COMPUTER NUMERICAL CONTROL OF
MACHINE TOOLS

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Chapter 18:
Computer Aided Manufacturing
# Chapter 18: Computer Aided Manufacturing (CAM)

1. **Definition & Strategic Role of CAM**
2. **Theory & Application**
3. **Numerical Control & CAM**
4. **Flexible Manufacturing Systems & CAM**
5. **CAM Software Survey**
6. **Future of CAM Systems**
7. **CAD/CAM Tutorial**

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Objectives of Chapter 18

- Understand **Computer Aided Manufacturing (CAM)** and its strategic role in the production
- Know about how **CAM** and **CNC** are strongly related
- Discuss about **Flexible Manufacturing Systems** and how **CAM** can be integrated
- Meet the variety of **CAM** software
- Learn some basic programming methods in a **CAM** software
**Definition**

Computer Aided Manufacturing (CAM) can be defined as the use of computer systems to **plan**, **manage** and **control** the **operations of a manufacturing plant** through either direct or indirect computer interface with the plant’s production resources.

- In other words, the **use of computer system in non-design activities** but in manufacturing process is called **CAM** (Elanchezhian et al. 2007)

**Strategic Role of CAM**

- The application of CAM in the production offers advantages to a company to **develop capabilities** by combining traditional economies of scale with economies of scope resulting in the **desired flexibility and efficiency**
Definition

Strategic Role of CAM

- Amongst other benefits provided by CAM, Post identifies the following (Post 2003):
  - Greater supervision of the production
  - Fast response to changes in market demand
  - Greater flexibility
  - Product variety
  - Small lot-sizes
  - Distributed processing capability
  - Reduced waste
History

- The roots of CAD/CAM trail back to the beginning of civilization, when the engineers of the ancient civilizations such as Egyptians, Greeks and Romans acknowledged the importance of the graphical communication.

- Later on, Leonardo Da Vinci developed technics, such as cross-hatching and isometric views.

- The invention of computers and xerography made possible the creation of graphics and visualization (Zeid 1991).

- In the early 1950s, shortly after the World War II, the need for complex parts led to the invention of the Numerical Control (NC) that substituted the requirements for skilled human machine operators (Chang et al. 2006).
History

- At the same time another invention, namely the *digital computer*, assisted the development of **NC** and provided the means for the creation of **robots**, **computer-aided design (CAD)**, **computer-aided manufacturing (CAM)** and **flexible manufacturing systems (FMS)**

- The utilization of **CAM** software systems began in large automotive and aerospace industries in 1950

- During the late 1950s, **APT (Automatically Programmed Tools)** was developed and in 1959, General Motors (GM) began to explore the potential of interactive graphics.

- By the mid-1960s, the term **Computer-Aided Design (CAD)** started to appear. GM announced their **DAC-1 system (Design Aided by Computers)** in 1964
The decade of 1970 can be characterized as the golden era of computer drafting and the beginning of ad hoc instrumental design applications (Zeid 1991)

Among the first CAD/CAM systems was UNISURF that was developed by Pierre Bezier in 1971 for the Renault industry and allowed surface modelling for automotive body design and tooling (Bezier 1989)

In 1979 the IGES (Initial Graphics Exchange Specification) was initiated and it enabled the exchange of model databases among CAD/CAM systems
Theory and Application

History

- Other notably standards that were developed in the same period include (Zeid 1991):
  
  - **GKS. ANSI** and ISO standard that interfaces the application program with the support package
  - **PHIGS**, that supports high function workstations and their related CAD/CAM applications
  - **VDI** (Virtual Device Metafile), that describes the functions needed to describe a picture
  - **NAPLPS**, that describes text and graphics in the form of sequences of bytes in ASCII code

- The computers evolved rapidly and today’s systems are capable of planning, scheduling, monitoring, decision-making and generally managing all the aspects of the manufacturing procedure, even “think” and adapt to changes automatically (Chang et al. 2006)
The immense international competition that appeared in 1980s and the high demand for industrial products became a worldwide phenomenon, therefore, manufacturers were forced to adapt to the changes.

Small batches, reduced inventories, dynamic environment and rapid changes of the environment call for increased flexibility and exploitation of the state of the art technological achievements.

CAM was recognized as a solution to effectively cope with the requirements in the shop-floor level.
The **CAM** systems act as an interface between **CAD** and **NC** machines.

The complex drawings created by **CAD** tools require “translation” in order to produce the coding for the **NC** machines.

