2

RPT – (A)

RAPID PROTOTYPING

MODULE – I.

INTRODUCTION :

Global Competition, Customer driven product customization accelerated product obsolescence and Continued demands for cost savings are forcing companies to look for New Technologies to improve their business processes and speed up the product development cycle.

Rapid Prototyping (RP) has emerged as a key enabling technology with its ability to shorten product design and development time. RP technologies can be virtual and physical.

VIRTUAL PROTOTYPING [VP] :

Virtual prototyping is a means of carrying out the analysis and simulation of products employing digital mock-ups (3D product representations). This allows product performance to be investigated before any physical parts are built. VP is usually integrated with CAD/CAM and sometimes referred to as Computer Aided Engineering [CAE]

PHYSICAL PROTOTYPING :

3d printing

Physical RP builds tangible objects from computer data without the need of Jigs or fixtures or NC programming. This technology is also referred to as Layer manufacturing. Solid-free form fabrication, material addition manufacturing and three dimensional printing.

PROTOTYPE : * A prototype is the first or original example of something that has been or will be copied or developed. It is a model or preliminary version.

** An approximation of a product or system or its components in some form for a definite purpose in its implementation.

HISTORICAL DEVELOPMENT :

The development of RP is closely tied in with the development of applications of computers in the industry. The increase in the use of computers has spurred the advancement in many computer – related areas including computer-aided design (CAD), computer-aided manufacturing (CAM) and computer Numerical Control (CNC) machine Tools.

In particular, the emergence of RP system could not have been possible without the existence of CAD. However, Numerous RP systems in existence concludes that other than CAD, many other technologies and advancements in other fields such as manufacturing systems and materials have also been crucial in the development of RP systems.

The historical development of relevant technologies related to RP from the estimated date of inception is shown below.

YEAR OF INCEPTION	TECHNOLOGY
1770	Mechanization
1946	First computer
1952	First Numerical control (NC) machine Tool.
1960	First commercial laser.
1961	First commercial robot.
1963	First Interactive graphics system (early version of computer-aided design).
1988	first commercial rapid prototyping system.

The roots of RP can be traced from two technical areas Topography and photosculpture.

1) TOPOGRAPHY :

A layered method was proposed by Blanther in 1890 for making moulds for topographical relief maps. Both positive and Negative 3D Surfaces were to be assembled from a series of wax plates cut along the topographical contour lines.

This method was further refined by perera (1940), Zang (1964), Gaskin (1973), Matsubara (1972). They described a layer manufacturing process to form Casting moulds. The layers of the moulds are produced from refractory particles Coated with a photo polymer resins. The resin is selectively cured using light.

Dimatteo (1976) proposed a process for layer manufacturing 3D objects from contoured Metallic sheets that are formed using Milling cutter. Nakagawa reported the use of lamination techniques for fabrication of blanking tools, press forming tools and injection moulding Tools.

2) PHOTOSCULPTURE :

A Technique proposed in the 19th Century for Creating replicas of 3D objects. Morioka (1935, 1944) proposed the use of structured lighting to create Contour lines of an object Photographically and then using these lines to cut and build the object from sheets.

Bogart (1979) proposed a technique that involves Photographing the object simultaneously with 24 cameras equally spaced around a Circular room and then using the silhouette of each photograph to carve 1/24th of a cylindrical portion of the object.

→ A method for fabricating objects from powdered materials by heating particles locally and fusing them together employing a laser, electron beam, or plasma beam as proposed by (Ciraud, 1972)

→ A process for producing plastic patterns by selective 3D polymerization of a photosensitive polymer at the intersection of two laser beams, proposed by Swainson, 1977

→ A photopolymer RP system for building objects in layers [Kodama, 1981]. A mask is used to control the exposure of UV source when producing the cross section of the model.

→ A system that directs a UV laser beam to a polymer layer by means of a mirror system on an x-y plotter proposed by Herbert, 1982.

