INTRODUCTION TO MODERN MANUFACTURING SYSTEMS

LECTURE GOAL

Discuss general characteristics and design principles of modern manufacturing systems:
• FMS
• CIM
• Agile Manufacturing

Manufacturing Concepts: Brief History

• FMS (early 1980’s)
• CIM (late 1980’s)
• Agile Manufacturing (US) (1990’s)
• Fractal (Germany)
• Biological (Japan)

Modern Manufacturing System (MMS) = universal term

FUNCTIONAL AREAS IN MANUFACTURING

Functional Area

Answer

Benefits: simplicity, sharing common values, ...

Pitfalls: Inefficiency due to interfaces

Challenge

Eliminate interfaces by merging different functional areas (e.g., product and process design = concurrent engineering)

Question:

What are the benefits and pitfalls of separation of manufacturing into functional areas?
Information Aspects of MMSs

Volume of information versus
• the level of hierarchy in an organization and
• the impact of decisions

Impact

Volume of information

Top management level
Plant level
Machine cell level
Shop-floor level

Level of hierarchy

Volume of information

Question:
What type of computer architecture is likely to prevail in the future
• centralized
• distributed?

Information Stored in Distributed Data Bases

Factory Communications

<table>
<thead>
<tr>
<th>MAP/TOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Layer</td>
</tr>
<tr>
<td>Presentation Layer</td>
</tr>
<tr>
<td>Session Layer</td>
</tr>
<tr>
<td>Transport Layer</td>
</tr>
<tr>
<td>Network Layer</td>
</tr>
<tr>
<td>Data Link Layer</td>
</tr>
<tr>
<td>Physical Layer</td>
</tr>
</tbody>
</table>

• Networking
• Standards

Part DB
Machine DB
Tool DB

Scheduling DB
Scheduling Record

Material Handling System DB
Pallet DB
Fixture DB

The University of Iowa
Intelligent Systems Lab
The University of Iowa
Intelligent Systems Lab

**Application Layer**: Provides all services directly comprehensible to application programs. For example, MAP/TOP uses a file transfer protocol known as FTAM and a protocol specifically designed for manufacturing applications referred to as MMS (Manufacturing Message Specification).

**Presentation Layer**: Restructures data from/to a standardized format within the network.

**Session Layer**: Synchronizes and manages dialogues between application programs.

**Transport Layer**: Provides transport, reliable data transfer from end node to end node. MAP/TOP use a well-known transport protocol standard developed by ISO known as TP4 (Transport Protocol class 4).

**Network Layer**: Performs packet routing and congestion control for data transfer between nodes.

**Data Link Layer**: Provides access to shared medium and improves the error rate for frames moved between physically adjacent nodes. MAP uses a well-known time-token protocol known as the token bus protocol and TOP uses a version of the Ethernet protocol.

**Physical Layer**: Encodes and physically transfers bits between adjacent nodes.

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**OSI Reference Model**

<table>
<thead>
<tr>
<th>Station A Layer Number</th>
<th>Station B Layer Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application 7</td>
<td>Application</td>
</tr>
<tr>
<td>Presentation 6</td>
<td>Presentation</td>
</tr>
<tr>
<td>Session 5</td>
<td>Session</td>
</tr>
<tr>
<td>Transport 4</td>
<td>Transport</td>
</tr>
<tr>
<td>Network 3</td>
<td>Network</td>
</tr>
<tr>
<td>Data link 2</td>
<td>Data link</td>
</tr>
<tr>
<td>Physical 1</td>
<td>Physical</td>
</tr>
</tbody>
</table>

**Communication medium**

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**MAP 2.2 Architecture**

- **Application**: Case, FTAM, MMS (RS-511), Directory services, Network management
- **Presentation**: Null
- **Session**: ISO session kernel
- **Transport**: ISO transport class 4
- **Network**: ISO connectionless network service
- **Data Link**: LLC class 1 or class 3, MAC 802.4
- **Physical**: IEEE 802.4 broadband, PSK modulation or carrierband FSK modulation

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**Mini-MAP Architecture**

- **User defined**: LSAP bindings
- **Network management**: LLC Class 1, MAC 802.4
- **LLC Class 3**: IEEE 802.4 broadband, PSK modulation or carrierband FSK modulation

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**Question:**

Is standardization helping or preventing proliferating of information systems?

