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Rapid Prototyping

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ABSTRACT- *Prototyping or model making is one of the important steps to finalize a product design. It helps in conceptualization of a design. Before the start of full production a prototype is usually fabricated and tested. RP process belong to the generative (or additive) production processes unlike subtractive or forming processes such as lathing, milling, grinding or coining etc. in which form is shaped by material removal or plastic deformation. Rapid prototyping, though a relatively new discipline, has proven to be a valuable tool in the reduction of the time and cost associated with developing new products. The value of rapid prototyping shows the promise of increasing even further as it matures and offers higher quality parts, in less time, and for lower costs.*

KEYWORDS*-Fill processes. Rapid Prototyping (RP),Stereolithography (SL),Stereo lithography Apparatus (SLA),Swift process*

I. Introduction

Rapid Prototyping (RP) is a type of Computer Aided Manufacturing (CAM) and refers to the automatic construction of mechanical models via additive fabrication (e.g., 3D printers, stereo lithography, selective laser sintering, etc.), as opposed to more traditional subtractive means (e.g., CNC). The RP industry emerged in 1987 when 3D Systems sold the first commercially available Stereo lithography Apparatus (SLA). In the following years, other RP companies emerged slowly at an approximate rate of one per year. Rapid prototyping has quickly grown in use and importance in industrial applications during the past decade. Originally used as a concept model generation system, it has grown to include manufacturing planning, assembly planning, fit and tolerance checking, and even limited run qualification parts for production operations. Continued research and development of older rapid prototyping processes and the introduction of new processes has fueled new interest in the possibility of fast and flexible “lot size of one” production capabilities.

Very recently, companies have begun to look at moving beyond rapid prototyping to *rapid manufacturing*. Additive- fabrication techniques offer many production benefits over traditional manufacturing techniques, such as the capability to create multiple, different geometries within a single production batch without the need for a change in tooling. As such, many manufacturers are looking to using RP technologies in the production (1) low volume, (2) replacement, and (3) made-to-order, customized parts.

II. Basic Principle Of Rapid Prototyping Processes

RP process belong to the generative (or additive) production processes unlike subtractive or forming processes such as lathing, milling, grinding or coining etc. in which form is shaped by material removal or plastic deformation. In all commercial RP processes, the part is fabricated by deposition of layers contoured in a (x-y) plane two dimensionally. The third dimension (z) results from single layers being stacked up on top of each other, but not as a continuous z-coordinate. Therefore, the prototypes are very exact on the x-y plane but have stair-stepping effect in z-direction. If model is deposited with very fine layers, i.e., smaller z-stepping, model looks like original. RP can be classified into two fundamental process steps namely generation of mathematical layer information and generation of physical layer model. Typical process chain of various RP systems is shown in figure It can be seen from figure 1 that process starts with 3D modeling of the product and then STL file is exported by tessellating the geometric 3D model. In tessellation various surfaces of a CAD model are piecewise approximated by a series of triangles and co-ordinate of vertices of triangles and their surface normal’s are listed. The number and size of triangles are decided by facet deviation or chordal error as shown in figure 2. These STL files are checked for defects like flip triangles, missing facets, overlapping facets,dangling edges or faces etc. and are repaired if found faulty. Defect free STL files are used as an input to various slicing software’s. At this stage choice of part deposition orientation is the most important factor as part building time, surface quality, amount of support structures, cost etc. are influenced. Once part deposition orientation is decided and slice thickness is selected, tessellated model is sliced and the generated data in standard data formats like SLC (stereolithography contour) or CLI (common layer interface) is stored. This information is used to move to step 2, i.e., generation of physical model. The software that operates RP systems generates laser-scanning paths (in processes like Stereolithography, Selective Laser Sintering etc.) or material deposition paths (in processes like Fused Deposition Modeling). This step is different for different processes and depends on the basic deposition principle used in RP machine. Information computed here is used to deposit the part layer-by-layer on RP system platform. The generalized data flow in RP is given in figure 2 The final step in the process chain is the post-processing task. At this stage, generally some manual operations are necessary therefore skilled operator is required. In cleaning, excess elements adhered with the part or support structures are removed. Sometimes the surface of the model is finished by sanding, polishing

or painting for better surface finish or aesthetic appearance. Prototype is then tested or verified and suggested engineering changes are once again incorporated during the solid modeling stage.

