38 INTEGRATED MANUFACTURING SYSTEMS

Review Questions

38.1 What are the main components of an integrated manufacturing system?

Answer. As stated in the text, the main components of an integrated manufacturing system are (1) workstations and/or machines, (2) material handling equipment, and (3) computer control. In addition, human workers are required to manage the system, and workers may be used to operate the individual workstations and machines.

38.2 What are the principal material handling functions in manufacturing?

Answer. The principal material handling functions in manufacturing are (1) loading and positioning work units at each workstation, (2) unloading work units from the station, and (3) transporting work units between workstations.

38.3 What is the difference between fixed routing and variable routing in material transport systems?

Answer. In fixed routing, all of the work units are moved through the same sequence of stations, which means that the processing sequence for all work units is either identical or very similar. In variable routing, different work units are moved through different workstation sequences, meaning that the manufacturing system processes or assembles different types of parts or products.

38.4 What is a *production line*?

Answer. A production line is a sequence of workstations at which individual tasks are accomplished on each work unit as it moves from one station to the next to progressively make the product.

38.5 Describe how manual methods are used to move parts between workstations on a production line.

Answer. The manual methods include (1) work units are simply passed by hand along a flat worktable from one station to the next, (2) work units are collected in boxes and then passed between stations, and (3) work units are pushed along a non-powered conveyor between stations.

38.6 Briefly define the three types of mechanized work part transfer systems used in production lines.

Answer. The three work transfer systems are (1) continuous transfer, in which parts move on a conveyor at a constant speed; (2) synchronous transfer, in which parts all move simultaneously from station-to-station with a stop-and-go action; and (3) asynchronous transfer, in which parts move independently between stations with a stop-and-go action.

38.7 Why are parts sometimes fixed to the conveyor in a continuous transfer system in manual assembly?

Answer. Because the parts are big and/or heavy and cannot be conveniently removed from the transfer system by a human worker.

38.8 What are the advantages of a mixed-model line over a batch-model line for producing different product styles?

Answer. Advantages of the mixed-model line include (1) no downtime between the different models due to line changeovers; (2) production rates can be matched to demand rates for the different models, and thus (3) inventory fluctuations can be avoided in which there are high inventories of some models while there are stock-outs of other models.

38.9 Why must a production line be paced at a rate higher than that required to satisfy the demand for the product?

Answer. Because all production lines suffer a certain amount of nonproductive time due to reliability problems. The lost time must be recovered by operating the line slightly faster than what would be required to satisfy demand.

38.10 Repositioning time on a synchronous transfer line is known by a different name. What is that name?

Answer. The repositioning time is called the transfer time; it is the time to move parts from one station to the next.

38.11 Why are single-station assembly cells generally not suited to high-production jobs?

Answer. The entire work cycle is performed at one station, so single-station cells usually operate at relatively slow production rates.

38.12 What are some of the reasons for downtime on a machining transfer line?

Answer. Reasons for downtime on a machining transfer line include tool changes, unpredictable mechanical and electrical failures, and normal wear and tear on the equipment.

38.15 Define *group technology*.

Answer. GT is a general approach in which similarities among parts are identified and exploited in design and manufacturing.

38.16 What is a *part family*?

Answer. A part family is a group of parts that possess similarities in geometric shape and size, or in the processing steps used in their manufacture.

38.17 Define *cellular manufacturing*.

Answer. Cellular manufacturing involves the production of part families using groups of machines (generally manually operated) to produce a certain part family or a limited set of part families.

38.18 What is the *composite part concept* in group technology?

Answer. In GT, a composite part is a hypothetical part that includes all of the design and/or manufacturing attributes of a given part family. The concept is useful in designing cells to produce the part family.

38.19 What is a *flexible manufacturing system*?

Answer. A flexible manufacturing system (FMS) is an automated group technology cell consisting of processing stations interconnected by an automated handling system and controlled by a computer.

38.20 What are the criteria that should be satisfied to make an automated manufacturing system flexible?

Answer. The flexibility criteria for an FMS are (1) the system must process different part styles in non-batch mode; (2) the system must be able to accept changes in the production schedule, (3) the system must deal gracefully with equipment breakdowns, and (4) the system must be able to accommodate new part style introductions.

38.21 Name some of the FMS software and control functions.

Answer. FMS software and control functions include (1) NC part programming, (2) NC part program download, (3) production control, (4) machine control, (5) workpart control, (6) tool management, (7) work transport control, and (8) general system management.

38.22 What are the advantages of FMS technology, compared to conventional batch operations?

Answer. Advantages include (1) higher machine utilization, (2) reduced work-in-process, (3) lower manufacturing lead times, and (4) greater flexibility in production scheduling.