RAPID PROTOTYPING — AN INTEGRAL PART OF TIME COMPRESSION ENGINEERING

Time-Compression Engineering (TCE) is also known as Concurrent Engineering. The main enabling technology behind TCE is 3D CAD modelling. Concurrency in performing different design and manufacturing activities presents an opportunity to compress the overall product development time while opening up possibilities to be creative by providing more time for design iterations.

Concurrent engineering environments have evolved considerably to integrate 3D modelling with CAM, CAE, RPT and a number of other applications. The 3D model becomes a central component of the whole product or project information base which means that in all design, analysis and manufacturing activities the same data is utilized. There is no duplication and no-misunderstanding. product information captured in this way can be copied and reused.

CONCEPTUAL DESIGN → DETAIL DESIGN → ENGINEERING ANALYSIS → PROTOTYPING → TOOLING → PRODUCTION

PARALLEL PHASES BETWEEN GEOMETRIC MODELLING & PROTOTYPING

GEOMETRIC MODELLING

FIRST PHASE: 2D wireframe

- Started in Mid-1960's
- Few straight lines on display, may be circuit path on PCB.
- Based on plan view of a mechanical component
- 'Natural' drafting technique

SECOND PHASE: 3D curve and surface modelling.

- mid 1970's
- Increasing Complexity
- Representing more information about precise, shape, size and surface contour of parts.

THIRD PHASE: Solid modelling

- Early 1980's
- Edges, surfaces and holes are knitted together to form a cohesive
- Computer can determine the inside of an object from the outside. It can trace across the object and readily find all intersecting surfaces and edges

PROTOTYPING

FIRST PHASE: manual prototyping

- Traditional practice for many centuries
- prototyping as a skilled crafts is traditional or manual.
- Based on material of prototype.
- Natural prototyping machine.

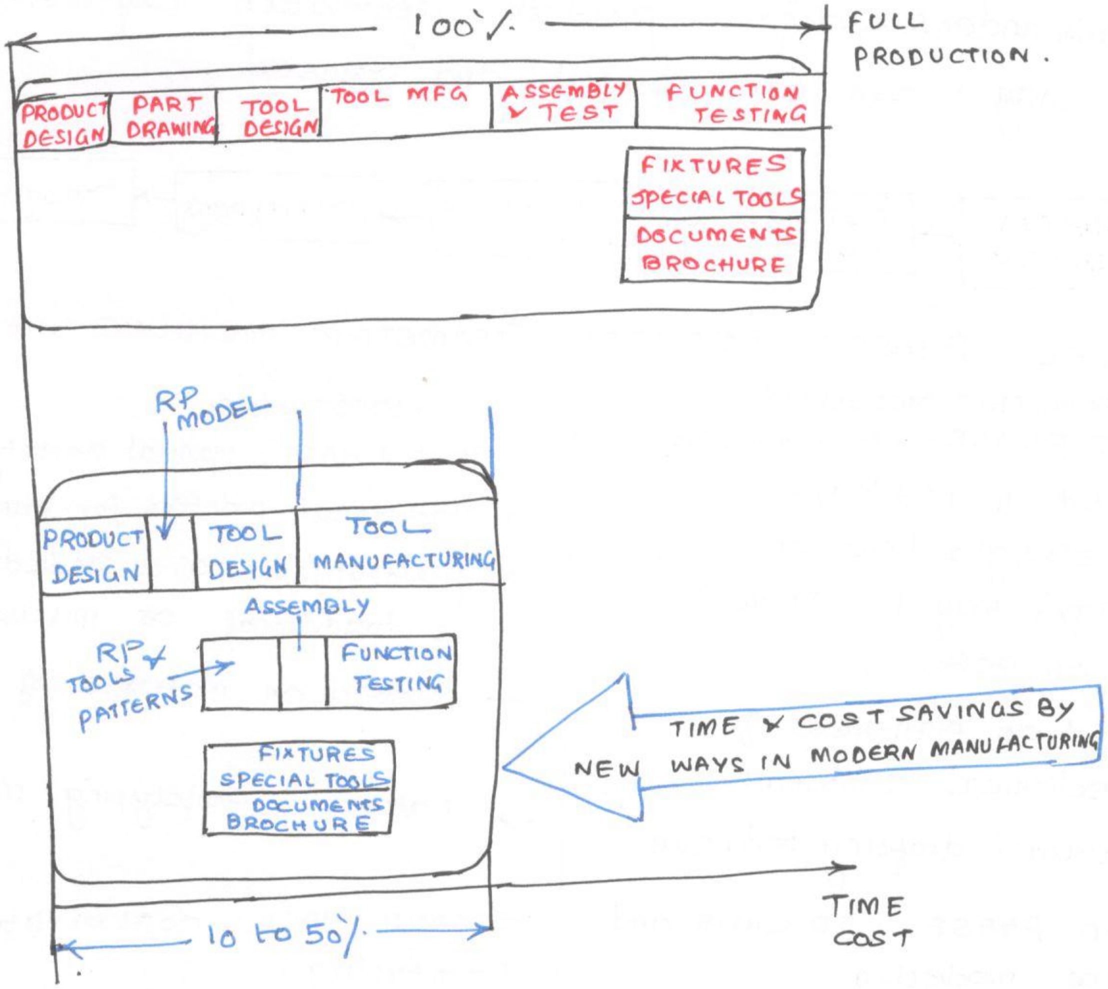
SECOND PHASE: Soft or virtual prototyping.

