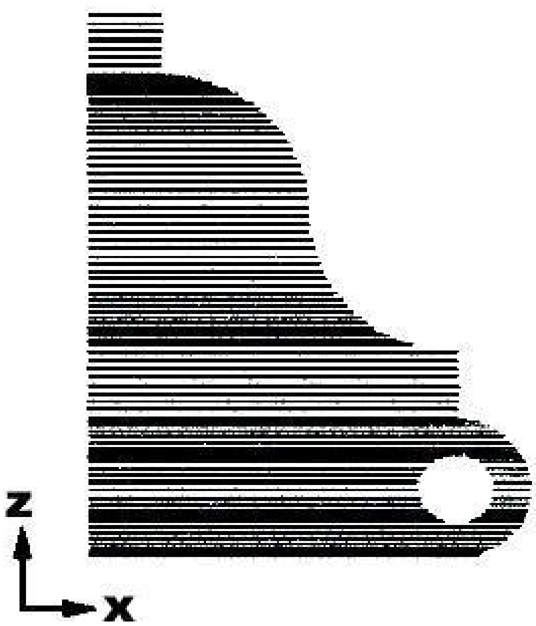
(3) Slicing the STL file

Slicing is defined as the creating contours of sections of the geometry at various heights in the multiples of layer thickness. Once the STL file has been generated from the original CAD data the next step is to slice the object to create a slice file (SLI). This necessitates the decision regarding part deposition orientation and then the tessellated model is sliced. Part orientation will be showing considerable effect on the surface as shown in the figures.



Effect of Part deposition Orientation

The thickness of slices is governed by layer thickness that the machine will be building in, the thicker the layer the larger the steps on the surface of the model when it has been built. After the STL file has been sliced to create the SLI files they are merged into a final build file. This information is saved in standard formats like SLC or CLI (Common Layer Interface) etc.



(4) Support Structures

As the parts are going to be built in layers, and there may be areas that could float away or of overhang which could distort. Therefore, some processes require a base and support structures to be added to the file which are built as part of the model and later removed.

(5) Manufacturing

As discussed previously, the RP process is additive i.e. it builds the parts up in layers of material from the bottom. Each layer is automatically bonded to the layer below and the process is repeated until the part is built. This process of bonding is undertaken in different ways for the various materials that are being used$_2$ but includes the use of Ultraviolet (UV) lasers, Carbon Dioxide (C) lasers, heat sensitive glues and melting the material itself etc.

(6) Post processing

The parts are removed from the machine and post processing operations are performed sometimes to add extra strength to the part by filling process voids or finish the curing of a part or to hand finish the parts to the desired level. The level of post processing will depend greatly on the final requirements of the parts produced, for example, metal tooling for injection molding will require extensive finishing to eject the parts but a prototype part manufactured to see if it will physically fit in a space will require little or no post processing.

History of RP system

- • It started in 1980's
- • First technique is Stereo lithography (SLA)
- • It was developed by 3D systems of Valencia in California, USA in 1986.
- • Fused deposition modeling (FDM) developed by stratasys company in 1988.
- • Laminated object manufacturing (LOM) developed by Helisis (USA).
- • Solid ground Curing developed by Cubitol corporation of Israel.
- • Selective laser sintering developed by DTM of Austin, Texas (USA) in 1989.
- • Sanders Model maker developed by Wilton incorporation USA in 1990.
- • Multi Jet Modeling by 3D systems.
- • 3-D Printing by Solygen incorporation, MIT, USA.

Applications

Most of the RP parts are finished or touched up before they are used for their intended applications. Applications can be grouped into
(1)Design (2) Engineering, Analysis, and Planning and (3) Tooling and Manufacturing . A wide rangeof industries can benefit from RP andthese include, but are not limited to, aerospace, automotive, biomedical, consumer, electrical and electronics products.

