Work Systems and How They Work

Part I

Chapters:

2. Manual Work and Worker-Machine Systems
3. Work Flow and Batch Processing
4. Manual Assembly Lines
5. Logistics Operations
6. Service Operations and Office Work
7. Projects and Project Management

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Manual Work & Worker-Machine Systems

Chapter 2

Sections:

1. Manual Work Systems
2. Worker-Machine Systems
3. Automated Work Systems
4. Determining Worker and Machine Requirements
5. Machine Clusters

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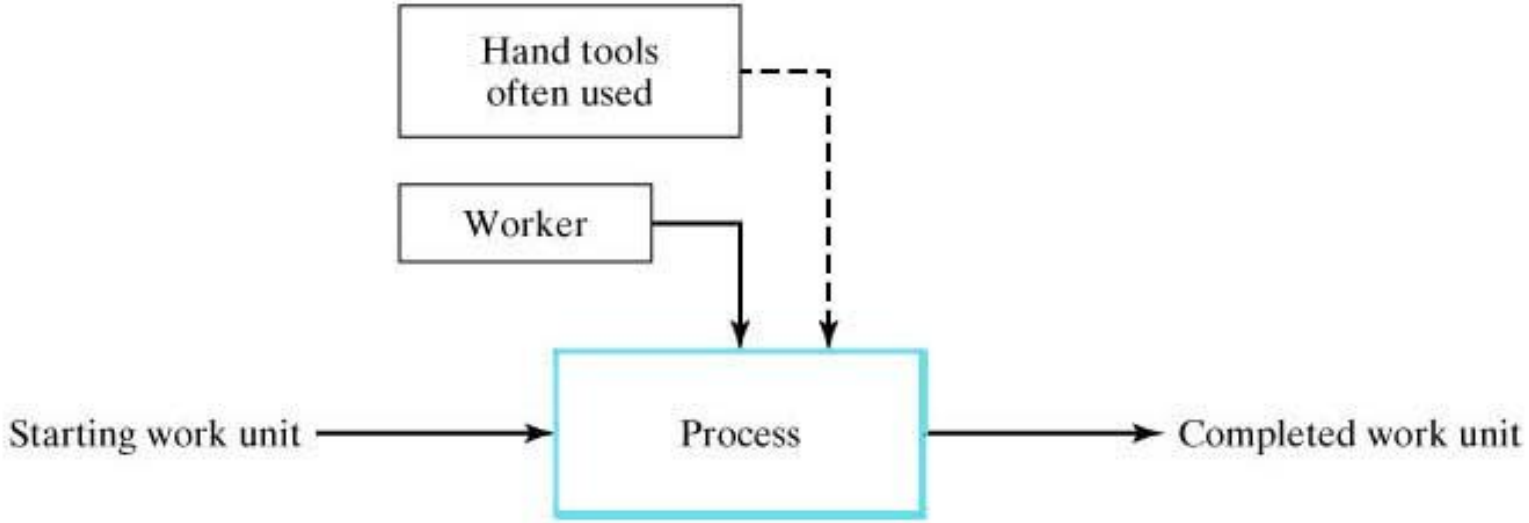
Three Categories of Work Systems

1. Manual work system
   - Worker performing one or more tasks without the aid of powered tools
2. Worker-machine system
   - Human worker operates powered equipment
3. Automated work system
   - Process performed without the direct participation of a human worker

