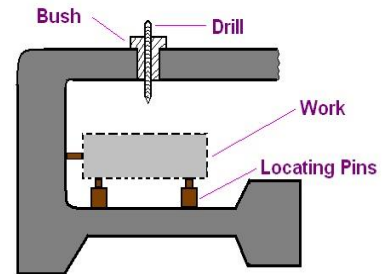
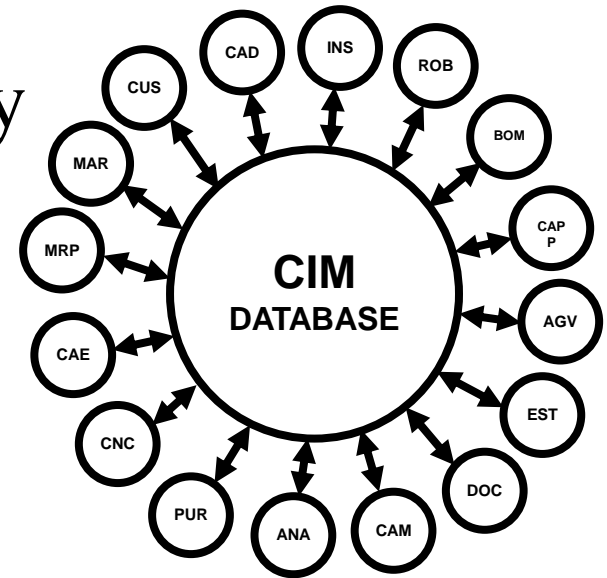


Tech 149: Unit 3

Production Engineering and Other CIM Subsystems

Computer-aided Engineering Tasks

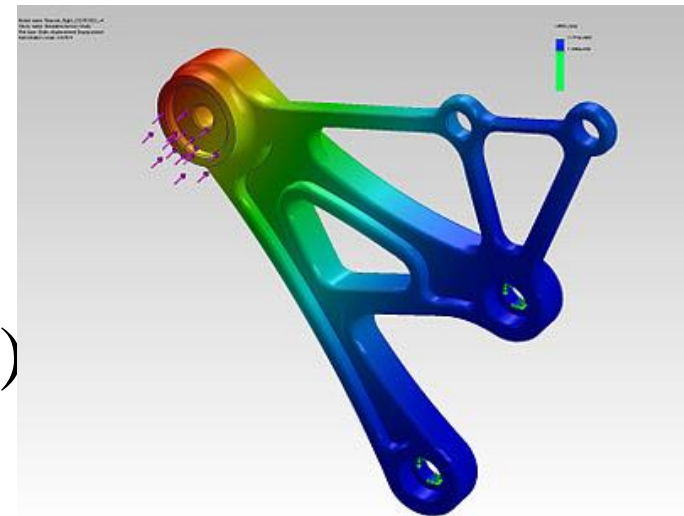
- Analysis for manufacturability and assembly
- Evaluation
- Process planning tasks
- CNC programming tasks
- Tool/fixture design
- Time standards tasks
- Plant layout & design
- Manufacturing cost estimation



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Computer-aided Engineering Analysis

- Finite-element analysis is most frequently used
- Mass property analysis
(Weight, volume, center of mass and moments of inertia of objects)



Computer-aided Engineering Evaluation

- Prototyping

Rapid prototyping techniques:

- 1) Stereolithography
- 2) Solid ground curing
- 3) Selective laser sintering
- 4) Three-dimensional printing
- 5) Fused-deposition modeling
- 6) Laminated object manufacturing

Chapter 24: Process Planning and Concurrent Engineering

PRODUCT NAME:		FLOW BEGIN	FLOW END	DATE		
PREPARED BY:		APPROVED BY:				
PROCESS SYMBOL AND NO. USED	<input type="radio"/> OPERATION ____ K INSPECTIONS ____ <input type="checkbox"/> DELAYS ____ <input type="checkbox"/> TRANSPORTATION ____ Δ STORAGE(S) ____					
	TASK NO.	PROCESS SYMBOLS	DESCRIPTIO OF TASK	TIME INVOLVED	MACHINE REQUIRED	TOOLING REQUIRED
	<input type="radio"/> <input type="checkbox"/> <input type="checkbox"/> K Δ					
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	<input type="radio"/> <input type="checkbox"/> <input type="checkbox"/> K Δ					

Sections:

1. Process Planning
2. Computer-Aided Process Planning
3. Concurrent Engineering and Design for Manufacturing
4. Advanced Manufacturing Planning

Process Planning

Determining the most appropriate manufacturing processes and the sequence in which they should be performed to produce a given part or product specified by design engineering

- Limitations imposed by available processing equipment and productive capacity of the factory must be considered
- Parts or subassemblies that cannot be made internally must be purchased from external suppliers

Who does Process Planning?

- Traditionally, process planning is accomplished by manufacturing engineers who are familiar with the particular processes in the factory and are able to read engineering drawings
- Based on their knowledge, skill, and experience, they develop the processing steps in the most logical sequence required to make each part
- Some details are often delegated to specialists, such as tool designers
 - But manufacturing engineering has overall responsibility

Details in Process Planning

- Interpretation of design drawings
 - The part or product design must be analyzed to begin the process planning procedure
 - Starting materials
 - Dimensions
 - Tolerances
- Processes and sequence
 - The process plan should briefly describe all processing steps used to produce the work unit and the order in which they will be performed

More Details in Process Planning

PRODUCT NAME:		FLOW BEGIN	FLOW END	DATE		
PREPARED BY:		APPROVED BY:				
PROCESS SYMBOL AND NO. USED	<input type="radio"/> OPERATION ____ K INSPECTIONS ____ <input type="checkbox"/> DELAYS ____ <input type="checkbox"/> TRANSPORTATION ____ <input type="triangle"/> STORAGE(S) ____					
	TASK NO.	PROCESS SYMBOLS	DESCRIPTIO OF TASK	TIME INVOLVED	MACHINE REQUIRED	TOOLING REQUIRED
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	<input type="radio"/> <input type="checkbox"/> <input type="triangle"/> K <input type="checkbox"/> <input type="triangle"/>					
	<input type="radio"/> <input type="checkbox"/> <input type="triangle"/> K <input type="checkbox"/> <input type="triangle"/>					

- Equipment selection

- The process planner attempts to develop process plans that utilize existing plant equipment

- Otherwise, the part must be purchased, or new equipment must be installed in the plant

- Tools, dies, molds, fixtures, and gages

- Design of special tooling is usually delegated to the tool design group, and fabrication is accomplished by the tool room

More Details in Process Planning

- Methods analysis
 - Hand and body motions, workplace layout, small tools, hoists for lifting heavy parts
 - Methods must be specified for manual operations (e.g., assembly) and manual portions of machine cycles (e.g., loading and unloading a production machine)
- Work standards
 - Time standards set by work measurement techniques
- Cutting tools and cutting conditions for machining operations

The Route Sheet

The document that specifies the details of the process plan

- The route sheet is to the process planner what the engineering drawing is to the product designer
- Route sheet should include all manufacturing operations to be performed on the work part, listed in the order in which they are to be performed

Route Sheet for Process Planning

Route Sheet		XYZ Machine Shop, Inc.				
Part no. 081099	Part name Shaft, generator	Planner MPGroover	Checked by: N. Needed	Date 08/12/XX	Page 1/1	
Material 1050 H18 Al	Stock size 60 mm diam., 206 mm length	Comments:				
No.	Operation description	Dept	Machine	Tooling	Setup	Std.
10	Face end (approx. 3 mm). Rough turn to 52.00 mm diam. Finish turn to 50.00 mm diam. Face and turn shoulder to 42.00 mm diam. and 15.00 mm length.	Lathe	L45	G0810	1.0 hr	5.2 min
20	Reverse end. Face end to 200.00 mm length. Rough turn to 52.00 mm diam. Finish turn to 50.00 mm diam.	Lathe	L45	G0810	0.7 hr	3.0 min
30	Drill 4 radial holes 7.50 mm diam.	Drill	D09	J555	0.5 hr	3.2 min
40	Mill 6.5 mm deep x 5.00 mm wide slot.	Mill	M32	F662	0.7 hr	6.2 min
50	Mill 10.00 mm wide flat, opposite side.	Mill	M13	F630	1.5 hr	4.8 min

Computer-Aided Process Planning

- During the last several decades, there has been considerable interest in automating the process planning function by computer systems
- Shop people knowledgeable in manufacturing processes are gradually retiring
- An alternative approach to process planning is needed, and computer-aided process planning (CAPP) provides this alternative

Benefits of CAPP

- Process rationalization and standardization
 - CAPP leads to more logical and consistent process plans than traditional process planning
- Increased productivity of process planners
- Reduced lead time to prepare process plans
- Improved legibility over manually written route sheets
- Incorporation of other application programs
 - CAPP programs can be interfaced with other application programs, such as cost estimating, work standards, and NC part programming

CAPP Systems

Computer-aided process planning systems are designed around either of two approaches:

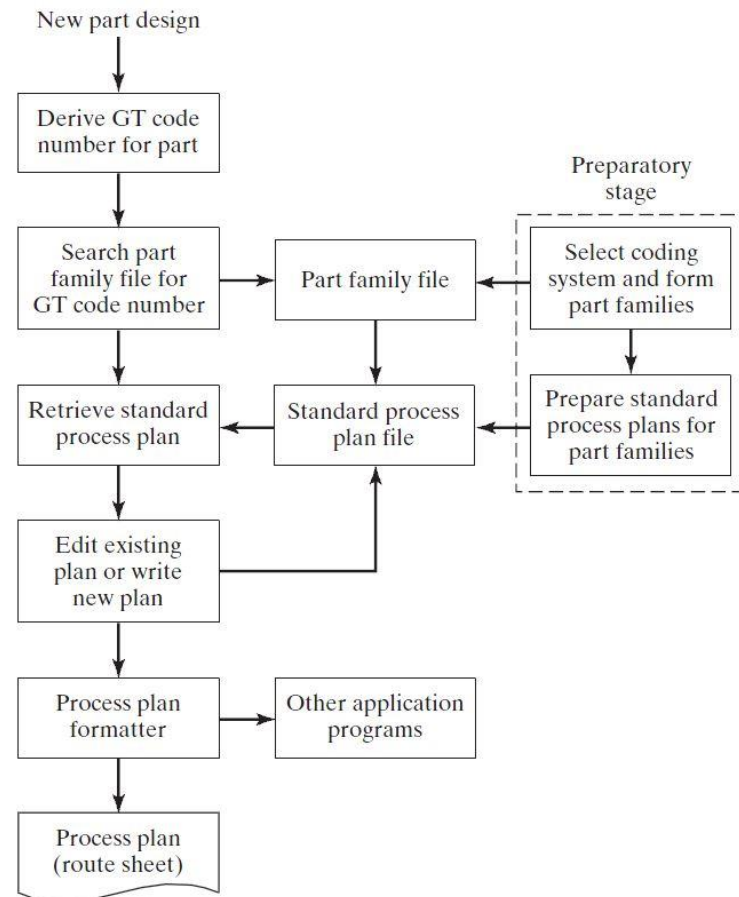
1. Retrieval systems
2. Generative systems

Retrieval CAPP Systems

- Based on group technology and parts classification and coding
- A standard process plan is stored in computer files for each part code number
 - The standard plans are based on current part routings in use in the factory, or on an ideal plan prepared for each family
 - For each new part, the standard plan is edited if modifications are needed
- Also known as variant CAPP systems

Retrieval CAPP System

Operation of a
retrieval type
computer-aided
process planning
system



Retrieval CAPP Systems - continued

- If the file does not contain a standard process plan for the given code number, the user may search the file for a similar code number
 - By editing an existing process plan, or starting from scratch, the user develops a new process plan that becomes the standard plan for the new part code
- Final step is the process plan formatter
 - Formatter may call other application programs: determining cutting conditions, calculating standard times, or computing cost estimates

Generative CAPP Systems

Rather than retrieving and editing an existing plan from a data base, the process plan is created using systematic procedures that might be applied by a human planner

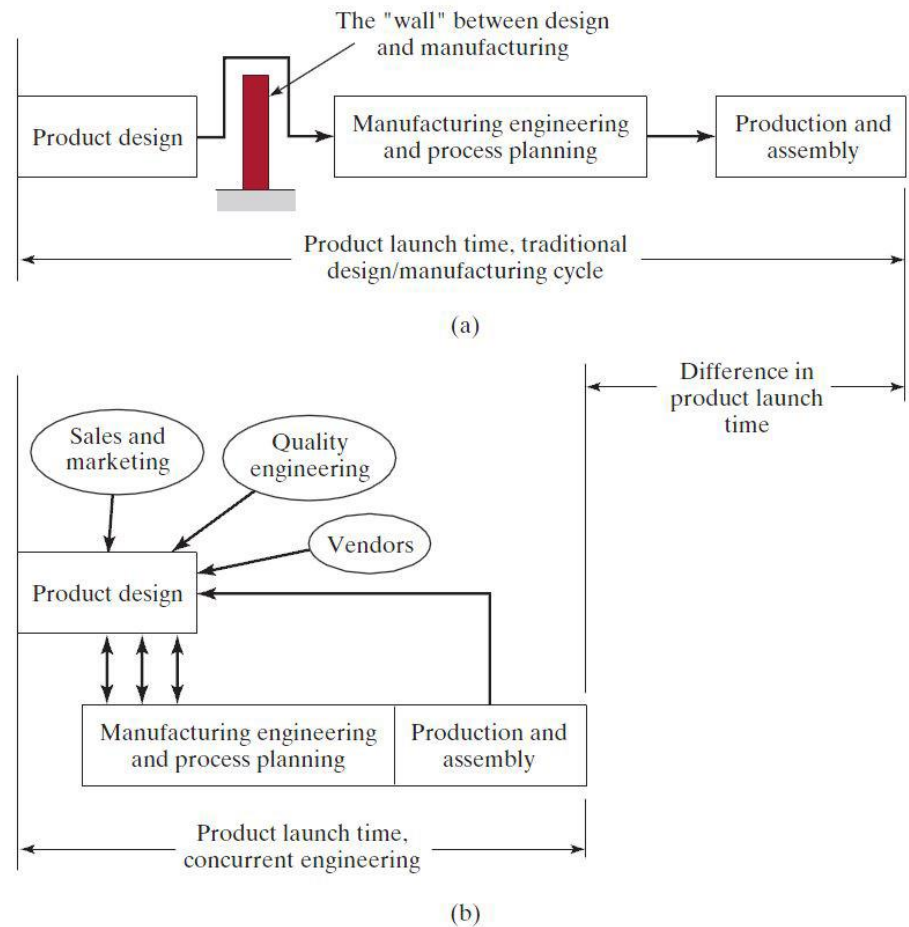
- In a fully generative CAPP system, the process sequence is planned without human assistance and without predefined standard plans
- Designing a generative CAPP system is a problem in expert systems
 - Computer programs capable of solving complex problems that normally require a human with years of education and experience

Product Development: Two Approaches

Comparison of:

(a) traditional product development cycle,

(b) product development using concurrent engineering



Traditional Approach to Launch a Product

- An approach to product design that tends to separate design and manufacturing engineering
- Product design develops the new design, sometimes with small regard for the manufacturing capabilities possessed by the company
 - There is little interaction between design engineers and manufacturing engineers who might provide advice on producibility

Concurrent Engineering

An approach to product design in which companies attempt to reduce elapsed time to bring a new product to market by integrating design and manufacturing engineering, and other functions

- Manufacturing engineering becomes involved early in the product development cycle
- In addition, other functions are also involved, such as field service, quality engineering, manufacturing departments, vendors, and in some cases customers

