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A REVIEW OF RAPID - PROTOTYPING TECHNIQUES

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ABSTRACT

The term rapid prototyping defines a class of technologies that can construct physical models layer by layer from CAD data. Today different rapid prototyping techniques are used. The paper presents a literature survey of some important commercial methods, identified for each of them their advantages and limitations.

1. Introduction

The term *rapid prototyping* (RP) refers to a class of technologies that can automatically construct physical models from Computer-Aided Design (CAD) data.

At least six different rapid prototyping techniques are commercially available, each with unique strengths. Because RP technologies are being increasingly used in non-prototyping applications, the techniques are often collectively referred to as *solid free-form fabrication*, *computer automated manufacturing*, or *layered manufacturing*. The latter term is particularly descriptive of the manufacturing process used by all commercial techniques. A software package "slices" the CAD model into a number of thin (~0.1 mm) layers, which are then built up one atop another.

Rapid prototyping is an "additive" process, combining layers of paper, wax, or plastic to create a solid object. In contrast, most machining processes (milling, drilling, grinding, etc.) are "subtractive" processes that remove material from a solid block. RP's additive nature allows it to create objects with complicated internal features that cannot be manufactured by other means.

Along with the reduction of part build time, rapid prototyping promotes simultaneous engineering.

The minimal time and cost demands of prototype production via RP leads to improved product quality because more time is available for design iteration and optimization. Furthermore, errors in part design can be caught early and require little effort to correct.

RP should not be viewed as a lone-standing technology, but rather as a link in the process chain to produce parts with various properties and lot size requirements. Reverse engineering (figure 1) further expands CAD /CAM to achieve a complete process chain, beginning with a physical part and ending with a prototype. Depending on the desired application, point clouds representing physical parts that have been measured by optical or tactile methods can be converted into a CAD format or used directly in a RP production process.

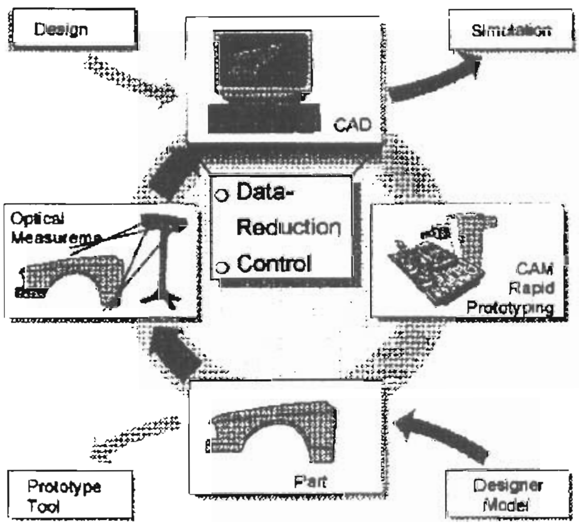

Fig.1

In what it follows, it will be present the main aspects of different RP processes.

2. Rapid Prototyping Techniques

2.1 Stereolitography

Stereolithography, patented in 1986, started the rapid prototyping technologies. The technique builds three-dimensional models from liquid photosensitive polymers that solidify when exposed to ultraviolet light. As shown in the figure 2, the model is built upon a platform situated just below the surface in a vat of liquid epoxy or acrylate resin. The model has a number of supports to assures the stability. A low-power highly focused UV laser traces out the first layer, solidifying the model's cross section while leaving excess areas liquid.

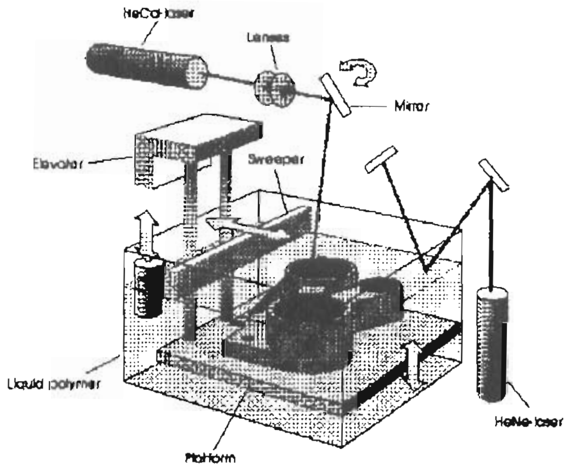

Fig. 2

Next, an elevator incrementally lowers the platform into the liquid polymer. A sweeper re-coats the solidified layer with liquid, and the laser traces the second layer atop 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.

The advantages of the process are: high detail and accuracy; can run without supervision; sharp-edges tend to fillet by resin, thus reducing the stepped effect between slices. The disadvantages are: extra time required for postcuring (up to 16h); polymer shrinks as it hardness – the result it stress that warps the part; toxic chemicals; limited selection of chemicals; addition of supports needed; work required after to remove supports.

