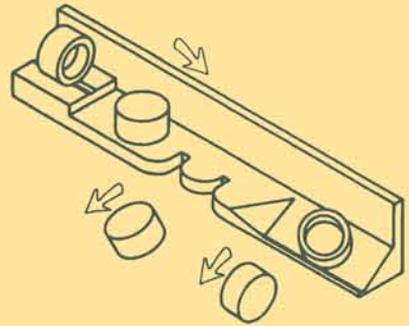
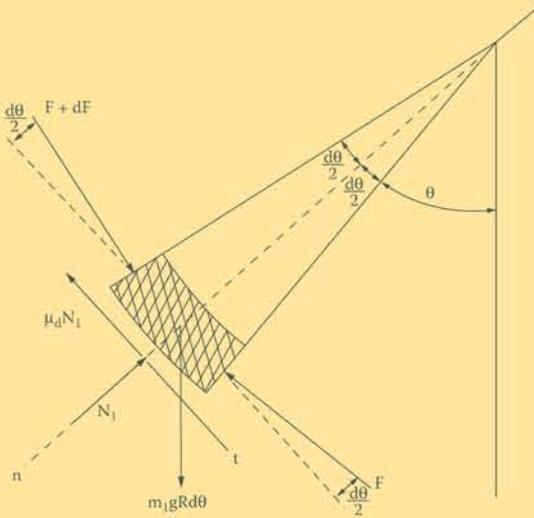




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Chapter 2

Automatic Assembly Transfer Systems

In automatic assembly, the various individual assembly operations are generally carried out at separate workstations. For this method of assembly, a machine is required for transferring the partly completed assemblies from workstation to workstation, and a means must be provided to ensure that no relative motion exists between the assembly and the workhead or robot while the operation is being carried out. As the assembly passes from station to station, it is necessary that it be maintained in the required attitude. For this purpose, the assembly is usually built up on a base or work carrier, and the machine is designed to transfer the work carrier from station to station; an example of a typical work carrier is shown in Figure 2.1. Assembly machines are usually classified according to the system adopted for transferring the work carriers (Figure 2.2). Thus, an in-line assembly machine is one in which the work carriers are transferred in line along a straight slideway, and a rotary machine is one in which the work carriers move in a circular path. In both types of machine, the transfer of work carriers may be continuous or intermittent.

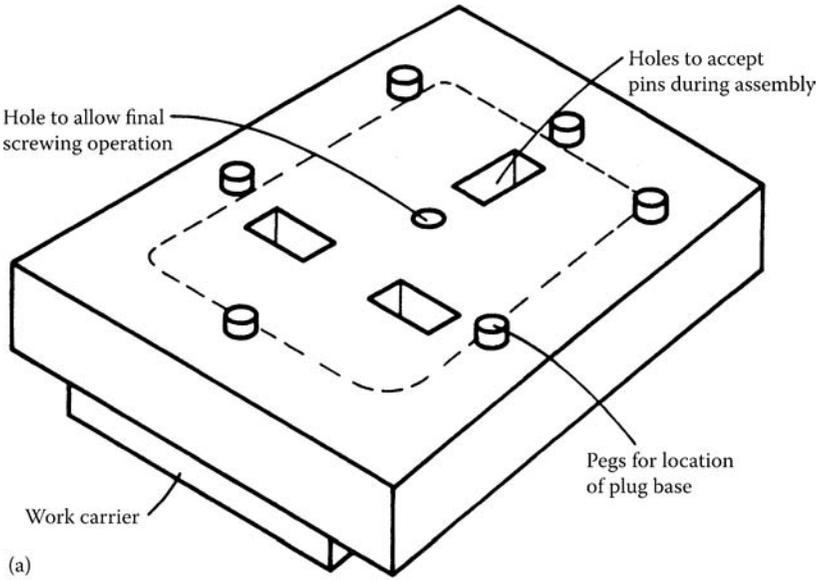
2.1 CONTINUOUS TRANSFER

With continuous transfer, the work carriers are moving at a constant speed while the workheads keep pace. When the operations are completed, the workheads return to their original positions and, again, keep pace with the work carriers. Alternatively, the workheads move in a circular path tangential to the motion of the work carriers. In either case, the assembly operations are carried out during the period in which the workheads are keeping pace with the work carriers.

