Sistem Produksi

Single-Station Manufacturing Cells

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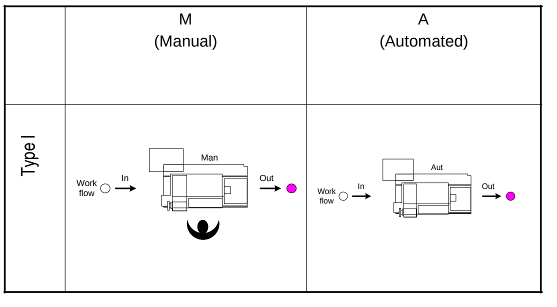
4. Analysis of Single-Station Cells

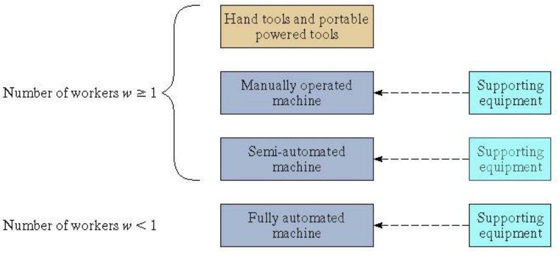
Single-Station Manufacturing Cells

- 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 Manufacturing Cells



Classification of Single-Station Manufacturing Cells



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 attention required continuously or for most of the cycle
- Worker operating semi-automatic machine
  - Worker loads & unloads parts, change cutting tools, 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

Variations of Single-Station Manned Cell

- Two (or more) workers required to operate machine ($n = 1, w > 1$)
  - Two workers required to manipulate heavy forging at forge press
  - Welder and fitter in arc welding work cell
  - Multiple workers combining their efforts to assemble one large piece of machinery at a single assembly station
- One principal production machine plus support equipment
  - Drying equipment for a manually operated injection moulding machine
  - Trimming shears at impression-die forge hammer to trim flash from forged part

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:
  - labour 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

Single-Station Automated Cell: supporting equipment

- Drying equipment used to dry the incoming plastic moulding compound plays a supporting role to the moulding machine
- A robot loading and unloading an automated production machine
- Bowl feeders and other parts-feeding devices used to deliver components in a single robot assembly cell

Enablers for Unattended Cell Operation

- For single model and batch model production:
  - Programmed operation for all steps in work cycle
  - Parts storage subsystem
  - Automatic loading, unloading, and transfer between parts storage subsystem and machine
  - Periodic attention of worker for removal of finished work units, resupply of starting work units, changes tools, and other machine tending
  - Built-in safeguards to avoid self-destructive operation or damage to work units or unsafe to workers

Enablers for Unattended Cell Operation

- For mixed model production:
  - 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

- Are 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 (min)

n_p = parts storage capacity of the storage subsystem (pc)

T_c = cycle time of the automated workstation (min/pc)

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

Parts Storage Capacity

- Typical objectives in defining the desired parts storage capacity n_p:
  - Make $n_p T_c$ = a fixed time interval that allows one worker to tend multiple machines
  - Make $n_p T_c$ = time between scheduled tool changes
  - Make $n_p T_c$ = one complete shift
  - Make $n_p T_c$ = one overnight ("lights-out operation")
- The time of unattended operation increases directly with storage capacity, so there is an advantage to designing the storage subsystem with sufficient capacity to satisfy the plant's operational objectives.

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_m = machine time

T_s = worker service time

Storage Capacity of One Part

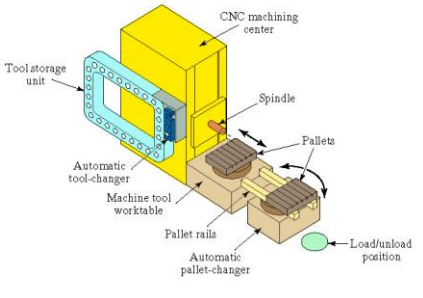
- Example: two-position automatic pallet changer (APC)
- With pallet changer, work cycle elements can be performed simultaneously

$$T_c = \max\{T_m, T_s\} + T_r$$

where:

T_r = repositioning time of pallet changer

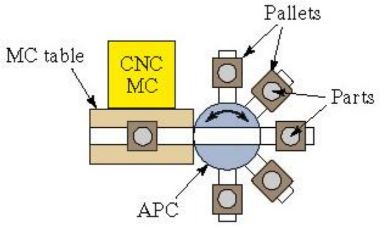
CNC Machining centre with Automatic Pallet Changer - Stores One Part



