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# A REVIEW ON RAPID PROTOTYPING AS ADVANCED MANUFACTURING TECHNOLOGY

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**Abstract:** In India the manufacturing scenario is undergoing major changes due to two reasons a revolutionary advancement in technology and opening of the economy to the world. A number of revolutionary concepts have emerged in the recent years. The most significant and the newest among them being rapid prototyping a technology which has the potential of directly converting the CAD date into the real object which has been the ultimate dream of the manufacturing technologies. A family of fabrication processes developed to make engineering prototypes in minimum lead time based on a CAD model of the item. This paper includes study of rapid prototyping method as a modern manufacturing technology.

**Keywords**: Rapid prototyping (RP), CAD, CAM, Manufacturing, GMP, LOM.

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## INTRODUCTION

With the globalization of economy the market has become very competitive and time is money. The period of theme between the birth of a product idea and the translation of that idea into reality is becoming shorter. This is where rapid prototyping comes. Rapid prototyping makes it possible to run through the development stages from design to prototype production as if by fast forward. This technology offers time saving about 90% and above.

## RAPID PROTOTYPING TECHNOLOGY

Rapid prototyping is a new name for a group of techniques that have largely developed during last ten years. They involve producing parts by adding layers of material on top of each layer to build a complete model.

Rapid prototyping refers to a range of new technologies for making dimensional prototypes in hours or minutes. While the conventional design phase to a plastic product time has been cut drastically by the swift development of electronic data processor (EDP) and computer aided technologies such as computer aided designing (CAD) and computer aided manufacturing (CAM) are no new comers, process does not stop at that As the CAD and the wide variety of software's, brilliant as it may be has one serious drawback, the virtual CAD model displayed on the computer screen cannot be touched or tested for its value in practical applications.

The rapid prototyping process match well with the current critical need of industry to shorten design cycle, to improve design quality with emerging prototyping methods, both designers and manufacturing engineers can see and hold physical model of the part designs in hours instead of weeks. They can sot and fix flaws quickly, although the cost of hardware is high. RP tech is so new that a standard name to describe it has yet to appear. Setup investment will range from Rs. 40 lacs to 2 crores. By rapid prototyping processes solid objects with prescribed shape, dimension and finish can be directly produced form CAD based geometry model data stored in a computer with human interventions.

Rapid prototyping can be of two types. The part obtained by rapid prototyping technology can be used as the prototype directly with requiring any further processing else the part obtained by rapid prototyping technology can be used to make moulds for casting the prototyping components.

Generative manufacturing processes (GMP) for the processes used to produce solid parts from CAD date directly in all types of GMP's the CAD model is split into layers of the slice. RP technologies are being used increasingly not only for prototypes but also to make production parts and production tooling.

There are various ways to classify the RP techniques that have currently been developed. The RP classification used here is based on the form of the starting material:

Liquid-based

Solid-based

Powder-based

RAPID PROTOYPING PROCESSES

TWO DIMENSIONAL LAYER BY LAYER TECHNIQUES :

SOLID FOIL POLYMERIZATION (SFP) :

In this process, solid polymerization is employed rather than liquid-to-solid polymerization as in most SL systems. The raw material consists of semi-polymerized plastic foil instead of liquid resins. Layer upon layer building process involves applying a foil to the newly created topmost, layer of the object and then polymerizing the required area by a scanning light beam. The illuminated portions polymerize further and stick to the layer underneath. Then illuminated portions also become insoluble due to polymerization so the unexposed portions can be removed later by dissolving them and the part with required shape and size will emerge. The raw material is in the form of thin foils. The actual creation is still done point-by-point (or line-by-line) instead of cutting along the boundaries of a cross section.