Concurrent Engineering

- All of these functions can contribute to a product design that performs well functionally, and is also manufacturable, assembleable, inspectable, testable, serviceable, maintainable, free of defects, and safe
 - All viewpoints have been combined to design a product of high quality that will deliver customer satisfaction
- Through early involvement of all interested parties, the total product development cycle time is reduced

Organizational Changes in DFM/A

- To implement DFM/A, a company must make organizational changes to provide closer interaction between design and manufacturing personnel
 - Often done by forming design project teams consisting of product designers, manufacturing engineers, and other specialties
 - In some companies, design engineers must spend some career time in manufacturing to learn about the problems encountered in making things

Examples of DFM/A Principles

- Minimize number of components in the product
- Use standard commercially available components wherever possible
- Use common parts across product lines
- Design parts with tolerances that are within process capability
- Design product for foolproof assembly
- Use modular design
- Shape parts and products for ease of packaging
- Eliminate or reduce adjustments

Other Product Design Objectives

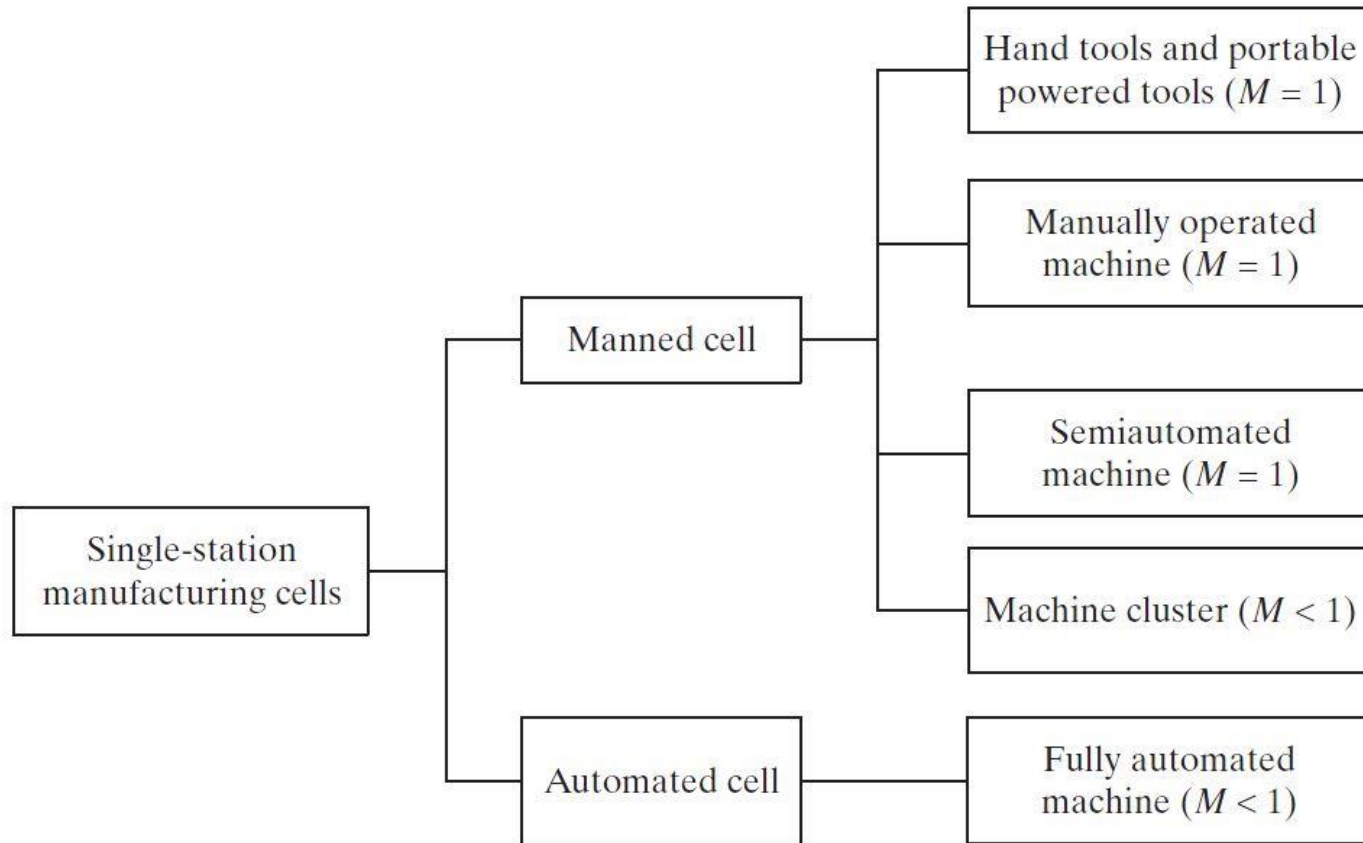
- Design for quality
 - Principles and procedures to ensure that the highest possible quality is designed into the product
- Design for product cost
 - Efforts to specifically identify how design decisions affect product costs and to develop ways to reduce cost through design
- Design for life cycle
 - Gives consideration to costs associated with reliability, maintainability, serviceability, etc., which may be a significant portion of the total cost of the product

Chapter 14: Single-Station Manufacturing Cells

Sections:

1. Single-Station Manned Cells
2. Single-Station Automated Cells
3. Applications of Single-Station Cells
4. Analysis of Single-Station Cells

Classification Scheme for Single-Station Manufacturing Cells



Single-Station Manufacturing Cells

- Most common manufacturing system in industry
- Operation is independent of other stations
- Perform either processing or assembly operations
- Can be designed for:
 - Single model production
 - Batch production
 - Mixed-model production

Single-Station Manned Cell

One worker tending one production machine
(most common model)

- Most widely used production method, especially in job shop and batch production
- Reasons for popularity:
 - Shortest time to implement
 - Requires least capital investment
 - Easiest to install and operate
 - Typically, the lowest unit cost for low production
 - Most flexible for product or part changeovers

Single-Station Manned Cell

Examples

- Worker operating a standard machine tool
 - Worker loads & unloads parts, operates machine
 - Machine is manually operated
- Worker operating semi-automatic machine
 - Worker loads & unloads parts, starts semi-automatic work cycle
 - Worker attention not required continuously during entire work cycle
- Worker using hand tools or portable power tools at one location

Single-Station Automated Cell

Fully automated production machine capable of operating unattended for longer than one work cycle

- Worker not required except for periodic tending
- Reasons why it is important:
 - Labor cost is reduced
 - Easiest and least expensive automated system to implement
 - Production rates usually higher than manned cell
 - First step in implementing an integrated multi-station automated system

Enablers for

Unattended Cell Operation

- For production of identical parts or products:
 - Programmed operation for all steps in work cycle
 - Parts storage system
 - Automatic transfer of work parts between storage system and machine
 - Periodic attention of worker for removal of finished work units, resupply of starting work units, and other machine tending
 - Built-in safeguards to avoid self-destructive operation or damage to work units

Enablers for Unattended Cell Operation

- For cells designed for part or product variety:
 - All of the preceding enablers, plus:
 - Work unit identification:
 - Automatic identification (e.g., bar codes) or sensors that recognize alternative features of starting units
 - If starting units are the same, work unit identification is unnecessary
 - Capability to download programs for each work unit style (programs prepared in advance)
 - Capability for quick changeover of physical setup

Parts Storage Subsystem and Automatic Parts Transfer

- Necessary conditions for unattended operation
- Given a capacity = n_p parts in the storage subsystem, the cell can theoretically operate for a time

$$UT = n_p T_c$$

where UT = unattended time of operation

- In reality, unattended time will be less than UT because the worker needs time to unload finished parts and load raw workparts into the storage subsystem

Storage Capacity of One Part

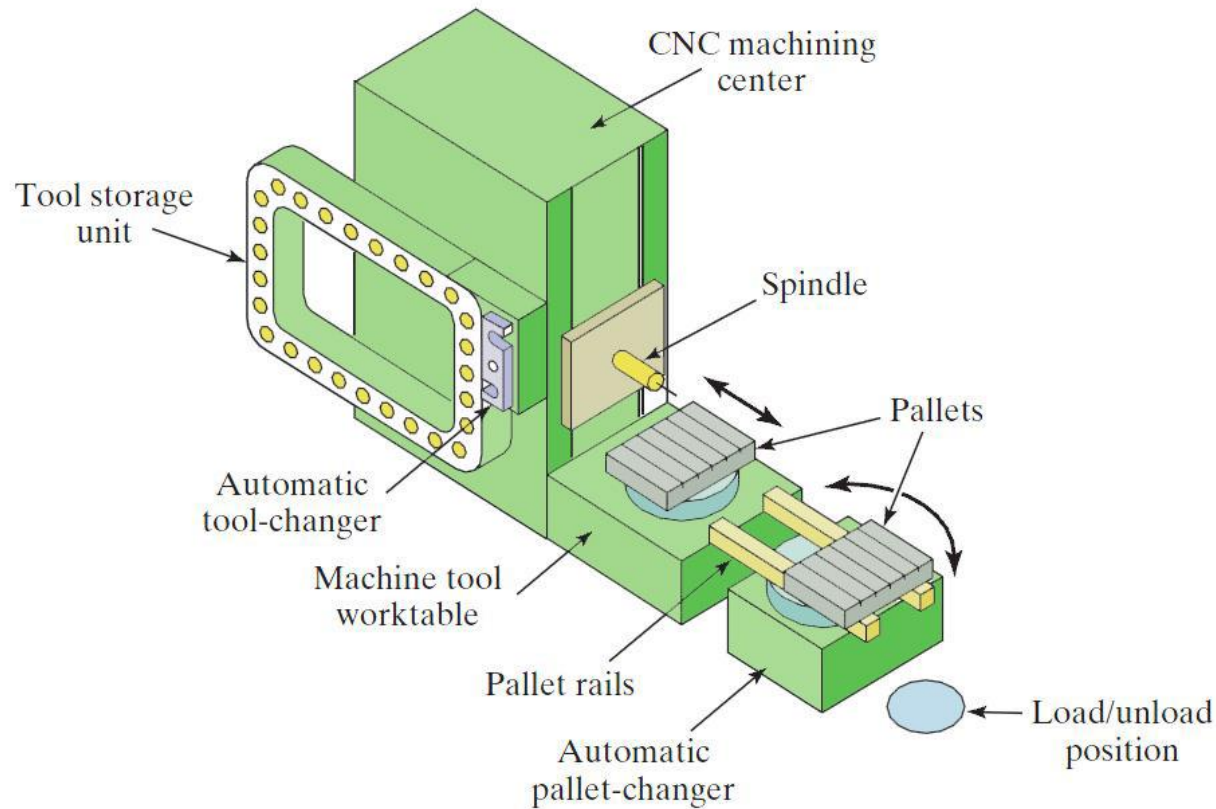
- Example: two-position automatic pallet changer (APC)
- With no pallet changer, work cycle elements of loading/unloading and processing would have to be performed sequentially

$$T_c = T_m + T_s$$

where T_c = cutting time, T_m = machine time and T_s = worker service time

- With pallet changer, work cycle elements can be performed simultaneously

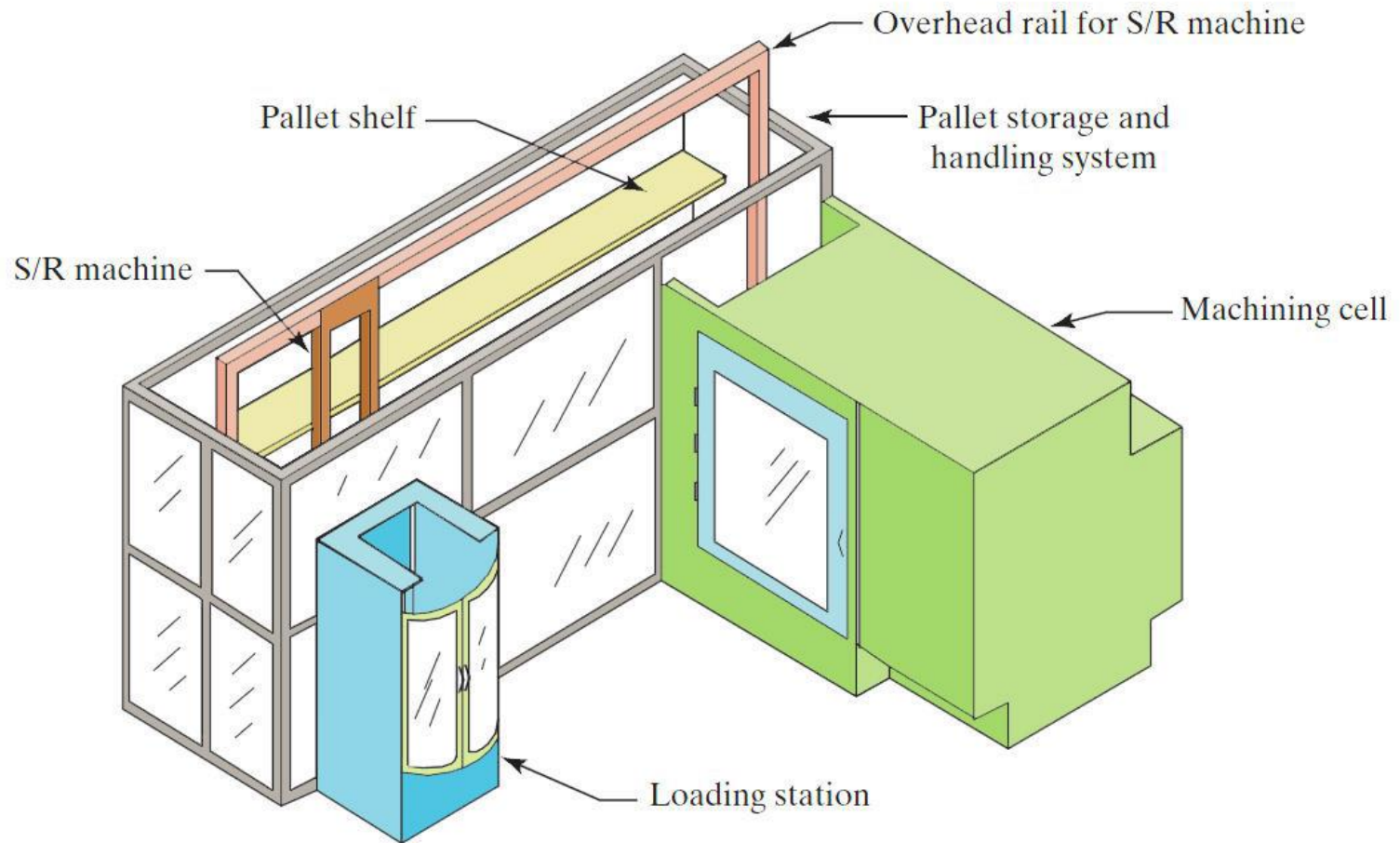
CNC Machining Center with Automatic Pallet Changer - Stores One Part



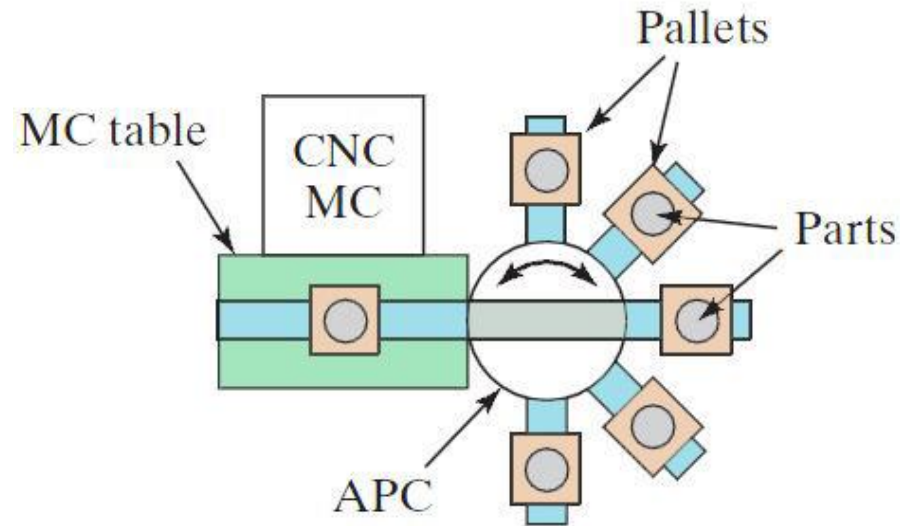
Storage Capacities Greater Than One

- Machining centers:
 - Various designs of parts storage unit interfaced to automatic pallet changer (or other automated transfer mechanism)
- Turning centers:
 - Industrial robot interface with parts carousel
- Plastic molding or extrusion:
 - Hopper contains sufficient molding compound for unattended operation
- Sheet metal stamping:
 - Starting material is sheet metal coil