Manual Work System



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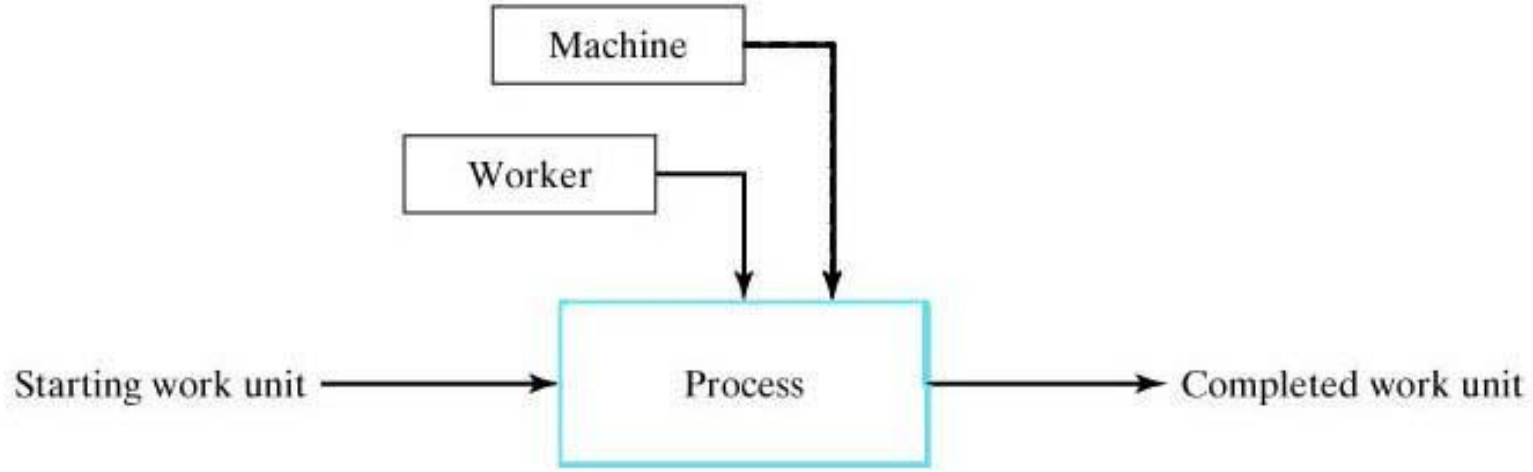
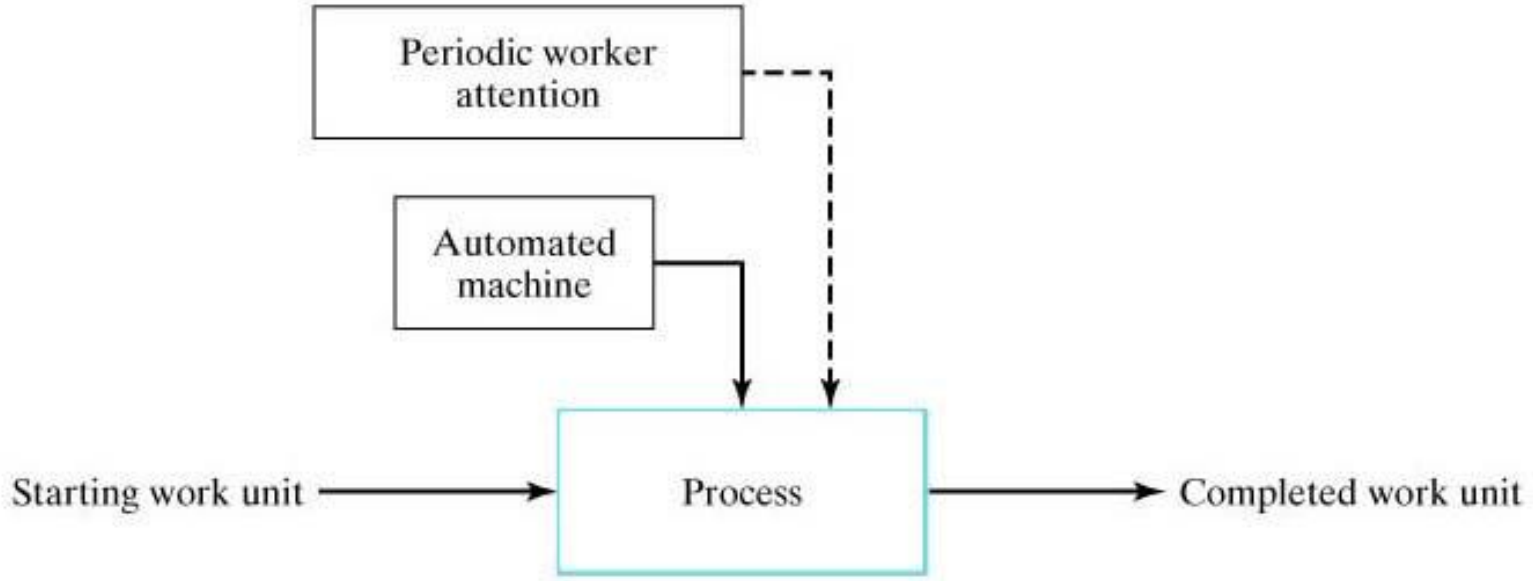
Worker-Machine System



