



Performance and Economics of Assembly Systems

Multi-station assembly machines may be classified into two main groups according to the system used to transfer assemblies from workstation to workstation:

1. **Indexing machines** : those assembly machines that transfer all the work carriers simultaneously and a stoppage of any individual workhead causes the whole machine to stop
2. **Free-transfer or nonsynchronous assembly machines** : the workheads are separated by buffers containing assemblies, and transfer to and from these buffers occurs when the particular workhead has completed its cycle of operations.

One of the principal problems in applying automation to the assembly process is the loss in production resulting from stoppages of automatic workheads when defective component parts are fed to the machine.

The quality levels of the parts to be used in automatic assembly must, therefore, be considered when an assembly machine is designed.



INDEXING MACHINES : EFFECT OF PARTS QUALITY ON DOWNTIME

n – Number of automatic workheads

t – Cycle Time

x - ratio of defective parts to acceptable parts

m - proportion of the defective parts causing machine stoppages

T - Time taken for an operator, on average, to locate the failure,
remove the defective part, and restart the machine.

N – Number of assemblies produced

Therefore, the **total downtime** due to stoppages in producing N assemblies will be $= mxnNT$

Since, each time the machine indexes, all assembly tasks are completed and one assembly is delivered from the machine;

hence, the **Machine Time** to assemble N assemblies = Nt sec



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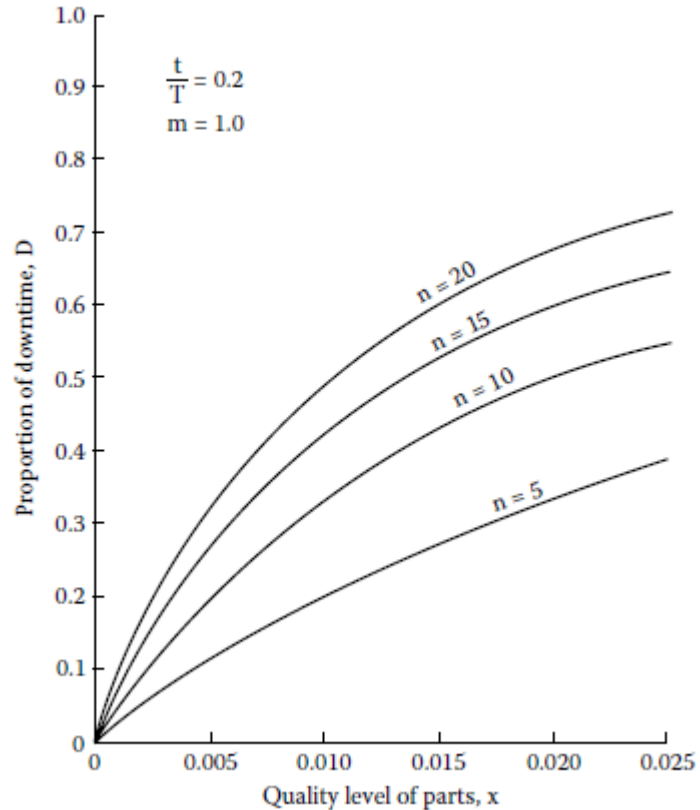
The proportion of downtime D on the machine is given by :

$$D = \frac{\text{Downtime}}{\text{Assembly Time} + \text{Downtime}} = \frac{mNxnT}{Nt + mNxnT} = \frac{mxn}{mxn + \frac{t}{T}}$$

For standard fasteners such as screws, which are often employed in assembly processes, an average value for x *might be between 0.01 and 0.02*. In other words, for every 100 acceptable screws, there would be between one and two defective ones. A higher quality level is generally available, but with screws, for example, a reduction of x to 0.005 *may double their price and seriously affect the cost of the final assembly*.



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➤ The downtime on an assembly machine having 10 automatic workheads is 0.33 of the total time available.

➤ These results show why it is rarely economical to use indexing machines having a large number of automatic workheads.

➤ They also illustrate why, in practice, it is advisable to allow for downtime when considering the use of an indexing assembly machine.

Effect of parts quality on indexing machine downtime; n is the number of automatic workheads, t the machine cycle time, T the time to correct a machine fault, and m the proportion of defective parts causing a machine stoppage.



EFFECTS OF PARTS QUALITY ON PRODUCTION TIME

In the preceding example, it was assumed that all the defective parts fed to the automatic workheads would stop the machine (that is, $m = 1$).