Storage Capacities Greater Than One

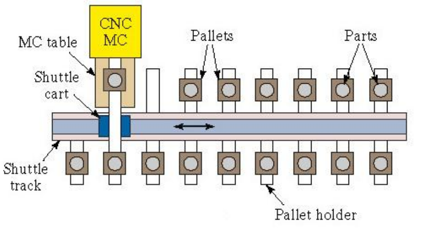
- Machining centres:
  - Various designs of parts storage unit interfaced to automatic pallet changer (or other automated transfer mechanism)
- Turning centres:
  - Industrial robot interface with parts carousel
- Plastic moulding or extrusion:
  - Hopper contains sufficient moulding compound for unattended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

Storage Capacities Greater Than One



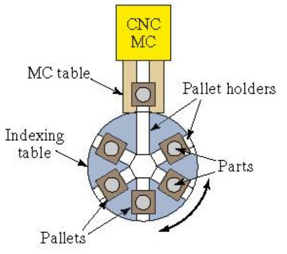
- Machining centre and automatic pallet changer with pallet holders arranged radially; parts storage capacity = 5

Storage Capacities Greater Than One



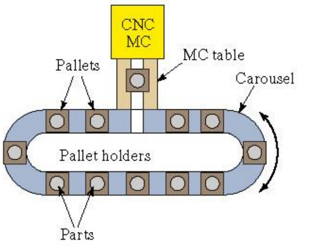
- Machining centre and in-line shuttle cart system with pallet holders along its length; parts storage capacity = 16

Storage Capacities Greater Than One



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

Storage Capacities Greater Than One



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

Applications of Single Station Manned Cells

- CNC machining centre (MC) with worker to load/unload
- CNC turning centre (TC) with worker to load/unload
- Cluster of two CNC turning centres with time sharing of one worker to load/unload
- Plastic injection moulding on semi-automatic cycle with worker to unload moulding, sprue, and runner
- One worker at electronics subassembly workstation inserting components into PCB
- Stamping press with worker loading blanks and unloading stampings each cycle

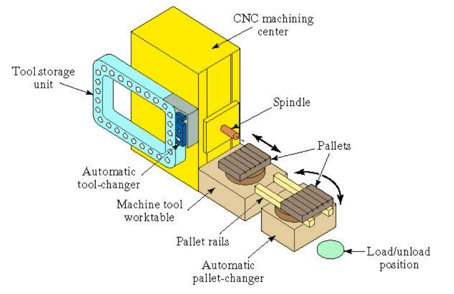
Applications of Single Station Automated Cells

- CNC MC with APC and parts storage subsystem
- CNC TC with robot and parts storage carousel
- Cluster of ten CNC TCs, each with robot and parts storage carousel, and time sharing of one worker to load/unload the carousels
- Plastic injection moulding on automatic cycle with robot arm to unload moulding, sprue, and runner
- Electronics assembly station with automated insertion machine inserting components into PCBs
- Stamping press stamps parts from long coil

CNC Machining centre

- "Machine tool capable of performing multiple operations that use rotating tools on a work part in one setup under NC control"
- Typical operations: milling, drilling, and related operations
- Typical features to reduce non-productive time:
  - Automatic tool changer
  - Automatic work part positioning
  - Automatic pallet changer

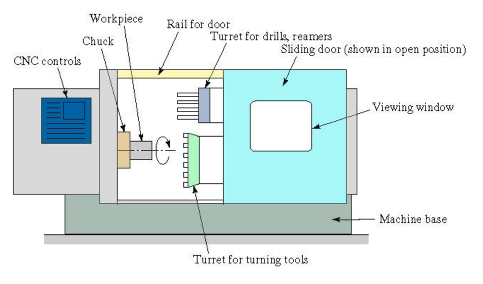
CNC Horizontal Machining centre



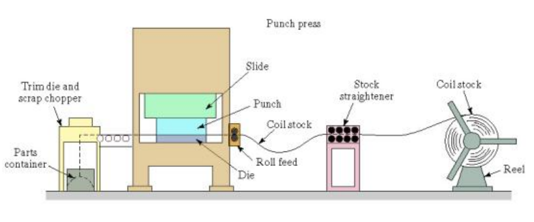
CNC Turning centre

- "Machine tool capable of performing multiple operations on a rotating work part in one setup under NC control"
- Typical operations:
  - Turning and related operations, e.g., contour turning
  - Drilling and related operations along work part axis of rotation

