UNIT 1- Module 1
INTRODUCTION OF ADDITIVE MANUFACTURING

Syllabus:

**Introduction:** Prototyping fundamentals, historical development, fundamentals of rapid prototyping, advantages and limitations of rapid prototyping, commonly used terms, classification of RP process.

**Textbook:** RAPID PROTOTYPING: PRINCIPLES AND APPLICATIONS by Chua C.K., Leong K.F. and LIM C.S.

INTRODUCTION

Subtractive Machining Processes: Milling, turning, drilling, planning, sawing, grinding, EDM, laser cutting, Water Jet Machining etc…

Additive Manufacturing: Stereo-lithography and Selective Laser Sintering

Formative Manufacturing Process: Bending, forging, electromagnetic forming and plastic injection moulding

Additive Manufacturing (AM) refers to a process by which digital 3D design data is used to build up a component in layers by depositing material. (From the International Committee F42 for Additive Manufacturing Technologies, ASTM)

Example: Stereo-lithography and Selective Laser Sintering

![Fig 1. Different types of Manufacturing Process](image)

![Fig 2. Additive Manufacturing Process Examples](image)
Additive Manufacturing (AM) also refers as 3D Printing, Rapid Prototyping.

Why for Additive Manufacturing?

- Product Customization can be possible
- Part Complexity products can be produced
- Wide range of Materials
- More Speed
- Part Quantity can be increased
- Cost can be reduced

![Fig. 2 Different components made with Additive Manufacturing](image)

**Prototype** is the first or original example of something that has been or will be copied or developed. It is a model for preliminary version and an approximation of a product (or system) or its components in some form for a definite purpose in its implementation. A **prototype** is an important and vital part of the product development process.

**e.g.:** A prototype of supersonic aircraft.

**Types of Prototypes:**

1. The implementation of the prototype from the entire product (or system) itself to its sub-assemblies and components…
2. The form of the prototype from a virtual prototype to a physical prototype…
3. The degree of the approximation of the prototype from a very rough representation to an exact replication of the product.

1. **The implementation aspect of the prototype** covers the range of prototyping the complete product (or system) to prototyping part of, or a sub-assembly or a component of the product.
An example of such a prototype is a test platform that is used to find the comfortable rest angles of an office chair that will reduce the risk of spinal injuries after prolonged sitting on such a chair.

2. Virtual prototypes that refers to prototypes that are nontangible, usually represented in some form other than physical, e.g. mathematical model of a control system. The second aspect of the form of the prototype takes into account how the prototype is being implemented.

An example is the visualization of airflow over an aircraft wing to ascertain lift and drag on the wing during supersonic flight.

3. It covers the degree of approximation or representativeness of the prototype. On one hand, the model can be a very rough representation of the intended product, like a foam model, to study the general form and enveloping dimensions of the product in its initial stage of development. On the other hand, the prototype can be an exact full scale exact replication of the product that models every aspects of the product

An example of this is the building of catches with different material to find the right “clicking” sound for a cassette player door.

Roles of prototypes play in the product development process are several. They include the following: (1) Experimentation and learning (2) Testing and proofing (3) Communication and interaction (4) Synthesis and integration (5) Scheduling and markers

Rapid prototyping typically falls in the range of a physical prototype, usually are fairly accurate and can be implemented on a component level or at a system level.

Rapid Prototyping of physical parts, or otherwise known as solid freeform fabrication or desktop manufacturing or layer manufacturing technology, represents the third phase in the evolution of prototyping.

History of Additive Manufacturing (Rapid Prototyping):

<table>
<thead>
<tr>
<th>Year of Inception</th>
<th>Technology</th>
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<tbody>
<tr>
<td>1770</td>
<td>Mechanization [4]</td>
</tr>
<tr>
<td>1946</td>
<td>First Computer</td>
</tr>
<tr>
<td>1952</td>
<td>First Numerical Control (NC) Machine Tool</td>
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<tr>
<td>1960</td>
<td>First commercial Laser [5]</td>
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<tr>
<td>1961</td>
<td>First commercial Robot</td>
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<tr>
<td>1963</td>
<td>First Interactive Graphics System</td>
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<tr>
<td></td>
<td>(early version of Computer-Aided Design) [6]</td>
</tr>
<tr>
<td>1988</td>
<td>First commercial Rapid Prototyping System</td>
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</tbody>
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Fig 3. History of Rapid Prototyping

<table>
<thead>
<tr>
<th>AM applications timeline</th>
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<tbody>
<tr>
<td>This timeline lays out past, present and potential future AM developments and applications.</td>
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<tr>
<td>(courtesy of Graham Tromans)</td>
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<tr>
<td>1968-1994 rapid prototyping</td>
</tr>
<tr>
<td>1994 rapid casting</td>
</tr>
<tr>
<td>1995 rapid tooling</td>
</tr>
<tr>
<td>2001 AM for automotive</td>
</tr>
<tr>
<td>2004 aerospace (polymers)</td>
</tr>
<tr>
<td>2005 medical (polymer jigs and guides)</td>
</tr>
<tr>
<td>2009 medical implants (metals)</td>
</tr>
<tr>
<td>2011 aerospace (metals)</td>
</tr>
<tr>
<td>2013-2016 nano-manufacturing</td>
</tr>
<tr>
<td>2013-2017 architecture</td>
</tr>
<tr>
<td>2013-2018 biomedical implants</td>
</tr>
<tr>
<td>2013-2022 in situ bio-manufacturing</td>
</tr>
<tr>
<td>2013-2032 full body organs</td>
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</tbody>
</table>
PHASES OF PROTOTYPING

