IE 469 Manufacturing Systems

Chapter 16 Tutorial

Geneva Mechanism

16.1 **(A)** A rotary worktable is driven by a Geneva mechanism with five slots. The driver rotates at 24 rev/min. Determine (a) the cycle time, (b) available process time, and (c) indexing time each cycle.

(a) $T_c = \frac{1}{N}$ N: rotational speed

$= \frac{1}{24} = 0.04167 \text{ min} = 2.5 \text{ sec}$

(b) $\theta = \frac{360}{n_s} = \frac{360}{5} = 72^\circ$

$T_s = \frac{(180 + \theta)}{360 N} = \frac{180 + 72}{360(24)} = 0.029 \text{ min} = 1.75 \text{ sec}$

(c) $T_r = \frac{180 - \theta}{360 N} = \frac{180 - 72}{360(24)} = 0.0125 \text{ min} = 0.75 \text{ sec}$

Automated Production Lines (No Internal Storage)

16.4 **(A)** A 12-station automated production line has an ideal cycle time of 30 sec. Line stops occur on average once every 20 cycles. When a line stop occurs, average downtime is 4.0 min. Cost of each starting work part is \$1.55, and the cost to operate the line is \$66/hr. Tooling cost is \$0.27 per work part. Determine (a) average hourly production rate, (b) line efficiency, and (c) cost of a workpiece produced.

(a) ✓ $T_c = \max\{T_{si}\} + T_r$

✓ $T_p = T_c + F T_d = 0.5 + \frac{1}{20}(4) = 0.7 \text{ min}$

$R_p = \frac{1}{0.7} = 1.42 \text{ pc/min} = 85.7 \text{ pc/hr}$

(b) $E = \frac{T_c}{T_p} = \frac{0.5}{0.7} = 0.714 = 71.4\%$

(c) $C_{pc} = C_m + C_o T_p + C_t$

$= 1.55 + \frac{66(0.7)}{60} + 0.27 = \$2.59/\text{pc}$

16.9 A ten-station rotary-indexing machine performs machining operations at nine workstations, and the tenth station is used for unloading and loading parts. The longest process time on the line is 1.75 min and the loading/unloading operation requires less time than this. It takes 9.0 sec to index the machine between workstations. Stations break down with a frequency of 0.006, which is considered equal for all ten stations. When breakdowns occur, it takes an average of 8.0 min to diagnose the problem and make repairs. The starting work part costs \$2.50 per unit. Operating cost of the indexing machine is \$96/hr, and tooling cost is \$0.38 per piece. Determine (a) line efficiency, (b) average hourly production rate, and (c) completed part cost.

HW

16.13 An eight-station rotary indexing machine performs the machining operations shown in the table below, with processing times and breakdown frequencies for each station. Transfer time is 0.15 min. A study of the system was undertaken, during which time 2000 parts were completed. The study also revealed that when breakdowns occur, the average downtime is 7.0 min. For the study period, determine (a) average hourly production rate, (b) line uptime efficiency, and (c) how many hours were required to produce the 2000 parts.

Station	Process	Process time	Breakdowns
1	Load part	0.50 min	0
2	Mill top	0.85 min	22
3	Mill sides	Max 1.10 min	31
4	Drill two holes	0.60 min	47
5	Ream two holes	0.43 min	8
6	Drill six holes	0.92 min	58
7	Tap six holes	0.75 min	84
8	Unload part	0.40 min	0

(a) $R_p = \frac{1}{T_p}$, $T_p = T_c + F T_d$

no. of breakdowns $= 0 + 22 + 31 + \dots + 84 + 0 = 250$

$F = \frac{250}{2000} = 0.125$

✓ $T_c = \max\{T_{si}\} + T_r = 1.1 + 0.15 = 1.25 \ \text{min/pc}$

✓ $T_p = 1.25 + (0.125)(7) = 2.125 \ \text{min/pc}$

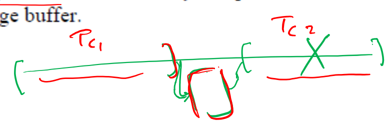
$R_p = \frac{1}{T_p} = \frac{1}{2.125} \times 60 = 28.23 \ \text{pc/hr}$

(b) $E = \frac{T_c}{T_p} = \frac{1.25}{2.125} = 0.588 = 58.8\%$

(c) $H = 2000 \times T_p$
$= \frac{2000 \times 2.125}{60}$
$= 70.83 \ \text{hr}$

Automated Production Lines with Storage Buffers (Appendix A16)

16.18 **(A)** A 30-station transfer line has an ideal cycle time of 0.75 min (T_c), an average downtime of 6.0 min per line stop occurrence (T_d), and a station failure frequency of 0.01 (p) for all stations. A proposal has been submitted to locate a storage buffer between stations 15 and 16 to improve line efficiency. Determine (a) the current line efficiency and production rate, and (b) the maximum possible line efficiency and production rate that would result from installing the storage buffer.