SURVEY OF APPLICATIONS

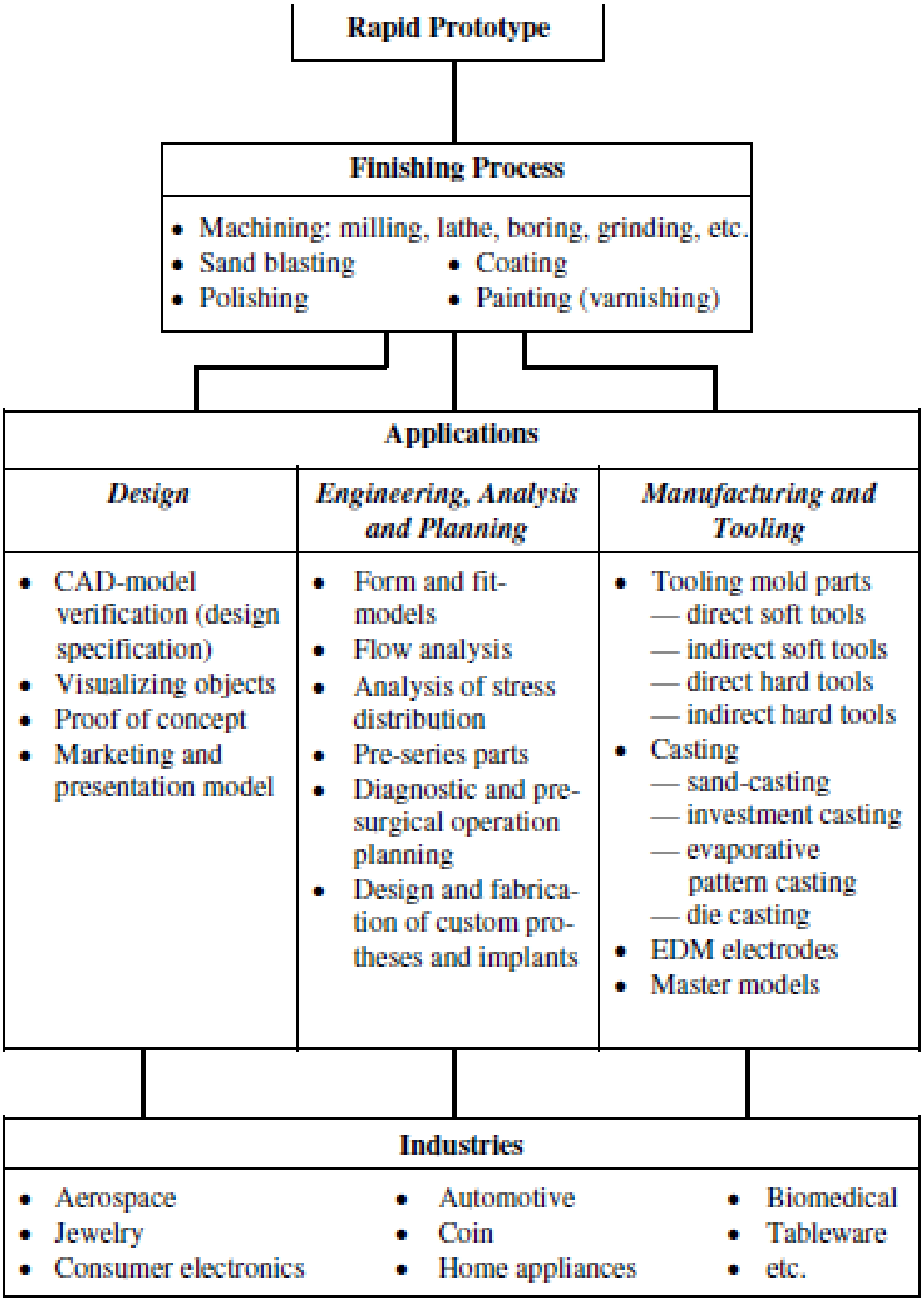
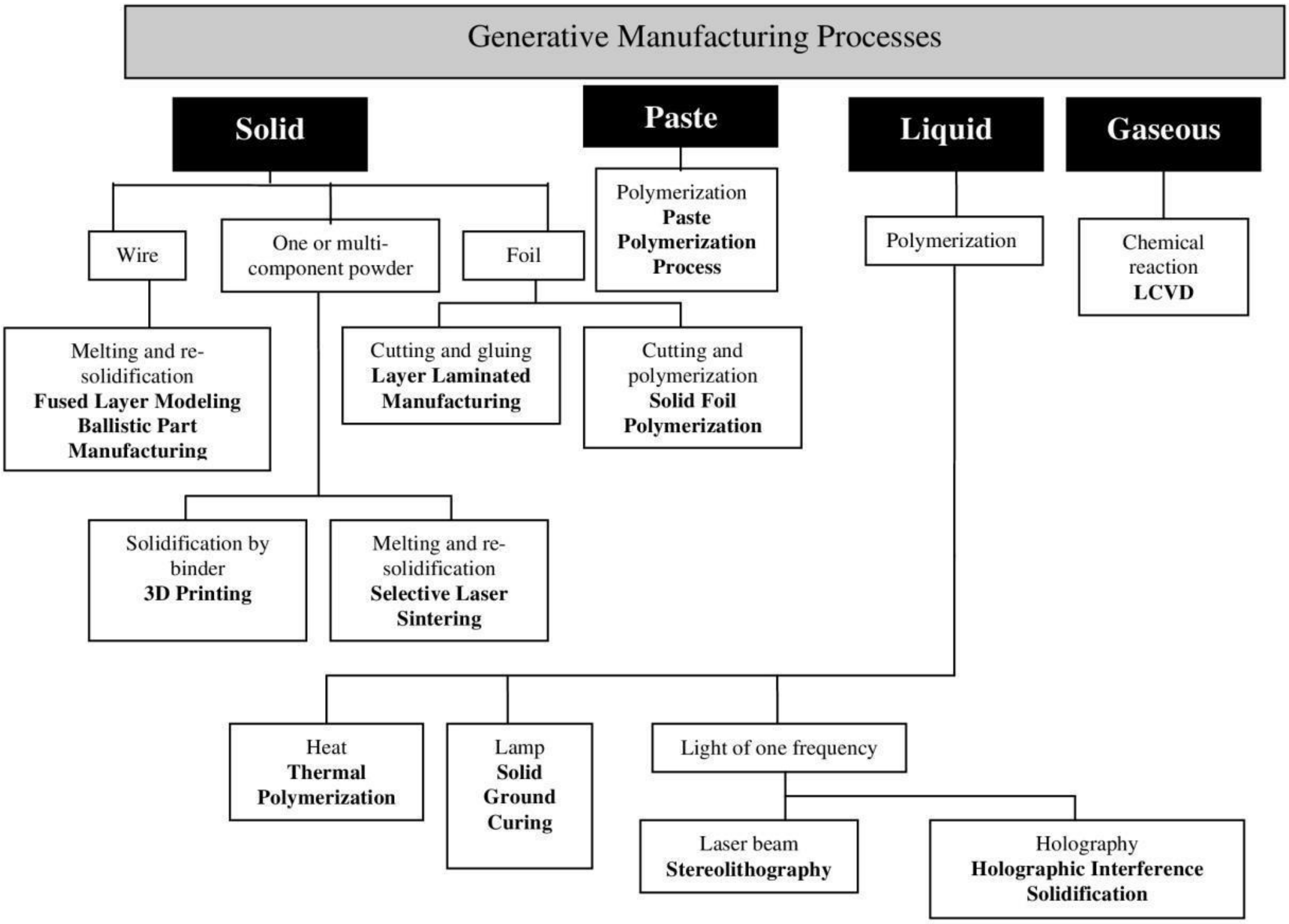