- mid 1970's
- Increasing Complexity
- virtual prototype can be stressed, simulated and tested, with exact mechanical and other properties.

THIRD PHASE: Rapid prototyping

- mid 1980's
- Benefit of a hard prototype made in a very short turnaround time is its main strong point (relies on CAD modeling)
- Hard prototype can also be used for limited testing.
- prototype can also assist in manufacturing of object.

RESULTS OF INTEGRATION OF RP TECHNOLOGIES



RP INFORMATION WORKFLOW:

The main stages in preparing and preprocessing data for automated fabrication of 3D objects are as follows.

1) DATA CREATION:

→ A 3D CAD package or 2D scanning device can be employed to create geometric data.

→ In both cases, the data must be represented in a model whose surface define a closed 3D volume without any holes, surfaces with zero-thickness or more than two surfaces meeting along common edges.

2) DATA EXPORT :

→ The valid 3D model is exported from the CAD package in a Neutral format, which in most cases is STL.

→ Some CAD packages allows the size of the generated file to be controlled by increasing or decreasing the model resolution.

3) DATA VALIDATION AND REPAIR :

→ The exported data is an approximation of the precise internal 3D model. During this approximation method, the model surfaces are represented with simple geometrical entities in the form of triangles.

→ STL models created in this way can contain considerable geometrical errors such as holes and overlapping areas along surface boundaries and generated files have to be validated before being further processed.

→ Some RP packages offer facilities for model repair, automatic and/or manual.

4) PART ORIENTATION AND SCALING :

→ RP systems builds parts along the Z-axis of their STL models.

→ Through Re-orientation of the parts relative to the model coordinate systems, their accuracy, surface finish and build time can be optimized.

→ RP systems allows some parts to be nested in a system chamber in order to be built simultaneously.

→ In addition, the parts can be scaled to compensate for anticipated anamolies that might be introduced because of processes such as deformation, Shrinkage, warpage and Curling.

5) SUPPORT STRUCTURES GENERATION :

→ Liquid based RP processes requires support structures to build overhanging areas of the parts.

→ These structures are usually generated automatically employing specialized software tools.

6) SETTING-UP OF PROCESS PARAMETERS :

→ Process related parameters are entered to specify the build style and desired system attributes

→ These parameters can be adjusted based on part requirements and the RP material being used.