CNC Turning centre



Automated Stamping Press

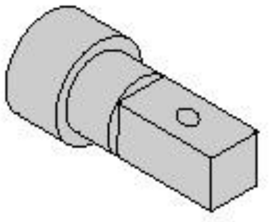


- Stamping press on automatic cycle producing stampings from sheet metal coil

CNC Mill-Turn centre

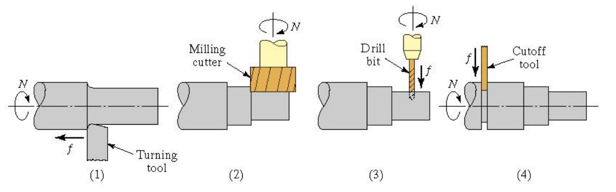
- "Machine tool capable of performing multiple operations either with single point turning tools or rotating cutters in one setup under NC control"
- Typical operations:
  - Turning, milling, drilling and related operations
- Enabling feature:
  - Capability to control position of c-axis in addition to x- and z-axis control (turning centre is limited to x- and z-axis control)

Part with Mill-Turn Features



- Example part with turned, milled, and drilled features

Sequence of Operations of a Mill-Turn centre for Example Part



1. Turn smaller diameter,
2. Mill flat 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 of the machined piece

Analysis of Single-Station Cells

- How many workstations are required to satisfy production requirements
- How many machines can be assigned to one worker in a machine cluster (a collection of two or more identical or similar machines that are serviced by one worker)

Analysis of Single-Station Cells: number of workstations required

- Determine the total workload that must be accomplished in a certain period (hour, week, month, year), where workload is defined as the total hours required to complete a given amount of work or to produce a given number of work units scheduled during the period
- Divide the workload by the hours available on one workstation in the same period

Analysis of Single-Station Cells: number of workstations required

$$WL = QT_c$$

where:

WL = workload scheduled for a given period (hr of work/hr or hr of work/wk)

Q = quantity to be produced during the period (pc/hr or pc/wk)

T_c = cycle time required per piece (hr/pc)

Analysis of Single-Station Cells: number of workstations required

- If the workload includes multiple parts or product styles that all be produced on the same type of workstation:

$$WL = \sum_{j=1}^{P} Q_j T_{cj}$$

Analysis of Single-Station Cells: number of workstations required

- Number of workstations:

$$n = \frac{WL}{AT}$$

where:

n = number of workstations

AT = available time on one station in the period (hr/period)

Analysis of Single-Station Cells: number of workstations required

- A total of 800 shafts must be produced in the lathe section of the machine shop during a particular week. Each shaft is identical and requires a machine cycle time T_c = 11.5 minutes. All of the lathes in the department are equivalent in terms of their capability to produce shaft in the specified cycle time. How many lathes must be devoted to shaft production during the given week, if there are 40 hr of available time on each lathe?

Analysis of Single-Station Cells: number of workstations required

- Several factors that complicate the computation of the number of workstations
  - Setup time in batch production
  - Availability/reliability
  - Utilization
  - Worker efficiency
  - Defect rate

Analysis of Single-Station Cells: number of workstations required

- Example (slide 37), suppose that a setup will be required for each lathe that used to satisfy the production requirements. The lathe setup for this type of parts take 3.5 hr. How many lathes are required during the week?
- Low utilization or overtime?

Analysis of Single-Station Cells: number of workstations required

- A total of 800 shafts must be produced in the lathe section of the machine shop during a particular week. The shafts are of 20 different types, each type being produced in its own batch. Average batch size is 40 parts. Each batch requires a setup and the average setup time in 3.5 hr. The average machine cycle time to produce a shaft T_c = 11.5 min. How many lathes are required during the week?