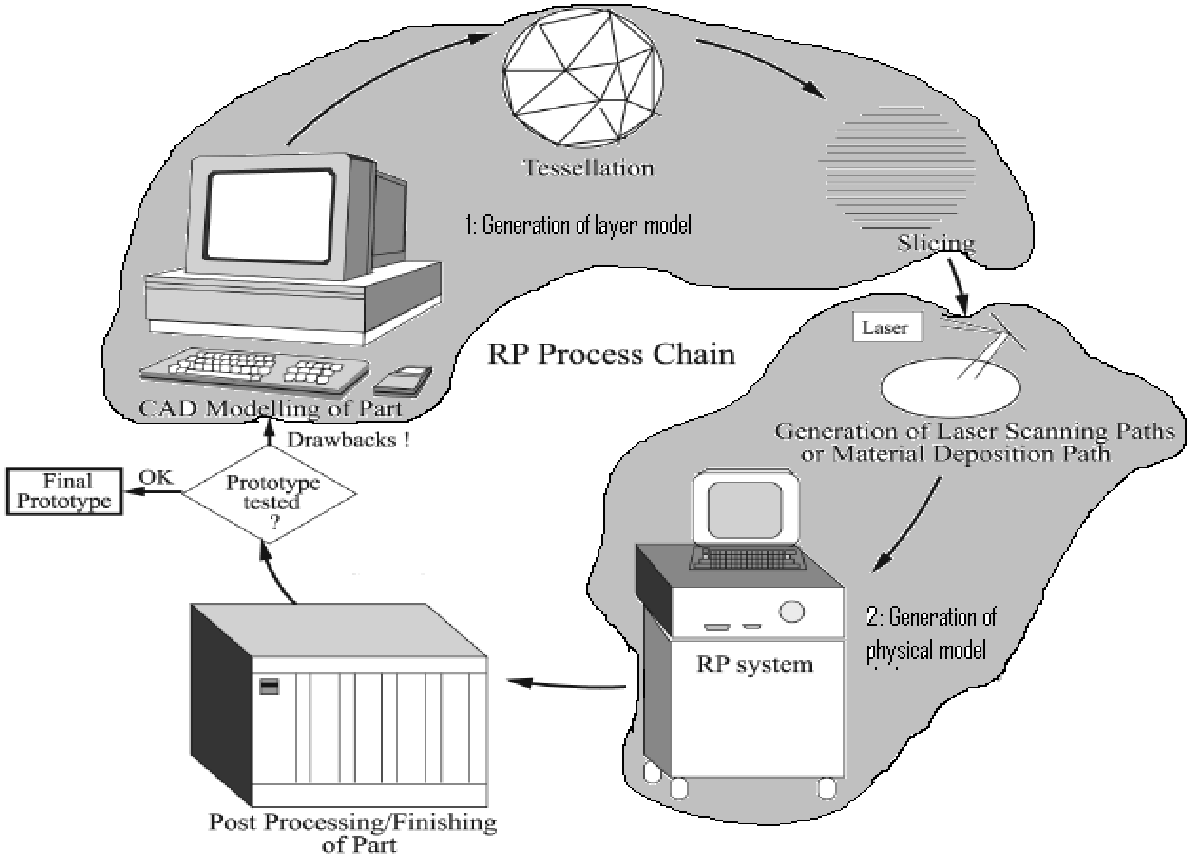

Fig.No.1 RP process chain showing fundamental process steps

Fig.No.2 Generalized illustration of data flow in RP Here, few important RP processes namely Stereolithography (SL),
Selective Laser Sintering (SLS), Fused Deposition Modeling (FDM) and Laminated Object Manufacturing (LOM). Out of which Stereolithography is described.