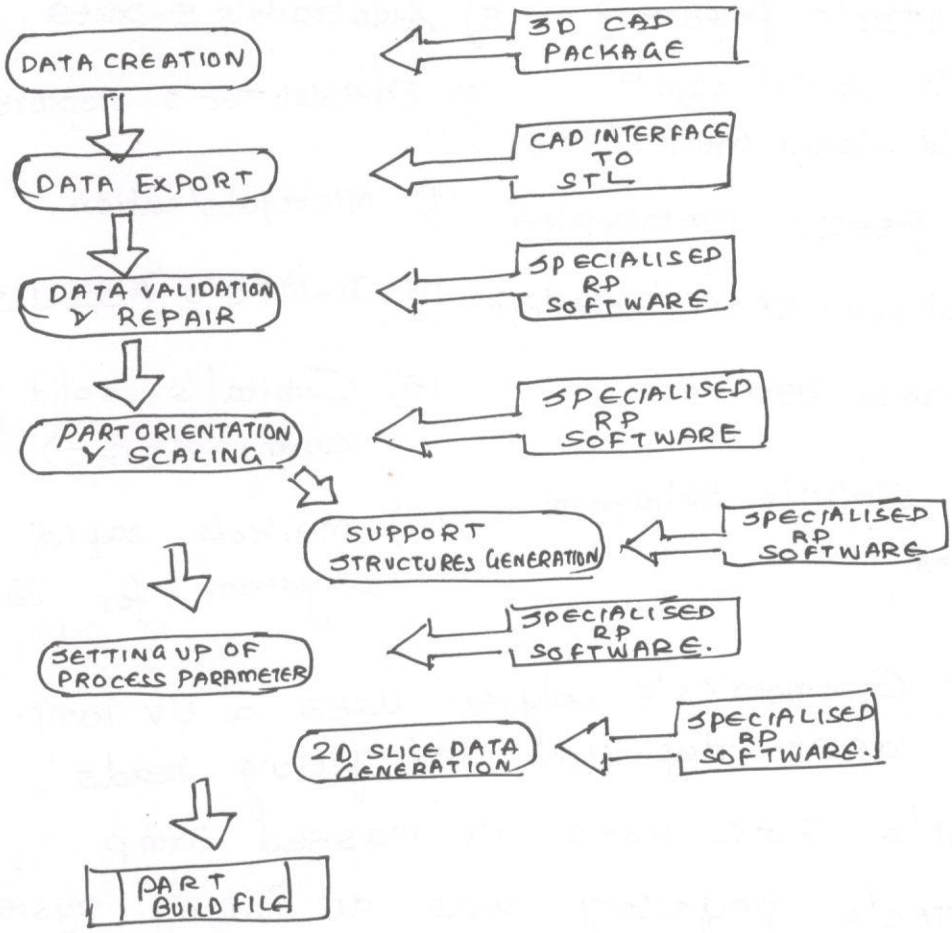
7) 2D – SLICE DATA GENERATION :

→ The STL file is sliced to produce successive cross sectional layers.

→ In each cross section, polylines are used to approximate the exterior and interior boundaries of the RP models.

→ These polyline boundaries can be offset by a particular value to compensate for process errors.

The RP Information workflow is shown below.



CLASSIFICATION OF RAPID PROTOTYPING SYSTEMS

All RP systems can be easily categorized into (i) Liquid-Based (ii) Solid based (iii) powder-Based.

LIQUID-BASED SYSTEM :

Liquid Based RP System have initial form of their material in liquid state. Through a process commonly known as 'Curing' the liquid is converted into the solid state.

The following RP systems fall into this category.

1) 3D systems Stereolithography apparatus (SLA)
2) Object Geometries Ltd's polyjet.
3) D-MEC's Solid Creation System.