Figure 7.1: Typical application areas of RP

Classification of RP systems

The professional literature in RP contains different ways of classifying RP processes. However, one representation based on German standard of production processes classifies RP processes according to state of aggregation of their original material and is given in figure



HISTORY OF RP SYSTEMS

Table 1.1: Historical development of Rapid Prototyping and related technologies

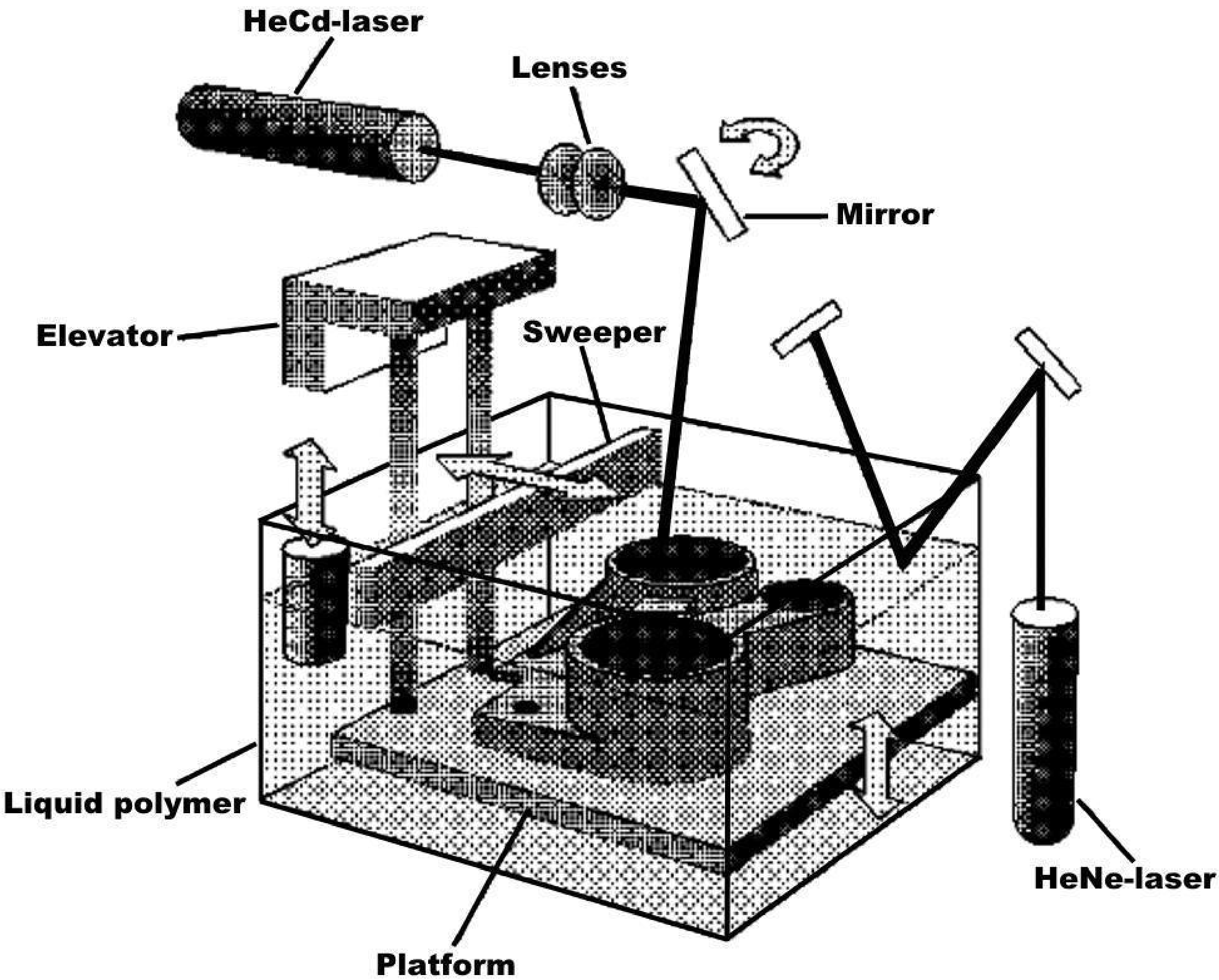
Year of Inception	Technology
1770	Mechanization [4]
1946	First Computer
1952	First Numerical Control (NC) Machine Tool
1960	First commercial Laser [5]
1961	First commercial Robot
1963	First Interactive Graphics System (early version of Computer-Aided Design) [6]
1988	First commercial Rapid Prototyping System