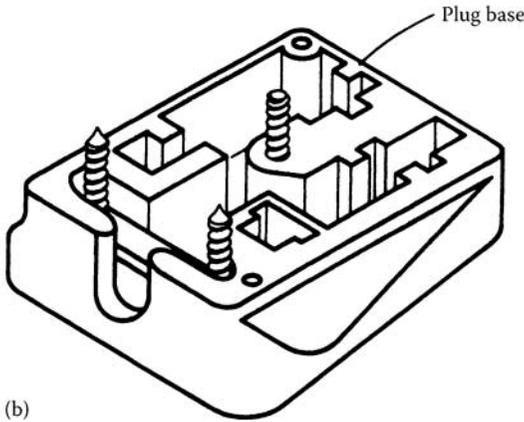
Continuous-transfer systems have limited application in automatic assembly because the workheads and associated equipment are often heavy and must therefore remain stationary. It is also difficult to maintain sufficiently accurate alignment between the workheads and work carriers during the operation cycle because both are moving. Continuous-transfer machines are most common in industries such as food processing or cosmetics, where bottles and jars have to be filled with liquids.

2.2 INTERMITTENT TRANSFER

Intermittent transfer is the system more commonly employed for automatic assembly. As the name implies, the work carriers are transferred intermittently, and the workheads remain stationary. Often, the transfer of all the work carriers



(a)



(b)

FIGURE 2.1 Work carrier suitable for holding and transferring three-pin power plug base.

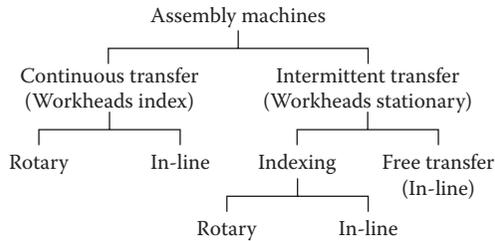


FIGURE 2.2 Basic types of assembly machines.

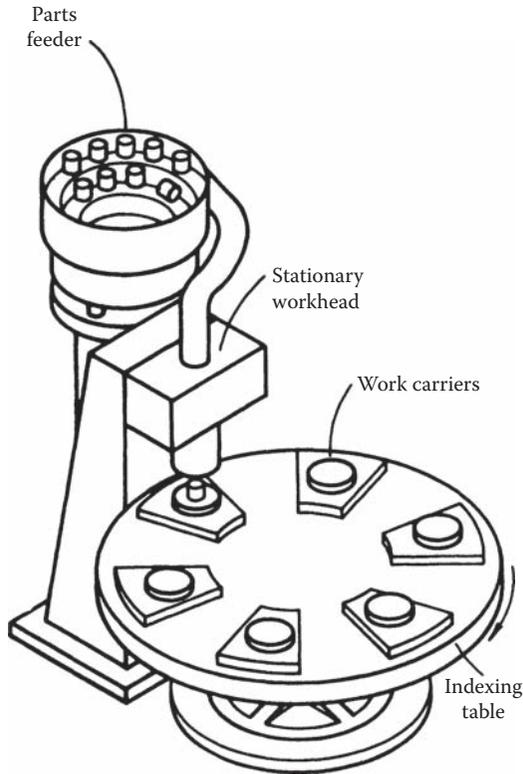


FIGURE 2.3 Rotary indexing machine (with one workhead shown).

occurs simultaneously, and the carriers then remain stationary to allow time for the assembly operations. These machines may be termed *indexing machines*, and typical examples of the rotary and in-line types of indexing machines are shown in Figure 2.3 and Figure 2.4, respectively. With rotary indexing machines, indexing of the table brings the work carriers under the various workheads in turn, and assembly of the product is completed during one revolution of the table. Thus, at the appropriate station, a completed product may be taken off the machine after each index. The in-line indexing machine works on a similar principle but, in this case, a completed product is removed from the end of the line after each index. With in-line machines, provision must be made for returning the empty work carriers to the beginning of the line. The transfer mechanism on in-line machines is generally one of two types: the shunting work carrier or the belt-driven work carrier.