2.1 Stereolithography

In this process photosensitive liquid resin which forms a solid polymer when exposed to ultraviolet light is used as a fundamental concept. 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. The laser scans the first layer and platform is then lowered equal to one slice thickness and left for short time (dip-delay) so that liquid polymer settles to a flat and even surface and inhibit bubble formation. The new slice is then scanned. Schematic diagram of a
typical Stereolithography apparatus is shown in figure 3 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.
It also reduces trapped volumes which are sometimes formed due to excessive polymerization at the ends of the slices and an island of liquid resin having thickness more than slice thickness is formed (Pham and Demov, 2001). Once the complete part is deposited, it is removed from the vat and then excess resin is drained. It may take long time due to high viscosity of liquid resin. The green part is then post-cured in an UV oven after removing support structures. Overhangs or cantilever walls need support structures as a green layer has

relatively low stability and strength. These overhangs etc. are supported if they exceed a certain size or angle, i.e., build orientation. The main functions of these structures are to support projecting parts and also to pull other parts down which due to shrinkage tends to curl up (Gebhardt, 2003). These support structures are generated during data processing and due to these data grows heavily specially with STL file s, as cuboid shaped support element need information about at least twelve triangles.

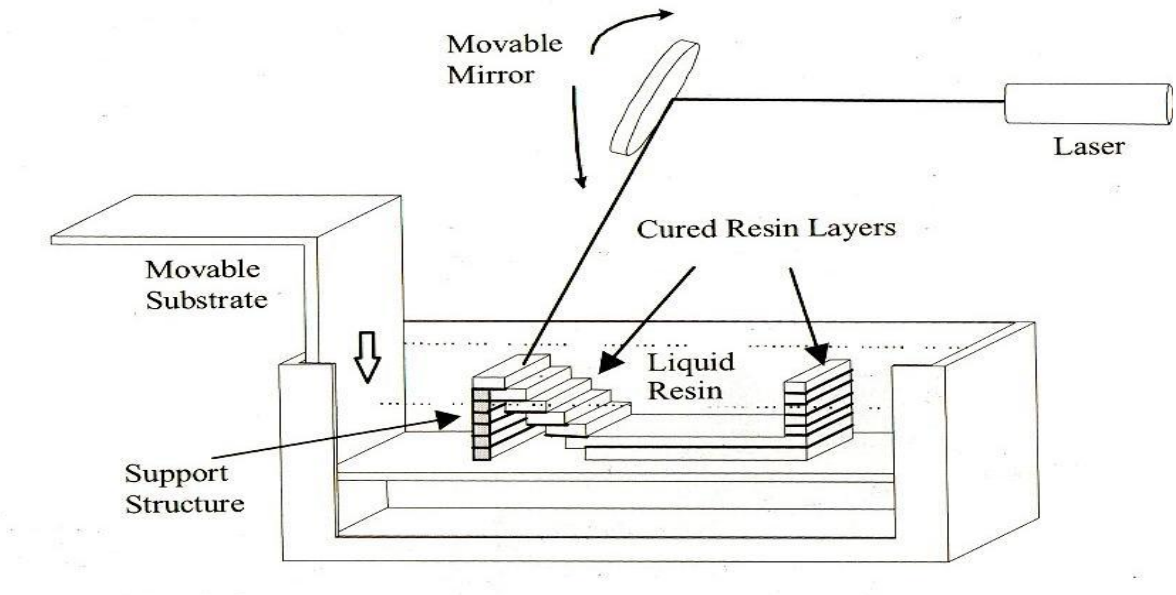

Fig.No.2 Stereolithography

III. Contoured Edge Slice Generation In Rapid Prototyping

Rapid prototyping processes can be broadly categorized into two categories - fill processes and sheet based processes [Kai and Fai, 1997]. Most liquid and powder fill-based rapid prototyping processes build parts one layer at a time by tracing the edge contour of a given layer and then filling in the volume. The time required to build a part
is, therefore, a function of the part volume. Sheet based processes are different in the sense that they merely cut the layer's edge contour from a solid sheet to generate the solid part. The time required for the process is only a function of part surface area. It clearly takes less time to trace only the perimeter of a contour than it does to trace that perimeter and fill it in, therefore sheet based processes are much faster.