Alongside with **CAD**, robotics and **CNC**, **CAM** is exploited by the majority of the production systems nowadays.

Some of the most recent developments in **CAM** systems include **rapid prototyping**, **micro-electromechanical systems** (**MEMs**), **nanotechnologies** and **artificial intelligence**.

Figure 1: Example of an up-to-date CAM software workspace
(Photo of MasterCAM)
The evolution of virtual manufacturing has led to the creation of work-cell simulation tools that are capable of developing, simulating and validating manufacturing processes.

Moreover, off-line programming of multi-device robotic and automated processes (virtual commissioning) offer optimization functionalities, from the concept to the implementation phase.

At the 2000s, commercial CAM suites provided complete solutions to Product Lifecycle Management (PLM) in multiple stages of the production, i.e. conceptualization, design (CAD), manufacturing (CAM) and engineering (CAE).

A great number of CAD tools exist today that provide functionalities of CAM/CAE (Chryssolouris 2005).
In Figure 2 the evolution of software and hardware systems related to CAD/CAM is presented (Chang et al. 2006)

<table>
<thead>
<tr>
<th>SOFTWARE</th>
<th>HARDWARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945</td>
<td>James T. Parsons Proposed NC concept</td>
</tr>
<tr>
<td></td>
<td>MIT servo mechanism lab</td>
</tr>
<tr>
<td></td>
<td>USAF NC milling m/c proj.</td>
</tr>
<tr>
<td>1950</td>
<td>1st successful demo</td>
</tr>
<tr>
<td>1953</td>
<td>Automatic tool changer – IBM</td>
</tr>
<tr>
<td></td>
<td>1st production skin-miller – G&amp;L</td>
</tr>
<tr>
<td></td>
<td>Machining center – K&amp;T</td>
</tr>
<tr>
<td>1960</td>
<td>1st industrial robot</td>
</tr>
<tr>
<td></td>
<td>CRT display</td>
</tr>
<tr>
<td></td>
<td>Adaptive control – Bendix</td>
</tr>
<tr>
<td>1965</td>
<td>7,700 NCs installed</td>
</tr>
<tr>
<td></td>
<td>CNC, DNC concept &amp; mini – computers, PLC</td>
</tr>
<tr>
<td></td>
<td>1st DNC system</td>
</tr>
<tr>
<td>1970</td>
<td>CAM, CAD/CAM</td>
</tr>
<tr>
<td></td>
<td>Microcomputers</td>
</tr>
<tr>
<td></td>
<td>FMS</td>
</tr>
<tr>
<td>1975</td>
<td>Superminicomputers</td>
</tr>
<tr>
<td>1980</td>
<td>Micro-based workstations</td>
</tr>
<tr>
<td></td>
<td>VM MAP LAN standard</td>
</tr>
<tr>
<td></td>
<td>Computer vision</td>
</tr>
<tr>
<td>1985</td>
<td>Automated factory</td>
</tr>
<tr>
<td></td>
<td>In-situ sensing &amp; control</td>
</tr>
<tr>
<td></td>
<td>MEMS</td>
</tr>
<tr>
<td>1990</td>
<td>Collaborative manufacturing</td>
</tr>
<tr>
<td>1995</td>
<td>Nano manufacturing</td>
</tr>
<tr>
<td>2000</td>
<td>Enterprise manufacturing</td>
</tr>
</tbody>
</table>
Application of CAM in the Production

- The utilization of **CAM** enables the **automation** and **computer support** of all the production activities on the **shop floor**, in order to manufacture parts designed with **computer-aided design (CAD)** and analysed with **computer-aided engineering (CAE)**.

- The equipment on the shop-floor, such as **robots**, **controllers**, **machine tools** and **machining centres** are controlled and operated using CAM systems (Post 2003).

- **CAM** technologies comprise **NC machines**, **expert systems**, **machine vision**, **robots**, **lasers** and **FMS technologies** used alongside with **computer hardware**, **databases** and **communication technologies**.

- **CAM** systems are tightly connected with **CAD systems**.
The CAD databases must reflect the manufacturing requirements such as tolerances and features.

The part drawings must be designed having in mind CAM requirements. Moreover, the manufacturing systems nowadays require high coordination due to their networking characteristics.

Synchronization among robots, vision systems, manufacturing cells, material handling systems and other shop floor tasks are challenging tasks that CAM addresses.