2.2. Laminated Object Manufacturing

In this technique, layers of adhesive-coated sheet material are bonded together to form a prototype. The original material consists of paper laminated with heat-activated adhesive and rolled up on spools. As shown in the figure 3, a feeder mechanism advances the sheet over the build platform, where a base has been constructed from paper and double-sided foam tape. Next, a heated roller applies pressure to bond the paper to the base. A laser cuts the outline of the first layer into the paper and then cross-hatches the excess area (the negative space in the prototype). Cross-hatching breaks up the extra material, making it easier to remove during post-processing. During the build, the excess material provides excellent support for overhangs and thin-walled sections. After the first layer is cut, the platform lowers out of the way and new material is advanced. The platform rises to slightly below the previous height, the roller bonds the second layer to the first, and the laser cuts the second layer. This process is repeated as needed to build the part, which will have a wood-like texture. Because the models are made of paper, they must be sealed and finished with paint or varnish to prevent moisture damage.

The process has the following advantages: no chemical changes, and minimal heating, so the shrinkage is trivial, and stress induced deformation is very small; no dependency between the developing time and the heating time; the laser only has to cut the part outline and hatching, not all the internal area; no supports needed; the system is inexpensive to maintain; non-toxic materials; the machines are well suited to desktop operation.

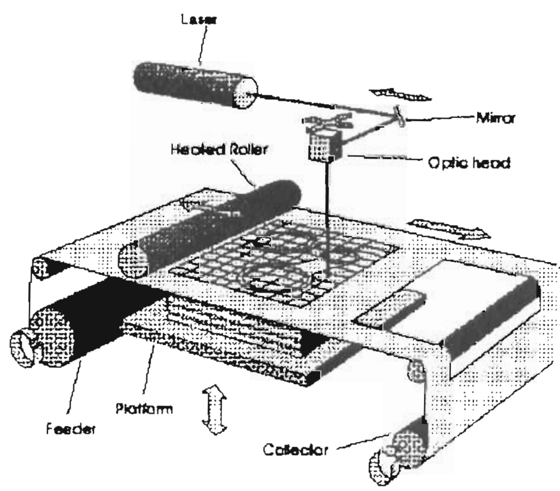

Fig.3

The process has the mainly disadvantages: removal of the tiles can be difficult because the laser cuts through the layers, not between them; delicate parts can be damage when removing tiles; enclosed volumes will trap the support material; the material properties change with the direction of the laminate; a great material percentage of the material is wasted; the surface is rough; machinability is limited because of delamination; ventilation is required for fumes when burning.

2.3. Selective Laser Sintering

Selective laser sintering was patented in 1989. The technique (figure 4) uses a laser beam to selectively fuse powdered materials into solid object. The materials being used or investigated include plastics, wax, metals and coated ceramics.

The process begins by laying down a thin layer of powder. After the powder is deposited on the part cylinder, the laser and scanner sinter, or melt, the powder into the desired two dimensional cross section. Next, the powder feed cylinder moves up to supply the next layer of powder and the part cylinder moves down to receive the next layer. The roller applies the layer of powder on the tabletop and levels and smoothes the new surface. The next section is then sintered, not only into desired cross section but also to the sintered layer beneath. As the part is built, the unsintered powder that remains in the part cylinder offers support for any overhangs or islands in the part, therefore no supports need to be built into the part.

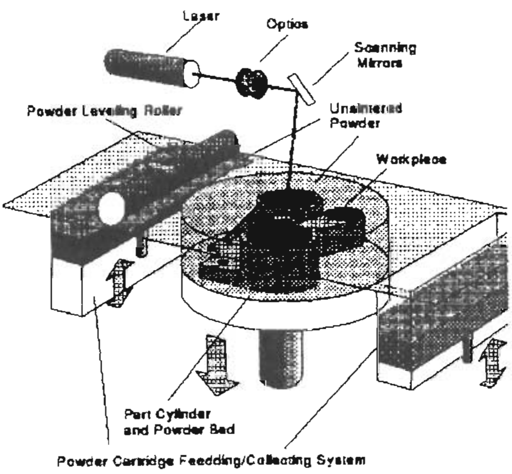

Fig. 4

The Laser Sintering process are classified into two groups: Indirect Laser Sintering and Direct Laser Sintering. Indirect Laser Sintering (which could also be called low-density matrix method) involve making relatively low-density metal objects and then infiltrating or post-sintering these objects to high density. Direct Laser Sintering (which could also be called high-density methods) creates high-density metal structure without a secondary processing step. The last method is still in the research stage.

The most acceptable parameters are: laser beam power; hatching distance; scanning speed.

The method advantages are: inexpensive and wide varieties of materials; safe materials; support not needed; reduced distortion from stress; produce parts simultaneously.

The method disadvantages are: rough surface finish; porosity of parts; the first layers may requires a base anchor to reduce thermal effects; part density may vary; material changes require cleaning of machine.