Analysis of Single-Station Cells: number of workstations required

$$AT = T \cdot A \cdot U$$

where:

AT = available time (hr)

T = actual clock time during the period (hr)

A = availability

U = utilization

Analysis of Single-Station Cells: number of workstations required

- Worker efficiency: the number of work units actually completed by the worker in a given period divided by the number of units that would be produced at standard performance
- An efficiency greater than 1.00 reduces the workload, while an efficiency less than 1.00 increases the workload

Analysis of Single-Station Cells: number of workstations required

- Defect rate: the fraction of parts produced that are defective
- A defect rate greater than zero increases the quantity of work units that must be processed in order to yield the desired quantity

Analysis of Single-Station Cells: number of workstations required

- The relationship between the starting quantity and the quantity produced:

$$Q = Q_o(1-q)$$

where:

Q = quantity of good units made in the process

Q_o = original or starting quantity

q = fraction defect rate

Analysis of Single-Station Cells: number of workstations required

- The combined effect of worker efficiency and fraction defect rate

$$WL = \frac{Q}{(1-q)}\frac{T_c}{E_w}$$

where:

E_w = worker efficiency

q = fraction defect rate

Analysis of Single-Station Cells: number of workstations required

- Suppose example (slide 40) that the anticipated availability of the lathes is 95%, and the expected utilization for calculation purposes is 100%. The expected worker efficiency during production = 110% and during setup = 100%. The fraction defect rate for the lathe work of this type is 3%. Other data from example (slide 37) are applicable. How many lathes are required during the week, given this additional information?

Analysis of Single-Station Cells: machine clusters

- The manning level is reduced from M = 1 to M = 1/n where n = # machines assigned to the worker
- Conditions must be satisfied to organize a collection of machines into a machine cluster:
  - The semi-automatic machine cycle is long relative to the service portion of the cycle that requires the worker's attention
  - The semi-automatic machine cycle time is the same for all machines
  - The machines that the worker would service are located in close enough proximity to allow time to walk between them
  - The work rules of the plant permit a worker to service more than one machine

Analysis of Single-Station Cells: machine clusters

- For the system to be perfectly balanced in terms of worker time and machine cycle time

$$n(T_s + T_r) = T_m + T_s$$

where:

n = number of machines
T_m = machine semi-automatic cycle time (min)
T_s = worker service time per machine (min)
T_r = worker positioning time between machines (min)

Analysis of Single-Station Cells: machine clusters

- The number of machines that should be assigned to one worker:

$$n = \frac{T_m + T_s}{T_s + T_r}$$

Analysis of Single-Station Cells: machine clusters

- n will not be an integer
  - n_1 = the integer that is less than n
  - n_2 = the integer that is greater than n
- Determine which of alternatives is preferable by introducing cost factors into analysis
  - C_L = the labour cost rate
  - C_m = machine cost rate

Analysis of Single-Station Cells: machine clusters

- Case 1: n_1 = maximum integer ≤ n
  - The worker will have idle time, and the cycle time of the machine cluster will be the cycle time of the machines

$$T_c = T_m + T_s$$

  - Assuming one work unit is produced by each machine during a cycle, we have the following cost:

Analysis of Single-Station Cells: machine clusters

- Case 1: n_1 = maximum integer ≤ n

$$C_{pc}(n_1) = \left(\frac{C_L}{n_1} + C_m\right)(T_m + T_s)$$

where:

$C_{pc}(n_1)$ = cost per work unit ($/pc)
C_L = labour cost rate ($/min)
C_m = cost rate per machine ($/min)
$(T_m + T_s)$ is expressed in minutes

Analysis of Single-Station Cells: machine clusters

- Case 2: n2 = minimum integer > n
  - The machines will have idle time, and the cycle time of the machine cluster will be the time it takes for the worker to service the n_2 machines

$$T_c = n_2(T_s + T_r)$$

Analysis of Single-Station Cells: machine clusters

- Case 2: n_2 = minimum integer > n
  - The corresponding cost per piece is given by:

$$C_{pc}(n_2) = (C_L + C_m n_2)(T_s + T_r)$$

Analysis of Single-Station Cells: machine clusters

- Case 3: in the absence of cost data needed to make these calculations, the corresponding number of machines to assign the worker is therefore given by:

$$n_1 = \max \text{int} \le \frac{T_m + T_s}{T_s + T_r}$$

Analysis of Single-Station Cells: machine clusters

- A machine shop contains many CNC lathes that operate on a semi-automatic machining cycle under part program control. A significant number of these machines produce the same part, whose machining cycle time = 2.75 min. One worker is required to perform unloading and loading of parts at the end of each machining cycle. This takes 25 sec. Determine how many machines one worker can service if it takes an average of 20 sec to walk between the machines and no machine idle time is allowed.

End of This Chapter