$T_{c1} = T_{c2} = T_c$

(a) $E = \frac{T_c}{T_p}$, $T_p = T_c + F T_d$
$= 0.75 + 30(0.01)(6) = 2.55 \ \text{min/pc}$

$E = \frac{0.75}{2.55} = 0.2941 = 29.41\%$

$R_p = \frac{1}{T_p} = 0.392 \ \text{pc/min} = 23.53 \ \text{pc/hr}$

(b) $T_{p1} = T_{p2} = 0.75 + 15(0.01)(6) = 1.65 \ \text{min/pc}$

$E_\infty = \frac{T_c}{T_p} = \frac{0.75}{1.65} = 0.4545 = 45.45\%$

$R_p = \frac{1}{T_p} = \frac{1}{1.65}(60) = 36.36 \ \text{pc/hr}$

16.26 A 16-station transfer line can be divided into two stages by installing a storage buffer between stations 8 and 9. The probability of failure at any station is 0.01. The ideal cycle time is 1.0 min and the downtime per line stop is 10.0 min. These values are applicable for both the one-stage and two-stage configurations. The downtime should be a considered constant value. The cost of installing the storage buffer is a function of its capacity. This cost function is $C_b = \$0.60b/\text{hr} = \$0.01b/\text{min}$, where b = the buffer capacity. However, the buffer can only be constructed to store increments of 10 (in other words, b can take on values of 10, 20, 30, etc.). The cost to operate the line itself is \$120/hr. Ignore material and tooling costs. Based on cost per unit of product, determine the buffer capacity b that will minimize unit product cost.

$p = 0.01$
$T_c = 1$ min
$T_d = 10$ min
$C_b = \$0.6\,b/\text{hr} = \$0.01\,b/\text{min}$

① first, we consider the no storage case ($b=0$):

$T_p = T_c + FT_d = 1 + 16(0.01)(10) = 2.6$ min/pc — no material or tool costs

$C_{pc} = C_L T_p$

unit cost ($b=0$): $C_{pc} = \overset{C_L}{120}\left(\frac{\overset{T_p}{2.6}}{60}\right) = 2(2.6) = \$5.2/\text{pc}$

$E_0 = \frac{T_c}{T_p} = \frac{1}{2.6} = 0.3846$ — (Efficiency when $b=0$)

② now consider the two-stage case (buffer in middle of line):

$T_p = T_c + FT_d = 1 + 8(0.01)(10) = 1.8$ min/pc

$E_1 = E_2 = \frac{T_c}{T_p} = \frac{1}{1.8} = 0.5555$

$C_{pc} = C_L T_p = (\underbrace{120 + 0.6\,b}_{C_L \text{ per hr}})\,T_p = (\underbrace{2 + 0.01\,b}_{C_L \text{ per min}})\,T_p$ — but T_p changes depending on buffer capacity $\underline{\underline{b}}$

$T_p = \frac{T_c}{E}$, but $E = ?$

$\longrightarrow$

$E_b = E_0 + \overset{?}{D_1'}\,\overset{?}{h(b)}\,E_2$

E_0 known from first case ($b=0$)
E_2 already calculated $= 0.5555$

$D_1' = \frac{F_1 T_d}{T_c + (F_1+F_2)T_d} = \frac{8(0.01)(10)}{1 + 16(0.01)(10)} = 0.3077$

Regarding $h(b)$, we refer to the constant repair distribution case ($r=1$):

Case 1: $r = 1.0$. $h(b) = \frac{B}{B+1} + L\frac{T_c}{T_d}\frac{1}{(B+1)(B+2)}$

B = max int $\leq b\frac{T_c}{T_d}$
B = max int $\leq 0.1\,b$
$L = b - B\frac{T_d}{T_c}$
$L = b - (0.1b)(10)$
$L = b - b = 0$

In this problem, $h(b) = \frac{B}{B+1}$ because $L = 0$

back to E_b:

$E_b = 0.3846 + 0.3077\left(\frac{B}{B+1}\right)0.5555$

$= 0.3846 + 0.1709\left(\frac{B}{B+1}\right) = \frac{0.5555B + 0.3846}{B+1}$

Now that we know E_b, we know T_p. $T_p = \frac{T_c}{E_b} = \frac{1}{E_b} = \frac{B+1}{0.5555B + 0.3846}$

Now back to C_{pc}:

$C_{pc} = (2 + 0.01\,b)\frac{B+1}{0.5555B + 0.3846}$ $\longrightarrow$ remember: $B = 0.1\,b$, $b = 10B$

$$\boxed{C_{pc} = (2 + 0.1B)\frac{B+1}{0.5555B + 0.3846}}$$ ☆

Now we have the unit cost as a function of buffer capacity.
Determine the unit cost for different capacity levels, then pick the capacity that yields the minimum unit cost.

- No capacity: $b=0$, $B=0$ $\longrightarrow$ $C_{pc} = \dfrac{2+(0.1)(0)(0+1)}{0.3846} = \$5.2/pc$
- $b=10$, $B=1$ $\longrightarrow$ $C_{pc} = \dfrac{(2+(0.1)(1))(1+1)}{0.9401} = \$4.468/pc$
- $b=20$, $B=2$ $\longrightarrow$ $C_{pc} = \dfrac{(2+(0.1)(2))(2+1)}{1.4956} = \$4.413/pc$
- $b=30$, $B=3$ $\longrightarrow$ $C_{pc} = \dfrac{(2+(0.1)(3))(3+1)}{2.0511} = \$4.485/pc$
- $b=40$, $B=4$ $\longrightarrow$ $C_{pc} = \dfrac{(2+(0.1)(4))(4+1)}{2.6066} = \$4.604/pc$
- $b=50$, $B=5$ $\longrightarrow$ $C_{pc} = \dfrac{(2+(0.1)(5))(5+1)}{3.1621} = \$4.744/pc$

Lowest cost is at $b=20$, $B=2$. Therefore, a buffer with a capacity of 20 should be selected.