The shunting work carrier transfer system is shown in Figure 2.5. In this system, the work carriers have lengths equal to the distance moved during one index. Positions are available for work carriers at the beginning and end of the assembly line, where no assembly takes place. At the start of the cycle of operations, the work carrier position at the end of the line is vacant. A mechanism

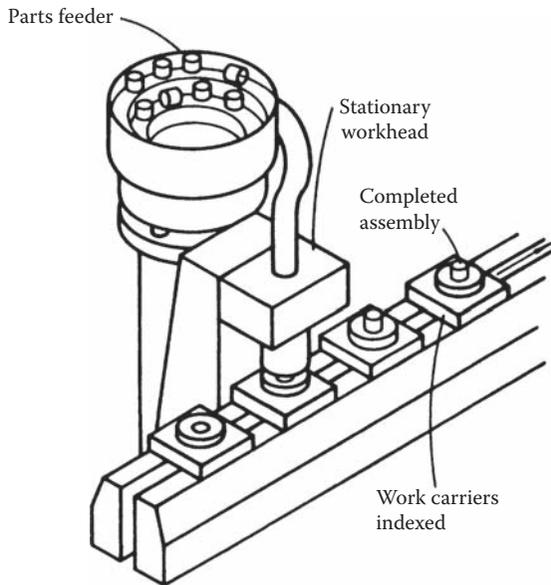


FIGURE 2.4 In-line indexing machine (with one workhead shown).

pushes the line of work carriers up to a stop at the end of the line, and this indexes the work carriers' position. The piston then withdraws, and the completed assembly at the end of the line is removed. The empty work carrier from a previous cycle that has been delivered by the return conveyor is raised into position at the beginning of the assembly line.

Although the system described here operates in the vertical plane, the return of work carriers can also be accomplished in the horizontal plane. In this case, transfer from the assembly line to the return conveyor (and vice versa) is simpler, but greater floor area is used. In practice, when operating in the horizontal plane, it is more usual to dispense with the rapid return conveyor and to fit further assembly heads and associated transfer equipment in its place (Figure 2.6). However, this system has the disadvantage that access to the various workheads may be difficult.

A further disadvantage with all shunting work carrier systems is that the work carriers themselves must be accurately manufactured. For example, if an error of 0.025 mm were to occur on the length of each work carrier in a 20-station machine, an error in alignment of 0.50 mm would occur at the last station. This error could create serious difficulties in the operation of the workheads. However, in all in-line transfer machines, it is usual for each work carrier, after transfer, to be finally positioned and locked by a locating plunger before the assembly operation is initiated.

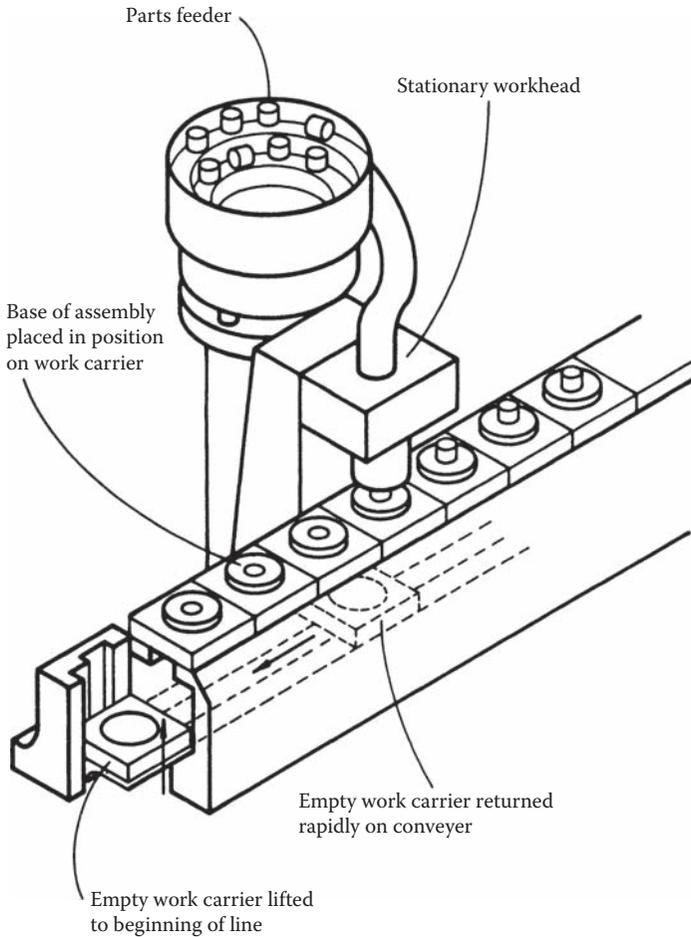


FIGURE 2.5 In-line transfer machine with shunting work carriers returned in vertical plane.