SELECTIVE POWER DINDING (SPB):

Selective power binding (also called three dimensional printing), being developed by Massachusetts Institute of Technology, is based on creating a solid object from a refractory power by selective binding through the application of a colloidal liquid silica binder. The liquid binder is applied selectively to thin layer of power, in the form of small droplets, using the ink-jet technology causing particles of power to stick together where the binder is supplied The process is also termed as 3 D-Printing by many. IN this process, a thin layer of ceramic power is laid on a flat bed. Next a fine jet of ceramic binder is ejected onto the powder at places where solidification is desires. This is done as the inkjet mechanism scans the layer by either ejecting the binder droplet at the identified locations or by deflecting the continuously emerging drops away from the locations where solidification is not wanted these are termed as drop-on-demand and continuous jet systems, respectively. The droplets are eclectically charged at the nozzle and then deflected by applying suitable voltages to electrodes located below the nozzle. The nozzle is moved across the powder surface in arrester scan while computer generated electrical signals control the deposit of the binder. After the selective binding of the topmost power layer is An ink-jet mechanism shown schematically above. A vacuum is applied to the reservoir such that a negative head pressure is maintained at the face plate capillary force at the face plate orifice prevents the binder liquid from being pulled in through the mechanism the mechanical impulse created on applying election of droplet from the face plate. The print head consists of an array of a large number of jet ports each one capable of operating at 10 kHz., with an array of high frequency jets, the layer solidification time can be 4 s layer for a drop-on-demand system with a layer size of 0.5 m x 0.5 m. it can be as low as a fraction of a second for continuous jet system. After building up the part is cured at 120 C for two hours. Then, the unbound powder is removed.

The major problem with the parts produced by this technique is inadequate surface finish. Removal of unbound powder from narrow passages and enclosed cavities also poses difficulties. This process is however very convenient for making moulds with integral cores. Since the fabrication of the mould and the core is done a single unit, the registration of cores to the mould is precise.

3. BALLISTIC PARTICLE MANUFACTURING:

Perception system inc. has developed the ballistic particle manufacturing technique for creating three-dimensional solid objects from the computer model directly as the name suggests, parts are produced by shooting droplets of molten material at required places. As in the selective powder binding process, here also material is supplied through an array of drop-on-demand ink-jet parts. Molten wax droplets, approximately 50 mm in a diameter, are ejected at rates upon 12,500 droplets per second. BPM is possible for both layer two dimensional fabrications and direct three- dimensional fabrication. Two dimensional layer-by-layer processes are based on generating layers by the water droplets. The usual slicing of the part-support integrated model yields two dimensional layers a portion of which belongs to the art to be generated and the rest to the support structure. The part is generated from was whereas the support is developed from polyethylene glycol, a synthetic was that is soluble in water. The deposition of was and polyethylene glycol is done by sorting droplets from an array of 32 piezoelectric ink jet ports operating at 10 kH2 on contact with the previously generated layer, the hot droplets momentarily melt the contact surface of the preciously deposited layer. On subsequent cooling and solidification, a homogeneous material is formed of the desired shape. After all the layer have been deposited the object is placed in warm bath to dissolve the support material, leaving the desired object The finished part is removed from the bath and cleaned. The accuracy depends on the accuracy of deposition was drops which is dependent on the location of the piezoelectric jet system. And the ballistic paths of the individual droplets thus it is important for the jet ports to be as close to the substrate as possible to allow for a random droplet dispersion angle of up to 5. In the currently available systems parts have been generated with 90 mm layer thickness as the support structure is removed by dissolving it in warm water is essential to ensure that the support structure material is not completely enclosed by the part material. Small holes provided in such cases are usually adequate to allow the support material to be dissolved from internal cavities. The models produced by this technique can be very useful for investment casting.

4. SHAPE MELTING (SM):

This process was developed by Babcock and Wilcox. The basic idea behind this process is to build parts directly from welding material melted by string an arc as in welding. This is similar to the technique often used in the industry to repair worn components broken gear teeth etc. A band or a thread of metal is melted and deposited by are welding and the desired shape is obtained by controlling the position of the welder with the help of a robot presently not possible. The major advantage of this process is that the material parts reduced by the process can be directly used for making functional prototypes. The advantages also include high strength, isotopic material properties and the possibility of developing material parts with tailored properties. Move over a uniform fine grained microstructure is produced by the process.

5. LAMINATED OBJECT MANUFACTURING (LOM):

In laminated object manufacturing parts are produced by successive bonding of layers of sheet materials and laser cutting of the cross section. Thin layers of material like aper, plastics and composites are used. Helyiss inc. (formerly hydrometrics inc) has released the first commercial model of loam system.

