CMS Poseidon 5-Axis CNC machine with a stroke size of 7500 x 3500 x 2000 mm.
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.
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.

**Implementation of a Typical CAD Process on a CAD/CAM system**

1. **Delineation of geometric model**
   - **Definition translator**
   - **Geometric model**
   - **Interface algorithms**
2. **Design and Analysis algorithms**
   - **Drafting and detailing**
   - **Documentation**
   - **To CAM Process**
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>
Geometric modeling of conceptual design

Is design evaluation Possible with available Standard software?

Design testing And evaluation

Is final design Applicable?

Drafting

Documentation

Geometric modeling and graphics package

Design package

Typical Utilization of CAD/CAM Systems in an Industrial Environment

Geometric modeling and graphics package

Process planning

CAPP package

Are there manufacturing discrepancies in CAD databases?

NC programming

NC package

Machining

Inspection

Inspection And Robotics package

Assembly

Develop customized programs and packages

No

Yes

No

Yes

No

Yes
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
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.

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.
How do CAD/CAM systems work?

- Developing NC code requires an understanding of:
  1. Part geometry
  2. Tooling
  3. Process plans
  4. Tolerances
  5. Fixturing

- Most CAD/CAM systems provide access to:
  1. Part geometry
  2. Tooling

Instructions can be generated for a generic NC machine
- A set of tool paths and positions can be automatically generated
- These paths can be edited and modified
- These paths and instructions can be “posted” to a specific machine
Numerical Control (NC)

Programmable automation in which the mechanical actions of a ‘machine tool’ are controlled by a program containing coded alphanumeric data that represents relative positions between a work head (e.g., cutting tool) and a work part.
The Basic NC Process

1. Engineering design of a part
2. Develop manufacturing plan for the part
3. Program numerical control instructions
4. Process the program to develop cutter location data set
5. Postprocess for a specific machine tool
6. Input medium for machine tool
NC Coordinate Systems

For flat and prismatic (block-like) parts:
- Milling and drilling operations
- Conventional Cartesian coordinate system
- Rotational axes about each linear axis

For rotational parts:
- Turning operations
- Only $x$- and $z$-axes
Motion Control Systems

Point-to-Point systems
- Also called position systems
- System moves to a location and performs an operation at that location
- (e.g., drilling)
- Also applicable in robotics

Continuous path systems
- Also called contouring systems in machining
- System performs an operation during movement
- (e.g., milling and turning)
Interpolation Methods

1. Linear interpolation
   - Straight line between two points in space

2. Circular interpolation
   - Circular arc defined by starting point, end point, center or radius, and direction

3. Helical interpolation
   - Circular plus linear motion

4. Parabolic and cubic interpolation
   - Free form curves using higher order equations
Absolute vs. Incremental Positioning

Absolute positioning: \textit{Move is: }x = 40, y = 50
Incremental positioning: \textit{Move is: }x = 20, y = 30.
Computer Numerical Control (CNC)

- Storage of more than one part program
- Various forms of program input
- Program editing at the machine tool
- Fixed cycles and programming subroutines
- Interpolation
- Acceleration and deceleration computations
- Communications interface
- Diagnostics

Machine Control Unit

- **Memory**
  - ROM - Operating system
  - RAM - Part programs

- **Central processing unit (CPU)**

- **Input/output interface**
  - Operator panel
  - Tape reader

- **System bus**

- **Machine tool controls**
  - Position control
  - Spindle speed control

- **Sequence controls**
  - Coolant
  - Fixture clamping
  - Tool changer
NC Application Characteristics (Machining)

- Batch and High Volume production
- Repeat and/or Repetitive orders
- Complex part geometries
- Many separate operations on one part

**Cost-Benefits of NC**

**Costs**
- High investment cost
- High maintenance effort
- Need for skilled programmers
- High utilization required

**Benefits**
- Cycle time reduction
- Nonproductive time reduction
- Greater accuracy and repeatability
- Lower scrap rates
- Reduced parts inventory and floor space
- Operator skill-level reduced
NC Part Programming

1. Manual part programming
2. Manual data input
3. Computer-assisted part programming
4. Part programming using CAD/CAM

Part program: sequence of instructions (blocks)

Block Format: Organization of words within a block in NC part program.