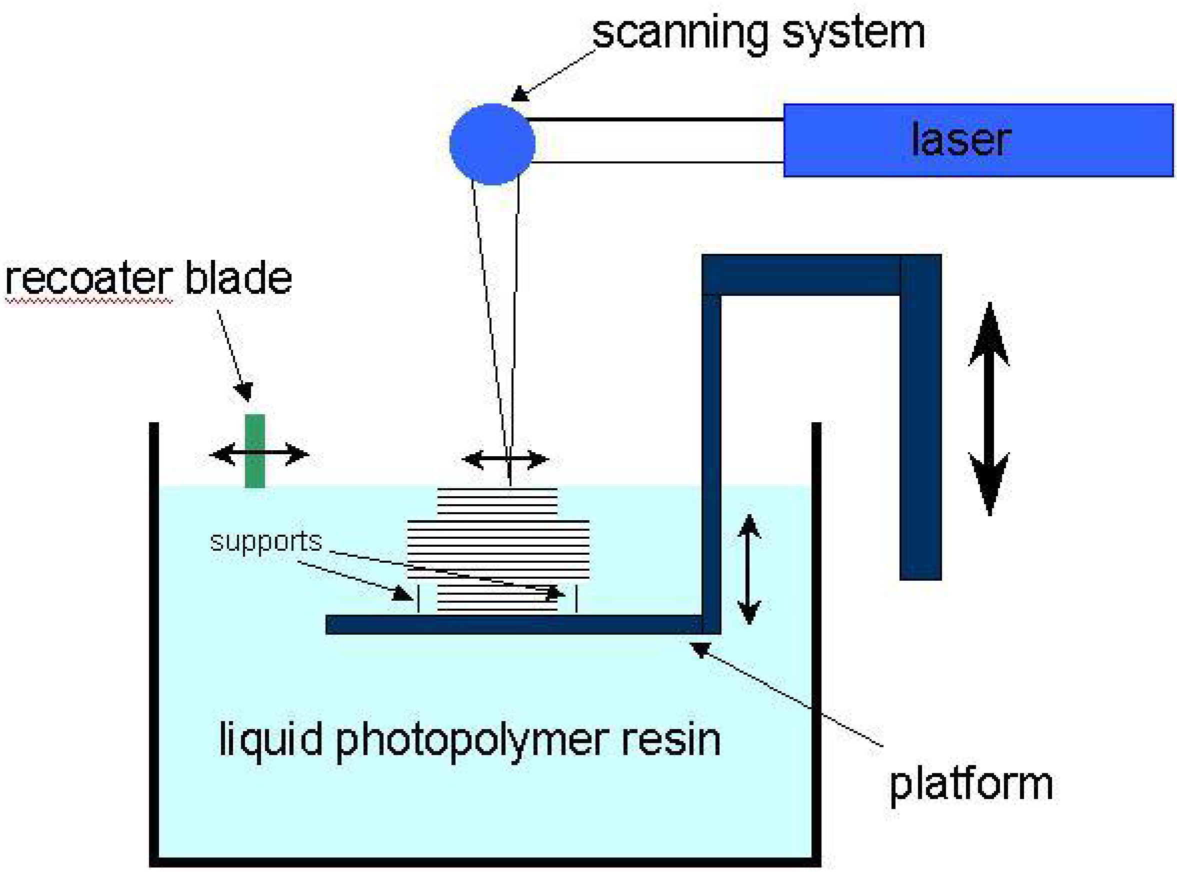
STEREOLITHOGRAPHY

Introduction:

It is the first RP system developed by 3D SYSTEMS of Valencia in California, USA in 1996.