Single-Station Cell Interfaced with Automated Pallet Storage System



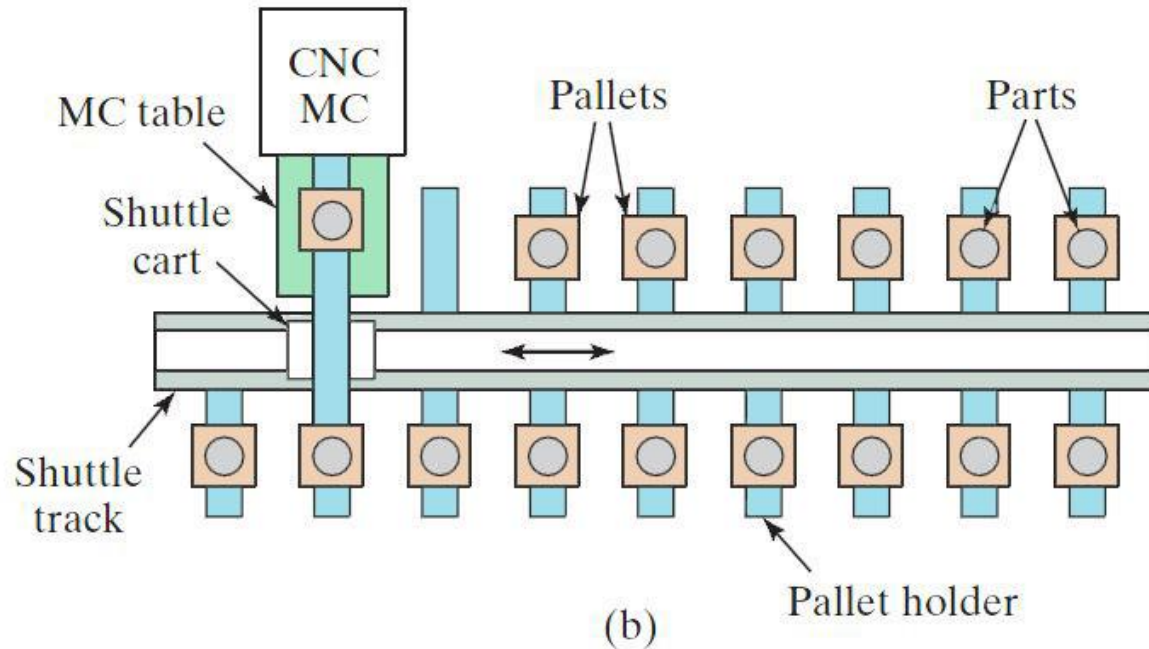
Alternative Designs of Storage Systems For Multiple Parts



(a)

Machining center and automatic pallet changer with pallet holders arranged radially; parts storage capacity = 5

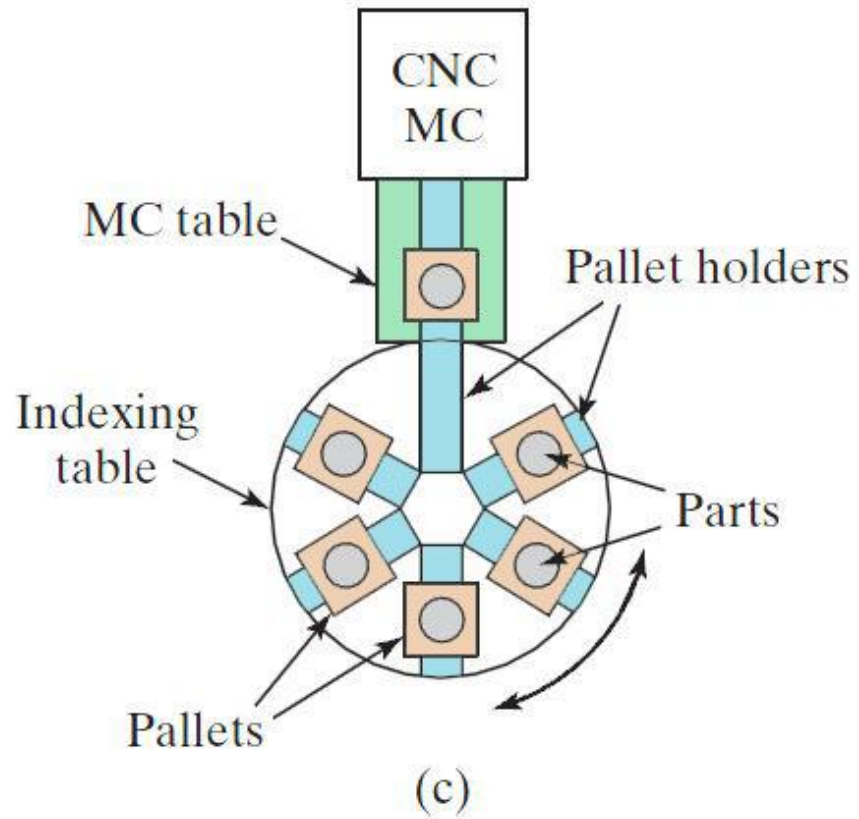
Alternative Designs of Storage Systems For Multiple Parts



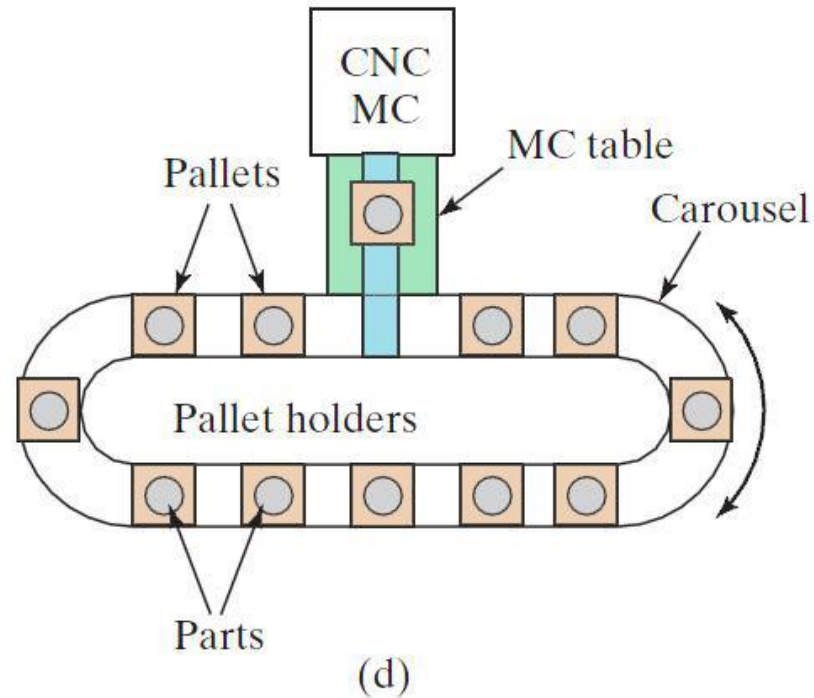
Machining center and in-line shuttle cart system with pallet holders along its length; parts storage capacity = 16

Alternative Designs of Storage Systems For Multiple Parts

Machining center
with pallets held
on indexing table;
parts storage
capacity = 6



Alternative Designs of Storage Systems For Multiple Parts



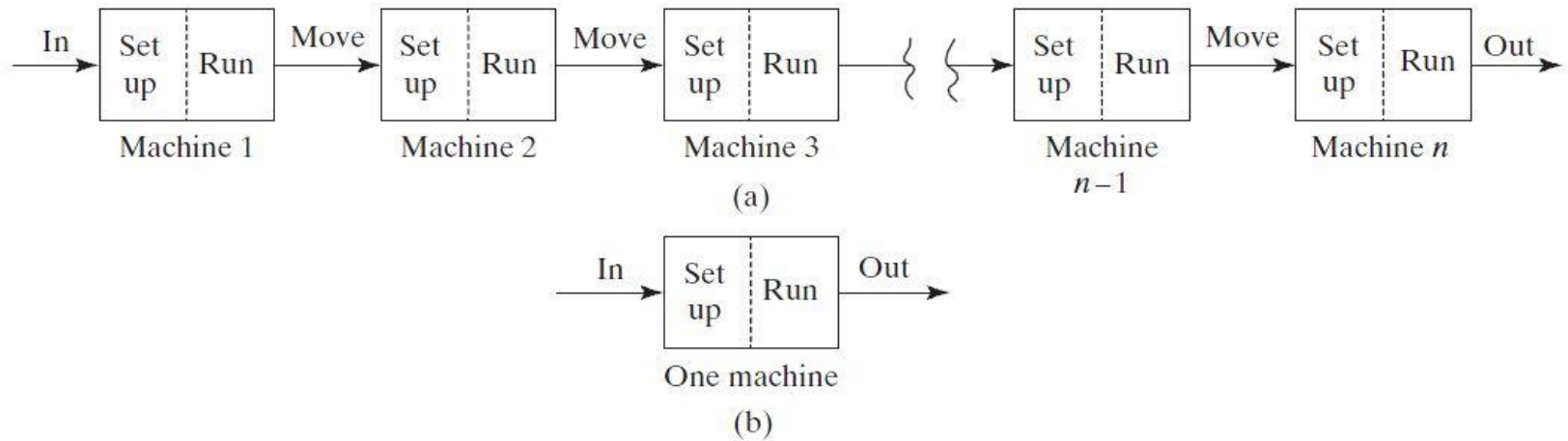
Machining center and parts storage carousel with parts loaded onto pallets; parts storage capacity = 12

CNC Machining Centers and Related Machine Tools

- Many single-station automated cells are designed around CNC machine tools
- Categories:
 - Machining centers
 - Turning centers
 - Mill-turn centers
 - Multitasking machines

CNC Machining Centers and Related Machine Tools

- Objective is to reduce the number of separate machines and setups required to process a given part as in (a) to as few as possible, ideally one machine and one setup as in (b)

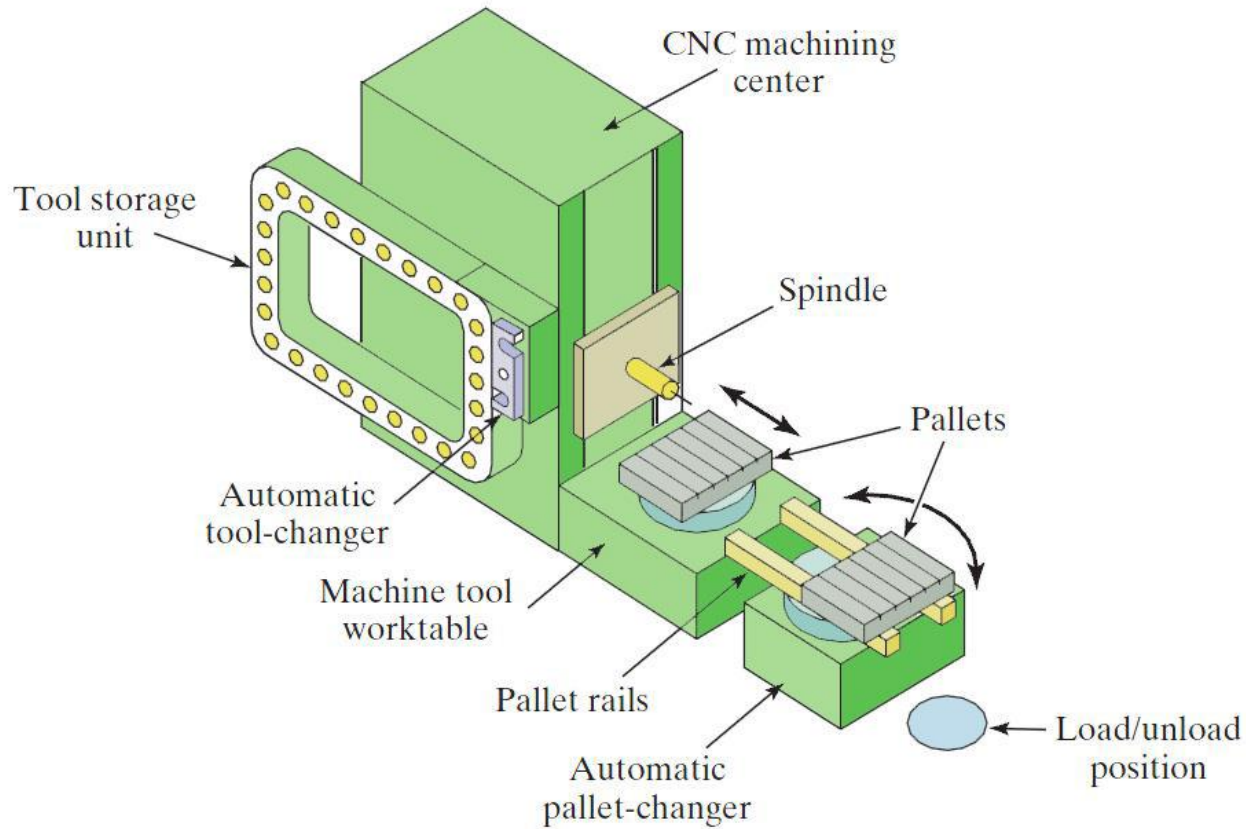


CNC Machining Center

Machine tool capable of performing multiple operations that use rotating tools on a work part in one setup under CNC control

- Typical operations: milling, drilling, and related operations
- Typical features to reduce nonproductive time:
 - Automatic tool-changer
 - Automatic work part positioning
 - Automatic pallet changer

