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AN OVERVIEW OF RAPID PROTOTYPING TECHOLOGY

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ABSTRACT

This paper provides an overview of rapid prototyping technology in brief and emphasizes on their ability to shorten the product design and development process. Classification of rapid prototyping processes and details of few important processes is given. An attempt has been made to include some important factors to be considered for proper utilization of potentials of rapid prototyping processes.

Keywords: Rapid prototyping, product design, utilization, processes

I. INTRODUCTION

Prototyping is an important stage in any product development process. 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. Manual prototyping by a skilled craftsman has been an age-old practice for many centuries. Second phase of prototyping started around mid-1970s, when a soft prototype modeled by 3D curves and surfaces could be stressed in virtual environment, simulated and tested with exact material and other properties. Third and the latest trend of prototyping, i.e., Rapid Prototyping (RP) by layer-by-layer material deposition, started during early 1980s with the enormous growth in Computer Aided Design and Manufacturing (CAD/CAM) technologies when almost unambiguous solid models with knitted information of edges and surfaces could define a product and also manufacture it by CNC machining. Rapid Prototyping technology employ various engineering, computer control and software techniques including laser, optical scanning, photosensitive polymers, material extrusion and deposition, powder metallurgy, computer control, etc. to directly produce a physical model layer by layer (Layer Manufacturing) in accordance with the geometrical data derived from a 3D CAD model.

Prototypes that will be required in the product design and development process are commonly divided into the following types.

- 3D sketches
- Cosmetic prototypes
- Engineering / Functional prototypes
- Samples for safety approval
- Marketing Samples

II. PRINCIPLE OF RAPID PROTOTYPING

Rapid Prototyping 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. Rapid Prototyping 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 normals are listed. The number and size of triangles are decided by facet deviation or chordal error. 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 (stereo lithography 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 Stereo lithography, 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.

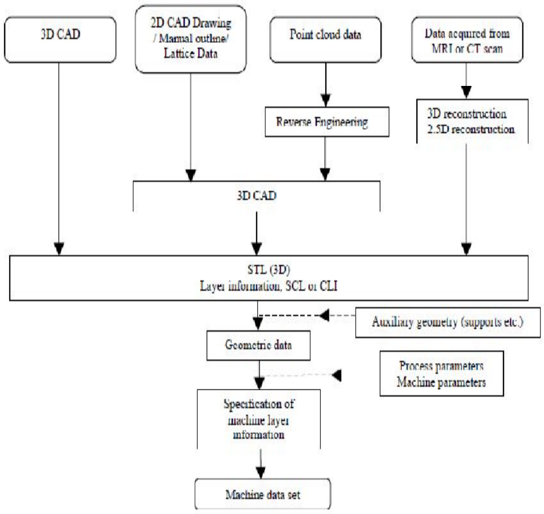

Fig. 1 Generalized data flow in Rapid Prototyping

Generalized illustration of data flow in Rapid Prototyping are necessary therefore skilled operator is required The final step in the process chain is the post-processing task. At this stage, generally some manual operations. 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.

III. RAPID PROTOTYPING PROCESSES

The professional literature in rapid prototyping contains different ways of classifying rapid prototyping processes. However, one representation based on German standard of production processes classifies rapid prototyping processes according to state of their original material and is given in figure 2.

