# Analysis of Single Station System

- **Work Load**:

The work load is the quantity of work units produced

during the period of interest multiplied by time (hrs) required for each unit

$$WL = QT_c$$

Where WL = work load scheduled; Q = quantity to be

produced/piece (hr/pc) d; and Tc = cycle time required

If work load includes mu $WL = \sum_i Q_j T_{cj}$ les then

If n = number of workstations & AT = available time on station in the period (hr/period)

Then

$$n = \frac{WL}{AT} \qquad WL = \frac{QT_c}{E_w(1-q)}$$

q = fraction defect rate

$E_w$ is worker efficiency

**Example:**

Suppose a certain facility produce 800 shafts in a lathe section during a particular week. Shafts are identical in shape and requires same machine cycles. $T_c$ = 11.5 min. determine number of lathes if there are 40 hours of available time on each lathe.

**The workload consists of 800 shafts at 11.5 min/shaft**

WL = 800(11.5 min) = 9200 min = 153.33 hr.

**Available Time = 40 hr , *n*=153.33 /40 = 3.83 lathes**

- In previous example set up time:3.5 hrs?

- Shaft type 20 differnt in own batch
- Average batch size: 40 parts
- set up time:3.5 hrs
- Tc: 11.5 min

$$AT = 40 - 3.5 = 36.5hrs$$

$$n = \frac{153.33}{36.5} = 4.2 = 5lathes$$

# Problem (determining W/stns)

- A stamping plant must be designed to supply an

automotive engine plant with sheet metal stampings. The plant will operate one 8-hour shift for 250 days per year and must produce 15,000,000 good quality stampings annually. Batch size = 10,000 good stampings produced per batch. Scrap rate = 5%. On average it takes 3.0 sec to produce each stamping when the presses are running. Before each batch, the press must be set up, and it takes 4 hr to accomplish each setup. Presses are 90% reliable during production and 100% reliable during setup. **How many stamping presses** will be required to accomplish the specified production?

# Solution

Production: $WL = \frac{15{,}000{,}000(3/3600)}{1-0.05} = 13{,}157.9$ hr/yr

$AT = 250(8)(0.90) = 1800$ hr/yr per press

Setup: number batches/yr = $\frac{15{,}000{,}000}{10{,}000}$ = 1500 batches = 1500 setups

WL = 1500(4) = 6000 hr/yr

AT = 250(8) = 2000 hr/yr per press.

$n = \frac{13{,}157.9}{1800} + \frac{6000}{2000} = 7.31 + 3.0 = 10.31 \rightarrow$ **11 presses**

Future production requirements in a machine shop call for several automatic bar machines to be acquired to produce three new parts (A, B, and C) that have been added to the shop's product line. Annual quantities and cycle times for the three parts are given in the table below. The machine shop operates one 8-hour shift for 250 days per year. The machines are expected to be 95% reliable, and the scrap rate is 3%. How many automatic bar machines will be required to meet the specified annual demand for the three new parts?

| Part | Annual demand | Machining cycle time |
|---|---|---|
| A | 25,000 | 5.0 min |
| B | 40,000 | 7.0 min |
| C | 50,000 | 10.0 min |

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**Solution**: AT = 250(8)(0.95) = 1900 hr/yr per machine

$WL = \frac{25000(5/60)}{1-0.03} + \frac{40000(7/60)}{1-0.03} + \frac{50000(10/60)}{1-0.03} = 2147.7 + 4811.0 + 8591.1 = 15{,}549.8$ hr/yr.

n = 15,549.8/1900 = 8.184 $\rightarrow$ **9 machines**.

A plastic extrusion plant will be built to produce 25 million meters of plastic extrusions per year. The plant will run three 8-hour shifts per day, 360 days per year. For planning purposes, the average run length = 3000 meters of extruded plastic. The average changeover time between runs = 2.5 hr, and average extrusion speed = 15 m/min. Assume scrap rate = 1%, and average uptime proportion per extrusion machine = 95% during run time. Uptime proportion during changeover is assumed to be 100%. If each extrusion machine requires 500 sq. ft of floor space, and there is an allowance of 50% for aisles and office space, what is the total area of the extrusion plant?

**Solution**: Production: $WL = \dfrac{25{,}000{,}000}{15(60)(1-0.01)} = 28{,}058.4$ hr/yr

$AT = 360(3)(8)(0.95) = 8208$ hr/yr.