First Model developed was 250/50 followed by 250/30, 3500, 5000 and 7000.





Principle:

SLA is a laser based Rapid Prototyping process which builds parts directly from CAD by curing or hardening a photosensitive resin with a relatively low power laser.

StereoLithography (SL) is the best known rapid prototyping system. The technique builds three-dimensional models from liquid photosensitive polymers that solidify when exposed to laser beam. The model is built upon a platform in a vat of photo sensitive liquid. A focused UV laser traces out the first layer, solidifying the model cross section while leaving excess areas liquid. In the next step, an elevator lowers the platform into the liquid polymer by an amount equal to layer thickness. A sweeper recoats the solidified layer with liquid, and the laser traces the second layer on 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.

Parameters:
Laser Type: Helium Cadmium Laser (He-Cd)
Laser Power: 24mW
Laser Life: 2000 hours
Re-coat material: Zaphir
Minimum Slice Thickness: 0.1mm
Beam Diameter: 0.2mm

Scan Speed: 0.75m/sec
Maximum Part Volume: 0.25x0.25x0.25 m
Maximum Part Weight: 9 kgs

Application Range

- • Processing large variety of photo-sensitive polymers including clear, water resistant and flexible resins
- • Functional parts for tests
- • Tools for pre series production tests.
- • Manufacturing of medical models
- • Manufacturing of electro-forms for Electro Discharge Machining (EDM)
- • Form-fit functions for assembly tests.

Advantages

- • Possibility of manufacturing parts which are impossible to produce conventionally using a single process.
- • Continuous unattended operation for 24 hours.
- • High resolution.
- • Any geometrical shape can be made with virtually no limitation.

Disadvantages

- • Necessity to have support structures
- • Accuracy not in the range of mechanical part manufacturing.
- • Restricted areas of application due to given material properties.
- • Labour requirements for post processing, especially cleaning.

Software:

i. **SLA CONTROL AND SET UP SOFTWARE**: It operates on SLA 250 and SLA 500 machines. It has got three packages. a) **SLA VIEW**: UNIX based system for viewing and positioning.

b) **BRIDGE WORKS**: UNIX based software for generating support structures.

c) SLA SLICE: Slicing and system operation software.

i ii. **MAESTRO**: UNIX based software

i iii. **MS WINDOWS NT SOFTWARE (3D LIGHT YEAR):** It is used for viewing, positioning, support generation and slicing, build station for operating SLA machine.

Build Materials Used:

Epoxy Resin, Acrylate Resin

Epoxy Resin has better material properties and less hazardous but require large exposure time for curing.

SLA HARDWARE:

The build chamber of SLA contains

1) A removable VAT that holds the build resin.

2) A detachable perforated build platen on a Z axis elevator frame

3) An automated resin level checking apparatus

4) VAT has a small amount of Z movement capability which allows computer to maintain a exact height per layer.

5) A recoated blade rides along the track at the top of the rack and serves to smooth the liquid across the part surface to prevent any rounding off edges due to cohesion effects.

6) Some systems have Zaphyrrecoater blade which actually softens up resin and delivers it evenly across the part surface.

7) Behind the build chamber resides the laser and optics required to cure resin.

8) Laser unit is long rectangular about 4 feet long and remains stationary.

Stereolithography Apparatus Operation:

1) The process begins with the solid model in various CAD formats

2) The solid model must consist of enclosed volumes before it is translated form CAD format into .STL FILE

3) The solid model is oriented into the positive octant of Cartesian co-ordinate system and then translate out Z axis by at least 0.25 inches to allow for building of supports

4) The solid model is also oriented for optimum build which involves placing complex curvatures in XY plane where possible and rotating for least Z height as well as to where least amount of supports are required

5) The .STL FILE is verified

6) The final .STL FILE one which supports in addition to original file are then sliced into horizontal cross sections and saved as slice file.

7) The slice files are then masked to create four separate files that control SLA machine ending with 5 extensions L, R, V and PRM.

8) Important one is V file. I.e. Vector file. The V file contains actual line data that the laser will follow to cure the shape of the part.