CNC Horizontal Machining Center

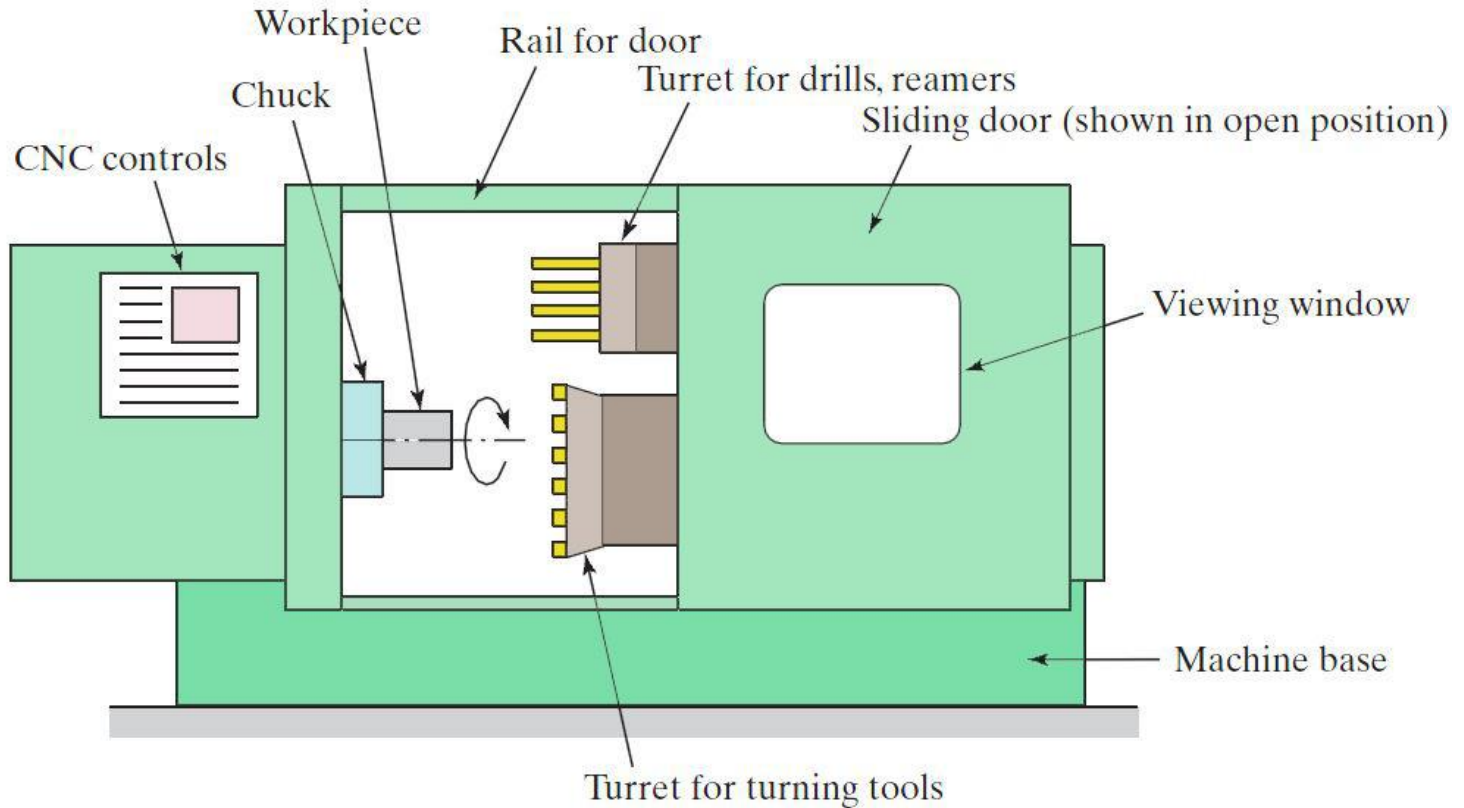


CNC Turning Center

Machine tool capable of performing multiple operations on a rotating workpart in one setup under NC control

- Typical operations:
 - Turning and related operations, e.g., contour turning
 - Drilling and related operations along workpart axis of rotation

CNC Turning Center

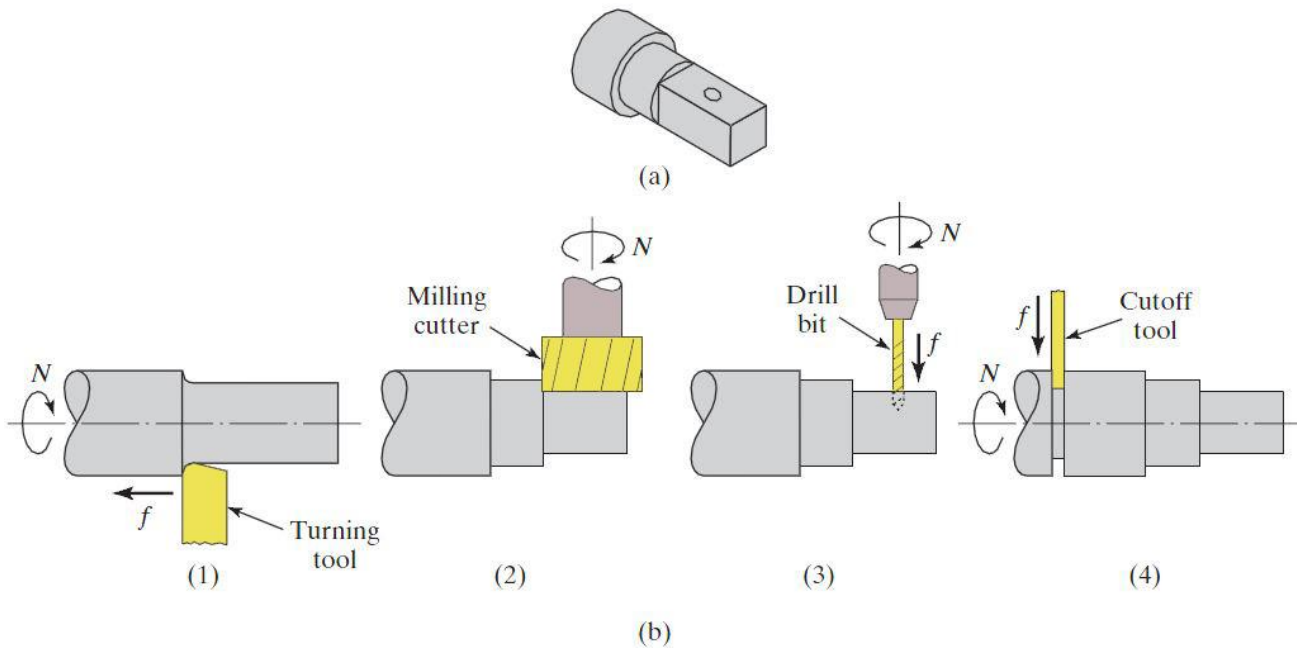


CNC Mill-Turn Center

Machine tool capable of performing multiple operations either with single point turning tools or rotating cutters in one setup under NC control

- Typical operations:
 - Turning, milling, drilling and related operations
- Enabling feature:
 - Capability to control position of c-axis in addition to x - and z -axis control (turning center is limited to x - and z -axis control)

Sequence of Operations of a Mill-Turn Center for Sample Part



(a) Sample part, (b) sequence of operations: (1) Turn smaller diameter, (2) mill flats with part in programmed angular positions, four positions for square cross section; (3) drill hole with part in programmed angular position, and (4) cut off machined piece

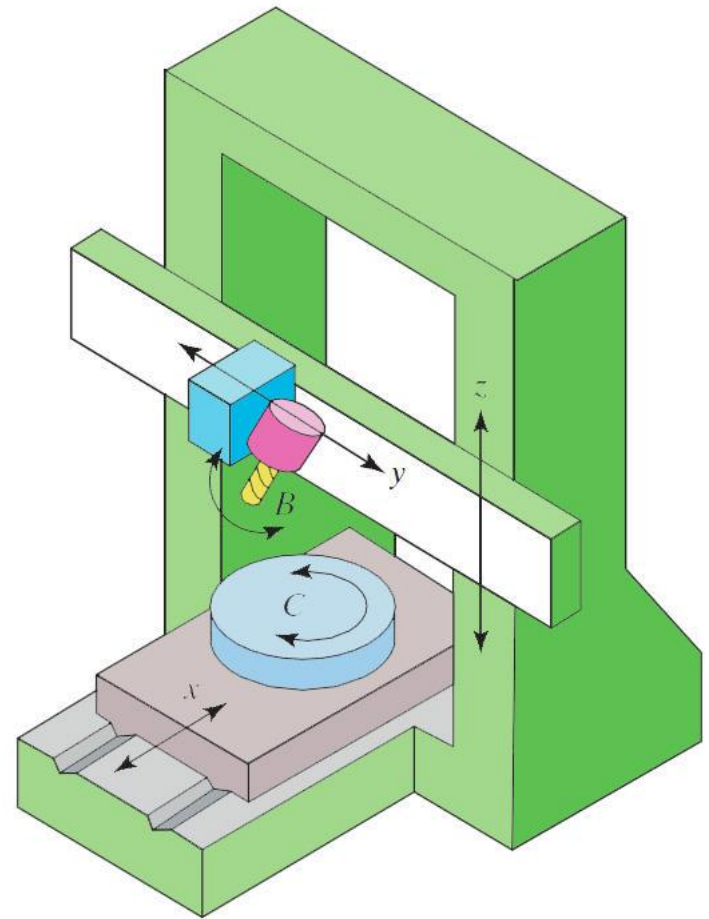
Multitasking Machine

- General configuration of a CNC machining center
- However, whereas a machining center performs milling and drilling operations, a CNC multitasking machine performs all three basic operations:
 - Milling
 - Drilling
 - Turning

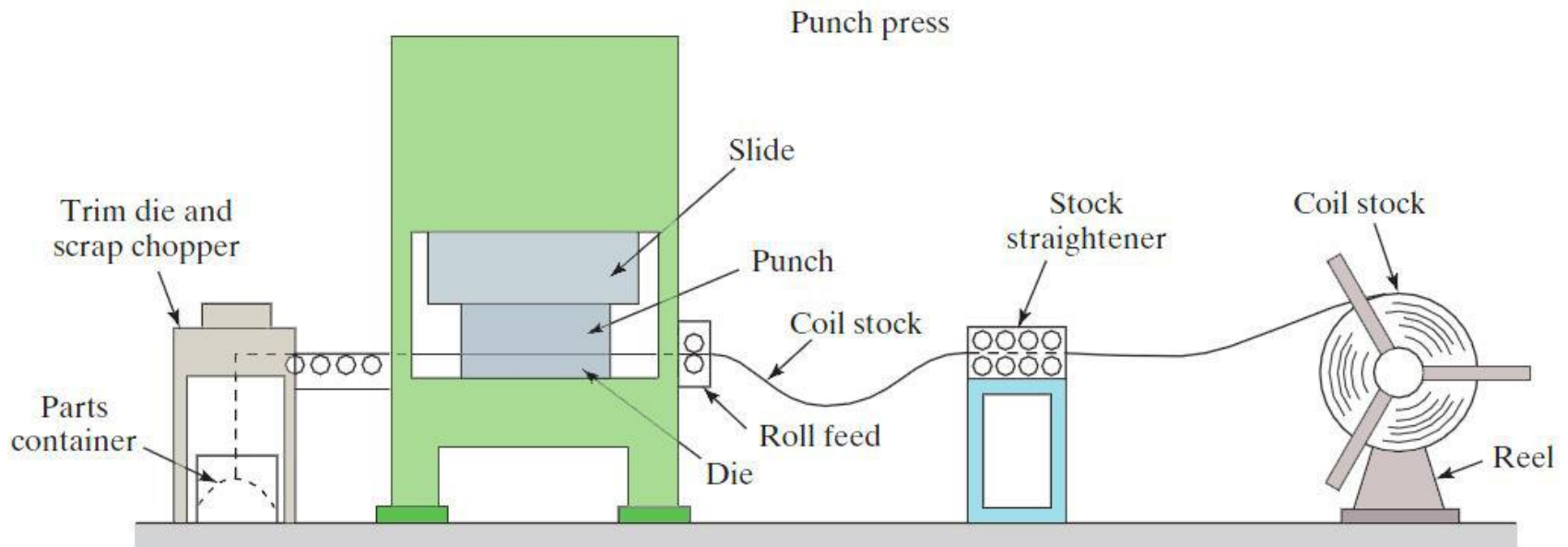
One Possible Design of a CNC Multitasking Machine

Worktable provides motion control of x - and C -axes

Gantry provides motion control of y -, z -, and B -axes



Automated Stamping Press



Stamping press on automatic cycle producing stampings from sheet metal coil

Chapter 18: Group Technology and Cellular Manufacturing

Sections:

1. Part Families and Machine Groups
2. Cellular Manufacturing
3. Applications of Group Technology
4. Analysis of Cellular Manufacturing

Group Technology (GT) Defined

A manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in design and production

- Similarities among parts permit them to be classified into part families
 - In each part family, processing steps are similar
- The improvement is typically achieved by organizing the production facilities into manufacturing cells that specialize in production of certain part families

Overview of Group Technology

- Parts in the medium production quantity range are usually made in batches
- Disadvantages of batch production:
 - Downtime for changeovers
 - High inventory carrying costs
- GT minimizes these disadvantages by recognizing that although the parts are different, there are groups of parts that possess similarities

Part Families and Cellular Manufacturing

- GT exploits the part similarities by utilizing similar processes and tooling to produce them
- Machines are grouped into cells, each cell specializing in the production of a part family
 - Called *cellular manufacturing*
- Cellular manufacturing can be implemented by manual or automated methods
 - When automated, the term *flexible manufacturing system* is often applied

When to Use GT and Cellular Manufacturing

1. The plant currently uses traditional batch production and a process type layout
 - This results in much material handling effort, high in-process inventory, and long manufacturing lead times
2. The parts can be grouped into part families
 - A necessary condition to apply group technology
 - Each machine cell is designed to produce a given part family, or a limited collection of part families, so it must be possible to group parts made in the plant into families

Problems in Implementing GT

1. Identifying the part families
 - Reviewing all of the parts made in the plant and grouping them into part families is a substantial task
2. Rearranging production machines into GT cells
 - It is time-consuming and costly to physically rearrange the machines into cells, and the machines are not producing during the changeover

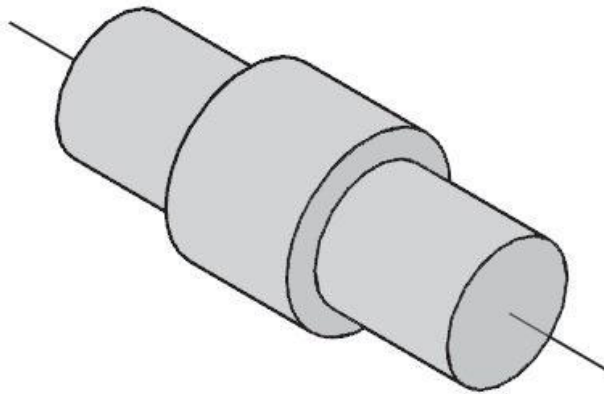
Part Family

A collection of parts that possess similarities in geometric shape and size, or in the processing steps used in their manufacture

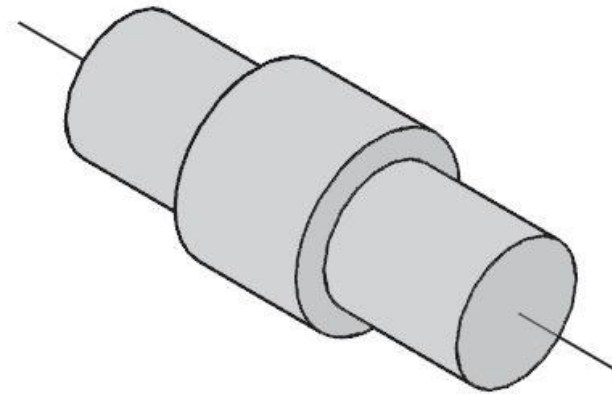
- Part families are a central feature of group technology
 - There are always differences among parts in a family
 - But the similarities are close enough that the parts can be grouped into the same family

Part Families

- Two parts that are identical in shape and size but quite different in manufacturing: (a) 1,000,000 units/yr, tolerance = ± 0.010 inch, 1015 CR steel, nickel plate; (b) 100/yr, tolerance = ± 0.001 inch, 18-8 stainless steel