Automated System



Some Definitions

Work unit – the object that is processed by the work system

- Workpiece being machined (production work)
- Material being moved (logistics work)
- Customer in a store (service work)
- Product being designed (knowledge work)

Unit operations – tasks and processes that are treated as being independent of other work activities

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Manual Work Systems

Human body accomplishing some physical task without an external source of power

- With or without hand tools
  - When hand tools are used, the power to operate them is derived from the strength and stamina of a human worker
- Other human faculties are required, such as hand-eye coordination and mental effort

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Pure Manual Work

- Material handler moving cartons in a warehouse
- Workers loading furniture into a moving van without the use of dollies
- Dealer at a casino table dealing cards
- Office worker filing documents
- Assembly worker snap-fitting two parts together

  (movement and handling of object)

Manual Work with Hand Tools

- Machinist filing a part
- Assembly worker using screwdriver
- Painter using paintbrush to paint door trim
- QC inspector using micrometer to measure a shaft diameter
- Material handling worker using a dolly to move furniture
- Office worker writing with a pen

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Cycle time analysis of manual work

- Work cycle is a cycle that is repeated with some degree of similarity and each cycle usually corresponds to the processing of one work unit.

Repetitive vs. Nonrepetitive Tasks

- Repetitive Task
  - Relatively short duration (usually a few minutes or less)
  - High degree of similarity from one cycle to the next
- Nonrepetitive Task
  - Takes a long time
  - Work cycles are not similar

- The task in repetitive and nonrepetitive work cycle can be divided in to work elements that consist of logical grouping of motions performed by the worker.
- The cycle time is the sum of the work element times.
- The focus is on repetitive work.

One Best Method Principle

Of all the possible methods that can be used to perform a given task, there is one optimal method that minimizes the time and effort required to accomplish it

- Attributed to Frank Gilbreth
- A primary objective in work design is to determine the one best method for a task, and then to standardize its use

Cycle Time Variations

- Once the method has been standardized, the actual time to perform the task is a variable because of:
  - Differences in worker performance
  - Variations in hand and body motions
  - Blunders and bungles by worker
  - Variations in starting work units
  - Extra elements not performed every cycle
  - Differences among workers
  - The learning curve phenomenon

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Worker Performance

Defined as the pace or relative speed of working

- As worker performance increases, cycle time decreases
- From the employer's viewpoint, it is desirable for worker performance to be high
- What is a reasonable pace to expect from a worker?

Normal Performance

A pace of working that can be maintained by a properly trained average worker throughout an entire work shift without deleterious short-term or long-term effects on the worker's health or physical well-being

- The work shift is usually 8 hours, during which periodic rest breaks are allowed
- Normal performance = 100% performance
- Common benchmark of normal performance:
  - Walking at 3 mi/hr

Normal Time

- The time to complete a task when working at normal performance
- Actual time to perform the cycle depends on worker performance

$$T_c = T_n / P_w$$

where T_c = cycle time, T_n = normal time, and P_w = worker performance or pace

Example: Normal Performance

- Given: A man walks in the early morning for health and fitness. His usual route is 1.85 miles. A typical time is 30 min. The benchmark of normal performance = 3 mi/hr.
- Determine: (a) how long the route would take at normal performance and (b) the man's performance when he completes the route in 30 min.

Example: Solution

(a) At 3 mi/hr, time = 1.85 mi / 3 mi/hr

= 0.6167 hr = 37 min

(b) Rearranging equation, $P_w = T_n / T_c$

P_w = 37 min / 30 min = 1.233 = 123.3 %

Alternative approach in (b):

Using v = 1.85 mi / 0.5 hr = 3.7 mi/hr

P_w = 3.7 mi/hr / 3.0 mi/hr = 1.233

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Standard Performance

Same as normal performance, but acknowledges that periodic rest breaks must be taken by the worker

- Periodic rest breaks are allowed during the work shift
  - Federal law requires employer to pay the worker during these breaks
- Other interruptions and delays also occur during the shift

PFD Allowance

To account for the delays due to:

- Personal time (P)
  - Bathroom breaks, personal phone calls
- Fatigue (F)
  - Rest breaks are intended to deal with fatigue
- Delays (D)
  - Interruptions, equipment breakdowns