Sheet material is dispensed as a ribbon from a foil and the unused portion is collected in a take up roll the material is coated with a heat sensitive thermal adhesive. When the fresh area comes over the working table a heated roller presses it down to the uppermost layer of the object under fabrication. After the top sheet adheres to the surface a $CO_2$ laser beam traces the bounders of the respective cross sections cutting the sheet the seed and the intensity of the beam are adjusted so that only the supper most layer is cut. To increase the speed of production more than one sheet can also be cut simultaneously. The material immediately outside the desired cross section is usually cross hatched by the laser beam into squares (called titles) to facilitate easy sepia\ration after the part generation is over. After a layer is fused and cut the platform is lowered by one sheet thickness and the ribbon of sheet material is pulled by a little more than the length of the cross x\section into the rewinding roll (take up roll) the process is repeated until all the cross sections have been deposited and cut.

Though the laser beam can cut the layers to separate a cross section from the ribbon of the work material it cannot separate the layers ones they are fused this results in a problem where an unwanted part of an upper layer remains fused to the previous cross section. A hallow part cannot be generated by LOM as the excess material remains trapped inside, such parts can be generated in pieces. The difficult in removing the unwanted material can be resolved by removing the excess material as it is produced on each layer. This is proposed to be done by a vacuum pump to suck away the loosened pieces to get attached to a screen. But compared to most other GMPs LOM is a fastest as the layer need not be created and the laser beam has to trace only the outline of a particular cross section. Since only the contour has to be cut an x-y scanner is quite well suite and makes the control simple and computationally less intensive the materials used in LOM are non-toxic and so the machine is suitable in an office environment. The sheet thickness usually lies in the ranges of 0.05 mm to 0.25 mm since there is no shrinkage distortion and internals stresses are not present in LOM parts.

B. DIRECT THREE – DIMENSIONAL TECHNIQUES:

1. BEAM INTERFERENCE SOLIDIFICATION (BIS) :

The early method for creating three-dimensional object directly was patented by Formico graphic Engine and Batelle participated in its develop end in the sixties. The material which is used in the process is a photo sensitive transparent liquid plastic (monomer) when the liquid is hit by a laser beam of a specific frequency it reaches a reversible meta stable state and no bonding reaction takes place. But when a part of the liquid that is already in such a metastable state is hit by another laser beam of a specific but different frequency polymerization of the meta stable state takes place resulting in solidification of a vowel represented by the intersection of the two beams. Such a liquid resin is kept in a transparent vat and two laser beams are placed on adjacent sides. With the beams at right angles to each other pattern creation takes place by solidifying the resin at the point of intersection of the two beams and by moving the laser beams so that their point of intersection traces the required volume.

Though the principle is conceptually very elegant it has not found much practical application because of a number of serious difficulties. The intensity of beam decreases continuously during its passage through the resin because of absorption. This makes it difficult to programme the laser beam movement so that all vowels' are of uniform characteristics. The problem is further complicated because of shadow effects produced by the parts already solidified to overcome this an elaborate planning of beam movement is necessary to avoid the formation of a voxel after the front portion is solidified this eliminates a major advantage the direct three dimensional fabrication techniques claim to possess over the two dimensional layer-by –layer building processes.

2. PROGRAMMABLE MOULDING (PM) :

This is another exotic GMP under development by the US Navey David Taylor Research Centre. In this process electric fields are used to shape electro logical resins into three dimensional objects such fluids in the presence of an electric field tend to solidify (due to increase in their viscosity locally) and cure at an accelerate rate. The first step in this process consists of depositing as insulating material on this sheets of a conducting material (vix thin aluminum foil) and the uncovered portions of the foils from electrodes whose shapes represent the cross sections of the various layers of the objects to be generated.