The role of CAD/CAM systems in the production can be as the intersection of five sets:

- design tools
- manufacturing tools
- geometric modelling
- computer graphics concepts and
- networking concepts (Zeid 1991)
Application of CAM in the Production

Figure 3: CAD/CAM and their constituents
Application of CAM in the Production

- Apart from the fact that the CAM technology has brought a revolution in manufacturing systems by enabling mass production and greater flexibility (Yeung 2003)

- It has also enabled the direct link between the three-dimensional (3D) CAD model and its production

- The data exchange between CAM, CAD and CAPP is a dynamic procedure and takes place through various production stages
Application of CAM in the Production

- **Data** is exchanged regarding process routes and machines between function of process route sequence and machine assignments from CAPP systems and identified manufacturing process and machines from CAM systems.

- Moreover, reports regarding setup methods, fixtures and operations sequences between function of setup planning and fixture selection in CAPP and function of identifying setups, fixtures, getting operation sequences and machined features in CAM are transmitted.

- Further to that, **information about cutting tools and cutting parameters** between:
  - Function of operation planning
  - Cutting tool selection
  - Cutting parameter selection
  - Optimization
  - **Edit and output** in CAPP and function of getting cutting tools and cutting parameters in CAM is exchanged.
Application of CAM in the Production

Figure 4: Role of CAM in a typical product lifecycle (Zeid 1991)
Finally, messages concerning process plan change suggestions between:

- function of operation planning
- cutting tool selection
- cutting parameter selection
- optimization
- edit and output in CAPP
- function of generating cutting path
- CNC code and
- simulation in CAM are exchanged

(Ming et al. 2008)
Figure 5: The collaboration between CAM, CAPP and CAD systems (Ming et al. 2008)
Application of CAM in the Production

- The data interface between CAM and CAD is displayed in Figure 6.

- The mechanical drawing files from CAD applications are required from the CAM system in order for a part to be manufactured.

- CAM programs represent a designed part as a wireframe of two or three dimensions.

- The NC programmer needs to define auxiliary geometry during the programming course and since the CAM program do not offer model editing abilities the need is presented for the CAM system to be combined with a CAD system (Seames 2002).

- Numerical Control refers to a system that includes hardware and software and control machine tools and other production equipment via numerical input (Post 2003).

- NC is a method of automatically operating a manufacturing machine based on a code of letters, numbers, and special characters.
Numerical Control (NC) and CAM

Figure 6: CAD/CAM links and flow of a computer-aided system (Rehg and Kraebber 2005)
Numerical Control (NC) and CAM

Numerical Control Reminders

- **Numerical Control** refers to a system that includes hardware and software and control machine tools and other production equipment via numerical input (Post 2003)

- **NC** is a method of automatically operating a manufacturing machine based on a code of letters, numbers, and special characters

- In 1947, John Parson of the Parsons Group, began experimenting with the idea of using tree-axis curvature data to control machine tool motion for the production of aircraft components. The project was funded by the US Air Force
Numerical Control Reminders

- In 1951 MIT (Massachusetts Institute of Technology), USA, assumed the project and the first NC machine was developed in 1950s at MIT (Seames 2002)

- The evolution of computers, led to the creation of Computer Numerical Control (CNC) in the 1970s

- The difference in NC and CNC lies in the controller technology

- While, NC functions need to be designed and implemented in hardware circuits, CNC functions can be implemented in CAM software.
Numerical Control Reminders

- The coding of the early **NC** machines and today's **CNCs** is performed using the same standards, namely **G&M codes** formalized as the **ISO 6893 standard** (International Standards Organization 1982)

- The codes were **stored in magnetic tapes**, the most common of which were $\frac{1}{4}$ - inch computer grade cassette tape

- The **Electronics Industries Association (EIA)** developed standards for tape format and coding (Seames 2002)
In order for the machine code to be produced, certain stages are required as shown in Figure 7.

Moreover, to ensure the interoperability and the seamless data exchange between the different stages of the chain that utilize different commercial tools and technologies, the STEP standards have been developed and formalized into:

- ISO10303 (International Standards Organization 1994) and evolved later to
- ISO14649 (International Standards Organization 2003) and
- ISO10303-AP238 (International Standards Organization 2004) commonly known as STEP NC.
Numerical Control (NC) and CAM

Figure 7: Manufacturing information flow in the state-of-the-art CAD/CAM/CNC chain (Newman et al. 2008)
Numerical Control (NC) and CAM

- The improvements in the computer technology led to the creation of Direct Numerical Control (DNC)

- DNC involves a computer that acts as a partial of full controller to one or more NC machines

- Further to that, improvements in the field led to the creation of Distributed Numerical Control, where several CNC machines are linked together inside a network allowing the gathering and storing of upstream and downstream shop-floor information

- In Figure 8 and Figure 9 the differences in the architecture of Direct and Distributed Numerical Control are presented
Numerical Control (NC) and CAM

Figure 8: Direct Numerical Control (Seames 2002)

Figure 9: Distributed Numerical Control (Seames 2002)
Flexible Manufacturing Systems (FMS) and CAM

- A **Flexible Manufacturing System (FMS)** is a reprogrammable manufacturing system capable of producing a variety of products automatically (Chryssoulouris 2005).