38.23 Define *computer integrated manufacturing*.

Answer. Computer integrated manufacturing (CIM) refers to the pervasive use of computer systems throughout a manufacturing organization, not only to monitor and control the operations, but also to design the product, plan the manufacturing processes, and accomplish the business functions related to production.

Problems

Answers to problems labeled **(A)** are listed in an Appendix at the back of the book.

Manual Assembly Lines

38.1 **(A)** A manual assembly line produces a small appliance whose work content time = 38.6 min. Rate of production = 50 units/hr, repositioning time = 6 sec, line efficiency = 95%, and balancing efficiency = 93%. How many workers are on the line?

Solution: $T_c = E/R_p$ = 60(0.95)/50 = 1.14 min
$T_s = T_c - T_r$ = 1.14 – 6/60 = 1.04 min
w = Min Int ≥ 38.6/(0.93 × 1.04) = 39.9 rounded up to **40 workers**

38.2 A manual assembly line has 20 workstations with one operator per station. Total work content time to assemble the product = 28.4 min. Production rate = 36 units per hour. An asynchronous transport system is used to advance the products from one station to the next, and the transfer time = 6 sec. The workers remain seated along the line. Proportion uptime = 0.96. Determine the balance efficiency.

Solution: $T_c = E/R_p$ = 60(0.96)/36 = 1.60 min
$T_s = T_c - T_r$ = 1.60 – 0.1 = 1.50 min
$E_b = T_{wc}/wT_s$ = 28.4/(20 × 1.5) = **0.947 = 94.7%**

38.3 A product whose annual demand = 80,000 units is produced on a manual assembly line. The line operates 50 wk/year, 5 shifts/wk, and 7.5 hr/shift. Work content time = 48.0 min.

Line efficiency = 0.97, balancing efficiency = 0.93, and repositioning time = 8 sec. Determine the (a) hourly production rate, (b) number of workers, and (c) number of workstations if the manning level is 1.4.

Solution: (a) R_p = 80,000/(50 × 5 × 7.5) = **42.67 units/hr**

(b) $T_c = E/R_p$ = 60(.97)/42.67 = 1.364 min
$T_s = T_c - T_r$ = 1.364 – 8/60 = 1.231 min
w = Min Int ≥ 48.0/(0.93 × 1.231) = 41.94 rounded up to **42 workers**

(c) $n = w/M$ = 42/1.4 = **34 stations**

38.4 A rider lawn mower is produced on a manual assembly line. Work content time = 49.5 min. The line has 25 workstations with a manning level = 1.2. Available shift time per day = 8 hr, but equipment downtime during the shift reduces actual production time to 7.5 hr, on average. This results in an average daily production of 244 units/day. Repositioning time per worker = 5% of cycle time. Determine the (a) line efficiency, (b) balancing efficiency, and (c) repositioning time.

Solution: (a) E = 7.5/8.0 = **0.9375 = 93.75%**

(b) R_p = 244/8 = 30.5 units/hr on average which includes the effect of line stops
R_c = 244/7.5 = 32.53 units/hr when line is running
T_c = 60/32.53 = 1.844 min
$T_s = T_c - T_r = T_c - 0.05T_c = 0.95\ T_c$ = 0.95(1.844) = 1.752 min
w = 25(1.2) = 30 workers
$E_b = T_{wc}/wT_s$ = 49.5/(30 × 1.752) = **0.942 = 94.2%**

(c) T_r = 0.05(1.844) = 0.092 min = **5.5 sec**

38.5 A product whose total work content time = 50 min is assembled on a manual production line at a production rate = 24 units per hour. From previous experience with similar products, it is estimated that the manning level will be close to 1.3. Assume that uptime proportion and line balancing efficiency are each = 1.0. If 9 sec are lost from the cycle time for repositioning, determine the (a) cycle time and (b) numbers of workers and stations on the line.

Solution: (a) Given that $E = E_b$ = 1.0, $T_c = E/R_p$ = 1.0(60)/24 = **2.5 min/unit**

(b) $T_s = T_c - T_r$ = 2.5 – 0.15 = 2.35 min
w = Min Int ≥ T_{wc}/E_bT_s = 50/(1.0 × 2.35) = 21.3 rounded up to **22 workers**

n = 22/1.3 = 16.9 rounded up to **17 stations**

38.6 **(A)** Production rate for an assembled product = 47.5 units per hour. Total work content time = 32 min of direct manual labor. The line operates at 95% uptime. Ten workstations have two workers on opposite sides of the line so that both sides of the product can be worked on simultaneously. The remaining stations have one worker. Repositioning time lost by each worker is 0.2 min/cycle. It is known that the number of workers on the line is two more than the number required for perfect balance. Determine the (a) number of workers, (b) number of workstations, (c) balancing efficiency, and (d) average manning level.