Currently, commercially available rapid prototyping processes all suffer from vertical layer edge effects.
The resultant "stair-stepped" surface that results on sloped or curved surfaces greatly impacts the overall part appearance and accuracy. Typical layer thickness in commercial RP systems is 0.003" – 0.008" (or 125 – 333 layers per inch). The "stair-stepped" effect can only be combated by contouring the actual edge of each layer to match that of the actual desired part geometry. This adds a level of complexity that has not found application in commercial systems as yet, though current research is addressing this area of RP. Figure 3 shows the benefits of contoured edges in RP parts.

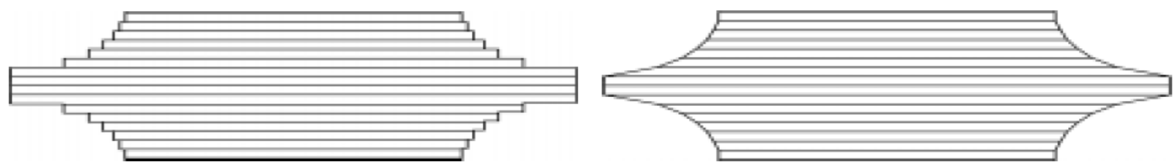

Fig.No.3 Vertical versus sloped edges on a curved surface
The approach taken with the CAM-LEM project [Cawley et. al, 1996],[Zheng et al., 1996] is to use sloped rather than vertical edges as shown in figure 1. The CAM-LEM process uses a high-powered laser with a 5-axis positioning system to machine sloped surfaces on the edges of each layer. The individual layers are post-assembled, and then sintered. An additional challenge with this technique is a requirement for a registration system for assembling layers after they have been cut. This "post assembly" operation introduces a potential

source of dimensional errors. The registration system commonly incorporates pins and often requires actual modifications to the geometry of the parts.Figure shows a top and side view of a post assembled part with a pin registration system. This obviously leads to the RP model not being as accurate a representation of the part as it could be.

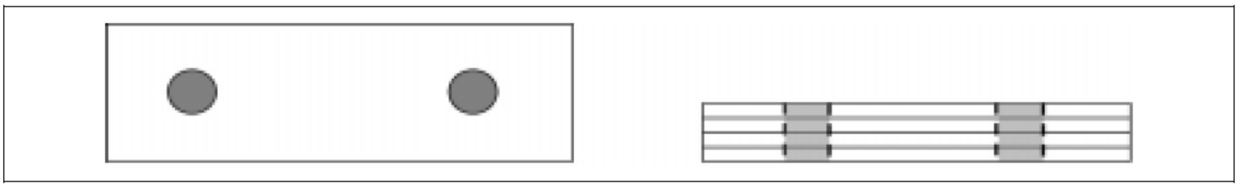

Fig.No.4 Common registration system for post assembly sheet-based RP techniques

3.1Current Trends in Rapid Prototyping

Rapid prototyping processes and techniques are moving toward a rather unique goal; that of providing a manufacturing process flexible and accurate enough to produce any part geometry required, to the necessary tolerances, with the appropriate material properties, quickly, and inexpensively. This “lot size of one” goal is the ultimate in manufacturing flexibility and represents the epitome of JIT manufacturing. While no rapid prototyping process currently available even approaches this goal, strides are being made in the material properties available, speed, and accuracy of the various processes. Rapid tooling techniques are also further reducing development cycles and planning horizons.