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**Example: Intelligent system**

- **Dispatcher**
- **Vision Module**
- **Voice Module**
- **Monitor**
- **TV camera**
- **Microphone**
- **IBM PCAT**
- **IBM S/1**
- **IBM robot**
- **Actuators and Sensors**
**COMPARISON OF AUTOMATED MANUFACTURING SYSTEMS IN U.S. VERSUS JAPAN**

<table>
<thead>
<tr>
<th>Manufacturing System Metric</th>
<th>U.S.</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>System development time (years)</td>
<td>2.5 to 3</td>
<td>1.25 to 1.75</td>
</tr>
<tr>
<td>Number of machines per system</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Types of parts produced per system</td>
<td>10</td>
<td>93</td>
</tr>
<tr>
<td>Annual volume per part</td>
<td>1,727</td>
<td>258</td>
</tr>
<tr>
<td>Number of parts produced per day</td>
<td>88</td>
<td>120</td>
</tr>
<tr>
<td>Number of new parts introduced per year</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>Number of systems with untended operations</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>Utilization rate (two shifts)*</td>
<td>52%</td>
<td>84%</td>
</tr>
<tr>
<td>Average metal-cutting time per day</td>
<td>8.3</td>
<td>20.2</td>
</tr>
</tbody>
</table>

* ratio of actual processing time to time available

**EXAMPLE: PHYSICAL LAYOUT OF AN AUTOMATED MACHINING SYSTEM**

**FEATURES OF AUTOMATED MANUFACTURING**

**O1. INCREASED DEGREE OF AUTOMATION**

- Robots
- AGVs
- Computer control

**O2. REDUCED NUMBER OF MACHINES**

**EXAMPLE: System layout**

Automated Storage and Retrieval System

- Machining Cell 1
- Machining Cell 2
- Machining Cell 3
- Functional Machining Facility
- Assembly Cell 1
- Assembly Cell 2
- Assembly Facility

AS/RS: automated storage and retrieval system; PB: part buffer; CMM: coordinate measuring machine; R: robot; VC: video camera; MC: machining center
03. LAYOUT PATTERN DETERMINED BY MHS

Linear Single-Row

Circular Single-Row

Linear Double-Row

Multi-Row

AGV: Automated Guided Vehicle

R: Robot

Machine

RACKS

SC

M1           M2           M3          M4

M8            M7           M6          M5

Machines arranged along racks of an ASRS

04. DECREASED NUMBER OF SETUPS

New Paradigm:
Divide a manufacturing task into small number of larger subtasks so that the number of setups can be reduced

EXAMPLE: Three-Dimensional Part

Classical Process Plan

<table>
<thead>
<tr>
<th>Setup number</th>
<th>Machine number</th>
<th>Operation</th>
<th>Volumes to be removed</th>
<th>Required tools</th>
<th>Required fixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M1</td>
<td>Milling</td>
<td>( v_5,v_4 )</td>
<td>T_3,T_2</td>
<td>F_1</td>
</tr>
<tr>
<td>2</td>
<td>M2</td>
<td>Drilling</td>
<td>( v_5,v_3 )</td>
<td>T_2,T_1</td>
<td>F_3</td>
</tr>
<tr>
<td>3</td>
<td>M1</td>
<td>Milling</td>
<td>( v_5 )</td>
<td>T_3</td>
<td>F_3</td>
</tr>
<tr>
<td>4</td>
<td>M4</td>
<td>Milling</td>
<td>( v_6 )</td>
<td>T_2</td>
<td>F_4</td>
</tr>
<tr>
<td>5</td>
<td>M3</td>
<td>Milling</td>
<td>( v_6 )</td>
<td>T_2</td>
<td>F_4</td>
</tr>
<tr>
<td>6</td>
<td>M4</td>
<td>Drilling</td>
<td>( v_6 )</td>
<td>T_2</td>
<td>F_4</td>
</tr>
</tbody>
</table>