9) R file is the range file which contains data for solid or open fields as well as re-coater blade parameters.

The four build files are downloaded to SLA which begins building supports with platen adjust above the surface level. The first few support layers are actually cured into perforations into platen, thus providing a solid anchor for the rest of the part.
By building, SLA uses laser to scan the cross section and fill across the surface of resin which is cured or hardened into the cross sectional shape. The platen is lowered as the slices are completed so that more resin is available in the upper surface of the part to be cured. Final step is Post Processing.

Post Processing:
1) Ultraviolet Oven (Post Curing Apparatus) 2) An Alcohol Bath.

Clean the part in the alcohol bath and then go for final curing.
Advantages:
1) Parts have best surface quality

2) High Accuracy

3) High speed

4) Finely detailed features like thin vertical walls, sharp corners & tall columns can be fabricated with ease.
Disadvantages:
1) It requires Post Processing. i.e. Post Curing.

2) Careful handling of raw materials required.

3) High cost of Photo Curable Resin.

Applications:
1) Investment Casting.

2) Wind Tunnel Modelling.

3) Tooling.

4) Injection Mould Tools.

Diagram:

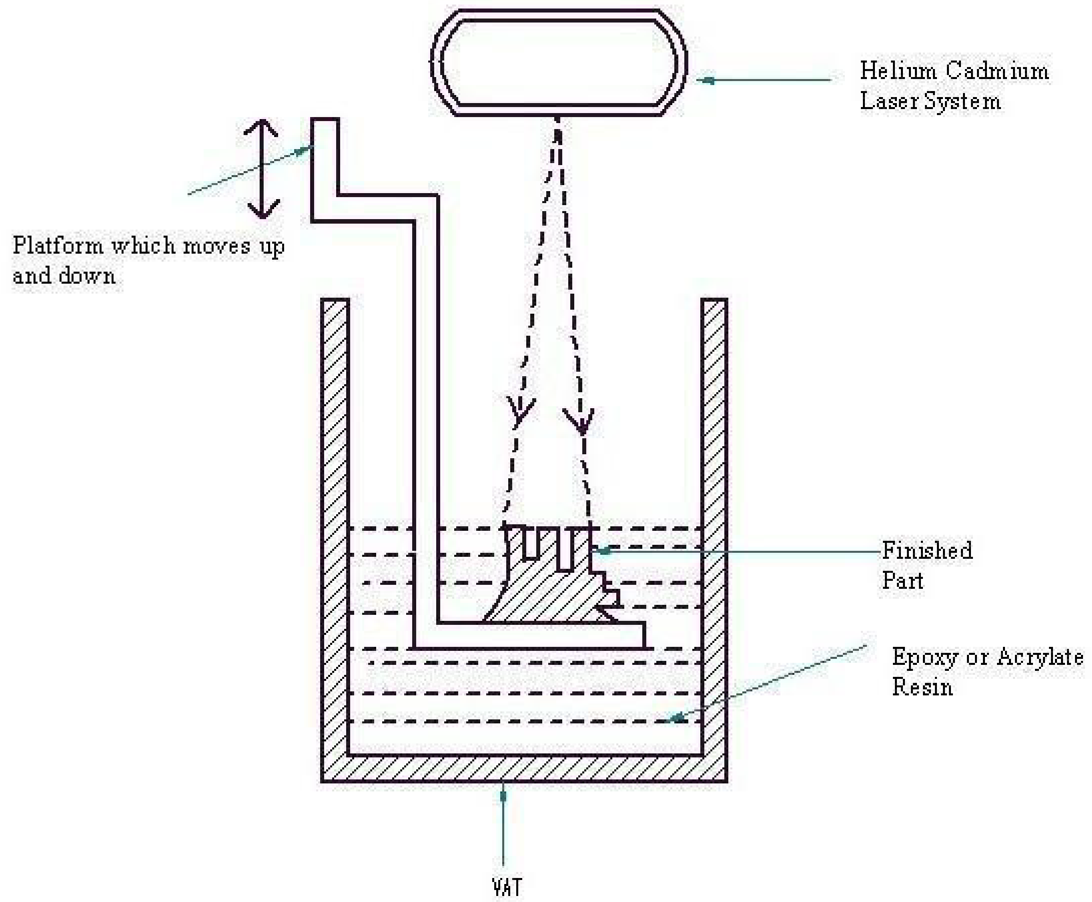


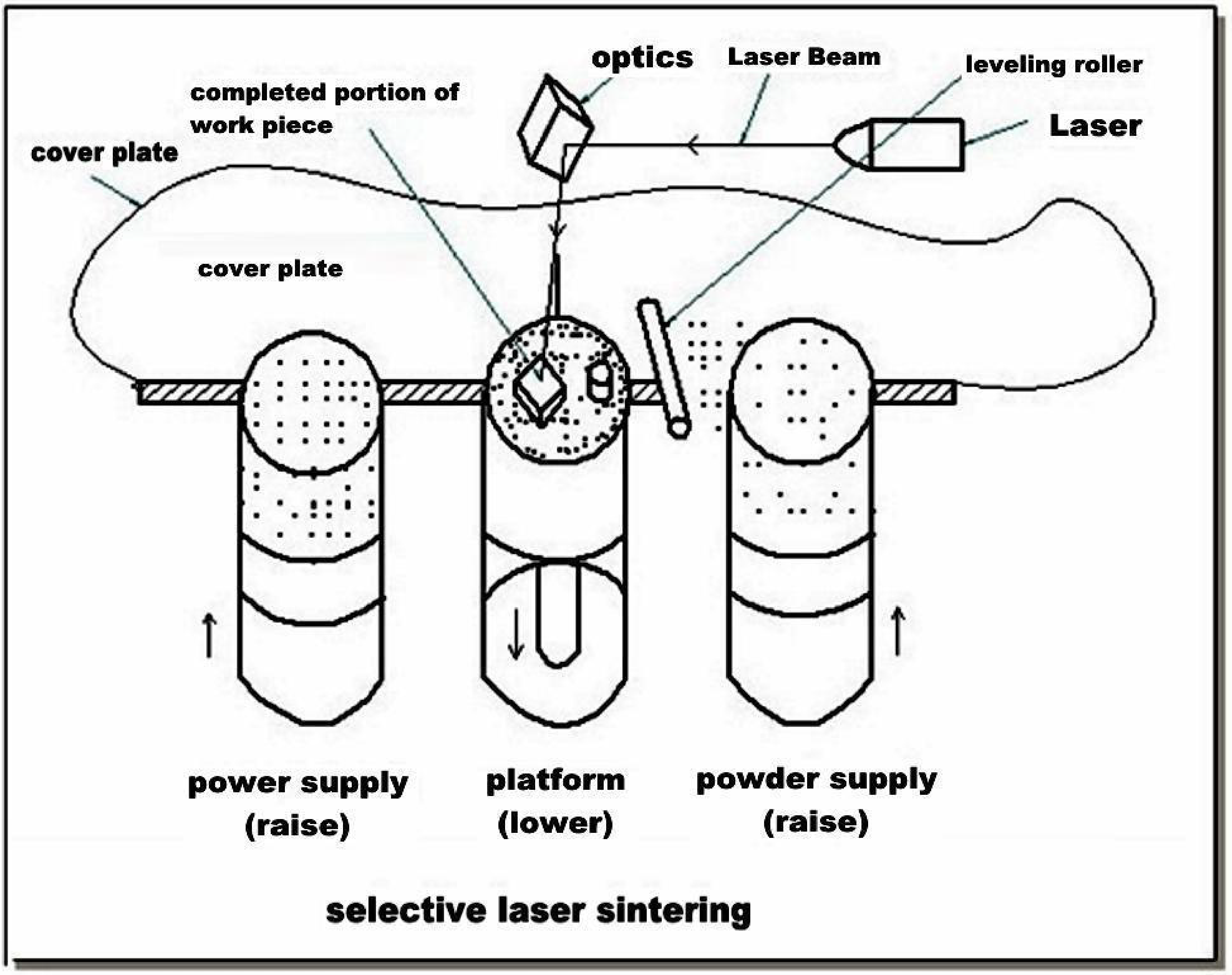
Fig: Stereolithography Apparatus

SELECTIVE LASER SINTERING

Introduction:

Selective Laser Sintering is a rapid prototyping process that builds models from a wide variety of materials using an additive fabrication method.Selective Laser Sintering was developed by university of Texas Austin in 1987.The build media for Selective Laser Sintering comes in powder form which is fused together by a powerful carbon dioxide laser to form the final product.
DTM sinter station 2500 is the machine used for the process.
Selective Laser Sintering begins like most other rapid prototyping processes with a standard
.STL CAD file format.DTM view software uses the .STL files. This software do the required orientation and scaling of parts.