Standard Time

Defined as the normal time but with an allowance added in to account for losses due to personal time, fatigue, and delays

$$T_{std} = T_n (1 + A_{pfd})$$

where T_{std} = standard time, T_n = normal time, and A_{pfd} = PFD allowance factor

- Also called the *allowed time*

Irregular Work Elements

- Elements that are performed with a frequency of less than once per cycle
- Examples:
  - Changing a tool
  - Exchanging tote pans of parts
- Irregular elements are prorated into the regular cycle according to their frequency

Example: Determining Standard Time

- Given: The normal time to perform the regular work cycle is 3.23 min. In addition, an irregular work element with a normal time = 1.25 min is performed every 5 cycles. The PFD allowance factor is 15%.
- Determine (a) the standard time and (b) the number of work units produced during an 8-hr shift if the worker's pace is consistent with standard performance.

Example: Solution

(a) Normal time $T_n = 3.23 + 1.25/5$

$= 3.48$ min

Standard time $T_{std} = 3.48\ (1 + 0.15)$

$= 4.00$ min

(b) Number of work units produced during an 8-hr shift

$Q_{std} = 8.0(60)/4.00 = 120$ work units

Standard Hours and Worker Efficiency

- Two common measures of worker productivity used in industry

Standard hours – represents the amount of work actually accomplished

$$H_{std} = Q\ T_{std}$$

Worker efficiency – work accomplished as a proportion of shift hours

$$E_w = H_{std} / H_{sh}$$

Worker-Machine Systems

- Worker operating a piece of powered equipment
- Examples:
  - Machinist operating a milling machine
  - Construction worker operating a backhoe
  - Truck driver driving an 18-wheeler
  - Worker crew operating a rolling mill
  - Clerical worker entering data into a PC

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Relative Strengths

Humans

- Sense unexpected stimuli
- Solve problems
- Cope with abstract problems
- Adapt to change
- Generalize from observations
- Make decisions on incomplete data

Machines

- Perform repetitive operations consistently
- Store large amounts of information
- Retrieve data from memory reliably
- Apply high forces and power
- Make routine decisions quickly

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Types of Powered Equipment

1. Portable power tools
   - Portable power drills, chain saws, electric hedge trimmers
2. Mobile powered equipment
   - Transportation equipment, back hoes, forklift trucks, electric power generator at construction site
3. Stationary powered machines
   - Machine tools, office equipment, cash registers, heat treatment furnaces