Word address format: used on all modern CNC controllers
Uses a letter prefix to identify each type of word, Spaces to separate words within the block,
Allows any order of words in a block, Words can be omitted if their values do not change from
the previous block.

Types of Words

N - sequence number prefix
G - preparatory words: Example: G00 = PTP rapid traverse move
X, Y, Z - prefixes for x, y, and z-axes
F - feed rate prefix
S - spindle speed
T - tool selection
M - miscellaneous command: Example: M07 = turn cutting fluid on
Example: Word Address Format

N001 G00 X07000 Y03000 M03
N002 Y06000

Cutter Offset

Cutter path must be offset from actual part outline by a distance equal to the cutter radius.
Manual Data Input

- Machine operator does part programming at machine
  - Operator enters program by responding to prompts and questions by system
  - Monitor with graphics verifies tool path
  - Usually for relatively simple parts
- Ideal for **small shop** that cannot afford a part programming staff
- To minimize changeover time, system should allow programming of next job while current job is running
Computer-Assisted Part Programming

- Write machine instructions using natural language type statements
- Statements translated into machine code of the MCU
- APT (Automatically Programmed Tool) Language

Sample Statements

- Part is composed of basic geometric elements and mathematically defined surfaces
- Examples of statements:
  - \texttt{P4 = POINT/35,90,0}
  - \texttt{L1 = LINE/P1,P2}
  - \texttt{C1 = CIRCLE/CENTER,P8,RADIUS,30}
- Tool path is sequence of points or connected line and arc segments
- Point-to-Point command: \texttt{GOTO/P4}
- Continuous path command: \texttt{GOLFT/L1,TANTO,C1}
NC Part Programming Using CAD/CAM
What do I need to begin MasterCAM?

- **Part geometry:** Draw or import
- **Tooling:** Library or create
- **Process plans:**
- **Fixtures:** Define orientation and location

**Mastercam** is a three-dimensional geometry creation engine along with features to aid in tool path generation and verification. MasterCAM allows tool path planning and NC code generation for a given part. This part can either be drawn in MasterCAM or imported from other CAD packages.

**MasterCAM Drawing**

- Geometrical part drawing: In-built CAD package [2D parts, 3D parts]
- Translators (include): [IGES, DXF (AutoCad), CADL (CADKey)]

**Tool Path Generation using MasterCAM**

- Tool path generation:
  - Extensive Tool library
  - Machining parameter selection
  - NC program generator
  - Animation to visualize machining operations
Getting Started with 2D Drawing

Create simple 2D Geometries using basic shapes say a Rectangle

Building 2D Geometry

Place and Dimension the Shape
Getting started with Toolpaths

Click on Main Menu [Toolpaths].
MasterCAM lists the different machining operations
Contouring Options

By Selecting Contour the various Contouring Options are listed. Select Chain and the geometry chains up and shows tool travel direction.

Defining Tool Parameters

Select the Contour type and Tool Parameters Window pops up. Feed the Right Parameters and Right Click to Select Specific Tools.

Selecting the Tools

MasterCAM has a whole range of tools in a tool library from which tool selections can be made. Now feed the correct parameters. You can also specify your own tools.
Displaying Toolpaths

Once both the Tool parameters and Contour Parameters have been Correctly defined. Click Ok to display the Toolpath.
Useful Links:

http://buildyourcnc.com/default.aspx
http://www.cnczone.com/
http://www.cnccontrols.com/
http://www.cncmasters.com/
http://www.advancedindustriesinc.com/
http://www.haascnc.com

http://cncci.com/resources/links.htm