CAD/CAM/CAE
Computer Aided Design/Computer Aided Manufacturing/Computer Aided Manufacturing

Part-1
Introduction to CAD/CAM
CAD/CAM

- **CAD/CAM** = Computer Aided Design and Computer Aided Manufacturing. It is the technology concerned with the use of computers to perform design and manufacturing functions.
• **CAD** can be defined as the use of computer systems to **perform certain functions in the design process**.

• **CAM** is the use of computer systems to **plan, manage and control the operations of manufacturing plant** through either direct or indirect computer interface with the plant’s **production resources**.
From CAM definition, the application of CAM falls into two broad categories:

1. Computer monitoring and control.
2. Manufacturing support application.
The Product Cycle and CAD/CAM

In order to establish the scope and definition of CAD/CAM in an engineering environment and identify existing and future related tools, a study of a typical product cycle is necessary. The following Figure shows a flowchart of such a cycle.
• The product begins with a need which is identified based on customers' and markets' demands.

• The product goes through two main processes from the idea conceptualization to the finished product:
  1. The design process.
  2. The manufacturing process.

The main sub-processes that constitute the design process are:
  1. Synthesis.
  2. Analysis.
Implementation of a Typical CAD Process on a CAD/CAM system

- Delineation of geometric model
  - Definition translator
  - Geometric model
  - Interface algorithms
  - Design and Analysis algorithms
  - Drafting and detailing
    - Documentation
      - To CAM Process

Design changes
### CAD Tools Required to Support the Design Process

<table>
<thead>
<tr>
<th>Design phase</th>
<th>Required CAD tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design conceptualization</td>
<td>Geometric modeling techniques; Graphics aids; manipulations; and visualization</td>
</tr>
<tr>
<td>Design modeling and simulation</td>
<td>Same as above; animation; assemblies; special modeling packages.</td>
</tr>
<tr>
<td>Design analysis</td>
<td>Analysis packages; customized programs and packages.</td>
</tr>
<tr>
<td>Design optimization</td>
<td>Customized applications; structural optimization.</td>
</tr>
<tr>
<td>Design evaluation</td>
<td>Dimensioning; tolerances; BOM; NC.</td>
</tr>
<tr>
<td>Design communication and documentation</td>
<td>Drafting and detailing…</td>
</tr>
</tbody>
</table>
Implementation of a Typical CAM Process on a CAD/CAM system

- Geometric model
- Interface algorithms
- Process planning
- NC programs
- Inspection
- Assembly
- Packaging

To shipping and marketing
## CAM Tools Required to Support the Design Process

<table>
<thead>
<tr>
<th>Manufacturing phase</th>
<th>Required CAM tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process planning</td>
<td>CAPP techniques; cost analysis; material and tooling specification.</td>
</tr>
<tr>
<td>Part programming</td>
<td>NC programming</td>
</tr>
<tr>
<td>Inspection</td>
<td>CAQ; and Inspection software</td>
</tr>
<tr>
<td>Assembly</td>
<td>Robotics simulation and programming</td>
</tr>
</tbody>
</table>
Definitions of CAD Tools Based on Their Constituents
Definition of CAD Tools Based on Their Implementation in a Design Environment

Design tools + Computer = CAD tools

Hardware
(control unit; display terminals; I/O devices)

Software (graphics; modeling; applications programs)
Definitions of CAM Tools Based on Their Constituents

- Networking concepts
- CAM tools
- Mfg tools
- CAD
Definition of CAM Tools Based on Their Implementation in a Manufacturing Environment

Mfg tools + Computer

Hardware
(control unit; display terminals; I/O devices)

Software (CAD; NC; MRP; CAPP…)

Networking

= CAM tools
Definitions of CAD/CAM Tools Based on Their Constituents

Mfg tools
Design tools
Networking
Geometric modeling
Computer graphics concepts

CAD/CAM tools
Definition of CAD/CAM Tools Based on Their Implementation in an Engineering Environment