The belt-driven work-carrier transfer system is illustrated in Figure 2.7. Basically, this machine uses an indexing mechanism that drives a belt or flexible steel band to which the work carriers are attached. The work carriers are spaced to correspond to the distance between the workheads.

Instead of attaching the work carriers rigidly to the belt, it is possible to employ a chain that has attachments to push the work carriers along guides. In this case, the chain index can be arranged to leave the work carriers short of their final position, allowing location plungers to bring them into line with the workheads.

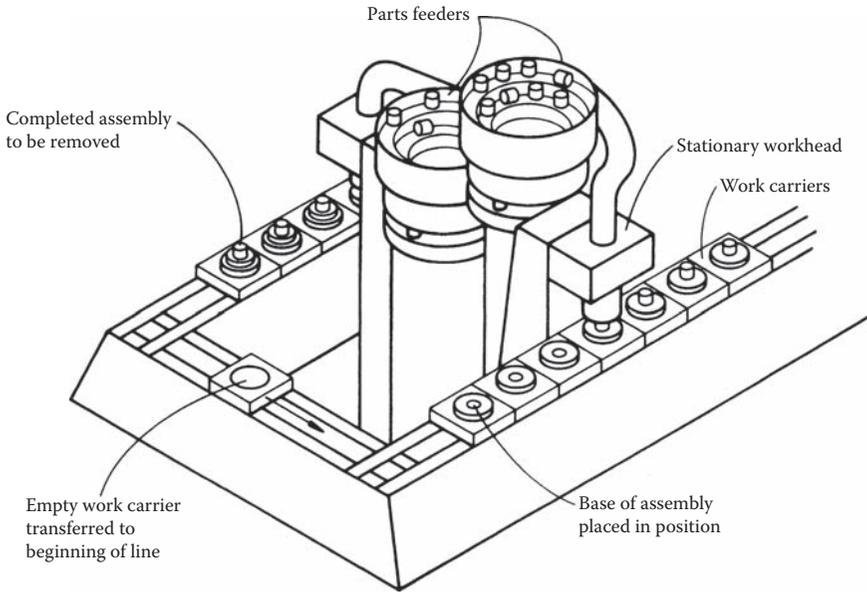


FIGURE 2.6 In-line transfer machine with shunting work carriers returned in horizontal plane.

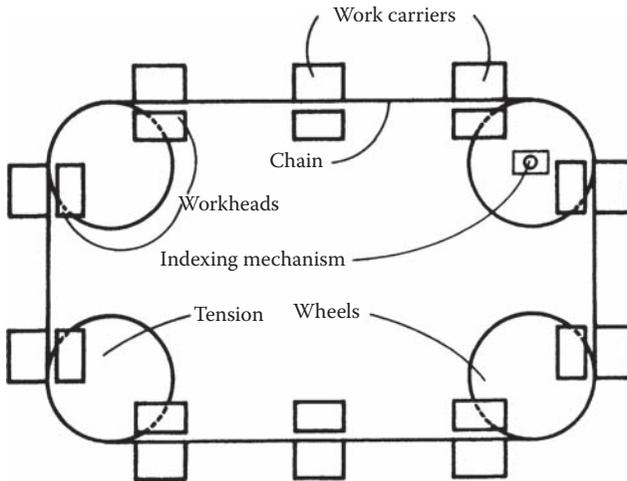


FIGURE 2.7 Belt-driven transfer system.

2.3 INDEXING MECHANISMS

Huby [1] lists the factors affecting the choice of indexing mechanism for an assembly machine as follows:

1. The required life of the machine
2. The dynamic torque capacity required
3. The static torque capacity
4. The power source required to drive the mechanism
5. The acceleration pattern required
6. The accuracy of positioning required from the indexing unit

Generally, an increase in the size of a mechanism increases its life. Experience shows which mechanisms usually have the longest life for given applications; this is discussed later.

The dynamic torque capacity is the torque that must be supplied by the indexing unit during the index of a fully loaded machine. The dynamic torque capacity is found by adding the effects of inertia and friction and multiplying by the life factor of the unit, the latter factor being derived from experience with the use of the indexing unit.