In practice, however, some of these defective parts would pass through the feeding devices and automatic workheads, but would not be assembled correctly and would result in the production of an unacceptable assembly.

In this case, the effect of the defective part would be to cause downtime on the machine equal to only one machine cycle.

The time taken to produce N assemblies, *whether these are acceptable or not*, is given by **$(Nt + mxnNT)$**

*and, if $m < 1$, only about **$[N - (1 - m)xnN]$** of the assemblies produced will be acceptable.*



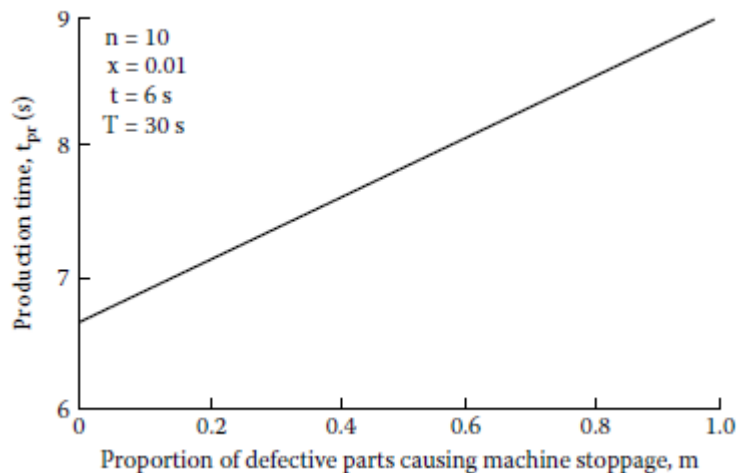
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The average production time t_{pr} of acceptable assemblies is therefore given by:

$$t_{pr} = \frac{Nt + m \cdot nNT}{N - (1 - m) \cdot nN}$$
$$= \frac{t + m \cdot nT}{1 - (1 - m) \cdot n}$$

Taking typical values of $x = 0.01$, $t = 6$ sec, $T = 30$ sec, and $n = 10$,

$$t_{pr} = \frac{30(2 + m)}{9 + m}$$



for a maximum production rate of acceptable assemblies, m should be as small as possible. In other words, when designing the workheads for an indexing assembly machine when a high production rate is required, it is preferable to allow a defective part to pass through the feeder and workhead and “spoil” the assembly rather than allow it to stop the machine.



EFFECT OF PARTS QUALITY ON THE COST OF ASSEMBLY

The total cost C_t of each acceptable assembly produced on an assembly machine

$$C_t = M t_{pr} + C_1 + C_2 + C_3 + \dots + C_n$$

Where, Mt is the total cost of operating the machine per unit time and includes operators' wages, overhead charges, actual operating costs, machine depreciation, and the cost of dealing with the unacceptable assemblies produced, and t_{pr} is the average production time of acceptable assemblies

Estimation of Mt : Assume:

1. a machine stoppage caused by a defective part will be cleared by one of the operators employed on the machine and that no extra cost will be entailed other than that due to machine downtime.
2. if a defective part passes through the workhead and spoils an assembly, it will take an extra assembly worker tc sec to dismantle the assembly and replace the non-defective parts in the appropriate feeding devices.



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Thus, the total operating cost M_t is given by

$$M_t = M + P_u t_c W_a$$

Where, M is the cost of operating the machine per unit time if only acceptable assemblies are produced and W_a is the assembly worker's rate, including overhead.

The number of unacceptable assemblies produced per unit time is denoted by P_u and is given by

$$P_u = \frac{(1 - m)xn}{t + mxnT}$$

Therefore,

$$M_t = M + \frac{(1 - m)xn t_c W_a}{t + mxnT}$$



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In estimating the cost C_i of an individual component part, it will be assumed that this can be broken down into :

- (1) the basic cost of the part, irrespective of quality level, and
- (2) a cost that is inversely proportional to x and that will therefore increase for better-quality parts.

Thus, the cost of each part may be expressed as :

$$C_i = A_i + \frac{B}{x}$$

In this equation, B is a measure of the cost due to quality level and, for the purposes of the present analysis, will be assumed to be constant regardless of the basic cost A_i of the parts.

So, the total cost C_t of each acceptable assembly becomes, after rearrangement,

$$C_t = \frac{M(t + mxnT) + (1 - m)xn t_c W_a}{1 - (1 - m)xn} + \sum_{i=1}^n A_i + \frac{nB}{x}$$



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This equation shows that the total cost of an assembly can be broken down as follows:

1. A cost that will decrease as x is reduced
2. A cost that is constant
3. A cost that will increase as x is reduced

It follows that, for a given situation, an optimum value of x will exist that will give a minimum cost of assembly.