Design and Mfg tools + Computer = CAD/CAM tools

Hardware

Software

Networking
Typical Utilization of CAD/CAM Systems in an Industrial Environment

Geometric modeling and graphics package

- Geometric modeling of conceptual design
- Is design evaluation Possible with available Standard software?
- Design testing And evaluation
- Is final design Applicable?
- Drafting
- Documentation

Yes

No

- Process planning
- Are there manufacturing discrepancies in CAD databases?
- No

Yes

- Develop customized programs and packages
- Programming package

- NC programming
- Machining
- Inspection
- Assembly

CAPP package

NC package

Inspection And Robotics package
Automation and CAD/CAM

Automation can be defined as the technology concerned with the application of complex mechanical, electronic, and computer-based systems in the operation and control of manufacturing systems.
Types of Manufacturing Systems

1. **Continuous-flow processes.** Continuous dedicated production of large amount of bulk product. Continuous manufacturing is represented by chemicals, plastics, petroleum, and food industries.

2. **Mass production of discrete products.** Dedicated production of large quantities of one product (with perhaps limited model variations). Examples include automobiles, appliances and engine blocks.

3. **Batch production.** Production of medium lot sizes of the same product. The lot may be produced once or repeated periodically. Examples: books, clothing and certain industrial machinery.

4. **Job-shop production.** Production of low quantities, often one of a kind, of specialized products. The products are often customized and technologically complex. Examples: prototypes, aircraft, machine tools and other equipment.
Production quantity

Continuous-flow production

Mass production

Batch production

Job shop production

Product variety
<table>
<thead>
<tr>
<th>Category</th>
<th>Automation achievements</th>
</tr>
</thead>
</table>
| Continuous-flow process        | • Flow process from beginning to end  
• Sensors technology available to measure important process variables  
• Use of sophisticated control and optimization strategies  
• Fully computer automated lines |
| Mass production of discrete products | • Automated transfer machines  
• Dial indexing machines  
• Partially and fully automated assembly lines  
• Industrial robots for spot welding, part handling, machine loading, spray painting, etc.  
• Automated material handling systems  
• Computer production monitoring |
| Batch production               | • Numerical control (NC), direct numerical control (DNC), computer numerical control (CNC).  
• Adaptive control machining  
• Robots for arc welding, parts handling, etc.  
• CIM systems.                                                                     |
| Job shop production            | • Numerical control, computer numerical control                                                                                                         |
Most of the automated production systems implemented today make use of computers. CAD/CAM in addition to its particular emphasis on the use of computer technology, is also distinguished by the fact that it includes not only the manufacturing operations but also the design and planning functions that precede manufacturing.

To emphasize the differences in scope between automation and CAD/CAM, consider the following mathematical model:
$$TT_{lc} = BQT_1 + BT_2 + T_3$$

$TT_{cl} = \text{total time during the product life cycle}$

$B = \text{The number of batches produced throughout the product life cycle.}$

$Q = \text{The number of units produced in each batch.}$

$T_1 = \text{The time required to produce one unit of product.}$

$T_2 = \text{The time associated with planning and setting up for each batch of production.}$

$T_3 = \text{The time required for designing the product and for all the other activities that are accomplished once for each different product.}$

$T_{lc} = \text{The average time spent on each unit of product during its life cycle} = T_1 + \frac{T_2}{Q} + \frac{T_3}{BQ}$
Automation technology is concerned with reducing
the with emphasis on the unit production

time $T_1$

$T_2$ & $T_3$ become very important in job shop manufacturing.

Automation technology is concerned with reducing
$T_1$ & $T_2$ the with emphasis on the unit production
time $T_1$

$T_2$ & $T_3$ become very important in job shop manufacturing.

CAD/CAM concerned with reducing all three
terms, but is perhaps focused on $T_2$ & $T_3$ terms. The emphasis in CAD/CAM includes the design and planning function of the product life cycle.
Advantages of CAD/CAM systems

- Greater flexibility.
- Reduced lead times.
- Reduced inventories.
- Increased productivity.
- Improved customer service.
- Improved quality.
- Improved communications with suppliers.

- Better product design.
- Greater manufacturing control.
- Supported integration.
- Reduced costs.
- Increased utilization.
- Reduction of machine tools.
- Less floor space.