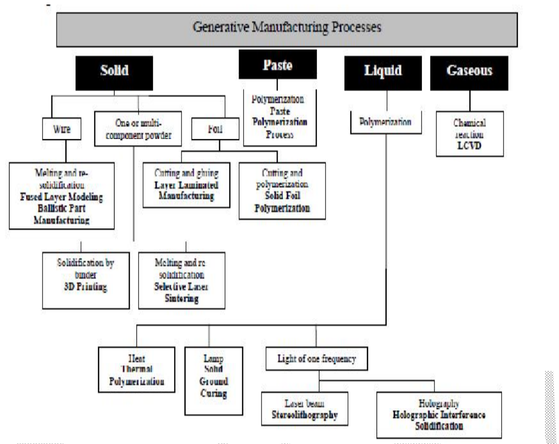

Fig. 2 Classification of rapid prototyping process

IV. MAIN IMPORTANT RAPID PROTOTYPING PROCESSES ARE DESCRIBED BELOW

1. **S**tereo lithography**:** Under action of a laser, a photosensitive liquid resin is solidified by a chemical transformation. The beam of light emitted by the laser is conducted on the resin surface by a set of dynamic mirrors. The move of these mirrors, driven by CAD software will make the light runs on the resin surface along the trajectory corresponding to the considered section. In its wake, the laser polymerizes the resin and only the exact section remains solidified. After realization of a section, the platform supporting the object being made goes down into the resin at a depth dependent on layer thickness (usually from 0.07 mm to 0.75 mm).S tacking-up of layers leads to a 3 dimensional part.

2. Solid Ground Curing**:** It is another method based on resin polymerization. Unlike stereo lithography, the process does not use a laser but a powerful ultra violet lamp coupled with a masking device. With this method, all points of a same section are simultaneously solidified. The mask, which is a negative of the section, is a glass plate

covered on appropriate zones with a black electrostatic toner so as photocopier machines (iconography).

3. Selective Laser Sintering**:** It requires a thermal laser used to fuse a powder material mixed with a binder. On laser wake, powder is heated slightly above its melting point and agglomerate when cooling. A thermal treatment can be useful to improve physical properties of the part and reduce porosity. Prototype materials used depend on the powder, usually made from plastic, sand, ceramic or metal components.

4. 3D Printing**:** is very similar to the previous technique. Its principle is based on powder agglomeration through deposition of binding droplets on the section points. When finished, the part is larger than it should be in order to compensate for the important shrinkage due to sintering. Here again, a thermal treatment will be required. 3D printing is sometimes used in ceramic molds making.

5. Fused Deposition Modeling**:** has been developed in 1988 uses a head mounted on a 3 axes CNC machine to depose a fused thread on the part being made. Solidification is instantaneous when bringing the thread into contact with the previous section. Thread materials used are wax, nylon, polypropylene, ABS… This process is quite fast and cheap and can be helpful to make empty parts.

6. Laminated Object Manufacturing**:** does not use material change of state. Sheets are cut out, piled up and stuck. Cutting out can, according to the techniques, be the last operation. A thin sheet of paper covered by a polypropylene film is deposed on the previous section and pressed under temperature. Heat makes the film melt which sticks the paper sheet. A laser cuts out the outline of the considered section at a depth corresponding to the thickness of the sheet. The final part is very similar to wood.

7. Stratoconception: is a process very simple to implement. Actually, it does not need specific machines. Various sections are cut out in a plate through techniques such as water cutting, laser cutting or even milling. Assembly is realized by sticking, fusion or locating. In order to save up materials, an optimization is done to select the most adapted cutting plan. Almost all solid materials can be used in Stratoconception. Moreover, as conventional machines are sufficient, large 3 Dimensional prototypes can be made.
8. The techniques presented so far are all based on matter adding. They are the most common methods used to realize, in a brief period, complex prototypes. Let us just mention here that another way to make prototypes consists in removing matter. Techniques such as high speed machining or hot thread cutting are also widely used in industry.

V. APPLICATIONS OF RAPID PROTOTYPING TECHNOLOGIES

Rapid prototyping technology has potential to reduce time required from conception to market up to 10-50 percent. It has abilities of enhancing and improving product development while at the same time reducing costs due to major breakthrough in manufacturing. Although poor surface finish, limited strength and accuracy are the limitations of rapid prototyping models, it can deposit a part of any degree of complexity theoretically. Therefore, rapid prototyping technologies are successfully used by various industries like aerospace, automotive, jewelry, coin making, tableware, saddletrees, biomedical etc. It is used to fabricate concept models, functional models, patterns for investment and vacuum casting, medical models and models for engineering analysis.

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