2.4. Fused Deposition Modeling

Stratasys, Inc. has developed the fused deposition modeling (FDM) technology which uses spools of thermoplastic filament for the fabrication of Prototypes (figure 5). Material is heated in a delivery head just beyond its melting point. The thermoplastic is then expelled from the head via a nozzle as a thin ribbon. The ribbon is deposited according to the geometry of the object as controlled by a computer. The FDM technology also builds prototypes in subsequent thin layers.

Layer thickness is dependent upon the physical properties of the material, extrusion pressure, delivery headspeed, and the dimensions of the nozzle exit. The temperatures of the liquefier and substrate are crucial to the surface finish of prototypes built using FDM technology.

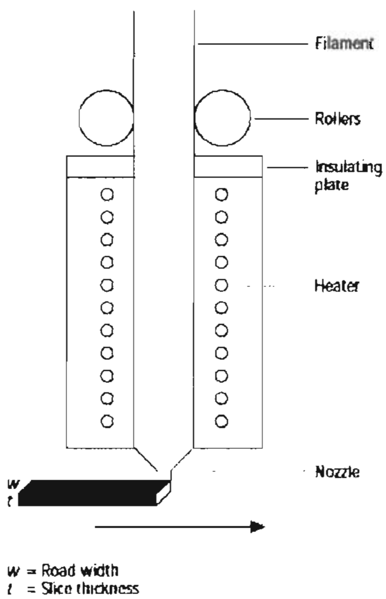

Fig. 5

FDM is an advantageous method as it offers a large variety of thermoplastic materials to build prototypes. Similarly, FDM is versatile in the environment in which it may be used. Due to the fact that no high-powered lasers are required in this technology, FDM machines may be used in an office environment as well as in laboratories.

2.5. Solid Ground Curing

Solid Ground Curing (SGC) was developed by Cubital, Ltd., in Israel. This technology involves the usage of photopolymer resins similar to those used in the stereolithography process. However, SGC technology does not uses lasers, rather, multiple steps must be completed to create prototypes.

Similar to other RP technologies, SGC requires a CAD model of the object to be prototyped. The CAD file is then downloaded to the Cubital work station or the Data Front End (DFE). The file is then converted into a Cubital Face List (CFL), which contains all necessary cross -section information for each layer. This information is used to create masks. A charge is created on a glass plate corresponding to the cross section of a layer. The charge is created by ionography. Next, black toner is spread across the plate and it adheres to the charged locations. Remaining toner is then removed. A substrate with a thin layer of resin is then moved to an exposure station (figure 6). The glass plate is then moved above the substrate and subjected to ultraviolet radiation. Thus, wherever the mask is transparent, the photopolymer is cured. Areas with the toner powder on the glass block out the radiation. After curing, an air knife removes any uncured resin remaining on the plate.

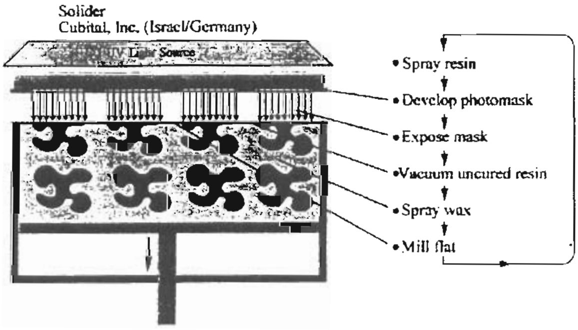

Fig. 6

The described procedures are repeated until the prototype is completed. SGC provides an advantage over all the other RP methods as it allows for prediction of build time. Each layer in the SGC process takes the same amount of time to build, independent of part geometry or size. Therefore, an accurate build time may be determined by multiplying the number of layers by the time per layer.

3. Conclusions

Rapid prototyping is an enable technology for concurrent engineering. Its goal is to reduce product development and manufacturing costs and lead times, thereby increasing competitiveness. Our interests in this field will grow, depending of our future material achievements.

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SINTEZA PRIVIND TEHNICILE DE RAPID PROTOTYPING

(Rezumat)

Termenul de rapid prototyping se referă la o clasă de tehnologii care se bazează pe construirea unor modele fizice plecându-se de la datele CAD ale acestora. La ora actuală se utilizează câteva tehnici diferite de rapid prototyping. În lucrare se prezintă o sinteză a acestor procedee, accentuându-se asupra avantajelor şi dezavantajelor fiecăruia în parte.

LA SYNTHÈSE SUR LES TECHNIQUES DES RAPID PROTOTIPYNG

(Résumé)

Le terme rapid prototyping décrit une class des technologies qui construisent les modèles physiques à partir des données CAD de celles-ci. Au présent ils existent quelques techniques des rapid prototyping. Cet article présent une synthèse de ces procédés en mettant en évidence les avantages et les désavantages de chacun.