- An **FMS** employs **programmable electronic controls** that, in some cases, can be set up for random parts sequences **without incurring any set-up time between parts**.

- Inside **FMSs**, the production components **require adaptability to a variety of product processing requirements** and therefore, CNC turning/machining centers and robotic workstations comprise the majority of equipment in these systems (Chryssoulouris 2005).

- **CAM** systems, **NC** and **robotics** offer **reprogramming capabilities** at the machine level with minimum setup time.
An FMS (Figure 10) comprise the following features:

- Interchangeable and/or specific machining units
- Various work pieces within a component range
- Usually free component selection

Figure 10. FMS with integrated CAD/CAM systems
Flexible Manufacturing Systems (FMS) and CAM

- The main challenge in the installation of a FMS lies to the control of the complex network of equipment and shop floor activities of such a system.

- By utilizing state of the art CAM systems, the implementation of FMS becomes feasible due to the benefits that CAM systems provide.

- The deployment of an FMS with integrated CAD/CAM systems offer a variety of benefits such as:
  - improved productivity through higher machine utilization,
  - shorter lead times,
  - more reliable production (self-correcting production and uniform quality),
  - reduced work-in-progress (Koenig 1990).

- Moreover, by integrating CAPP systems into FMS, the process plans can be created rapidly and consistently and total new processes can be developed as fast as plans similar to those for existing components (Rehg and Kraebber 2005).
The benefits of FMS with CAD/CAM systems can be found in Table 1.

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Machine/process control</th>
<th>Production and measurement control</th>
<th>Design and planning control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operate equipment around the clock</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimize direct labour</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Minimize lead time</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Reduction of in process inventory</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce tools and fixture requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obtain high flexibility</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Benefits of FMS with integrated CAD/CAM systems (Koenig 1990)
CAM Software

- CAM software can be divided into 2D and 3D applications. The 2D means that the CAM system imports a 2D drawing file from a CAD system and calculates a tool path with all movements taking place on a constant Z-level.

- Several tool paths on different Z-levels can be combined to create a 3D result, which is then called 2.5D machining.

- A 3D CAM system in contrast imports a full 3D CAD model and calculates tool paths to create a 3D result.

- A second distinction of CAM systems is between simple and high-end CAM software.
The high-end CAM software targets large enterprises that require absolute control of the manufacturing parameters in order to produce an optimum result.

High-end systems include functionalities that support a fourth or for full 5 axis machining:

- constant tool loading features
- automatic step-over calculation
- automatic detection
- removal of rest material
- rendered machining simulations

Software vendors are currently developing integrated CAD/CAM systems, further enhancing the capabilities of today's CAM applications.
CAM Software Survey

Table 2 gives a glimpse of the status of CAM technology by presenting some of the most popular CAD/CAM systems, the software vendors and some notable features of each one.

<table>
<thead>
<tr>
<th>CAD/CAM suite</th>
<th>Vendor</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAD/CAM v7.0</td>
<td>Cimatron</td>
<td>• Solid modelling capabilities range from wireframe and surfaces to parametric solids</td>
</tr>
<tr>
<td></td>
<td>[<a href="http://www.cimatron.com">www.cimatron.com</a>]</td>
<td>• 2.5 to 5-axis milling, drilling, turning, punching, and wire EDM tool paths generation</td>
</tr>
<tr>
<td>VERICT</td>
<td>GCTech</td>
<td>• Multi-axis milling, drilling, and turning</td>
</tr>
<tr>
<td></td>
<td>[<a href="http://www.cgtech.com">www.cgtech.com</a>]</td>
<td>• Optimizes NC tool paths automatically</td>
</tr>
<tr>
<td>MasterCAM</td>
<td>CNC Software Inc.</td>
<td>• Simulates and optimizes NURBS interpolation</td>
</tr>
<tr>
<td></td>
<td>[<a href="http://www.mastercam.com">www.mastercam.com</a>]</td>
<td>• Intel-based 2.5-axis milling and drilling package</td>
</tr>
<tr>
<td>CATIA</td>
<td>Dassault Systemes</td>
<td>• 5-axis positioning and lathe operation handling</td>
</tr>
<tr>
<td></td>
<td>[<a href="http://www.catia.com">www.catia.com</a>]</td>
<td>• Creates CAD geometry and wire EDM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Generative machining and assisted manufacturing that captures manufacturing and process know-how and automates repetitive NC functions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Networking and collaborative design feature</td>
</tr>
<tr>
<td>CADDS Version 5</td>
<td>PTC</td>
<td>• 2.5-, 3-, and 5-axis machining</td>
</tr>
</tbody>
</table>
## CAM Software Survey