4) EnvisionTec's perfactory. 5) Autotrade's E-Darts.
6) CMET's solid object ultraviolet-laser printer (SOUP) 7) EnvisionTec's Bioplotter.
8) Rapid freeze prototyping 9) Microfabrication.
10) Microfabrica EFAB Technology 11) D-MEC's ACCULAS
12) Two laser Beams 13) Cubital's solid ground curing (SGC)
14) Teijin Seiki's Solid form system 15) Meiko's rapid prototyping system for Jewelry industry

→ Object Geometries's polyjet uses a UV lamp for curing after deposition via jetting heads.

→ Cuboidal's SGC uses UV masked lamp.

→ EnvisionTec's perfactory uses an imaging system called digital light processing

→ DMEC's ACCULAS uses a different system called digital mirror device (DMD)

→ EnvisionTec's Bioplotter uses an extrusion method in a liquid medium.

→ Rapid freeze involves the freezing of water droplets and deposits in a manner just like FDM to create the prototype.

→ Microfabrica EFAB Technology uses an electro deposition method in a liquid medium.

SOLID BASED RP SYSTEM :

Solid Based RP System are meant to encompass all forms of material in the solid state. Solid form can include the shape in the form of wires, rolls, laminates and pellets.

RP System falls into this definition :

1) Stratasy's fused deposition modeling (FDM)
2) Solid scape's bench top system .
3) Cubic Technologie's laminated object Manufacturing [LOM]
4) 3D Systems multi-jet modeling system [MJM]
5) Solidimension's plastic sheet lamination (PSL)/3D system's invision LD sheet lamination .
6) Kira's paper lamination Tech (PLT)
7) CAM-LEM's CL 100 .
8) Shape deposition manufacturing process .

→ Method's 1, 2, 4, 7, 8 belongs to the category of melting and solidifying or Fusing method.

→ Cutting and Gluing or Joining method is used for RP systems in 3, 5, 6,

POWDER BASED RP SYSTEM

The following RP system fall into this definition .

1) 3D System's Selective Laser Sintering [SLS]
2) Z Corporation's Three-dimensional printing [3DP]
3) EOS's EOSINT systems .
4) Optomec's laser Engineering Net shaping [LENS]
5) Arcam's Electron Beam melting [EBM]
6) Concept Laser GmbH's Laser CusinG
7) Sintermask Technologies AB's selective mask sintering (SMS)
8) 3 D - Micromac AG's microsintering
9) The Ex one Company's prometal .

10) Soligen's direct shell production casting
11) Fraunhofer's multiphase Jet solidification.
12) Aeromet Corporation's lasform Technology.

All the above RP system employ Joining / Binding method. The method of joining / Binding differs for the above system in that some employ a laser while others use a binder / glue to achieve the Joining effect.

RAPID PROTOTYPING :-

→ Rapid prototyping (RP) refers to the physical modeling of a design using specialized machining Technology. RP systems quickly produce models and prototype parts from model data (3D, CAD), MRI Scan data and data created from 3D digitizing systems.

→ Using an additive approach to building shapes, RP systems Join liquid, powder, or sheet materials to form physical objects.

→ Layer by Layer, RP machines fabricate plastic, wood, Ceramic and Metal powders using thin, horizontal Cross sections of a computer model.

→ Rapid prototyping is having 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.

STEPS IN RP TECHNOLOGY :

1) Creation of the CAD model of design
2) Conversion of CAD model into STL format
3) Slicing of STL file into thin sections.
4) Building part Layer by Layer.
5) Post processing / finishing and the Joining processes.