Changeover: number runs/yr $= \dfrac{25{,}000{,}000}{3000} = 8{,}333$ runs/yr $= 8{,}333$ changeovers/yr

$WL = 8{,}333(2.5) = 20{,}833$ hr/yr

$AT = 360(3)(8) = 8640$ hr/yr per machine

$n = \dfrac{28{,}058}{8208} + \dfrac{20{,}833}{8640} = 3.42 + 2.41 = 5.83 \;\; 6$ machines.

# Example

- A new forging plant must supply parts to the automotive industry. **Because forging is a hot operation the plant will operate 24 hr per day, five days per week, 50 weeks per year. Total output from the plant must be 10.000.000 forging per year in batches of 1250 parts per batch. Anticipated scrap rate is 3%.** Each forging cell will consists of a furnace to heat the parts, a forging press, and a trim press. Parts are placed in the furnace an hour prior to forging; they are then removed and forged and trimmed on at a time. **On average the forging and trimming cycle takes 0.6 min to complete one part.**

- Each time a new batch is strated the forging cell must be changed over, which consist of changing the forging and trimming dies for the next part style . **It takes 2.0 hr on average to complete a changeover between batches. Each cell is considered to be 96% reliable during operation and 100 % reliable during changeover.** Determine the number of forging cells that will be required in the new plant.

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**Solution**: Production: $WL = \dfrac{10{,}000{,}000(0.6/60)}{1-0.03} = 103{,}092.8$ hr/yr

$AT = 50(5)(3)(8)(0.96) = 5760$ hr/yr.

Setup: number batches/yr $= \dfrac{10{,}000{,}000}{1250} = 8000$ batches/yr $= 8000$ setups/yr

$WL = 8000(2) = 16{,}000$ hr/yr per cell

$AT = 50(5)(3)(8) = 6000$ hr/yr.

$n = \dfrac{103{,}092.8}{5760} + \dfrac{16{,}000}{6000} = 17.90 + 2.67 = 20.57 \rightarrow$ **21 forging cells**

# Example

- A CNC machining center has a programmed cycle time 25 min for a certain part. The time to unload the finished part and load a starting work unit =5 min.

a) If loading and unloading are done directly onto the machine tool table and no automotic storage capacity exists at the machine , what are the cycle time and hourly production rate ? b) If the machine tool has an automotic pallet changer so that unloading and loading can be accomplished while the machine is cutting another part, the repositioning time =30 sec., What are the total cycle time and hourly production rate ?

- c) If the machine tool has an automotic pallet changer that interfaces with a parts storage unit whose capacity is 12 parts, and the repositioning time time 30 sec, what are the total cycle time and hourly production rate ? Also how long does it take to perform the loading and unloading of the 12 parts by the human worker, and what is the machine can operate unattended between parts changes ?

a) $T_c=25+5=30$ min /pc

$R_c=60/30=2$ pc/hr

b) $T_c = \max(25,5)+0.5 =25.5$ min /pc

$R_c =60/25.5= 2.35$ pc/hr

c) $T_c= \max(25,5) +0.5 =25.5$ min /pc

$R_c =60/25.5= 2.35$ pc/hr

Time to load and unload $12*5=60$ min

$UT= 12(25.5)-60 =246$ min $=4.1$ hr

# Machine Cluster

- A **machine cluster** is defined as a collection of two or more machines producing parts or products with identical cycle times and is serviced by one worker.

Whereas **machine cell** consists of one or more machines

organized to produce family of parts/products

Consider a collection of single work station, all products are same in parts and operating on same semi-automatic cycle time Let Tm = machine cycle time

Ts = Servicing time by worker

If worker is always available when servicing is NEEDED and

machine never idle

$\boxed{T_c = T_m + T_s}$

If more than one machine is assigned to the worker, a certain amount of time will; be lost because of walking from one machine to the next called repositioning time $T_r$.

Time required for operator to service one machine is $\boxed{T_s + T_r}$ and time to service 'n' machines is $\boxed{n(T_s + T_r)}$.

For system to be balanced

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

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

$\boxed{n(T_s + T_r)}$---------- cannot be balanced with $T_c$ of machine

# Scenarios

$n_1$ and $n_2$

Introducing cost factors

Let $C_L$ = labor cost rate

$C_m$ = machine cost rate

**Case 1**: if $n_1$ = max. integers ≤ n, worker will have idle time and cycle time of machine cluster will be cycle time of machine i.e. $T_c = T_m + T_s$

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

**Case 2**: if $n_2$ = min. integers > n, machine will have idle time and cycle time of machine cluster will be time it takes for worker to service $n_2$ machines which is n(Ts + Tr ).