With $m = 1$,

$$C_t = Mt + MxT + \frac{nB}{x} + \sum_{i=1}^n A_i \quad \dots\dots (1)$$

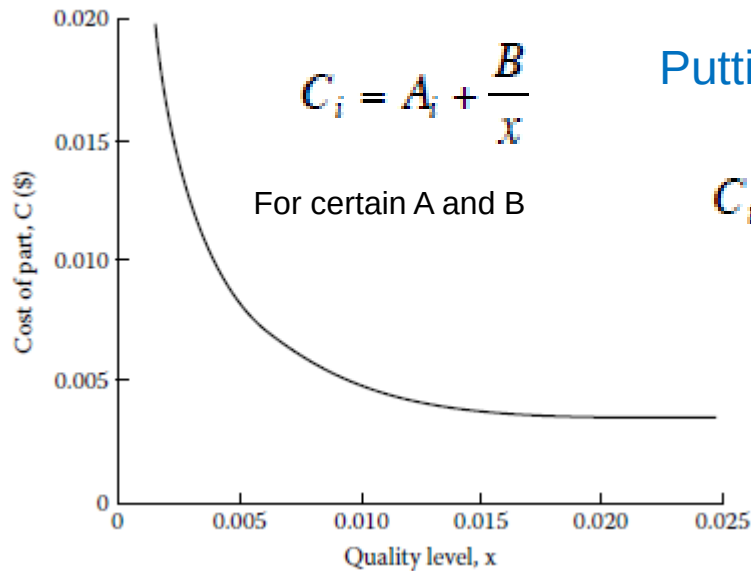
cost of	+	cost of	+	cost of	+	basic
assembly		downtime		parts		cost of
operations				quality		parts

For the optimum value of x , giving the minimum cost of assembly:

$$x_{\text{opt}} = \left(\frac{B}{MT} \right)^{1/2}$$



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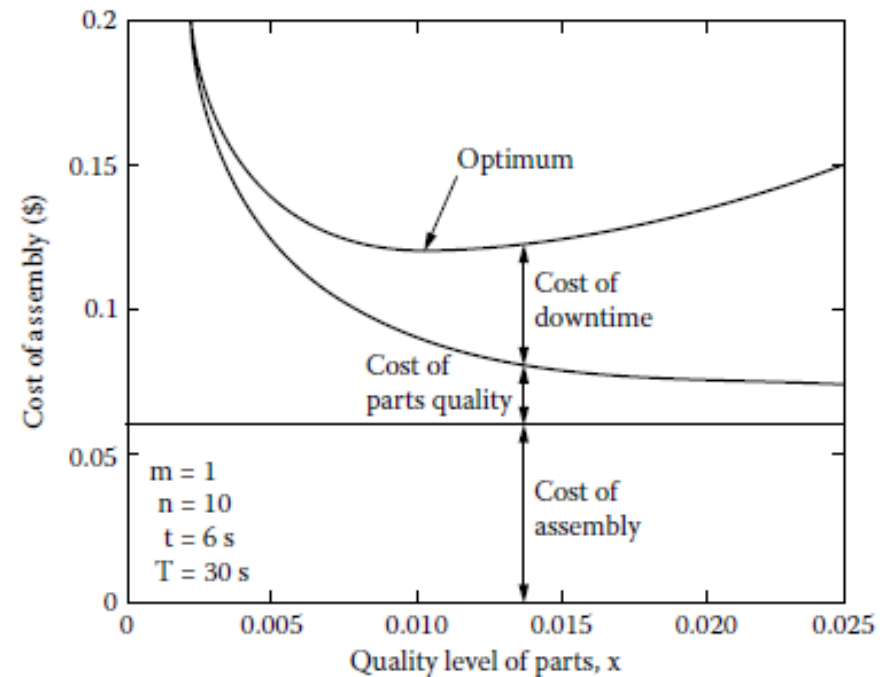