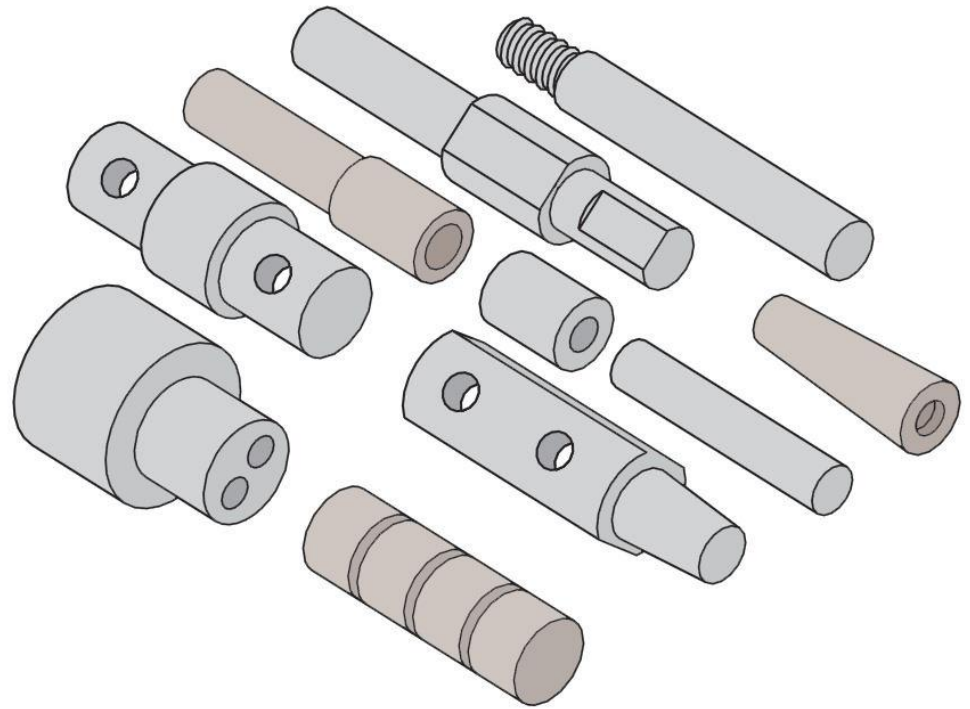
(a)



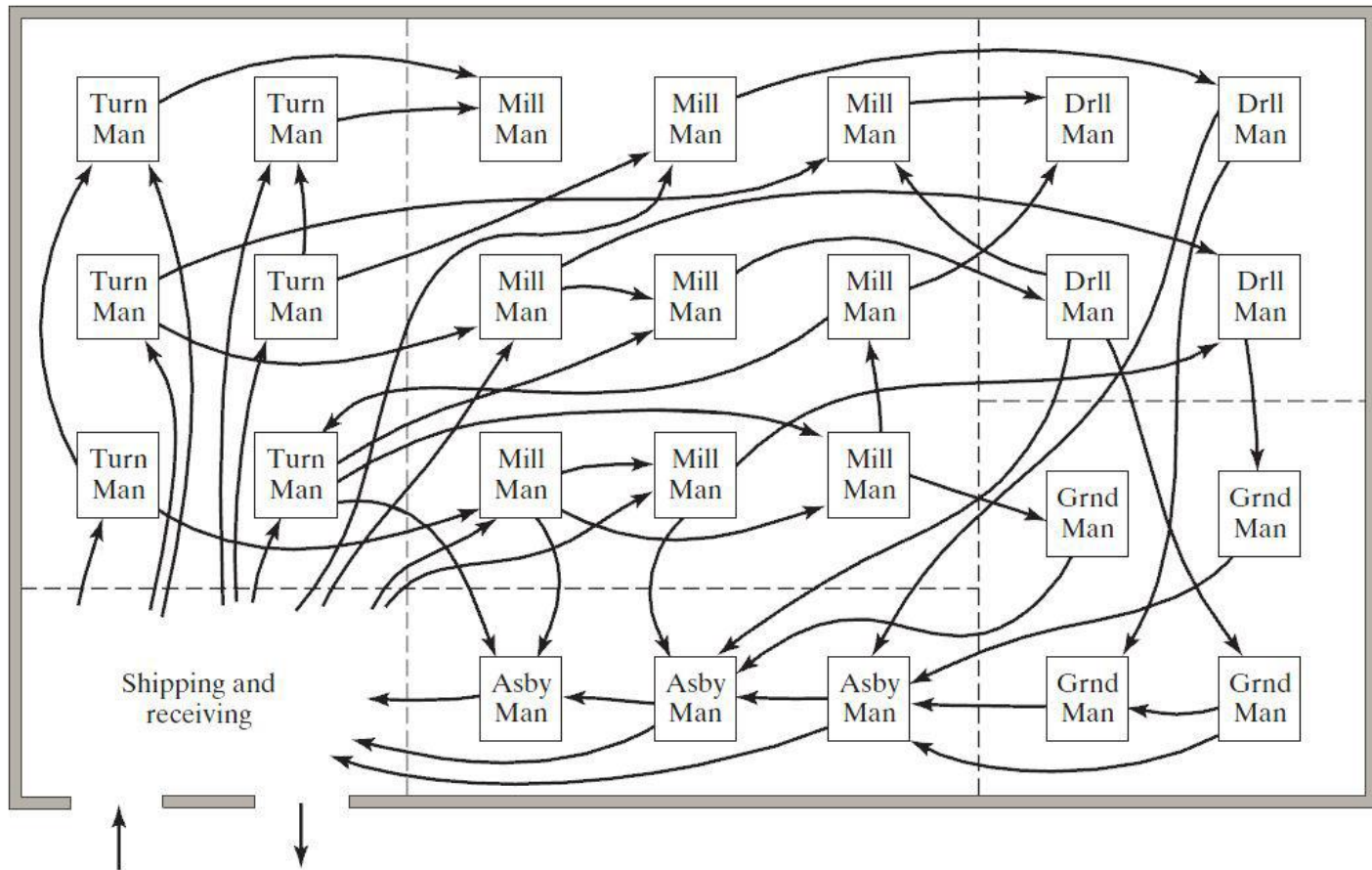
(b)

Part Families

- Ten parts are different in size, shape, and material, but quite similar in terms of manufacturing
- All parts are machined from cylindrical stock by turning; some parts require drilling and/or milling

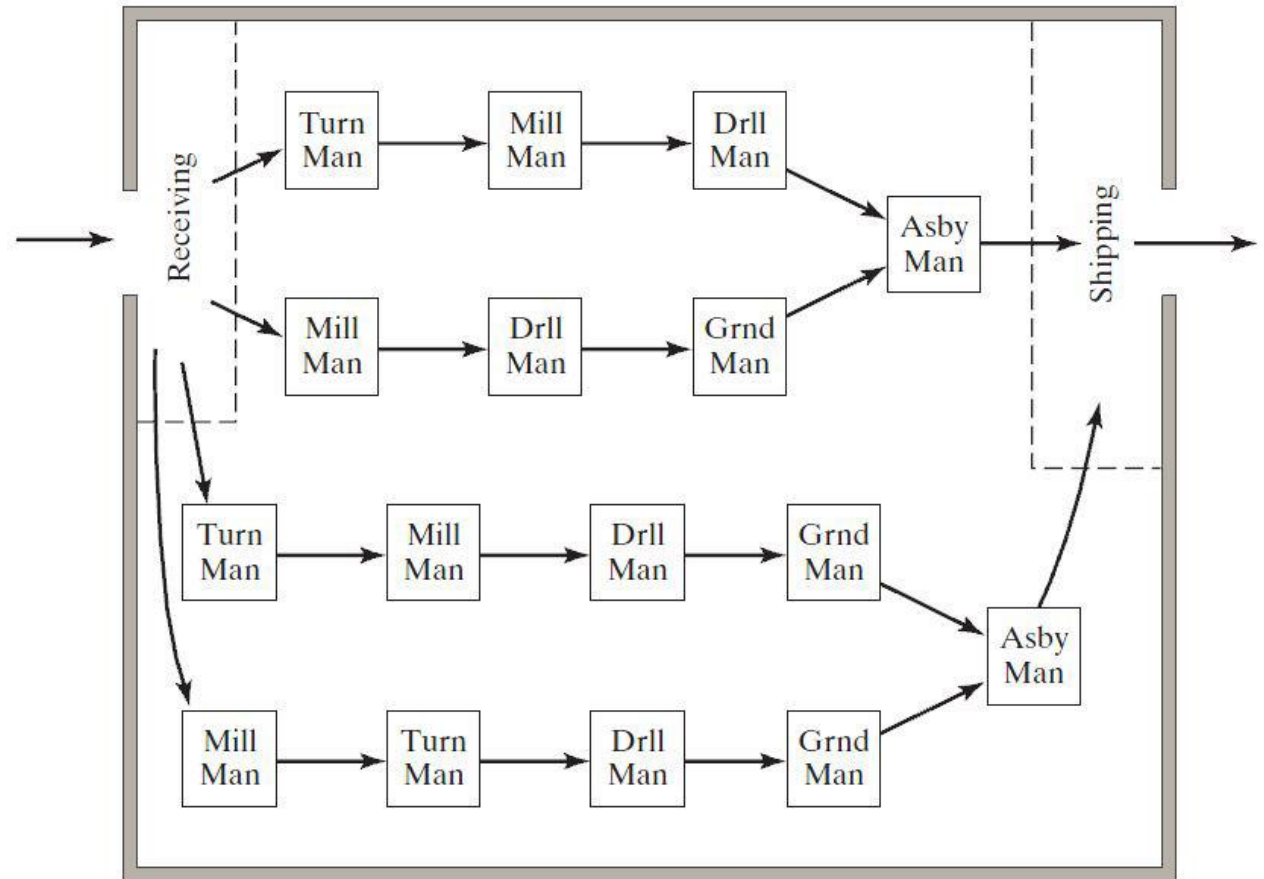


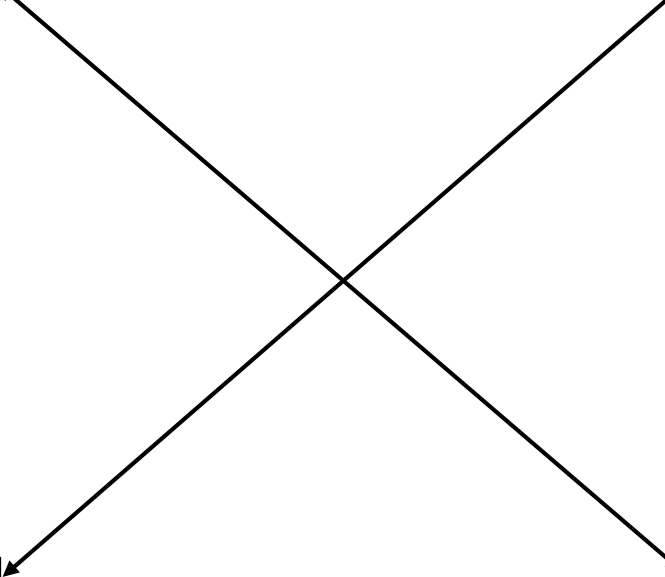
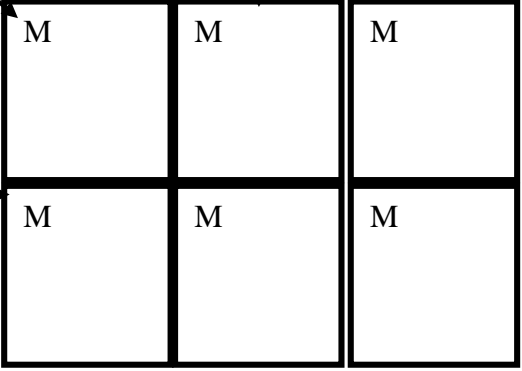
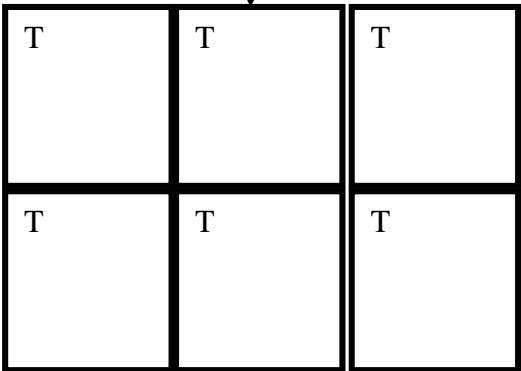
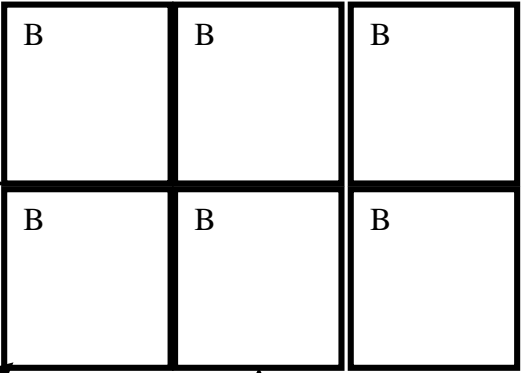
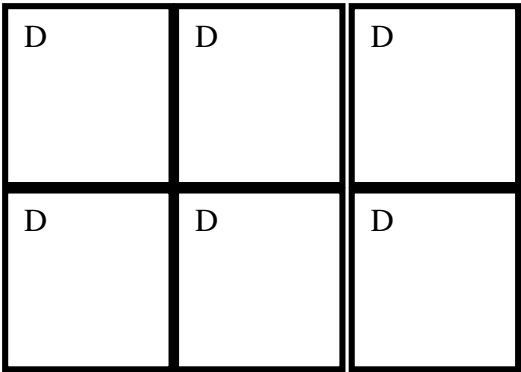
Traditional Process Layout



Cellular Layout Based on GT

- Each cell specializes in producing one or a limited number of part families





Ways to Identify Part Families

1. Intuitive grouping (aka *visual inspection*)
 - Using best judgment to group parts into appropriate families, based on the parts or photos of the parts
2. Parts classification and coding
 - Identifying similarities and differences among parts and relating them by means of a coding scheme
3. Production flow analysis
 - Using information contained on route sheets to classify parts

Parts Classification and Coding

Identification of similarities among parts and relating the similarities by means of a numerical coding system

- Most time consuming of the three methods
- Must be customized for a given company or industry
- Reasons for using a coding scheme:
 - Design retrieval
 - Automated process planning
 - Machine cell design

Features of Parts Classification and Coding Systems

- Most classification and coding systems are based on one of the following:
 - Part design attributes
 - Part manufacturing attributes
 - Both design and manufacturing attributes

Part Design and Manufacturing Attributes

Design Attributes

- Major dimensions
- Basic external shape
- Basic internal shape
- Length/diameter ratio
- Material type
- Part function
- Tolerances
- Surface finish

Manufacturing Attributes

- Major process
- Operation sequence
- Batch size
- Annual production
- Machine tools
- Cutting tools
- Material type

Cellular Manufacturing

Application of group technology in which dissimilar machines or processes are aggregated into cells, each of which is dedicated to the production of a part family or limited group of families

- Typical objectives of cellular manufacturing:
 - To shorten manufacturing lead times
 - To reduce WIP
 - To improve quality
 - To simplify production scheduling
 - To reduce setup times