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

In absence of cost data workers must have some idle time and machine will be utilized 100%

$$\boxed{n_1 = \text{max. integers} \leq \frac{T_m + T_s}{T_s + T_r}}$$

# Problem (M/c Cluster)

The CNC grinding section has a large number of machines devoted to grinding of shafts for the automotive industry. The machine cycle takes 3.6 min to grind the shaft. At the end of this cycle, an operator must be present to unload and load parts, which takes 40 sec.

(a) Determine how many grinding machines the worker can service if it takes 20 sec to walk between the machines and no machine idle time is allowed. (b) How many seconds during the work cycle is the worker idle? (c) What is the hourly production rate of this machine cluster?

- **Solution**:

(a) $n = (3.6 + 0.667)/(0.667 + 0.333) = 4.267$ rounded down to 4 machines to avoid machine idle time

(b) Machine cycle time = 3.6 + 0.667 = 4.267 min

Worker time per machine = 0.667 + 0.333 = 1.00 min

Worker idle time = 4.267 – 4.00 = 0.267 min = 16 sec

(c) Given $T_c = 4.267$ min and 4 machines, $R_p = 4(60)/4.267 = 56.25$ pc/hr

# Problem (M/c Cluster)

- The screw machine department has a large number of machines devoted to the production of a certain component that is in high demand for the personal computer industry. **The semiautomatic cycle for this component is 4.2 min per piece**. At the end of the machining cycle, an operator must unload the finished part and load raw stock for the next part. **This servicing time takes 21 sec and the walking time between machines is estimated at 24 sec.**

# Problem (M/c Cluster)

a) Determine how many screw machines one worker can service if no idle machine time is allowed. (b) How many seconds during the work cycle is the worker idle? (c) What is the hourly production rate of this machine cluster if one part is produced per machine each cycle?

**Solution**: (a) $n = (4.2 + 0.35)/(0.35 + 0.40) = 6.07$ rounded down to 6 machines to avoid machine idle time

(b) Machine cycle time = 4.2 + 0.35 = 4.55 min

Worker time per machine = 0.35 + 0.40 = 0.75 min

Worker idle time = 4.55 – 6(0.75) = 0.05 min = 3 sec

(c) Given $Tc$ = 4.55 min and 6 machines, $Rp$ = 6(60)/4.55 = 79.12 pc/hr

# Problem (M/c Cluster)

- A worker is currently responsible for tending two machines

in a machine cluster. The service time per machine is 0.35 min and the time to walk between machines is 0.15 min. The machine automatic cycle time is 1.90 min. If the worker's hourly rate = $12/hr and the hourly rate for each machine = $18/hr, determine (a) the current hourly cost for the cluster, and (b) the current cost per unit of product, given that two units are produced by each machine during each machine cycle. (c) What is the % idle time of the worker? (d) What is the optimum number of machines that should be used in the machine cluster, if minimum cost per unit of product is the decision criterion?

# Solution

(a) $C_o = \$12 + 2(\$18) = \mathbf{\$48.00/hr}$

(b) $T_c = T_m + T_s = 1.90 + 0.35 = 2.25$ min/cycle

$$R_c = 2(2)\left(\frac{60}{2.25}\right) = 106.67 \text{ pc/hr}$$

$$C_{pc} = \frac{\$48/\text{hr}}{106.67\text{pc}/\text{hr}} = \mathbf{\$0.45/pc}$$

c) Worker engagement time /cycle = 2(Ts+Tr) = 2(0.35+0.15) =1 min

Idle time IT =$\frac{2.25-1.0}{2.25}$= 0.555= 55.5%

d) n=$\frac{1.9+0.35}{0.35+0.15} = \frac{2.25}{0.5}$= 4.5 machines

n1= 4 machines Cpc(4) = (12/4+18)$\frac{2.25}{60}$ = $ 0.788/ 2 pc      $ 0.394/pc

n1 =5 machines Cpc(5) = (12+18x5)$\frac{0.5}{60}$ = $ 0.850/ 2 pc      $ 0.425/pc

Use **n1= 4 machines**