Putting the value of $x_{\text{opt}} = \left(\frac{B}{MT} \right)^{1/2}$ In Eq. 1

$$C_i(\min) = Mt + 2n(MBT)^{1/2} + \sum_{i=1}^n A_i$$

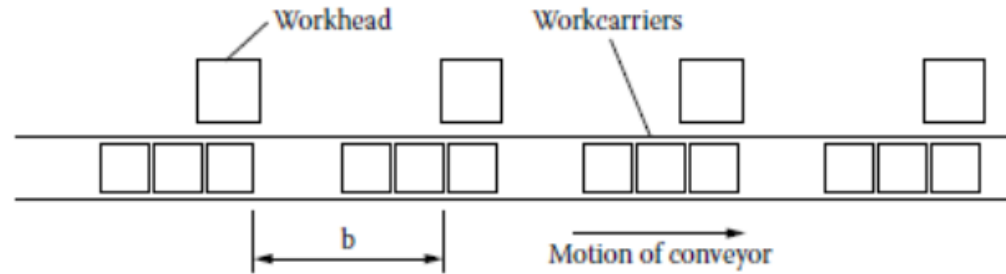
It is possible to draw two main conclusions :

1. for the situation analyzed, it would be preferable to allow a defective part to pass through the workhead and spoil the assembly rather than to allow it to stop the indexing machine. This would not only increase the production rate of acceptable assemblies but would also reduce the cost of assembly.
2. An optimum quality level of parts always exists that will give minimum cost of assembly.





Performance of a Free Transfer Machine

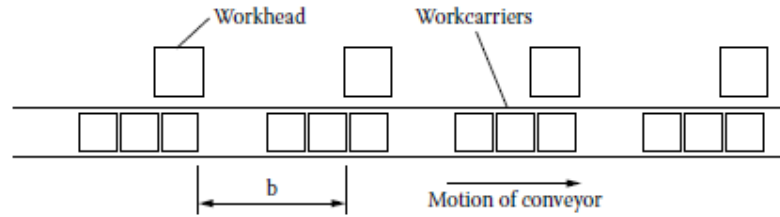


Any workhead on a free-transfer assembly machine will be forced to stop under **THREE** different circumstances:

1. If a defective part is fed to the workhead and prevents the completion of its cycle of operations. Then an interval of T seconds elapses before the fault is cleared and the workhead is re-started.
2. If the adjacent workhead up the line has stopped and the supply of assemblies in the buffer storage between them is exhausted.
3. If the adjacent workhead down the line has stopped and the buffer storage between them is full.



Performance of a Free Transfer Machine



- For a typical workhead on a free-transfer machine producing N assemblies, Nx stoppages will occur if m is unity. If each fault takes T sec to correct, the downtime on the first workhead due to its own stoppages is given by NxT .
- If two adjacent workheads have “ a ” assemblies in the buffer storage between them, then a fault in the 1 workhead will prevent the 2 from working after a time lag of “ at ” seconds.
- A fault in 2 will prevent the 1 from working after a time lag of $[(b-a)t]$ sec.
- Assumption is made that no workhead will stop while another has stopped..



Performance of a Free Transfer Machine

For the workhead 1: (producing N assemblies)

- ❖ Nx stoppages will occur when $m=1$. If each fault takes T sec to correct, the downtime on the first workhead due to its own stoppages is given by NxT .
- ❖ Average downtime in 2 is the same as 1 which is NxT .
- ❖ But a fault in 2 will prevent 1 from working for a period of $Nx[T - (b - a_1)t]$ sec
- ❖ Similarly, stoppages of 3 will prevent the 1 from working for a period of $Nx[T - (2b - a_1 - a_2)t]$ sec

Similar expressions can be derived from the effects of 4.

Therefore, the total downtime on 1, while producing N assemblies will be:

$$d_1 = TNx + [T - (b - a_1)t]Nx + Nx[T - (2b - a_1 - a_2)t] + Nx[T - (3b - a_1 - a_2 - a_3)t]$$

$$\text{Or, } \frac{d_1}{Nx} = T + [T - (b - a_1)t] + [T - (2b - a_1 - a_2)t] + [T - (3b - a_1 - a_2 - a_3)t]$$



Performance of a Free Transfer Machine

The analysis is based on the fact that over a long period, the average downtime on each workhead must be the same, i.e,

$$d_1 = d_2 = d_3 = d_4$$

Then all the equations of $\frac{d_1}{N_x}, \frac{d_2}{N_x}, \frac{d_3}{N_x}, \frac{d_4}{N_x}$ could be solved simultaneously to get

the values of $a_1 \dots a_3$ in terms of “b”

Putting these values in the equations of $\frac{d_1}{N_x}, \frac{d_2}{N_x}, \frac{d_3}{N_x}, \frac{d_4}{N_x}$ the downtime of machines can be found out.