<table>
<thead>
<tr>
<th>Software</th>
<th>Company</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Gibbs CAM</td>
<td>Gibbs &amp; Associates</td>
<td>• Quick re-sequencing of operations, tool size modifications, feed and speed changes, and multiple part programming</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.gibbsnc.com">www.gibbsnc.com</a></td>
<td></td>
</tr>
<tr>
<td>NX CAM</td>
<td>Siemens</td>
<td>• High Definition 3D technology</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.plm.automation.siemens.com">http://www.plm.automation.siemens.com</a></td>
<td>• PMI Driven Feature Based Machining</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Synchronized point distribution</td>
</tr>
<tr>
<td>PowerMILL</td>
<td>Delcam</td>
<td>• Multi-axis machining</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.delcam.com">www.delcam.com</a></td>
<td>• Object linking and embedding for design and modelling</td>
</tr>
<tr>
<td>Helix Engineering</td>
<td>MicroCADAM</td>
<td>• Addresses the needs of sheet metal design and fabrication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Flat-wrap and flat-pattern provides methods for unbending or flattening a surface or solid</td>
</tr>
<tr>
<td>SurfCAM Version 6.0</td>
<td>Surfware Inc.</td>
<td>• Machines undercut surfaces in one setup</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.surfware.com">www.surfware.com</a></td>
<td>• Parametric design capabilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Creates optimized tool paths according to user-defined tolerances</td>
</tr>
<tr>
<td>Alphacam</td>
<td>Planit</td>
<td>• Parallel and Flat Area 3D Machining</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.alphacam.com/">http://www.alphacam.com</a></td>
<td>• Adaptive Feed Rate Support for Z Contour Roughing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Editable Spline/Polyline Tool Paths</td>
</tr>
<tr>
<td>Tebis CAM</td>
<td>Tebis</td>
<td>• 2 1/2 axis machining</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.tebis.com/">http://www.tebis.com</a></td>
<td>• Creation of collision-safe tool paths for 5-side complete machining</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Neutral and control-specific post-processing</td>
</tr>
</tbody>
</table>

**Table 2:** Commercial CAD/CAM suites
The solutions provided by the leading CAD/CAM vendors, offer high-end features, like:

- parametric modelling for solid shapes
- 2 ½ to 5 axis machining tool path generation
- networking and collaborative design features
- post processing capabilities
- re-sequencing of operations
- simulation and optimization of NURBS interpolation and
- generative machining and
- assisted manufacturing that captures manufacturing and process know-how and automates repetitive NC functions
CAM and related technologies Vendors Market share in 2009

- For 2009, **Dassault Systèmes** was the market leader on the basis of both direct vendor revenues received and end-user payments for CAM software and services.

- **Delcam** was the leader in terms of industrial seats shipped.

- **Planit Holdings** was the leader on the basis of industrial seats installed.

- **Siemens PLM Software’s NX** was the leader in industrial seats shipped by brand.

- **CNC Software’s Mastercam** was the leader in both industrial and educational seats installed by brand name.

- **OPEN MIND Technologies** was named as the most rapidly-growing vendor, although their revenue growth rate was only 1.6% (Table 2).
Figure 11: Market share of CAD/CAM software vendors in 2009
Future of CAM Systems

- The manufacturing environment is characterized by ever changing dynamics and evolution.

- The production procedure is based more and more on virtual simulations and networking features, in factory level as well as and global level.

- The need is presented for effective coordination, collaboration and communication amongst all the aspects of production, from humans to machines.

- The future CAM systems need to focus on collaborative technics, effective communication and efficient data exchange.
Moreover, **Artificial Intelligence (AI)** will allow the development of “thinking” **tools** and the exploitation of **AI** in the **CAM** systems will offer **automatic optimization of NC tool paths** and benefit from knowledge-based systems.

