COURSE: ADVANCED MANUFACTURING PROCESSES

Module No. 5: OTHER PROCESSES

Lecture No-2 Rapid Prototyping Technology (RPT)

Background:
In this age of fast growth (rapid technology age), customer demands are increasing rapidly. Customers do not like to wait. The traditional processing time needs to be shortened. It is a ‘Buyers market’ today, instead of a ‘Sellers market’ as it used to be in the past. In the quest for fast manufacturing, all non-productive times need to be eliminated. The traditional method involves time loss on concept designing, manufacturing, assembly and testing. For example, in case of a foundry, lot of time is spent on pattern designing, making, getting the casting done and then evaluating its performance. This initially involves designing and redesigning, until a satisfactory product is developed, which is a very slow process. In order to get this time recovered, to overcome the slow trend and grow up with the requirements of the next generation, the most logical answer to the future of design and manufacturing is the Rapid Prototyping Technology (RPT).

Introduction:
Rapid prototyping (RP) is a technology wherein the physical modeling of a design is done using a specialized machining technology. The systems used in rapid prototyping quickly produce models and prototype parts from three-dimensional (3D) computer aided design (CAD) model data, magnetic resonance imaging (MRI) scan data and such data created from 3D digitizing systems. Using an additive approach for building shapes, the systems in RP join different materials like liquids or powder to form some physical objects. Layer by layer, the RP machines fabricate these powdered ceramic, wood, plastic and metal powders using very small and thin horizontal cross sections of the generated computer model. Rapid prototyping is an emerging technology, the definition of which is derived from the key concept - making it rapid. Rapid prototyping is creating a profound impact on the way companies produce models, prototype parts, and tooling. A few companies are now using it to produce final manufactured parts. It is
believed that rapid prototyping shall occupy a major share in manufacturing techniques in the years to come.

Steps in RPT

- Creation of the CAD model of the (part) design,
- Conversion of the CAD model into Standard Tessellation Language (STL) format,
- Slicing of the STL file into thin sections,
- Building part layer by layer,
- Post processing/finishing/joining.

Major RP Technologies:

1. Photo Masking or Solid Ground Curing technique.
2. LOM (Laminated Object Manufacturing)
3. SLA (Stereolithography)
4. FDM (Fused Deposition Modeling)
5. SLS (Selective Laser Sintering)
6. Thermo Jet Process
7. 3D Printing
8. Ballistic Particle Manufacturing (BPM)

1. Photo masking or Solid Ground Curing :

A mask is generated by electro-statically charging a glass plate with negative image of cross section of the required part. In the meantime, a thin liquid polymer is spread across the surface of the work-plane. The mask plate with a negative image of the liquid polymer is positioned over the thin polymer layer and exposed under the ultraviolet laser lamp for few seconds.

All parts of the exposed photopolymer layer get solidified with one exposure. However, the area shaded by the mask is left in a liquid form and is wiped off with vacuum suction head and replaced by hot wax which acts as a support to the solidified polymer layer. A face mill makes the surface of wax and polymer flat and to desired thickness. All the above steps are repeated till final model embedded in removable wax is obtained.
2. Laminated Object Manufacturing:

This technique is especially suited for producing parts from laminated paper, plastic, metal etc. The schematic of an LOM setup is shown in Fig. 5.2.1. A laser beam cuts the contour of part cross-section. Several such sections when glued or welded yield the prototype. The layers are built up by pulling a long, thin sheet of pre-glued material across the base plate and fixing it in place with a heated roller that activates the glue. Then a laser beam is scanned over the surface and cuts out the outline of that layer of the object. The laser intensity is set at just the level needed to cut through a single layer of material. Then the rest of the paper is crosshatched to make it easier to break away later. The base plate moves down, and the whole process starts again. The sheet of material is made significantly wider than the base plate, so when the base plate moves down, it leaves a neat rectangular hole behind. This scrap material is wound onto a second roller, pulling a new section across the base plate. At the end of the build process, the little crosshatched columns are broken away to free the object. The material used is usually paper, though acrylic plastic sheet, ceramic felts can be used. The LOM is particularly suitable for large models.
1. Stereolithography (SLA):

In this technology, the part is produced in a vat containing a liquid which is a photo-curable resin acrylate. Under the influence of light of a specific wavelength, small molecules are polymerized into larger solid molecules. The SLA machine, whose schematic is shown in Fig. 5.2.2, creates the prototypes by tracing the layer cross sections on the surface of liquid polymer pool with a laser beam. In the initial position the elevator table in the vat is in the top most position. The laser beam is driven in X and Y directions by programme driven mirrors to sweep across the liquid surface so as to make it solidified to a designed depth (say, 1 mm). In the next cycle, the elevated table is lowered further. This is repeated until the desired 3-D model is created. The figure shows a modified design in which a contact window allows the desired area to be exposed to light, masking the area which remains liquid.

![Fig. 5.2.2 Schematic of the Stereo lithographic process used in RPT.](image)

4. Fused Deposition Modeling:

In this technique, a spool of thermoplastic filament is fed into a heated FDM extrusion head. The X and Y movements are controlled by a computer so that the exact outline of each section of the
In this technique, the object is made by squeezing a continuous thread of polymer through a narrow, heated nozzle that is moved over the base plate. The thread melts as it passes through the nozzle, only to get hardened again immediately as it touches (and sticks to) the layer below. A support structure is needed for certain shapes, and this is provided by a second nozzle squeezing out a similar thread, usually of a different color in order to make it easier to distinguish them. At the end of the build process, the support structure is broken away and discarded, freeing the object. The FDM method produces models that are physically robust. Wax can be used as the material, but generally models are made of ABS plastic.