The static torque capacity is the sum of the torques produced at the unit by the operation of the workheads. If individual location plungers are employed at each workhead, these plungers are usually designed to withstand the forces applied by the workheads; in such a case, the static torque capacity required from the indexing unit will probably be negligible. The power required to drive an indexing unit is obtained from the dynamic torque applied to the unit during the machine index.

The form of the acceleration curve for the indexing unit may be very important when there is any possibility that a partially completed assembly may be disturbed during the machine index. A smooth acceleration curve will also reduce the peak dynamic torque and will thus assist the driving motor in maintaining a reasonably constant speed during indexing, thereby increasing the life of the machine. The accuracy of the indexing required will not be great if locating plungers are employed to perform the final positioning of the work carriers or indexing table.

Various indexing mechanisms are available for use on automatic assembly machines; typical examples are given in Figure 2.8 to Figure 2.10. These mechanisms fall into two principal categories: those that convert intermittent translational motion (usually provided by a piston) into angular motion by means of a rack and pinion or ratchet and pawl (Figure 2.8), and those that are continuously driven, such as the Geneva mechanism (Figure 2.9) or the crossover or scroll cam shown in Figure 2.10.

For all but very low-speed or very small indexing tables, the rack-and-pinion or ratchet-and-pawl mechanisms are unsuitable because they have a tendency to overshoot. The acceleration properties of both these systems are governed entirely

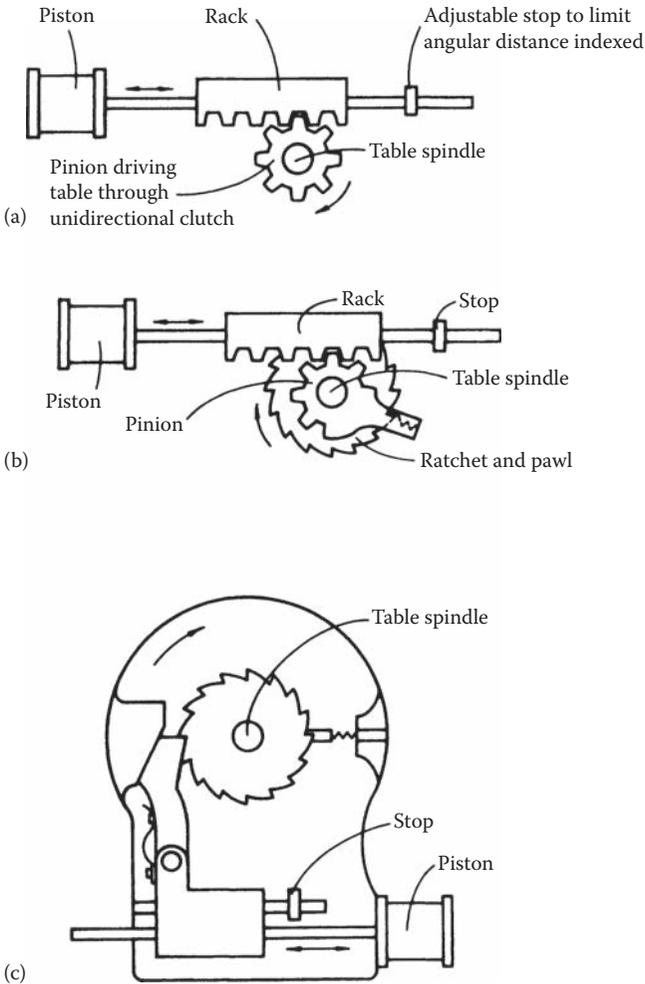


FIGURE 2.8 Indexing mechanisms: (a) rack and pinion with unidirectional clutch; (b) rack and pinion with ratchet and pawl; (c) ratchet and pawl.

by the acceleration pattern of the linear power source. To ensure a fairly constant indexing time, if the power source is a pneumatic cylinder, it is usual to underload the cylinder, in which case the accelerations at the beginning and end of the stroke are very high and produce undesirable shocks. The ratchet-and-pawl mechanism requires a takeup movement and must be fairly robust if it is to have a long life. The weakest point in the mechanism is usually the pawl pin and, if this is not well lubricated, the pawl will stick and indexing will not occur.