Composite Part Concept

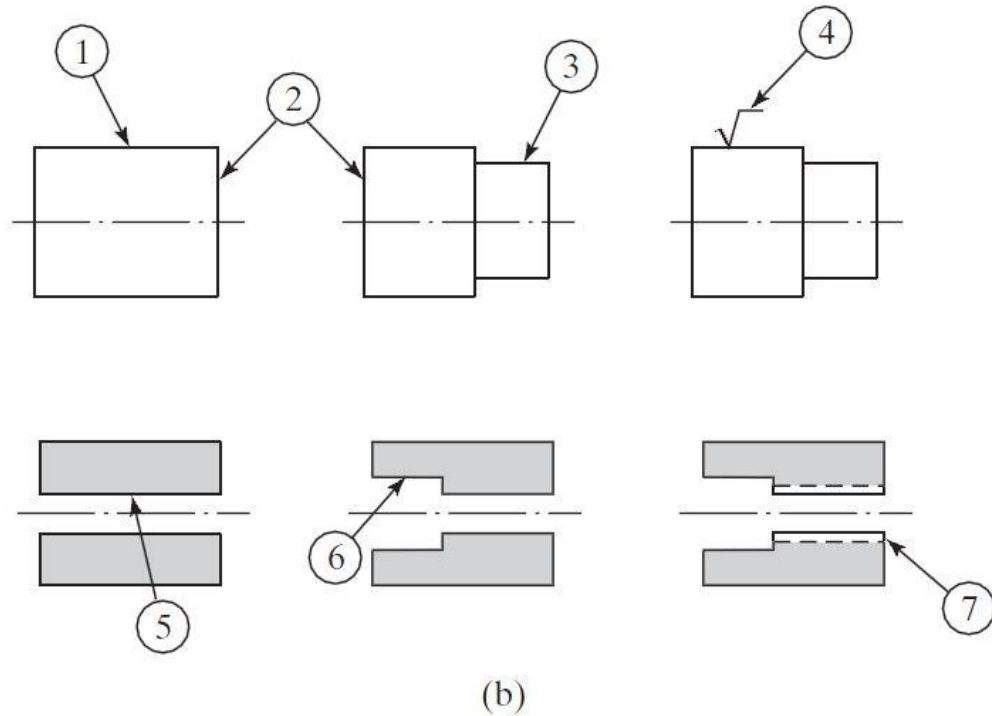
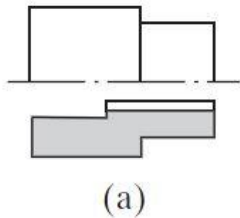
A *composite part* for a given family is a hypothetical part that includes all of the design and manufacturing attributes of the family

- In general, an individual part in the family will have some of the features of the family, but not all of them
- A production cell for the part family would consist of those machines required to make the composite part
- Such a cell would be able to produce any family member, by omitting operations corresponding to features not possessed by that part

Composite Part Concept

Composite part concept: (a) the composite part for a family of machined rotational parts, and (b) the individual features of the composite part

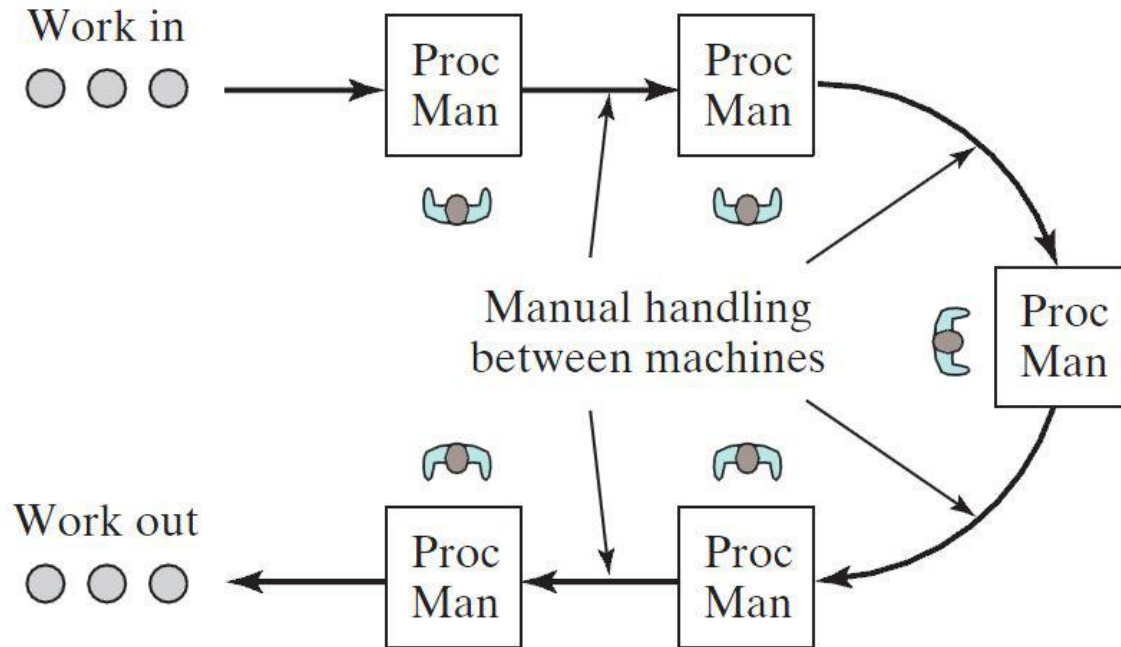
Composite part consisting of all seven design and processing attributes



Machine Cell Designs

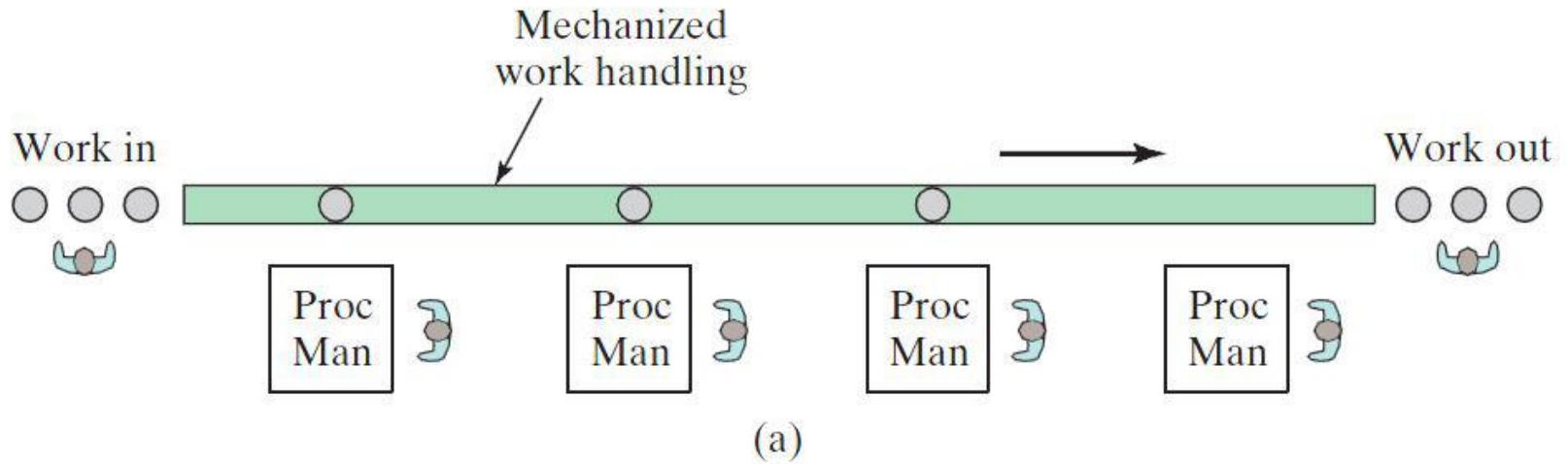
1. Single machine
2. Multiple machines with manual handling
 - Often organized into U-shaped layout
3. Multiple machines with semi-integrated handling
4. Automated cell – automated processing and integrated handling
 - Flexible manufacturing cell
 - Flexible manufacturing system

Machine Cell with Manual Handling



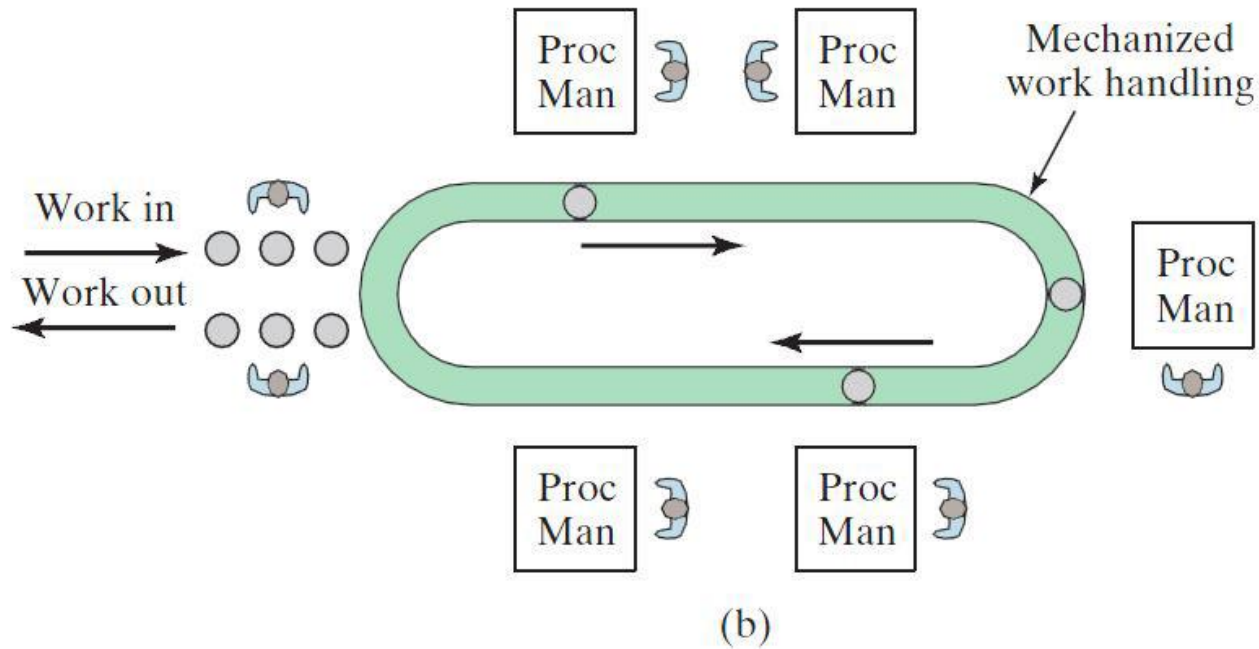
U-shaped machine cell with manual part handling between machines

Cell with Semi-Integrated Handling



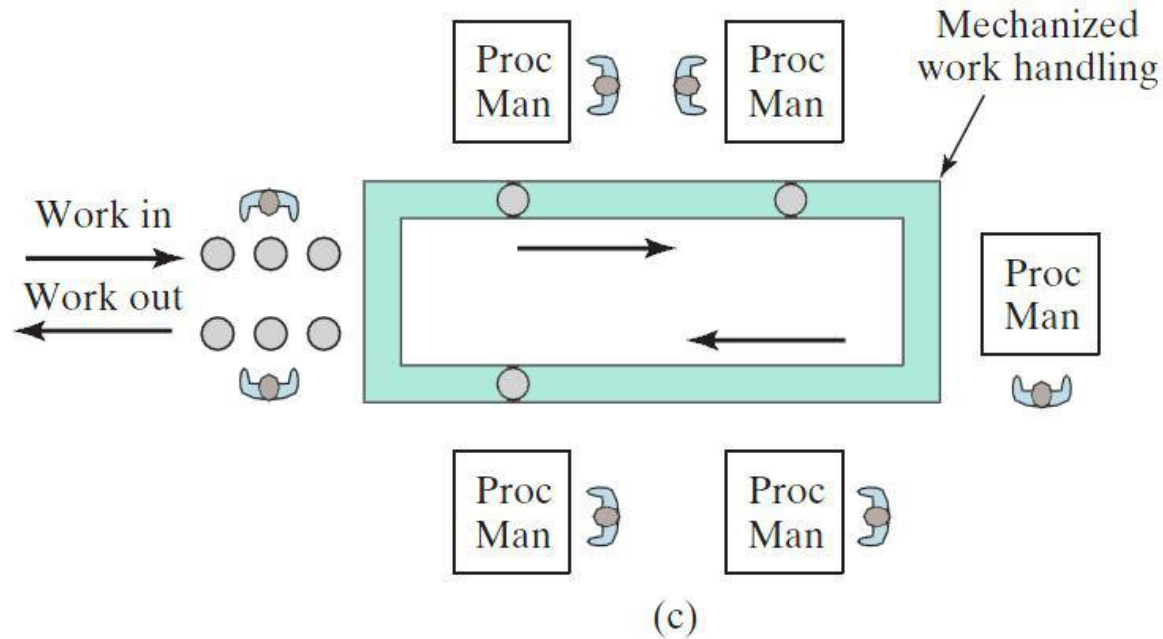
In-line layout using mechanized work handling between machines

Cell with Semi-Integrated Handling



Loop layout allows variations in part routing between machines

Cell with Semi-Integrated Handling



Rectangular layout also allows variations in part routing and allows return of work carriers if they are used

Key Machine Concept

- Applies in cells when there is one machine (the key machine) that is more expensive or performs certain critical operations
 - Other machines in the cell are supporting machines
 - Important to maintain high utilization of key machine, even if this means lower utilization of supporting machines

Manufacturing Applications of Group Technology

- Different ways of forming machine cells:
 - Informal scheduling and routing of similar parts through selected machines to minimize setups
 - Virtual machine cells – dedication of certain machines in the factory to produce part families, but no physical relocation of machines
 - Formal machine cells – machines are physically relocated to form the cells
- Automated process planning
- Modular fixtures
- Parametric programming in NC

Benefits of Group Technology in Manufacturing

- Standardization of tooling, fixtures, and setups is encouraged
- Material handling is reduced
 - Parts are moved within a machine cell rather than the entire factory
- Process planning and production scheduling are simplified
- Work-in-process and manufacturing lead time are reduced
- Improved worker satisfaction in a GT cell
- Higher quality work

Product Design Applications of Group Technology

- Design retrieval systems
 - Industry survey: For new part designs,
 - Existing part design could be used – 20%
 - Existing part design with modifications – 40%
 - New part design required – 40%
- Simplification and standardization of design parameters such as tolerances, chamfers, hole sizes, thread sizes, etc.
 - Reduces tooling and fastener requirements in manufacturing

Chapter 19: Flexible Manufacturing Systems

Sections:

1. What is a Flexible Manufacturing System?
2. FMC/FMS Components
3. FMS Applications Considerations
4. Analysis of Flexible Manufacturing Systems
5. Alternative Approaches to Flexible Manufacturing

Where to Apply FMS Technology

- The plant presently either:
 - Produces parts in batches or
 - Uses manned GT cells and management wants to automate the cells
- It must be possible to group a portion of the parts made in the plant into part families
 - The part similarities allow them to be processed on the FMS workstations
- Parts and products are in the mid-volume, mid-variety production range

Flexible Manufacturing System - Defined

- A highly automated GT machine cell, consisting of a group of processing stations (usually CNC machine tools), interconnected by an automated material handling and storage system, and controlled by an integrated computer system
- The FMS relies on the principles of GT
 - No manufacturing system can produce an unlimited range of products
 - An FMS is capable of producing a single part family or a limited range of part families

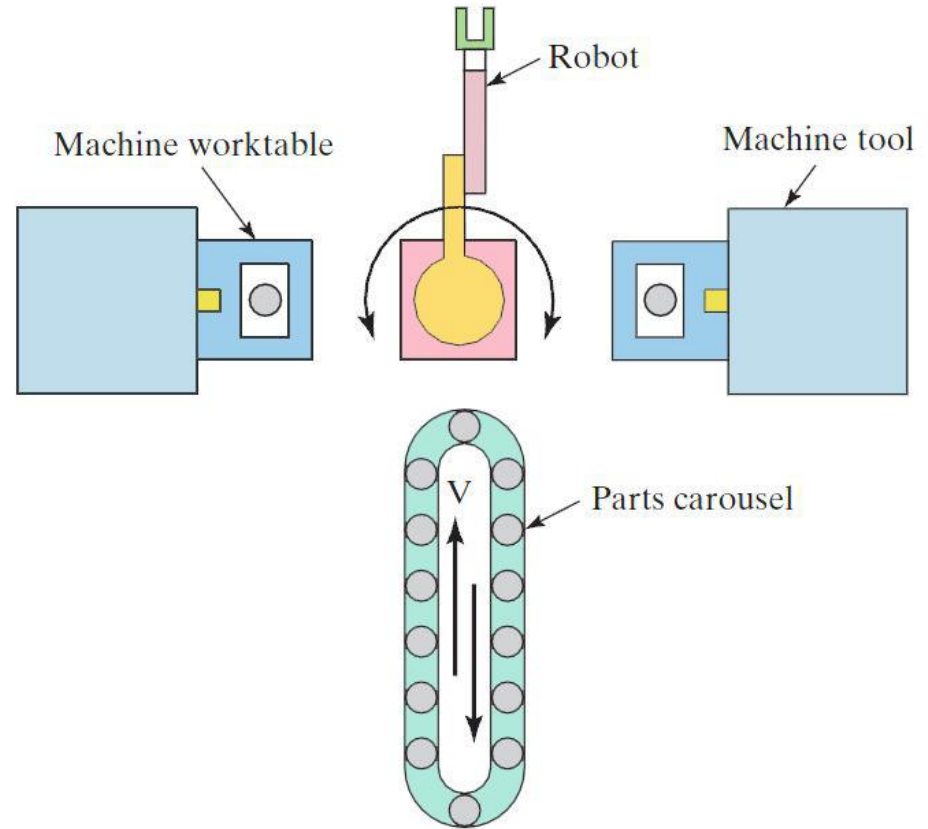
Flexibility Tests in an Automated Manufacturing System

To qualify as being flexible, a manufacturing system should satisfy the following criteria (“yes” answer for each question):

1. Can it process different part styles in a non-batch mode?
2. Can it accept changes in production schedule?
3. Can it respond gracefully to equipment malfunctions and breakdowns?
4. Can it accommodate introduction of new part designs?