![Fig. 5.2.3 Schematic of the FDM process](image)

5. Selective Laser Sintering (SLS):

In this method, a thin layer of powder is applied using a roller. The SLS uses a laser beam to selectively fuse powdered materials, such as nylon, elastomers and metals into a solid object as shown in the Fig. 5.2.4. The CO₂ laser is often used to sinter successive layers of powder instead of liquid resin. Parts are built upon a platform which sits just below the surface in a bin of the heat-fusible powder. A beam of laser then traces the pattern on the very first layer thereby sintering it together. The platform is further lowered by the height of the second layer and
powder is again applied. This process is continued until the part is completed. The excess amount of powder at each layer helps to support the part during its build-up.

**Fig. 5.2.4 Schematic of the Selective Laser Sintering process**

6. 3-D Systems:

In this system, in order to build a part, the machine spreads a single layer of powder onto the movable bottom of a build box. A binder is then printed onto each layer of powder to form the shape of the cross-section of the model. The bottom of the build box is then lowered by one layer thickness and a new layer of powder is spread. This process is repeated for every layer or cross-section of the model. Upon completion, the build box is filled with powder, some of which is bonded to form the part, and some of which remain loose. The steps involved in the process are shown in Fig. 5.2.5.
7. **Thermo Jet Process:**

This technique uses an inkjet printing head with a binder material to bind ceramic and other powders spread by roller prior to application by a spray gun. Wax parts produced in this system can be used as sacrificial patterns for investment casting. The main advantage of the method is in the production of relatively complex castings without the need for a tooling, and hence cost effective. Complex metal parts may be produced from computer aided design (CAD) models in a relatively short period of time. Wax patterns need to be finished to a high standard. One problem with the system is the requirement of a support system. The support system leaves undulations on all downward facing surfaces of the pattern. Therefore, the supports need to be removed, and surfaces are required to be cleaned by hand. This process is best suited to small number of complex parts that would otherwise require a significant amount of coring to accommodate undercut features.

8. **Ballistic Particle Manufacturing (BPM):**

The BPM system uses piezo-driven inkjet mechanism to shoot droplets of molten materials which get cold-welded together on a previously deposited layer. A layer is created by moving the droplet nozzle in X and Y directions. The base-plate is lowered by a specified distance after a layer is formed, and a new layer is created on the top of the previous one; finally the model is created.
RAPID MANUFACTURING:

Rapid manufacturing may be considered as an extension of Rapid-Prototyping technology. It involves automated production of parts by instructions directly fed by the CAD data which is modeled earlier. Currently, only a few final products are prepared by these machines. This technology is not suitable for mass production but for small batches and one-off production articles, it is cheaper since no tooling is involved. Some of the final components that are produced are: customized dinner-ware, helmets for individual heads (customized), jewellery patterns, spark erosion electrodes and reverse engineering parts.

Applications of RPT:

- It is mainly used in modeling, Product Design and Development,
- Reverse Engineering applications,
- Short Production Runs and Rapid Tooling,
- In medical applications, RPT is used to make exact models resembling the actual parts of a person, through computer scanned data, which can be used to perform trial surgeries,
- RP techniques are used to make custom-fit masks that reduce scarring on burn victims,
- Selective laser sintering (SLS) has been used to produce superior socket knees,
- Very tiny, miniature parts can be made by electrochemical fabrication,
- In jewelry designs, crafts and arts.

Future developments:

- As the Rapid Prototyping Technology gets further advanced, it can lead to substantial reduction in build-up time for manufacturing.
- Further improvement in laser optics and motor control can improve the accuracy.
- The development of new materials and polymers so that they are less prone to curing and temperature induced warpages.
- Much anticipated development is the introduction of non-polymeric materials including metals, ceramics, composites and powder metallurgy.
- Developments in ceramic composites can further increase the range of rapid prototyping.
• Currently, the size is also a restriction; capability for larger parts shall be expected in the near future.

• Currently, the demand is low and with the further technology advancement, awareness and training, this can be increased.

• Advancement in computing systems and viability to support net designs from a distant country to be fed directly on the RP machines for manufacturing is a new possibility.

**Limitations and Challenges ahead:**

• Unfamiliarity with the application of RPT exists. Therefore, its complete adaptability and how exactly this new and advanced technology will be of help and is not known.

• In view of high equipment cost, very few organizations can invest in these new machines.

• Currently, RPT is more limited to modeling, specimen making and designing.

• The RPT is at present limited to making of paper and plastic type products only.

• Replacing steel by composites is still not easy and people fear its implications.

• RP companies usually limit the marketing efforts and industry awareness; hence most engineering and manufacturing professionals are not fully aware of the RP potentials.

The Fig. 5.2.6 indicates some common appliances, wherein the blades of fan, covers and components of oven, projectors are made by the rapid manufacturing techniques.
Fig. 5.2.6 Some applications of Rapid Manufacturing