Solution: (a) $T_c = E/R_p = 0.95(60)/47.5 = 1.2$ min
$T_s = T_c - T_r = 1.2 - 0.2 = 1.0$ min
If perfect balance, then $E_b = 1.0$ and w = Min Int $\geq T_{wc}/E_bT_s = 32/(1.0 \times 1.0) = 32$ workers
But with 2 additional workers, $w = 32 + 2 =$ **34 workers**

(b) $n = 10 + (34 - 2 \times 10) = 10 + 14 =$ **24 stations**

(c) $E_b = T_{wc}/wT_s = 32/(34 \times 1.0) =$ **0.941 = 94.1%**

(d) $M = w/n = 34/24 =$ **1.417**

38.7 An automobile final assembly plant has an annual production capacity of 200,000 cars. The plant operates 50 wk/yr, 2 shifts/day, 5 days/wk, and 8.0 hr/shift. It is divided into three departments: (1) Body shop, (2) paint shop, and (3) trim-chassis-final department. The body shop welds the car bodies using robots, and the paint shop coats the bodies. Both of these departments are highly automated. Trim-chassis-final has no automated workstations. Cars are moved by a continuous conveyor. There are 15.0 hr of work content time on each car in this department. If the average manning level is 2.2, balancing efficiency = 93%, proportion uptime = 95%, and a repositioning time of 0.15 min is allowed for each worker, determine the (a) hourly production rate of the plant and (b) number of workers and workstations in trim-chassis-final. (c) What is the average labor cost per car in trim-chassis-final if the hourly worker rate = \$30 and fringe benefits add \$15/hr. Ignore cost of supervision, maintenance, and other indirect labor.

Solution: (a) $R_p = 200{,}000/(50 \times 10 \times 8) =$ **50.0 units/hr**

(b) $T_c = E/R_p = 60(0.95)/50 = 1.14$ min
$T_s = T_c - T_r = 1.14 - 0.15 = 0.99$ min
w = Min Int $\geq T_{wc}/E_bT_s = 15.0 \times 60/(0.93 \times 0.99) = 977.5$ rounded to **978 workers/shift**
Total number of workers over two shifts = 1956
$n = w/M = 978/2.2 = 444.3$ rounded up to **445 stations**

Check: Annual workload WL = 200,000 cars × 15 hr/car = 3,000,000 hr of work
With 1956 workers, available service time = 1956(50 × 10 × 8) = 3,912,000 hr
But this does not include the effect of E, E_b, and E_r. $E = 0.95$ (given), $E_b = 0.93$ (given), and $E_r = 0.99/1.14 = 0.8684$.
Usable service time = 3,912,000(0.95)(0.93)(0.8684) = 3,912,000(0.767) = 3,001,409 hr
Close enough. The difference is round up error on the number of workers.

(c) The plant operates (50 weeks/yr)(10 shifts/week)(8 hr/shift) = 4000 hr/yr
Total hourly labor rate = \$30 + \$15 = \$45/hr
Total labor cost = (1956 workers)(2000 hr/wrkr-yr)(\$45/hr) = \$176,040,000
Labor cost in trim-chassis-final per car = 176,040,000/200,000 = \$880.20/car

Automated Production Lines

38.8 An automated transfer line has 22 stations and operates with an ideal cycle time of 1.25 min. Probability of a station failure = 0.005, and average downtime when a breakdown occurs is 6.0 min. Determine the (a) average production rate and (b) line efficiency.

Solution: (a) $F = np = 22(0.005) = 0.11$

T_p = 1.25 + 0.11(6.0) = 1.25 + 0.66 = 1.91 min
R_p = 60/T_p = 60/1.91 = **31.4 units/hr**

(b) $E = T_c/T_p$ = 1.25/1.91 = **0.654 = 65.4%**

38.9 **(A)** A 20-station transfer line operates with an ideal cycle time of 0.72 min. Station breakdowns occur with a frequency of 0.004. Average downtime = 4.0 min per line stop. Determine the (a) ideal hourly production rate, (b) frequency of line stops, (c) average actual production rate, and (d) line efficiency.

Solution: (a) Ideal production rate $R_c = 1/T_c$ = 1/0.72 = 1.389 pc/min = **83.33 pc/hr**

(b) Frequency of line stops on the line $F = np$ = 20(0.004) = **0.08**

(c) Actual average production cycle time T_p = 0.72 + 0.08(4.0) = 0.72 + 0.32 = 1.04 min
Actual average production rate R_p = 1/1.04 = **0.962 pc/min = 57.7 pc/hr**

(d) E = 0.72/1.04 = 0.692 = **69.2%**

38.10 A 12-station transfer line has an ideal cycle time = 0.64 min, which includes the transfer time of 6 sec. Breakdowns occur once every 25 cycles, and the average downtime per breakdown is 7.5 min. The transfer line is scheduled to operate 16 hr per day, 5 days per week. Determine the (a) line efficiency, (b) number of parts the transfer line produces in a week, and (c) the number of downtime hours per week.