Process Plan for a Modern Manufacturing System

<table>
<thead>
<tr>
<th>Setup number</th>
<th>Machine number</th>
<th>Operation</th>
<th>Volumes to be removed</th>
<th>Required tools</th>
<th>Required fixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MC1</td>
<td>Milling and Drilling</td>
<td>( v_5,v_4 ), ( T_3,T_2 )</td>
<td>( T_5 )</td>
<td>PF_1</td>
</tr>
<tr>
<td>2</td>
<td>MC2</td>
<td>Milling and Drilling</td>
<td>( v_5,v_6 ), ( T_3 )</td>
<td>( T_4 )</td>
<td>PF_2</td>
</tr>
</tbody>
</table>
Question:
What would be an ideal manufacturing system for the reduced number of setups?

Answer:
Raw material → Machine → Final part

O5. Increased processing time per load
- More than one part on a fixture
- More operations performed on one part on one machine

Benefit:
Decreased unit machine loading/unloading time

O6. Increased volume and flow of information
- New resources, sensors, robots, etc.
- Increased need for monitoring and decision making

O7. Batch size is determined by constraints, e.g., capacity of fixtures, order size, and so on
- Reduced order size
- High cost of fixtures

The Economic Lot Size: Traditional Approach
OPERATIONAL CHARACTERISTICS OF A MANUFACTURING SYSTEM ARE TO A LARGE DEGREE DETERMINED BY ITS DESIGN

Which design is superior?

1: Machine center
2: Fixture
3: Robot
4: Pallet
5: Pallet with fixture
6: Conveyor

Question:

Do the observations discussed apply to other processes besides machining?

If yes, give examples.

ASSEMBLY PROCESS

Example

Product C with four parts

Traditional Assembly Line

PARTS FOR ASSEMBLY

\[
\begin{align*}
\text{AS}_1 & : (P_1, P_2) \\
\text{AS}_2 & : (P_1, P_3, P_4) \\
\text{AS}_3 & : (P_1, P_2, P_3, P_4)
\end{align*}
\]

FINAL PRODUCT C
Modern Assembly System

PARTS FOR ASSEMBLY \( P_1, P_2, P_3, P_4 \)

ASSEMBLY STATION FAS_1

ASSEMBLY STATION FAS_2

FINAL PRODUCT C

Question: What are the advantages of serial assembly system over the parallel system?

<table>
<thead>
<tr>
<th>Serial System</th>
<th>Parallel System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TOOL MANAGEMENT

Type 1 Tool Assignment

\[ \text{t1, t2, t3, t4, t5, t6} \]

\[ \text{M1, M2, M3} \]

AGV

3 copies of each tool

Advantages
- a backup set of tools is available
- a backup machine is available
- tool handling system is simple

Disadvantages
- more than one set of identical tools is required
- identical NC programs are stored in more than one machine
- high tool magazine capacity is required

Type 2 Tool Assignment

\[ \text{t1, t1} \]

\[ \text{t2, t2} \]

\[ \text{t3, t3} \]

\[ \text{t4, t4} \]

\[ \text{t5, t5} \]

\[ \text{t6, t6} \]

\[ \text{M1, M2, M3} \]

AGV

2 copies of each tool
Advantages
• a backup set of tools is available
• NC program is stored in one machine only
• tool handling system is simple

Disadvantages
• more than one set of identical tools is required
• no backup machine
• high tool magazine capacity required

Tools in TSHS: \{t_1, t_2, t_3, t_4, t_5, t_6\}

TOOL STORAGE DEVICES AND SYSTEMS

Tool magazines
1: Factory floor 2: Automated guide vehicle loaded with tools
3: Robot arm 4: Tool magazine 5: Machine

Storage Systems
Rack Stocker  Disk Stocker

+ SYSTEMS (TS/RSs) SIMILAR TO AS/RSs