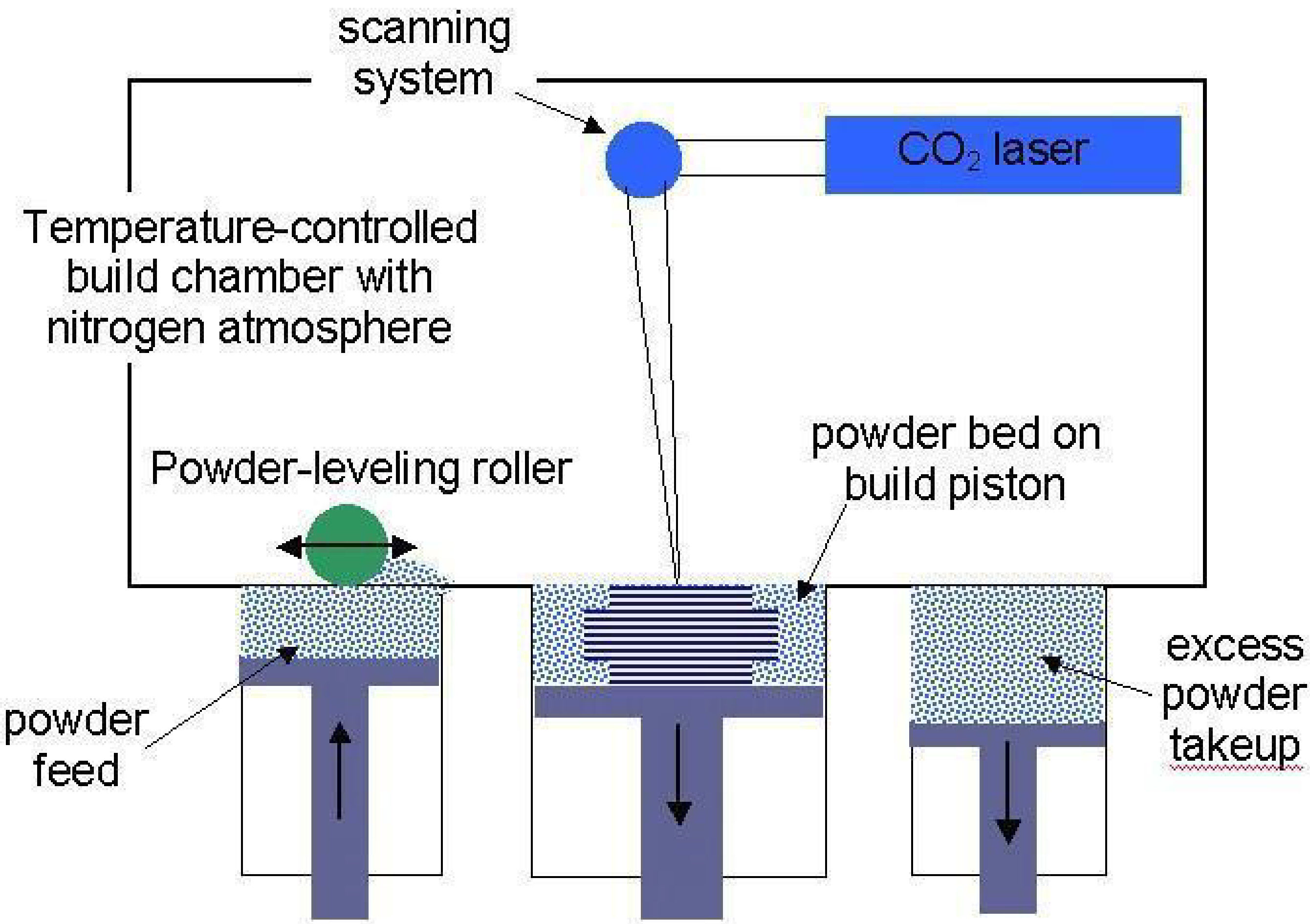
This machine has auto nesting capabilities which will place multiple part optimally in the build chamber for best processing speed and results. Once the .STL file is placed and parameters are set the model is directly built from the file.



The sinter station has built piston at the center and feed piston on the either side. The model is built layer by layer like other rapid prototyping process so that the build piston will begin at the top of its range and will lower in increments of the set layer size as parts are built. With the build piston at the top a thin layer of powder is spread across the build area by the roller from one of the feed piston. The laser then cures in a raster sweeps motion across the area of the parts being built.The part piston lowers and more powder is deposited and the process is continued until all of the part is built.The build media is removed from the machine. It is a cake of powder. This cake is taken to the breakout station where excess powder is removed from the part manually with brushesthe excess powder that has been removed can be kept for recycling and can be reused. Some material needs additional finishing. Some of the finishing techniques include grid blasting, sanding, polishing, drilling, taping and coating.

Purpose of Selective Laser Sintering:

To provide a prototyping tool
To decrease the time and cost of design to product cycle.
It can use wide variety of materials to accommodate multiple application throughout the manufacturing process



Applications:
1. As conceptual models.

2. Functional prototypes.

3. As Pattern masters.

Advantages:

1. Wide range of build materials.
2.
3. 2. High throughput capabilities.
4.
5. 3. Self-supporting build envelop.
6.
7. 4. Parts are completed faster.
8.
9. 5. Damage is less.

10.

11. 6.Less wastage of material

12. **Disadvantages:**

13. 1. Initial cost of system is high.

14.

15. 2. High operational and maintenance cost.

16.

17. 3. Peripheral and facility requirement.