3.2 Swift Process

As previously described, the aim of most rapid prototyping researchers is to develop faster and less expensive processes that produce strong, dimensionally accurate parts. A sketch of the proposed SWIFT (Solvent Welding Freeform Fabrication Technique) process configuration is shown in Figure 6. The process starts with solvent wieldable thermoplastic sheets that have been cut to a suitable standard size and loaded into a sheet feeder. Solvent wieldable thermoplastics such as ABS, polystyrene, PVC, and polycarbonate are widely available from plastics suppliers in sheet form. The sheets are fed forward via a pair of pinch rollers. As the sheet is fed forward, it first passes through a solvent masking station whose function is to prevent unwanted welding in selected areas. From the solvent masking station, the sheet feeds over a solvent applicator that applies solvent to the underside of the sheet. The sheet feeding continues until the sheet is positioned over the build platform. There, a platen is lowered, thus pressing the sheet down onto the stack of previously assembled sheets. As the underside of the new sheet comes into contact with the top surface of the previously applied sheet, the solvent dissolves polymer chains at the interface between the two sheets. The solvent then evaporates or is absorbed into the mass of the sheets, allowing new molecular bonds between the two sheets to be established, resulting in an interface weld and a solid part. This action takes place very quickly, and in practice, the platen only needs to maintain pressure for 3 – 5 seconds. The platen is then retracted, and a CNC milling machine with a small diameter end mill machines the cross sectional contour of the sheet (or part layer) that has just been applied. Note that the process does not require special registration or post assembly of the machined sheets as they are preassembled prior to machining. Once each o f the layers has been added to the part and subsequently machined, the part is removed from the build platform and is complete.

A contoured edge for individual slices or layers can only be generated via a query of the solid model, most commonly represented in rapid prototyping as a .STL file format. The following algorithm has been implemented for use with the SWIFT rapid prototyping system. Firstly, the STL file of the model is read and the data for all the facets is stored in a convenient and systematic way so that it is easily accessible. Then, from the information of all the facets, the points of intersection (called the trigger points) at a specific Z-height are then determined. These trigger points are later analyzed and sorted so that they are grouped into various loops that are formed due to the intersection of the Zplane and the part. A contoured edge algorithm [De Jager P. J., 1996] is then used to generate the Gcode for machining the layer. The algorithm is as follows, with a flowchart provided in figure 6 Read STL file.

2 Generate trigger points of intersection. 3 Join the adjacent trigger points to form a loop of segments. Sweep each of these segments, in a direction determined by the facet surface normal’s in the STL file, half the layer thickness above and below the cutting plane to form rectangles.4 Determine the intersection segments of the intersecting rectangles.

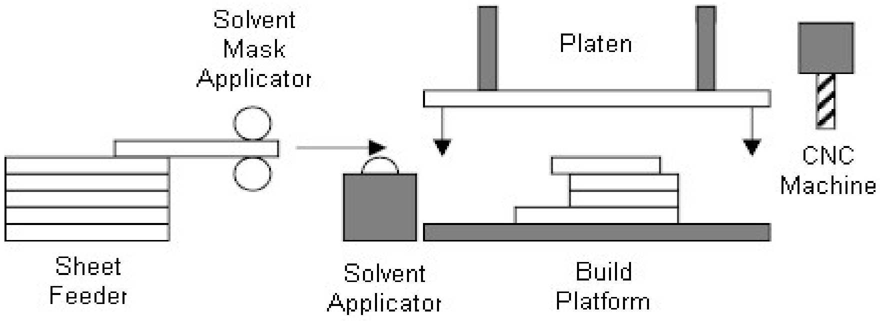

Fig.No.5The proposed SWIFT machine configuration

These intersection segments correspond to discreet cutter locations during machining of that loop 5 Using geometric relationships, the coordinates and the angles “A” and “C” for 5-axis GCode can be computed for each of these cutter locations 6 Sequencing all these cutter locations in a given loop generates the 5-axis G-Code for machining the contour.