STEREOLITHOGRAPHY (STL)

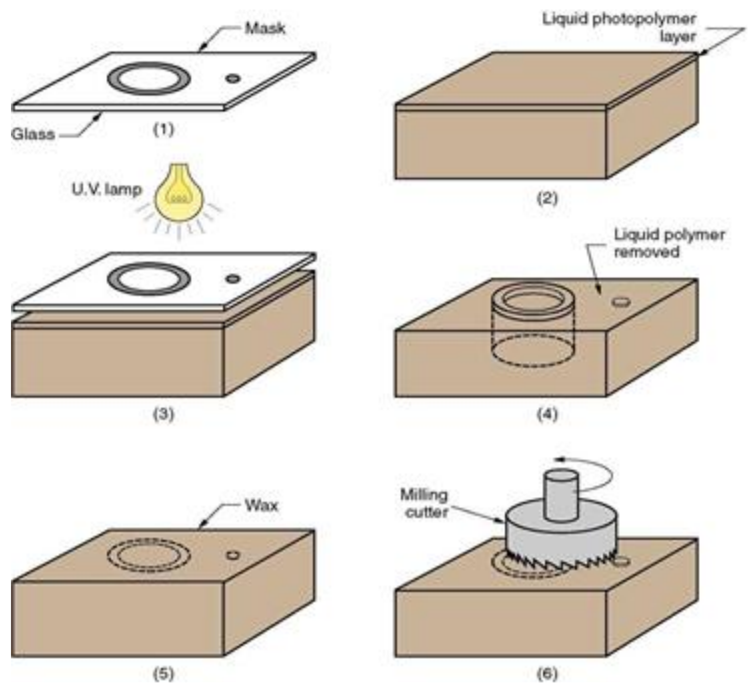
RP process for fabricating a solid plastic part out of a photosensitive liquid polymer using a directed laser beam to solidify the polymer Part fabrication is accomplished as a series of layers. Each layer is added onto the previous layer to gradually build the 3-D geometry. The first addition RP technology - introduced 1988 by 3D Systems Inc. based on the work of Charles Hull. Each layer is 0.076 mm to 0.50 mm (0.003 in to 0.020 in.) thick. Thinner layers provide better resolution and more intricate shapes; but processing time is longer. Starting materials are liquid monomers. Polymerization occurs on exposure to UV light produced by laser scanning beam.

Scanning speeds ~ 500 to 2500 mm/s

4) Solid Ground Curing (SGC)

Like stereolithography, SGC works by curing a photosensitive polymer layer by layer to create a solid model based on CAD geometric data. Instead of using a scanning laser beam to cure a given layer, the entire layer is exposed to a UV source through a mask above the liquid polymer, Hardening takes 2 to 3 s for each layer.

SGC steps for each layer: (1) mask preparation, (2) applying liquid photopolymer layer,(3) mask positioning and exposure of layer, (4) uncured polymer removed from surface, (5) wax filling, (6) milling for flatness and thickness.




In SGC, Sequence for each layer takes about 90 seconds. Time to produce a part by SGC is claimed to be about eight times faster than other RP systems.

The solid cubic form created in SGC consists of solid polymer and wax. The wax provides support for fragile and overhanging features of the part during fabrication, but can be melted away later to leave the free-standing part.

IV. RAPID PROTOTYPING APPLICATIONS:

Applications of rapid prototyping can be classified into three categories:

- Design
- Engineering analysis and planning
- Tooling and manufacturing

1) Design Applications: Designers are able to confirm their design by building a real physical model in minimum time using RP.

Design benefits of RP:

- Reduced lead times to produce prototypes
- Improved ability to visualize part geometry
- Early detection of design errors
- Increased capability to compute mass properties

Engineering Analysis and Planning: Existence of part allows certain engineering analysis and planning activities to be accomplished that would be more difficult without the physical entity.

- Comparison of different shapes and styles to determine aesthetic appeal
- Wind tunnel testing of streamline shapes
- Stress analysis of physical model
- Fabrication of pre-production parts for process planning and tool design

Tooling Applications

When RP is used to fabricate production tooling it is called as rapid tool making (RTM).

Two approaches for tool-making:

- Indirect RTM method
- Direct RTM method

**CONCLUSION:-**

Small batches of plastic parts that could not be economically molded by injection molding because of the high mold cost similarly parts with intricate internal geometries that could not be made using conventional technologies without assembly. Also One-of-a-kind parts such as bone replacements that must be made to correct size for each user. So rapid prototyping makes it possible to run through the development stages from design to prototype production as if by fast forward in the age of advance Manufacturing.

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