Solution: (a) T_p = 0.64 + 7.5/25 = 0.64 + 0.30 = 0.94 min
Line efficiency E = 0.64/0.94 = 0.681 = **68.1%**

(b) R_p = 60/0.94 = 63.83 pc/hr
Weekly production = 5(16)(63.83) = 5106.4 pc/wk rounded to **5106 pc/wk**

(c) Proportion of downtime per cycle = 0.30/0.94 = 0.319
In 80 hours, total downtime = 0.319(80) = **25.53 hr**
Check: There are 5106.4 cycles in 80 hr. Each cycle includes an average of 0.30 min of downtime. Total downtime = 5106.4(0.30/60) = 25.53 hr

38.11 A dial-indexing table has 6 stations. One station is used for loading and unloading, which is accomplished by a human worker. The other five perform processing operations that are automated. The longest operation takes 11 sec, and the indexing time = 4 sec. Each automated station has a frequency of failure = 0.01 (assume that the frequency of failures at the load/unload station = 0). When a failure occurs, it takes an average of 3.0 min to make repairs and restart. Determine (a) hourly production rate and (b) line efficiency.

Solution: (a) Assume p = 0 at the manual station
$F = np$ = 1(0) + 5(.01) = 0.05
T_c = 11/60 + 4/60 = 0.25 min
$T_p = T_c + FT_d$ = 0.25 + 0.05(3.0) = 0.25 + 0.15 = 0.40 min
R_p = 60/0.40 = **150 units/hr**

(b) $E = T_c/T_p$ = 0.25/0.40 = **0.625 = 62.5%**

38.12 **(A)** A 7-station transfer line has been observed over a 40-hr period. The process times at each station are as follows: station 1, 0.80 min; station 2, 1.10 min; station 3, 1.15 min; station 4, 0.95 min; station 5, 1.06 min; station 6, 0.92 min; and station 7, 0.80 min.

Transfer time between stations = 6 sec. The number of downtime occurrences = 110, and hours of downtime = 14.5 hr. Determine the (a) number of parts produced during the week, (b) average actual production rate in parts/hour, and (c) line efficiency. (d) If balancing efficiency were computed for this line, what would it be?

Solution: (a) $T_c = 1.15 + 0.10 = 1.25$ min
$EH = 40E = 40 – 14.5 = 25.5$ hrs
$Q = 25.5(60)/1.25 =$ **1224 pc** during the 40 hour period

(b) $R_p = 1224/40 =$ **30.6 pc/hr**

(c) $40E = 25.5$ $E = 25.5/40$ **= 0.6375 = 63.75%**

(d) $T_{wc} = \Sigma\, T_s = 0.80 + 1.10 + 1.15 + 0.95 + 1.06 + 0.92 + 0.80 = 6.78$ min
n(maximum T_s) = 7(1.15) = 8.05 min
$E_b = 6.78/8.05 =$ **0.842 = 84.2%**

38.13 A 12-station transfer line was designed to operate with an ideal production rate = 50 parts/hr. However, the line does not achieve this rate, because line efficiency = 0.60. It costs $75/hour to operate the line, exclusive of materials. The line operates 4000 hr/yr. A computer monitoring system has been proposed that will cost $25,000 (installed) and will reduce downtime on the line by 25%. If the value added per unit produced = $4.00, will the computer system pay for itself within 1 year of operation? Use expected increase in revenues resulting from the computer system as the criterion. Ignore material and tooling costs in your calculations.

Solution: $T_c = 60/R_c = 60/50 = 1.2$ min
$T_p = T_c/E = 1.2/.6 = 2.0$ min
$R_p = 60/T_p = 60/2.0 = 30$ pc/hr

In the current system:
Annual production $Q = 4000R_p = 4000(30) = 120{,}000$ units/yr
Revenues = $\$4.00Q = \$4.00(120{,}000) = \$480{,}000$/yr.
Cost to operate line = $\$75H = \$75(4000) = \$300{,}000$/yr

With computer monitoring system:
$T_c = 1.2$ min and $T_p = 2.0$ min. $FT_d = T_p – T_c$. This is reduced by 25% with new system.
$FT_d = (1 – 25\%)(2.0 – 1.2) = 0.75(0.8) = 0.6$ min
$T_p = 1.2 + 0.6 = 1.8$ min
$R_p = 60/1.8 = 33.33$ pc/hr
Annual production $Q = 4000(33.33) = 133{,}333$ units/yr
Revenues = $4.00(133,333) = $533,333/yr.
Cost to operate line = same as in current system (neglecting increased cost of new system)

Difference in revenues = $533,333 – $480,000 = **$53,333/yr**. This is more than enough to justify the $25,000 investment.