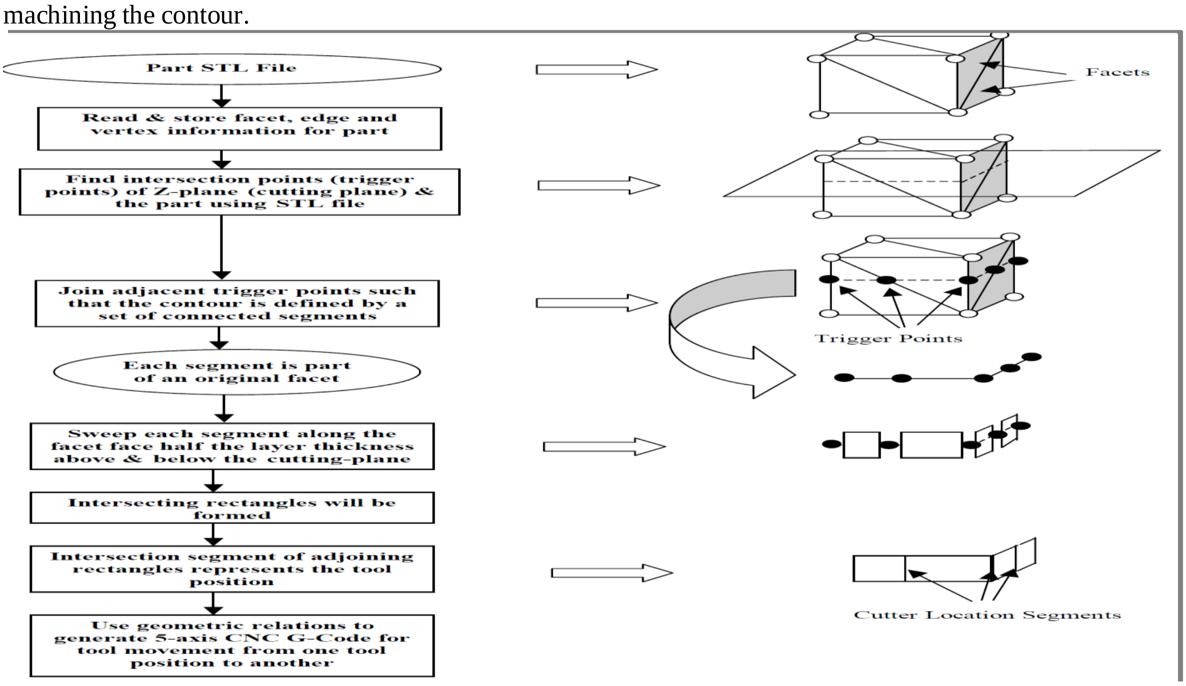

Fig.No.6Algorithm Flowchart

IV. 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. This paper has presented some of the results of research and development activities regarding rapid prototyping in general and the SWIFT rapid prototyping process in particular. Results have shown that the SWIFT process is feasible and has advantages over most commercially available rapid prototyping processes with regard to cost, accuracy and speed.

References

[1 Pulak M. Pandey,Department of Mechanical Engineering Indian Institute of Technology, Delhi 1-15.

[2] Ashley, S. "Rapid prototyping is coming of age" *Mechanical Engineering, vol. 117, no. 7*,July 1995, 62 – 68.

[3] James B. Taylor, Ph.D., Denis R. Cormier, Ph.D.,Sandesh Joshi, and Vivek Venkataraman, contoured edge slice generation in rapid prototyping via 5-axis machining

[4] Cawley, J., Heuer, A., Newman, W., and Mathewson, B. Computer-Aided Manufacturing of Laminated Engineering Materials, *American Ceramic Society Bulletin, Volume 75, No. 5*,May 1996,75-79.

[5] Jelena Milovanović, Miroslav Trajanović, Medical applications of rapid prototyping, Facta universitatis,Series: *Mechanical Engineering Vol.5, No 1*, 2007, 79 – 85.