Automated Manufacturing Cell

Automated cell
with two
machine tools
and robot that
transfers parts
between
carousel and
machine tools



Is it flexible?

Is the Robotic Work Cell Flexible?

1. Part variety test

- Can it machine different part configurations in a mix rather than in batches?

2. Schedule change test

- Can production schedule and part mix be changed?

Is the Robotic Work Cell Flexible?

3. Error recovery test

- Can it operate if one machine breaks down?
 - Example: while repairs are being made on the broken machine, can its work be temporarily reassigned to the other machine?

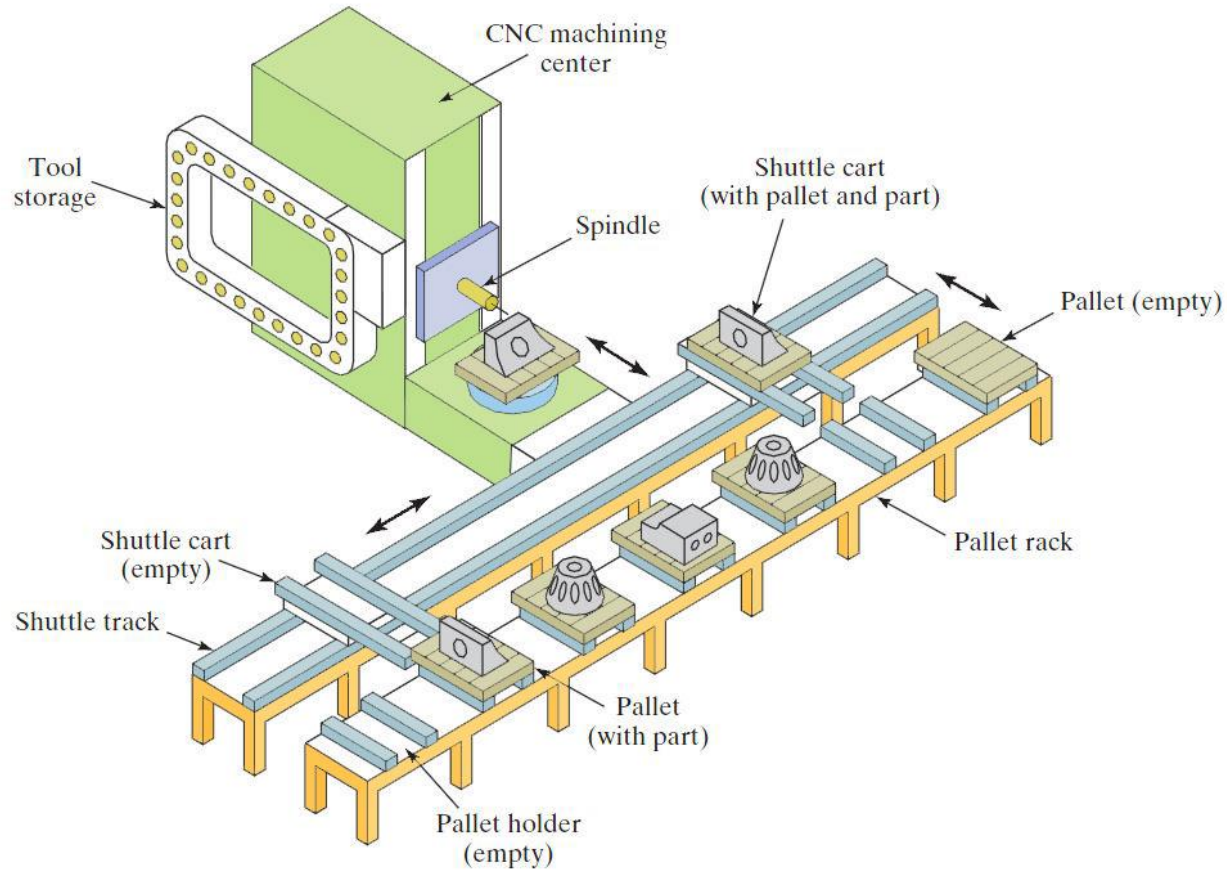
4. New part test

- As new part designs are developed, can NC part programs be written off-line and then downloaded to the system for execution?

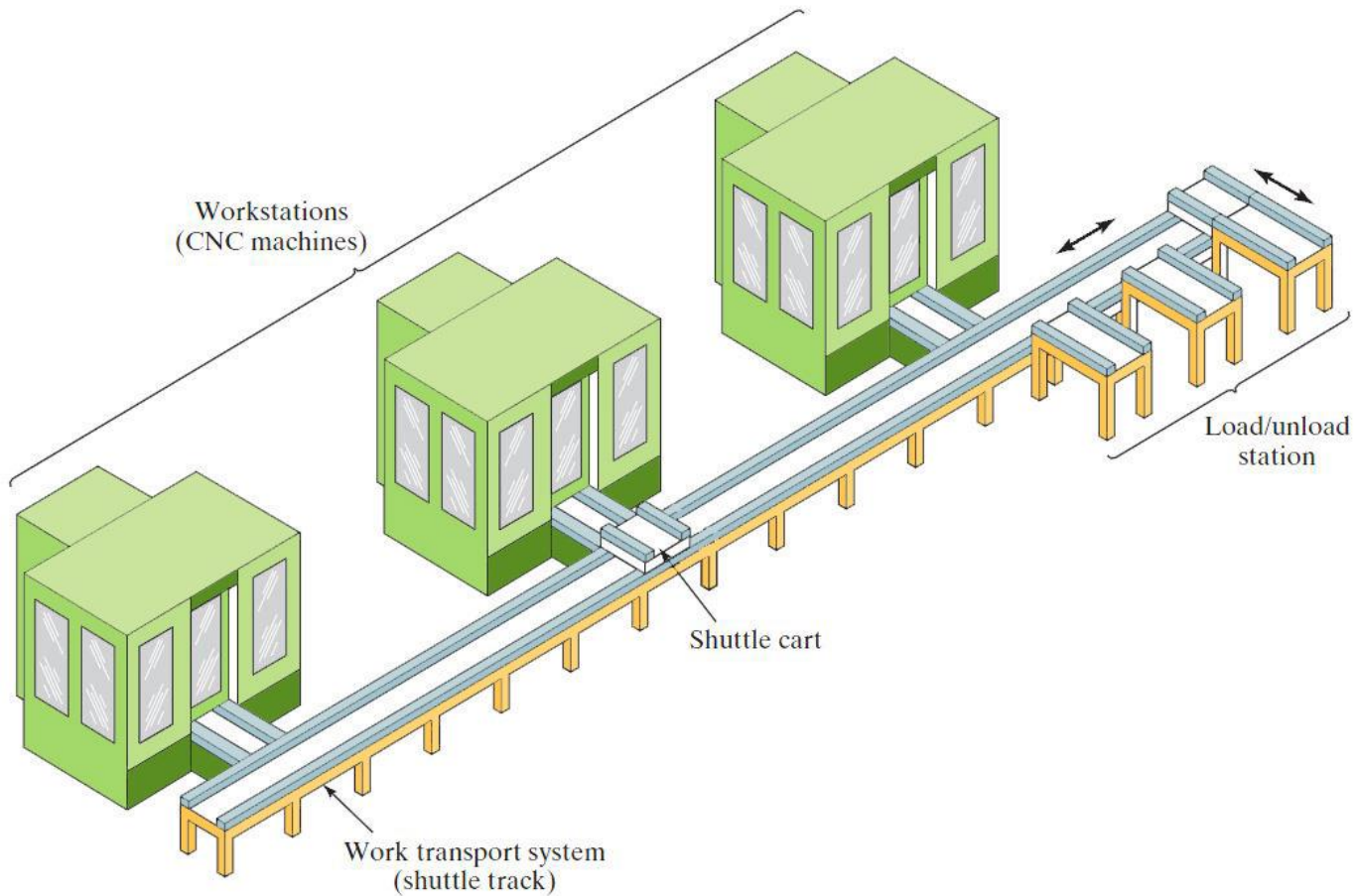
Types of FMS

- Kinds of operations
 - Processing vs. assembly
 - Type of processing
 - If machining, rotational vs. non-rotational
- Number of machines (workstations):
 1. Single machine cell ($n = 1$)
 2. Flexible manufacturing cell ($n = 2$ or 3)
 3. Flexible manufacturing system ($n = 4$ or more)

Single-Machine Manufacturing Cell



Flexible Manufacturing Cell



Flexibility Comparisons for the Three Types of Cells and Systems

TABLE 19.1 Four Tests of Flexibility Applied to the Three Types of Manufacturing Cells and Systems

Four Tests of Flexibility				
System Type	1. Part Variety	2. Schedule Change	3. Error Recovery	4. New Part
Single-machine cell	Yes, but processing is sequential, not simultaneous.	Yes	Limited recovery due to only one machine.	Yes
Flexible manufacturing cell (FMC)	Yes, simultaneous production of different parts.	Yes	Error recovery limited by fewer machines than FMS.	Yes
Flexible manufacturing system (FMS)	Yes, simultaneous production of different parts.	Yes	Machine redundancy minimizes effect of machine breakdowns.	Yes

FMS Types and Level of Flexibility

1. Dedicated FMS

- Designed to produce a limited variety of part styles
- The complete universe of parts to be made on the system is known in advance
- Part family likely based on product commonality rather than geometric similarity

2. Random-order FMS

- Appropriate for large part families
- New part designs will be introduced
- Production schedule is subject to daily changes

Flexibility Comparison for Dedicated and Random-Order FMS

TABLE 19.2 Four Tests of Flexibility Applied to Dedicated and Random-Order Systems

Four Tests of Flexibility				
System Type	1. Part Variety	2. Schedule Change	3. Error Recovery	4. New Part
Dedicated FMS	Limited. All parts are known in advance.	Limited changes can be tolerated.	Usually limited by sequential processes.	No. New part introductions are difficult.
Random-order FMS	Yes. Substantial part variations are possible.	Frequent and significant changes are possible.	Machine redundancy minimizes effect of machine breakdowns.	Yes. System is designed for new part designs.

FMS Components

1. Workstations
2. Material handling and storage system
3. Computer control system

In addition, people are required to manage and operate the system

Duties Performed by Human Labor

- Loading and unloading parts from the system
- Changing and setting cutting tools
- Maintenance and repair of equipment
- NC part programming
- Programming and operating the computer system
- Overall management of the system

Workstations

- Load/unload station(s)
 - Factory interface with FMS
 - Manual or automated
 - Includes communication interface with worker to specify parts to load, fixtures needed, etc.
- CNC machine tools in a machining type system
 - CNC machining centers
 - Milling machine modules
 - Turning modules
- Assembly machines

Material Handling and Storage

- Functions:
 - Random, independent movement of parts between stations
 - Capability to handle a variety of part styles
 - Standard pallet fixture base
 - Workholding fixture can be adapted
 - Temporary storage
 - Convenient access for loading and unloading
 - Compatibility with computer control

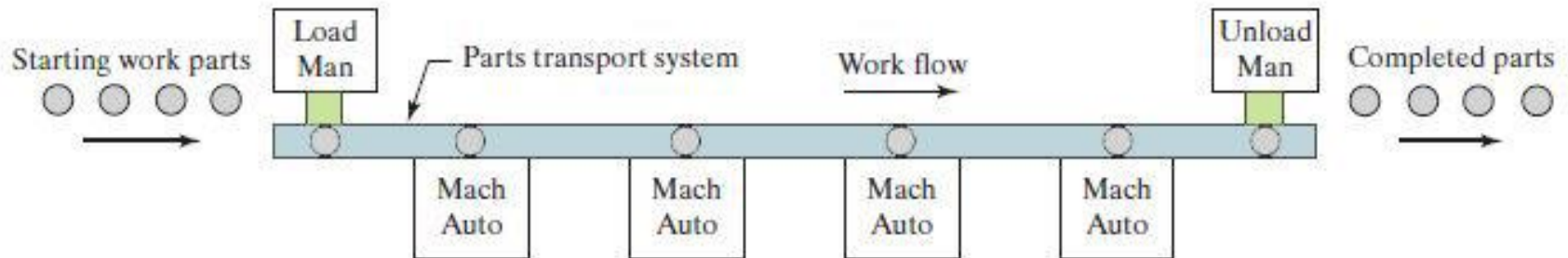
Material Handling Equipment

- Primary handling system establishes basic FMS layout
- Secondary handling system - functions:
 - Transfers work from primary handling system to workstations
 - Position and locate part with sufficient accuracy and repeatability for the operation
 - Reorient part to present correct surface for processing
 - Buffer storage to maximize machine utilization

Types of FMS Layouts

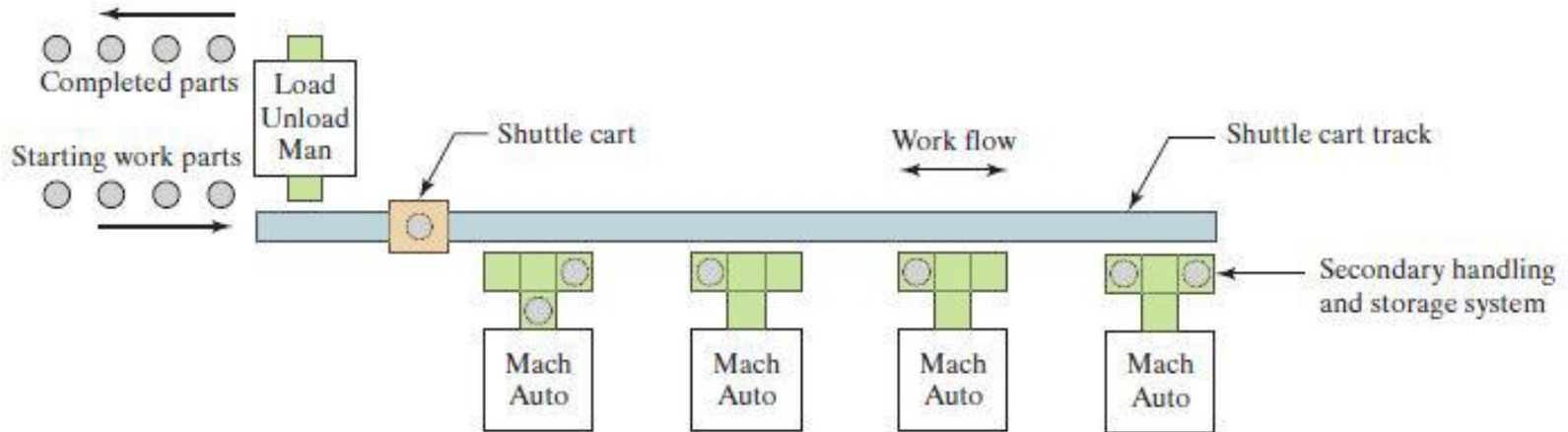
- The layout of the FMS is established by the material handling system
- Four basic FMS layouts
 1. In-line
 2. Loop
 3. Open field
 4. Robot-centered cell