Adding to that, **self-evolving robots** are a fairly new concept and will have positive impact on **CAM** systems.

The development of **self-evolving robots** can bring on **CAM** advantages on a more economical approach to robotics.

The **cost of designing and building a robot will be reduced** from millions of dollars to just a few thousand dollars.
Future of CAM Systems

- In the future, the use of these inexpensive robots to assemble parts, clean up spills, and perform many other specific tasks in a factory will become a reality (Post 2003)

- Moreover, **Virtual commissioning** is a new concept that addresses the complexity of the production systems and the need for short ramp-up time

- In the **Virtual commissioning** approach, virtual prototypes are used for the commissioning of control software in parallel to the manufacture and assembly of the particular production system (Reinhart and Wunsch 2007)
Virtual commissioning is tightly connected with CAD/CAM software and the advances in the second impact the first.

Finally, digital manufacturing incorporates technologies for the virtual representation of:
- factories
- buildings
- resources
- machine systems equipment
- labour staff and their skills, as well as
- for the closer integration of product, and
- process development through modelling and simulation.

The implementation of digital manufacturing is relying on state-of-the-art CAD/CAM and CAPP systems and their evolution (Chryssolouris et al. 2008).
Future of CAM Systems

Figure 12: CAD/CAM and Digital Factory
Design Part

Assembly Part

Design Stock

Prismatic machining

Figure 13a: CAD/CAM Process to generate G-Code
Machining simulation

Figure 13b: CAD/CAM Process to generate G-Code
CATIA-CAM Tutorial
On Catia starting screen we select “Start”, “Machining” and “Prismatic Machining”.

**NOTE:** The design part and the stock must have been designed and assembled before this step.
Starting screen of “Prismatic Machining” Workbench
Program Basic Settings

Machine operation menu

- Drill
- Pocketing
- Pocketing for internal milling
- Profile contouring
- Curve following
- Grove Milling
- Point to Point
- Prismatic Roughing
- 4axis pocketing
Firstly we select “Tools” then “Option”.

On the appearing menu we select from the process tree the “Machining” section.
- The options we focus on are: "Post Processor, Controller Emulation folder" and "Tool output point"

We select:
- IMS
- Tool Tip

- Since these settings are selected, "OK" to close "option" menu
Then we have to choose the proper machine, the coordinate system and define the role for every part.

Firstly we select part operation from the process tree and by double-clicking the menu appears.
We click on machine tab:

- Then select 3-axis machine (default choice) and in the tooling tab MillanddrillStarterSet
In the Numerical Control tab we select:

- Controller Emulation: Fanuc5x
- Post Processor: fanuc0.lib
- Post Processor Table: IMSPPCC_Mill.pptable
- NC data type: ISO

We select OK to save changes and return on previous menu
We select Reference Machining Axis System:

On the appearing window the coordinate system appears on the reference machining axis
By selecting the center point, we define the center point on our design, and by choosing X and Z axis a menu appears to define the directions of these axis depending on the process

The result is that the coordinate system is determined:
We select **Design Part:**

- Choosing this option we define the design part that is going to be manufactured.

We select **Stock:**

- Choosing this option we define the stock that we will process.
The final form of the Part Operation menu should be like the one of the image.

We click OK and leave menu.
We select **Manufacturing Program**, from the tree and start adding processes:

We select **Pocketing**

Then the corresponding areas of the part that the arrows indicate:
We select the tooling tab, then more and insert cutter’s diameter of 5mm then we return to second tab.

By right clicking we remove all islands.

Click replay then OK.
We select **point-to-point** tab and the menu appears.

Then we select import new feature and we select the **perimeter**

Double click on an empty screen area and return to menu

Then we select **replay**, OK and again OK to close the menu.
The process is the same like the previous pocket, then we select as the arrows indicate:
Final form of the manufacturing program
On the procedure tree, we select manufacturing program and by right clicking, we select “Manufacturing Program.1 object” then “Generate NC Code Interactively”
1. We select NC code then browse
2. Name the folder that G-code files will be saved in
3. Then we click execute, to generate G-code and we are asked for a number to name of the code
Vocabulary Introduced to Chapter 18

- Computer Aided Technologies (CAx)
- Computer Aided Design (CAD)
- Computer Aided Engineering (CAE)
- Computer Integrated Manufacturing (CIM)
- Flexible Manufacturing Systems (FMS)
- Computer Aided Process Planning (CAPP)
- Numerical Control (NC)
- Computer Numerical Control (CNC)
References


