COMPUTER AIDED MANUFACTURING

IML 332E CAD&M
LECTURE NOTES

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COMPUTER AIDED MANUFACTURING TOPICS

- Numerical Control Systems (NC, CNC) and Machine Tools
- Numerical Part Programming (Manual and Automatic/CAPP)
- CAD-CAM-CNC Systems Integration
  - Automation in Manufacturing and Computer Integrated Manufacturing (CIM)
  - Flexible Manufacturing Cells (FMC) and Systems (FMS)
  - Sensors and Process Monitoring Systems
- Rapid Prototyping Methods
  - Computer Aided Special and Nontraditional Manufacturing Methods
COMPUTER AIDED MANUFACTURING

DEFINITION:
Effective utilization of computer technology in the MANAGEMENT, CONTROL and OPERATIONS of the manufacturing facility through either direct or indirect computer interface with the physical and human resources of the company (after CAMI).

Dominant Operation:
Numerical Control (NC) part programming

Common (and narrower) concept for CAM:
Computer assisted part programming

Logical Starting point:
Manual part programming

NUMERICAL CONTROL (NC)

DEFINITION:
The control of operation of machine tools (M/T) (or other sheet-working and welding machines) by a series of coded instructions called the program, which consists mainly of alphanumeric characters (numbers and letters).

Main Characteristics:
Preplanned and predictable

Therefore, NC is a typical form of:
Programmable Automation.
BRIEF HISTORY OF CNC M/T

<table>
<thead>
<tr>
<th>Time</th>
<th>Characteristic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Industrial Revolution</td>
<td>Basic Concept</td>
<td>J. Jackard’s method to control textile looms by using punched cards.</td>
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<tr>
<td>2nd World War</td>
<td>2D Manual Applications</td>
<td>Parson’s 2-D Coordinate table operated by two people.</td>
</tr>
<tr>
<td>1947</td>
<td>1st modern concept</td>
<td>Parsons’ NC proposal for milling helicopter rotor blades.</td>
</tr>
<tr>
<td>1952</td>
<td>1st effectively functioning version</td>
<td>MIT’s first NC Milling machine</td>
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<tr>
<td>1956</td>
<td>1st industrial contract</td>
<td>USAF’s contract for 100 NC Milling machines to 8 co.s.</td>
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<tr>
<td>1956-1962</td>
<td>Difficult years</td>
<td>Big opposition against NC M/T in the contractors of USAF</td>
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<tr>
<td>1961</td>
<td>1st industrial success</td>
<td>Point-to-point control drill pressed</td>
</tr>
<tr>
<td>1970</td>
<td>1st CNC</td>
<td>Storing the programs on a computer in add. to tapes.</td>
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</table>

ADVANTAGES OF NC

- NC M/T ensure positioning accuracy and repeatability with their DESIGN, CONSTRUCTION and CONTROLS: Good for making many of the same part.
- Complex shaped components can be made automatically, with high precision and reliability.
- Parts that require a long series of operation can be made with minimal accumulated error.
- NC M/T can operate in hostile and hazardous environments.
- Since most work is shifted to offices from the shop-floor, production can be monitored by the management directly.
- NC M/T mostly are capable of conducting more than one machining operation at a time or in a sequence without repeating the part set-up.
- Minimum idle time and increased productivity.
- Interchangeability of work between different production plants.
NC MACHINE MOTIONS
IML 332E: CAM Introduction

TYPES OF NC SYSTEMS
IML 332E: CAM Introduction

**Point-to-point control system** (Numerical positioning control, NPC)
NC Drill presses used in drilling precise patterns of holes.

**Straight cut system**
Feed rate at each
Axis is controlled
Independently, one at
A time. Used in face
milling, Pocketing etc.

**Contouring system** (continuous path system)
- Each servo motor can be controlled in varying speeds in coordination to
  produce angular lines and curves.
- Some simpler systems of this type use the method of breaking down the
curved into smaller linear segments which are connected to each other in a
tip-to-tail fashion.
Point-to-Point vs. Contouring Control

CNC was first introduced in 1970 by replacing the hardwired MCU of a conventional NC system by a microcomputer which accomplishes all the functions of an MCU with its software.

What is new?