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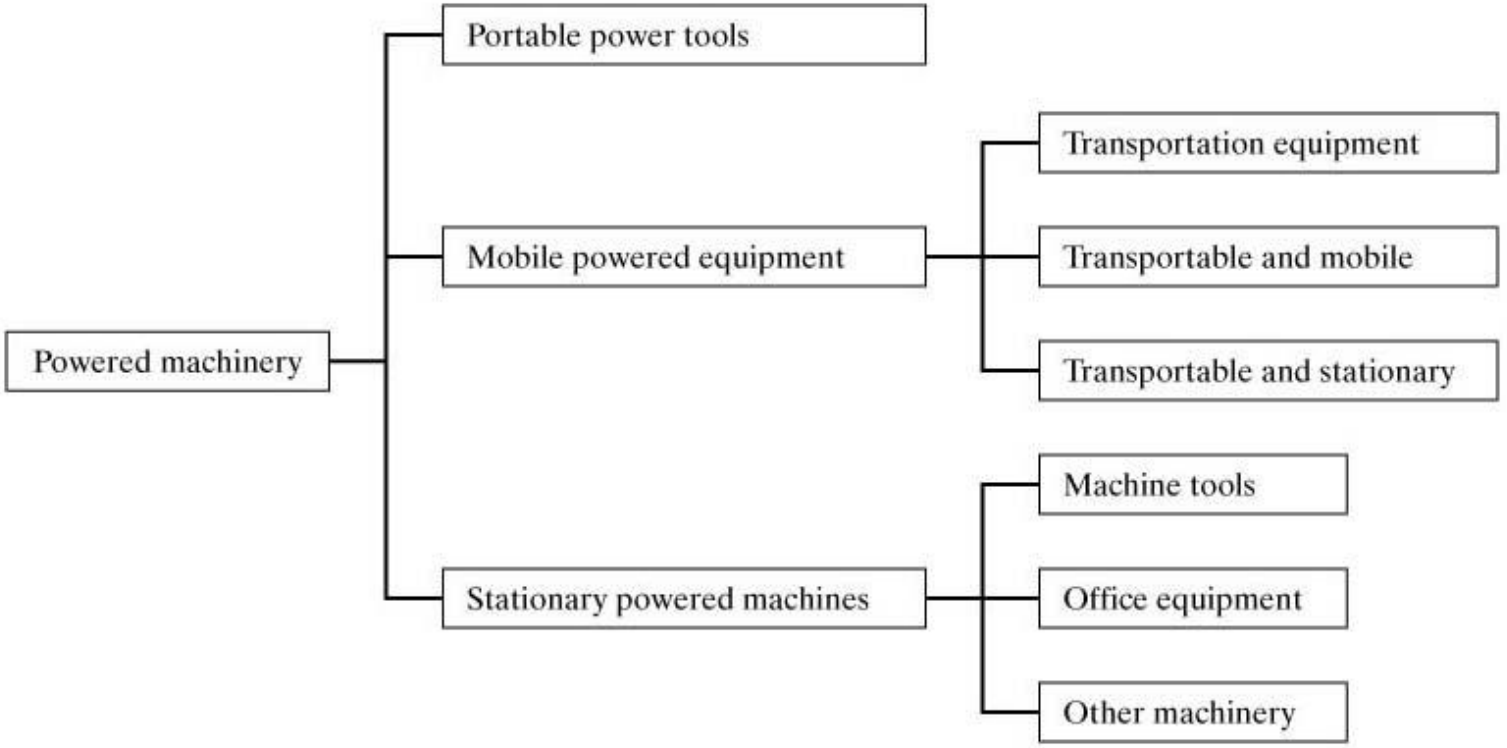
Classification of Powered Machinery



Numbers of Workers and Machines

One worker and

One machine

- Taxicab driver and taxi

Multiple workers and

One machine

- Ship's crew

One worker and

Multiple machines

- Machine cluster

Multiple workers and

Multiple machines

- Emergency repair crew responding to machine breakdowns

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Level of Operator Attention

- Full-time attention
  - Welders performing arc welding
- Part-time attention during each work cycle
  - Worker loading and unloading a production machine on semi-automatic cycle
- Periodic attention with regular servicing
  - Crane operator in steel mill
- Periodic attention with random servicing
  - Firefighters responding to alarms