FMS In-Line Layout



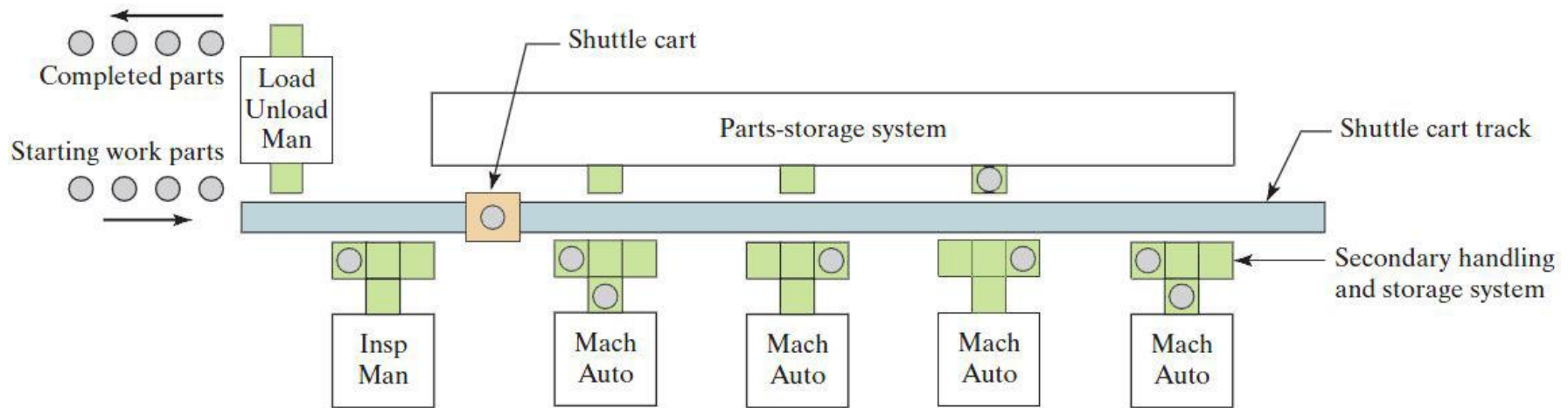
- Straight line flow, well-defined processing sequence similar for all work units
- Work flow is from left to right through the same workstations
- No secondary handling system

FMS In-Line Layout

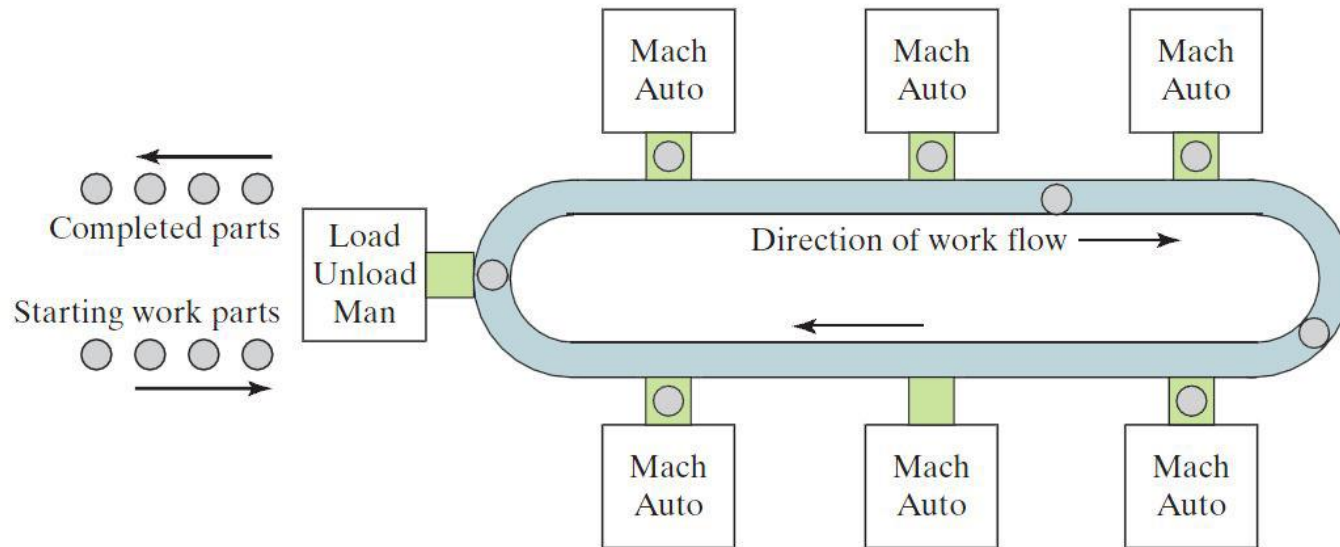


- Linear transfer system with secondary parts handling system at each workstation to facilitate flow in two directions

FMS In-Line Layout with Integrated Storage System

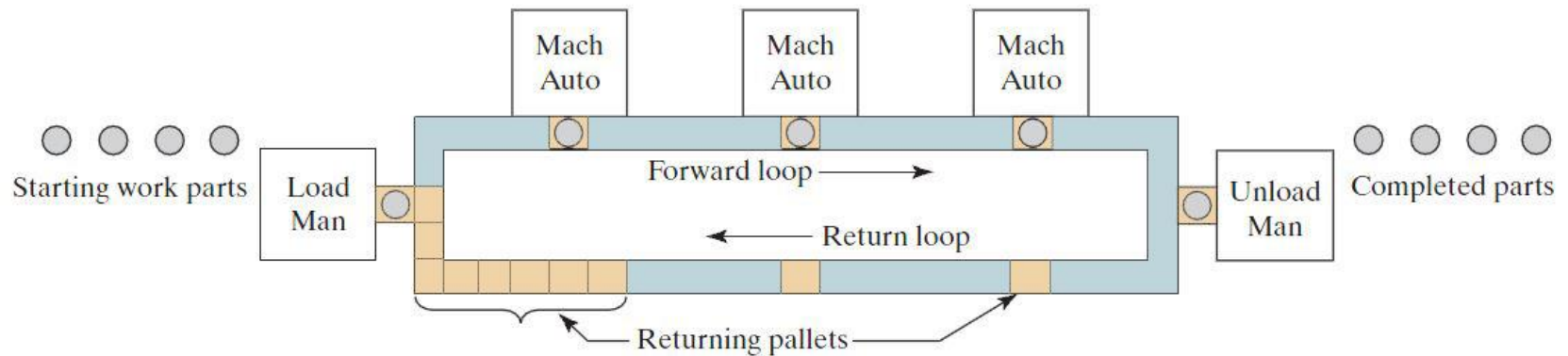


FMS Loop Layout



- One direction flow, but variations in processing sequence possible for different part types
- Secondary handling system at each workstation

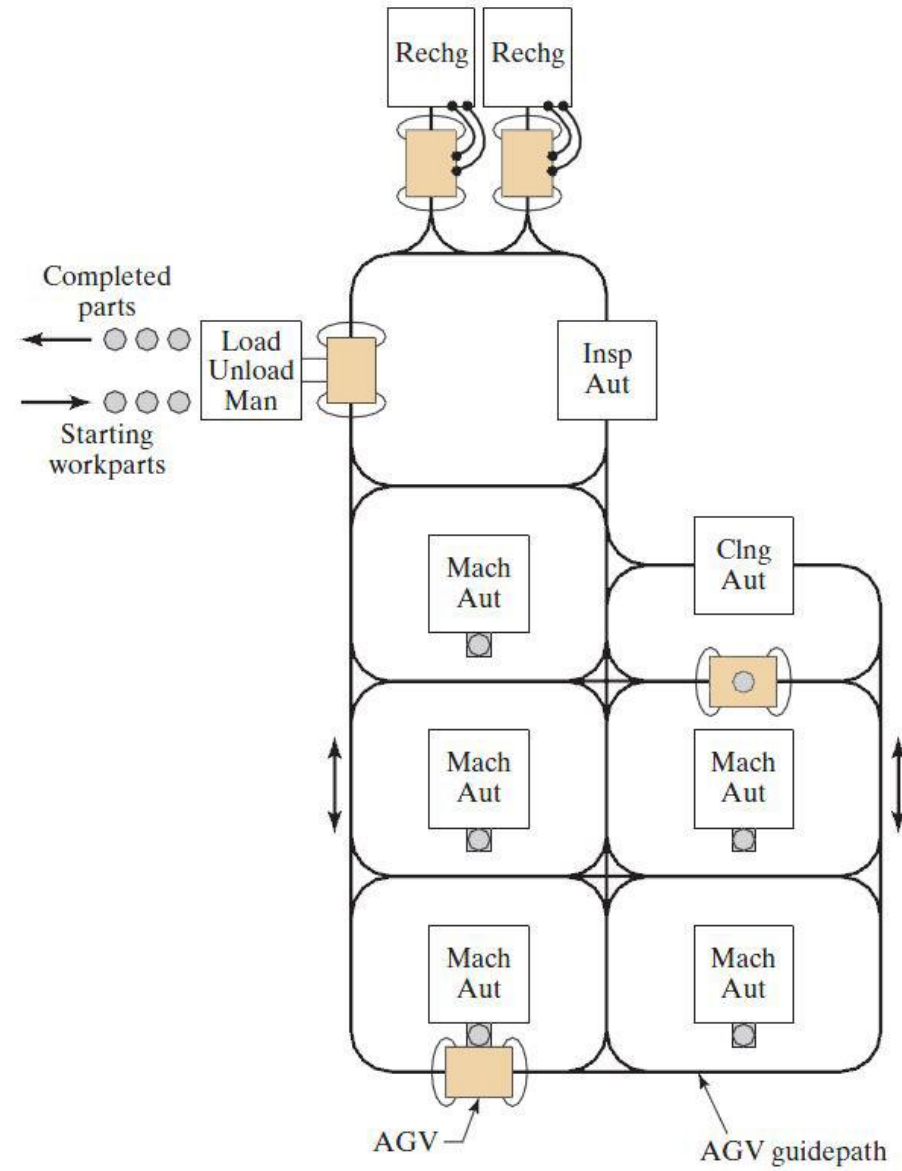
FMS Rectangular Layout



- Rectangular layout allows recirculation of pallets back to the first station in the sequence after unloading at the final station

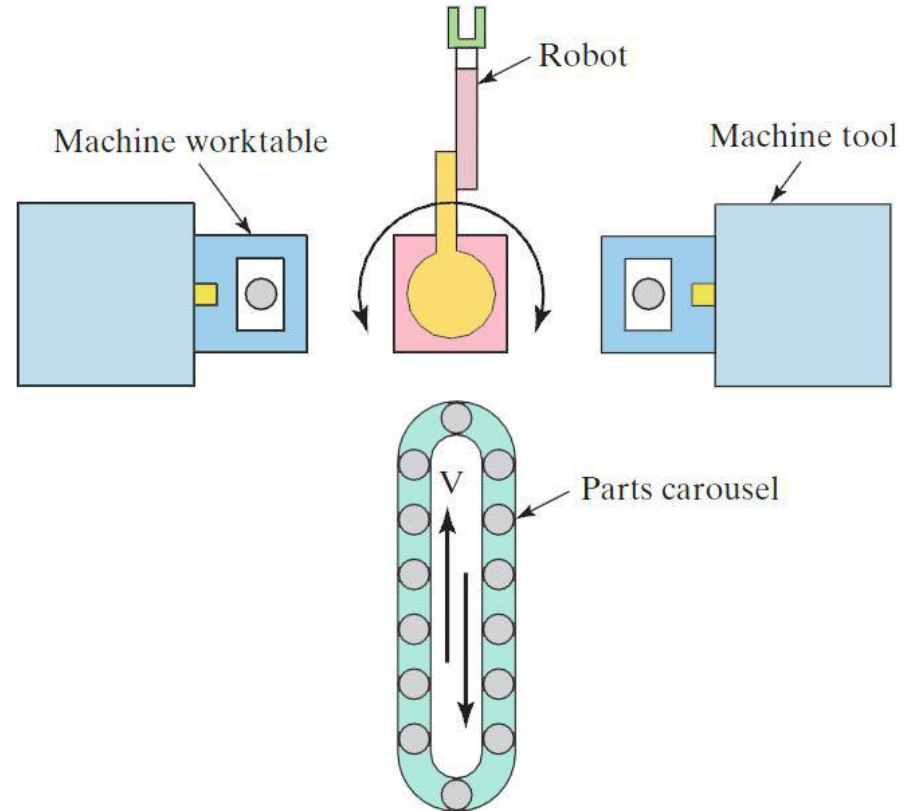
FMS Open Field Layout

- Multiple loops and ladders, suitable for large part families



Robot-Centered Cell

- Suited to the handling of rotational parts and turning operations



FMS Computer Control System

1. Workstation control
 - Individual stations require controls, usually computerized
2. Distribution of control instructions to workstations
 - Central intelligence required to coordinate processing at individual stations
3. Production control
 - Product mix, machine scheduling, and other planning functions

FMS Computer Functions

4. Traffic control

- Management of the primary handling system to move parts between workstations

5. Shuttle control

- Coordination of secondary handling system with primary handling system

6. Workpiece monitoring

- Monitoring the status of each part in the system

FMS Computer Functions

7. Tool control

- Tool location
 - Keeping track of each tool in the system
- Tool life monitoring
 - Monitoring usage of each cutting tool and determining when to replace worn tools

8. Performance monitoring and reporting

- Availability, utilization, production piece counts, etc.

9. Diagnostics

- Diagnose malfunction causes and recommend repairs

FMS Applications

- Machining – most common application of FMS technology
- Assembly
- Inspection
- Sheet metal processing (punching, shearing, bending, and forming)
- Forging

FMS Operations Management Issues

- Scheduling and dispatching
 - Launching parts into the system at appropriate times
- Machine loading
 - Deciding what operations and associated tooling at each workstation
- Part routing
 - Selecting routes to be followed by each part

FMS Benefits

- Increased machine utilization
 - Reasons:
 - 24 hour operation likely to justify investment
 - Automatic tool changing
 - Automatic pallet changing at stations
 - Queues of parts at stations to maximize utilization
 - Dynamic scheduling of production to account for changes in demand
- Fewer machines required
- Reduction in factory floor space required

FMS Benefits

- Greater responsiveness to change
- Reduced inventory requirements
 - Different parts produced continuously rather than in batches
- Lower manufacturing lead times
- Reduced labor requirements
- Higher productivity
- Opportunity for unattended production
 - Machines run overnight ("lights out operation")

Agile Manufacturing

- Means a company's ability to respond quickly to customer needs and market changes while still controlling costs and quality.
- Agile manufacturing companies tend to exhibit the following four characteristics:
 1. Organize to master change – adapting to a changing environment and new market opportunities
 2. Leverage the impact of people and information – providing the resources that personnel need
 3. Cooperate to enhance competitiveness – partnering with other companies to form virtual enterprises
 4. Enrich the customer – producing products that are perceived by customers as solutions to problems

Sales and Marketing Sub-Systems

- Customer support and identification
- Data collection and analysis
- Forecasting tasks
- Master production schedule (MPS)
- Promotional and advertising tasks
- Purchasing
- Shipping and receiving