- Feed rate control, buffering, position loop control ...
- Ability to edit and store programs
- Ability to produce punched (or magnetic) tapes, diskettes etc.
- Expanded tool offsets
- Expanded control of machine-sequence operations
- Digitizing
- Circular and more advanced (NURBS etc.) interpolation
- Parametric programming
- Do loops
- Roughening to a defined shape
- Subroutines
- Diagnostic capability
- On-screen geometric programming
- ...
CNC Machining - Horizontal Milling Center

- 14,000 rpm spindle with HSK-63A adapter
- 1,575 in/min (40 m/min) feed rate
- 1,000 psi through spindle coolant
- 22" x 22" x 22" envelope
- FANUC 16MB controller with Makino software

Figure 9.2 An NC machine system.
ELEMENTS OF NC

- **Tape (Media) Reader** (electromechanical, electromagnetic, optical etc.)
- **Machine Control Unit (MCU)** (sends control signals to servomechanism)
- **Servomechanism(s)** (amplify signals from the MCU, and send them to servomotors)
- **Controlled element** (tool, turret, M/T table: the numerically controlled part of M/T)
- **Feedback unit** (records the achieved tool movement and sends them to the MCU)
Ball Screw vs. Lead Screw

CNC Machining - Turning
CNC Machining – Turning

Centering and counter-sinking

Drilling

Truing hole with boring cutter

Final sizing with reamer
CNC Milling - Cutting Tools

**Cutting Tool Geometry**
- Flat end mill
- Ball-nose end mill

**Kinds of Cutting Edge**
- Solid cutting tools
- Indexable inserts

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CNC Milling and CAM: Generation of Cutting Tool Paths and Part Programs

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UNIGRAPHICS
USE OF (CAD &) CAM TECHNOLOGY

<table>
<thead>
<tr>
<th>Machining</th>
<th>Milling, Turning, Drilling, Grinding, Finishing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nontraditional Processes</td>
<td>Electric Discharge (EDM: Wire &amp; Plunge), Electro Chemical (ECM), Water Jet, PCB &amp; Micro chip Manufacturing</td>
</tr>
<tr>
<td>Rapid Prototyping</td>
<td>SLA, SLS, FDM, LOM, SGC, Milling</td>
</tr>
<tr>
<td>Robot programming</td>
<td>Welding, painting, finish, hoisting and conveying, sheet forming</td>
</tr>
<tr>
<td>Measurement &amp; Re-engineering</td>
<td>CMM (Computerized Measurement Mach.)</td>
</tr>
<tr>
<td>Metal Forming</td>
<td>Sheet blanking and bending in Punch Press, Plasma Arc Cutting, Sheet bending in CNC Press Brake, Spinning, etc...</td>
</tr>
<tr>
<td>Microelectronic Devices</td>
<td>Microchips, Printed circuit boards,</td>
</tr>
</tbody>
</table>

Commercial CAM Software

- I-DEAS
- CATIA
- PRO-Engineer
- Unigraphics
- Cimatron
- Work-NC
- Power Mill
- Hyper Mill
- CAM Works
- Master CAM
- Surf-CAM
- NC-Gibbs
- Auto-CAD based CAM programs
- ....
Basic Advantages

In mass production
- Better geometric repeatability
- Combining many operations in one machine
- Flexibility: Many different parts on one machine
- Flexibility: Quick and easy implementation of design modifications

In production of tools, dies and molds
- Quick and hassle-free production of complex 3-D surfaces
- Drastic Time reduction in part programming
- Accurate production of the geometry developed during the CAD stage and verified in the CAE stage

Realization of a Product via Computer Aided Processes
Phases in Die & Mold Production

- **Design (CAD & CAE)**
  - Selection of support components and design of functional components
  - Tool Path Generation

- **Tool Path Generation (CAM)**
  - NC programs are needed for machining of EDM electrodes or for direct machining of functional components

- **Machining (CAM)**
  - Typical processes: electro-discharge machining and CNC machining (turning and/or milling)

- **Benching**
  - The tooling is assembled
  - Critical dimensions are checked: Coordinate Measuring Machine (CMM)
  - Hand finishing: Grinding and polishing.

- **Tryout**
  - During tryout, a limited number of parts are produced with the die or mold
  - Minor changes on the tooling may be necessary for required performance

Die & Mold Components

- **Functional Components**
  - Die
  - Punch
  - Blank holder
  - Cavity inserts
  - Ejector pins
  - etc.

- **Support Components**
  - Guide pins and bushings
  - Holding plates
  - etc.
**Milling of Sculptured Surface**

**Die & Mold Production Information Flow**

- Digitized Part Data
- Part File
- Part Drawing
- Prototypes / Models
- Part Design for Manufacturing
- Die / Mold Initial Design
- Process Modelling and Structural Analysis
- Die / Mold Design Satisfactory?

Data for CMM

A

N

Y

B
Business Card Holder - Design Phase

Part Design

Process Simulation

Die & Mold Production – Design Phase

Fused Deposition Modeling (FDM)

Principle

Supply

Example
**Business Card Holder - Design Phase**

- Glass Window
- Cavity Plate
- Ejector Plate
- Gas Nozzle Support
- Logo Insert
- Mold Base
- Plate
- Insert

**Business Card Holder - Machining Phase**

- ERC/NSM

**ERC/NSM**