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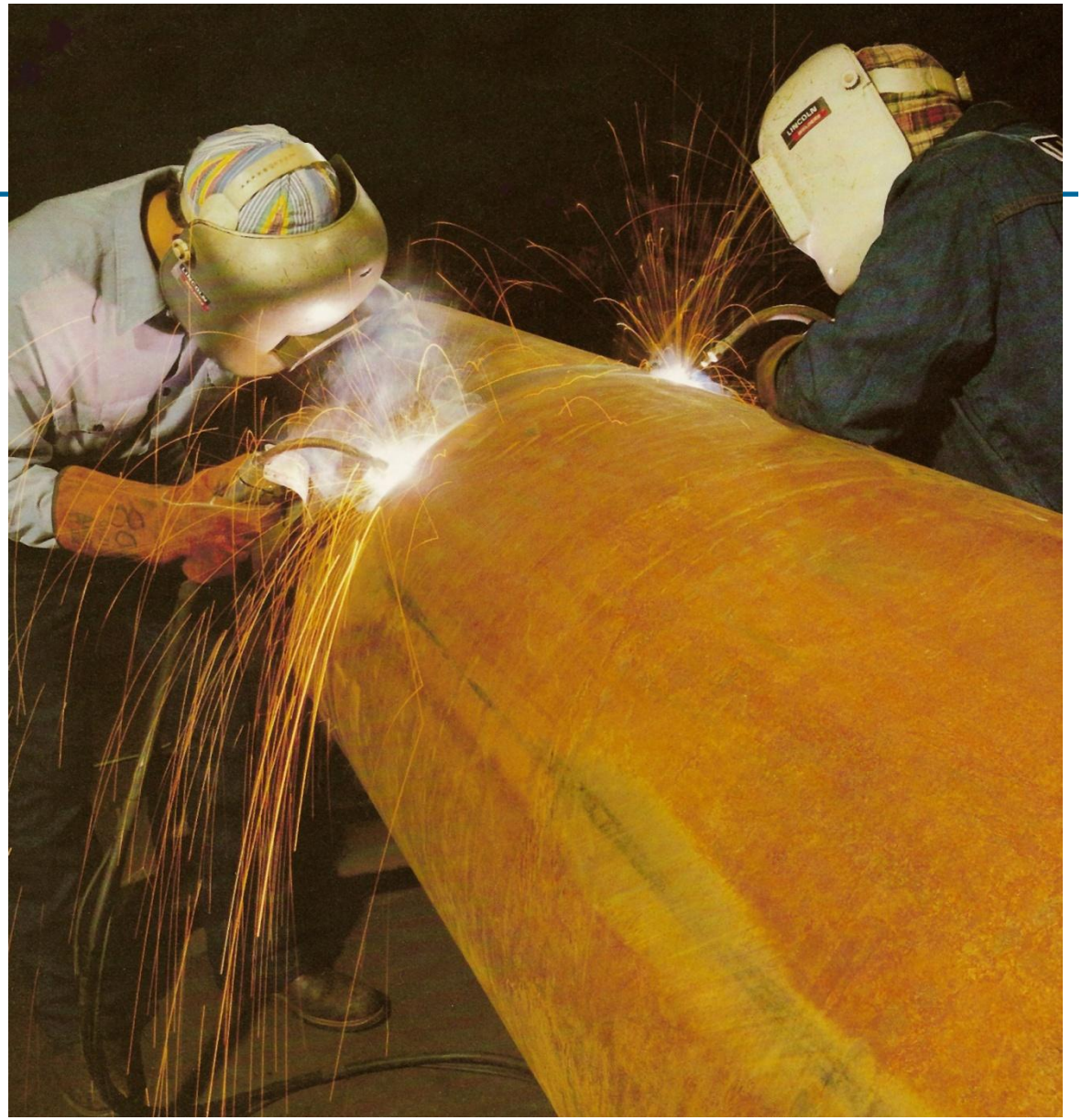
Two welders performing arc welding on pipe - requires full-time attention of workers (photo courtesy of Lincoln Electric Co.)



Cycle Time Analysis

- Two categories of worker-machine systems in terms of cycle time analysis
  - Systems in which the machine time depends on operator control
    - Carpenter using power saw to cut lumber
    - Cycle time analysis is same as for manual work cycle
  - Systems in which machine time is constant and independent of operator control
    - Operator loading semi-automatic production machine

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No Overlap: Worker and Machine

- Worker elements and machine elements are sequential
  - While worker is busy, machine is idle
  - While machine is busy, worker is idle
- Normal time for cycle

$$T_n = T_{nw} + T_m$$

- Standard time for cycle

$$T_{std} = T_{nw}\,(1 + A_{pfd}) + T_m\,(1 + A_m)$$

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Internal Work Elements

- Some worker elements are performed while machine is working
  - *Internal work elements* performed simultaneously with machine cycle
  - *External work elements* performed sequentially with machine cycle
- Desirable to design the work cycle with internal rather than external work elements

Normal Time and Standard Time

- Normal time

$$T_n = T_{nw} + \text{Max}\{T_{nwi} , T_m\}$$

- Standard time

$$T_{std} = T_{nw} (1 + A_{pfd}) + \text{Max}\{T_{nwi}(1 + A_{pfd}) , T_m(1 + A_m)\}$$

- Actual cycle time

$$T_c = T_{nw} / P_w + \text{Max}\{T_{nwi}/P_w , T_m\}$$

Automated Work Systems

Automation is the technology by which a process or procedure is accomplished without human assistance

- Implemented using a program of instructions combined with a control system that executes the instructions
- Power is required to drive the process and operate the control system

Levels of Automated Systems

- *Semiautomated* machine
  - Performs a portion of the work cycle under some form of program control
  - Human worker tends the machine for the rest of the cycle
  - Operator must be present every cycle
- *Fully automated* machine
  - Operates for extended periods of time with no human attention

Automated robotic spot welding cell (photo courtesy of Ford Motor Company)