THE STL FORMAT :

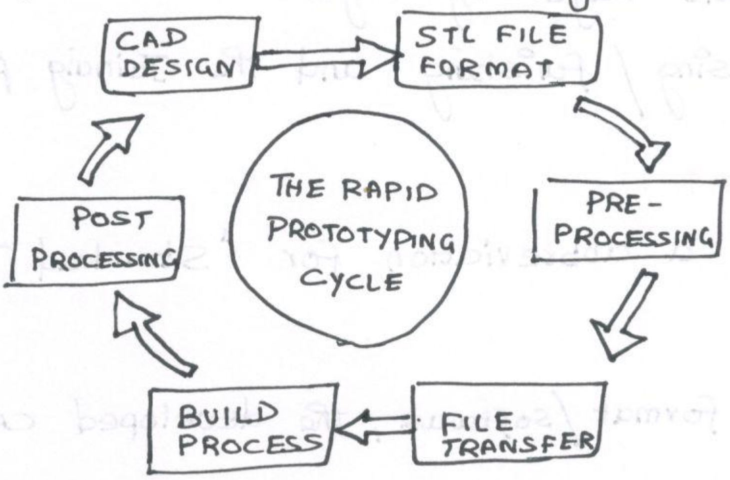
* The STL is a abbreviation for "Standard Triangulated Language"

* Through this format / software; the developed CAD model is

Converted into the form of Millions of small triangles.

* This later helps in storing and conversion of data.
* After the STL has been preprocessed and saved into a new slice file format, the new file can then be transferred to the RP system. File transfer can be done several ways, from manually transferring by disk or tape to Network transfer.

  Since more complicated files are usually very large, a local area Network or Internet is almost essential for easy file transfer.
* Once the final file formats are transferred to the RP device, the Build process occurs. Most RP machines build parts within a few hours.
* Upon completion of the Build process, Post processing of the part must occur. This includes removal of the part from the machine, as well as any necessary support removal and finishing, sanding or painting improving its appearance & durability.
* If the finished parts meets the necessary requirements, the cycle is complete. Otherwise, iterations can be implemented in the CAD file and cycle is repeated.
* The process is schematically shown.



DIFFERENT NAMES OF RPT

* Solid free form fabrication (SFF)
* Desktop manufacturing
* Automated fabrication.
* Tool-less Manufacturing
* Free-form fabrication.

* With the usage of stronger plastics and even metallic Materials in RP processes, parts can be produced that will withstand amount of stress and higher temperature ranges.

→ These parts can be applied in applications such as transonic wind-Tunnel testing, Snap-fit components, such as buckles, electronic devices, medical devices.

→ The capability to print a part in hours and plug it directly into an application is a powerful advantage to any manufacturing, design

SURVEY OF APPLICATIONS :

1) used in modeling, product design and development
2) Reverse Engineering applications.
3) Short production runs and Rapid Tooling.
4) 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.
5) RP techniques are used to make Custom-fit marks that reduce scarring on burn victims.

6) RP techniques like Selective Laser Sintering (SLS) has been used to produce socket knees which are of superior quality

7) Very tiny, miniaturized parts can be made by electrochemical fabrication.

8) In Jewelry designs, crafts and arts.

Advantages of Rapid prototyping:

a) Process is fast and accurate.
b) Superior quality surface finish is obtained
c) Separate material can be used for component and support
d) No need of Jigs and fixtures.
e) No need of mould or other Tools.
f) Post processing includes only finishing and cleaning
g) Minimum material wastage.
h) Reduces Product development time considerably.

RPT-A5

RAPID PROTOTYPE

FINISHING PROCESS

- Machining : milling, Lathe, Boring, Grinding
- Sand blasting
- Polishing
- Coating
- Painting

APPLICATIONS

DESIGN	Engineering analysis and planning	Manufacturing and Tooling
• CAD-model verification (design specification) • Visualizing objects • Proof of concept • Marketing and presentation model	• Form and fit models • Flow Analysis • Analysis of stress distribution • Pre series parts • Diagnostic and pre-surgical operation planning • Design and fabrication of custom prostheses & implants	• Tooling mold parts – direct soft tools – Indirect soft tools – direct hard tools • Casting – sand casting – Investment casting – pattern casting – die casting. • EDM • Master models.

INDUSTRIES

- Aerospace
- Automotive
- Biomedical
- Jewelry
- Coin
- Tableware
- Consumer electronics
- Home appliances
- others.