Prototyping or model making in the traditional sense is an age-old practice. The fabrication of prototypes is experimented in many forms — material removal, castings, moulds, joining with adhesives etc. and with many material types — aluminium, zinc, urethanes, wood, etc. Prototyping processes have gone through three phases of development, the last two of which have emerged only in the last 20 years. Like the modeling process in computer graphics [8], the prototyping of physical models is growing through its third phase.

i. First Phase: Manual Prototyping
ii. Second Phase: Soft or Virtual Prototyping
iii. Third Phase: Rapid Prototyping

FUNDAMENTALS OF RAPID PROTOTYPING
Common to all the different techniques of RP is the basic approach they adopt, which can be described as follows (see figure 4):

(1) A model or component is modelled on a Computer-Aided Design/ Computer-Aided Manufacturing (CAD/CAM) system. The model which represents the physical part to be built must be represented as closed surfaces which unambiguously define an enclosed volume. This means that the data must specify the inside, outside and boundary of the model. This requirement ensures that all horizontal cross sections that are essential to RP are closed curves to create the solid object.

(2) The solid or surface model to be built is next converted into a format dubbed the “STL” (STereoLithography) file format which originates from 3D Systems. The STL file format approximates the surfaces of the model by polygons. Highly curved surfaces must employ many polygons, which means that STL files for curved parts can be very large. However, there are some rapid prototyping systems which also accept IGES (Initial Graphics Exchange Specifications) data provided.

(3) A computer program analyses a STL file that defines the model to be fabricated and “slices” the model into cross sections. The cross sections are systematically recreated through the solidification of either liquids or powders and then combined to form a 3D model. Another possibility is that the cross sections are already thin, solid laminations and these thin laminations are glued together with adhesives to form a 3D model.

The development of RP can be seen in four primary areas. The Rapid Prototyping Wheel in Figure 1.3 depicts these four key aspects of Rapid Prototyping. They are: Input, Method, Material and Applications.
ADVANTAGES OF RAPID PROTOTYPING

The benefits of RP systems are immense and can be categorized into direct and indirect benefits.
Additive Manufacturing

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Fig. 6. Integration of Rapid Prototyping Technology within product cycle. The figure results that depending on the size of production, savings on time and cost could range from 50% up to 90%.

Fig. 7 Current and Potential industries for Additive Manufacturing
CLASSIFICATION OF RAPID PROTOTYPING

Classification of RP systems broadly by the initial form of its material, i.e. the material that the prototype or part is built with. In this manner, all RP systems can be easily categorized into (i) Liquid based RP, (ii) Solid based RP and (iii) Powder based RP

1. **Liquid-based RP** systems have the initial form of its material in liquid state. Through a process commonly known as curing, the liquid is converted into the solid state. The below systems belong to this category: 3D Systems’ Stereolithography Apparatus (SLA), Cubital’s Solid Ground Curing (SGC), Sony’s Solid Creation System (SCS), CMET’s Solid Object Ultraviolet-Laser Printer (SOUP), Autostrade’s E-Darts, Teijin Seiki’s Soliform System, Meiko’s Rapid Prototyping System for the Jewelry Industry, Denken’s SLP, Autostrade’s E-Darts, Teijin Seiki’s Soliform System, Meiko’s Rapid Prototyping System for the Jewelry Industry, Denken’s SLP, Autostrade’s E-Darts, Teijin Seiki’s Soliform System, Meiko’s Rapid Prototyping System for the Jewelry Industry, Denken’s SLP, Autostrade’s E-Darts, Teijin Seiki’s Soliform System, Meiko’s Rapid Prototyping System for the Jewelry Industry, Denken’s SLP, Autostrade’s E-Darts, Teijin Seiki’s Soliform System, Meiko’s Rapid Prototyping System for the Jewelry Industry, Denken’s SLP.

2. **Solid-based RP** systems are meant to encompass all forms of material in the solid state. In this context, the solid form can include the shape in the form of a wire, a roll, laminates and pellets. The below systems belong to this category: Cubic Technologies’ Laminated Object Manufacturing (LOM), Stratasys’ Fused Deposition Modeling (FDM), Kira Corporation’s Paper Lamination Technology (PLT), 3D Systems’ Multi-Jet Modeling System (MJM), Solidscape’s Model Maker and Pattern Maker, Beijing Yinhua’s Slicing Solid Manufacturing (SSM), Melted Extrusion Modeling (MEM) and Multi-Functional RPM Systems (M-RPM).

3. In a **Powder-based RP** the material will be in powder is by-and-large in the solid state. However, it is intentionally created as a category outside the solid-based RP systems to mean powder in grain-like form. All the below systems employ the Joining/Binding method. The method of joining/binding differs for the above systems in that some employ a laser while others use a binder/glue to achieve the joining effect.

   1. **3D Systems’s Selective Laser Sintering (SLS)**
   2. **Z Corporation’s Three-Dimensional Printing (3DP)**
3. EOS’s EOSINT Systems
4. Optomec’s Laser Engineered Net Shaping (LENS)
5. Soligen’s Direct Shell Production Casting (DSPC)
6. Fraunhofer’s Multiphase Jet Solidification (MJS)
7. Acram’s Electron Beam Melting (EBM)
8. Aeromet Corporation’s Lasform Technology
9. Precision Optical Manufacturing’s Direct Metal Deposition (DMD™)
10. Generis’ RP Systems (GS)
11. Therics Inc.’s Theriform Technology
12. Extrude Hone’s Prometal™ 3D Printing Process

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