The Geneva-type indexing mechanism has more general applications in assembly machines, but its cost is higher than the mechanisms described earlier. It is capable of transmitting a high torque relative to its size and has a smooth

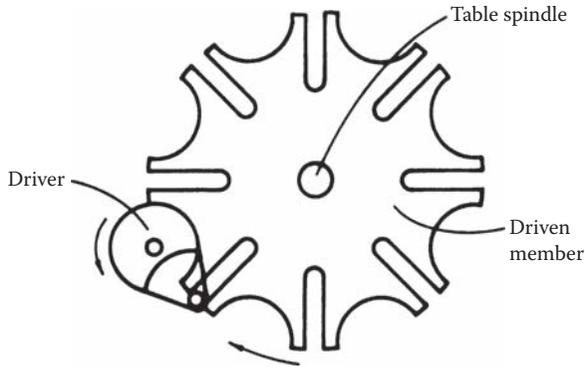


FIGURE 2.9 Geneva mechanism.

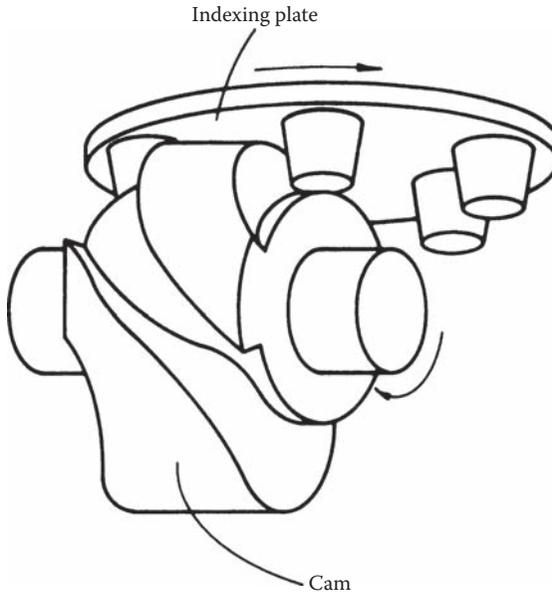


FIGURE 2.10 Crossover cam indexing unit.

acceleration curve. However, it has a high peak dynamic torque immediately before and after the reversal from positive to negative acceleration. In its basic form, the Geneva mechanism has a fairly short life, but wear can be compensated for by adjustment of the centers. The weakest point in the mechanism is the indexing pin, but breakages of this part can be averted by careful design and avoidance of undue shock reactions from the assembly machine. A characteristic of the Geneva mechanism is its restriction on the number of stops per revolution.

This is primarily due to the accelerations that occur with three-stop and more than eight-stop mechanisms.

In a Geneva mechanism, the smaller the number of stops, the greater the adverse mechanical advantage between the driver and the driven members. This results in a high indexing velocity at the center of the indexing movement and gives a very peaked acceleration graph. On a three-stop Geneva, this peaking becomes very pronounced and, because the mechanical advantage is very high at the center of the movement, the torque applied to the index plate is greatly reduced when it is most required. The solution to these problems results in very large mechanisms relative to the output torque produced.

As the number of stops provided by a Geneva mechanism increases, the initial and final accelerations during indexing increase although the peak torque is reduced. This is due to the increased difficulty in placing the driver center close to the tangent of the indexing slot on the driven member.

For a unit running in an oil bath, the clearance between the driver and driven members during the locking movement is approximately 0.025 mm. To allow for wear in this region, it is usual to provide a small center-distance adjustment between the two members. The clearance established after adjustment is the main factor governing the indexing accuracy of the unit, and this will generally become less accurate as the number of stops is increased. Because of the limitations in accuracy, it is usual to employ a Geneva mechanism in conjunction with a location plunger; in this way, a relatively cheap and accurate method of indexing is obtained.

The crossover cam type of indexing mechanism shown in Figure 2.10 is capable of transmitting a high torque, has a good acceleration characteristic, and is probably the most consistent and accurate form of indexing mechanism. Its cost is higher than that of the alternative mechanisms described earlier, and it also has the minor disadvantage of being rather bulky. The acceleration characteristics are not fixed as with other types of indexing mechanisms, but a crossover cam can be designed to give almost any required form of acceleration curve. The normal type of cam is designed to provide a modified trapezoidal form of acceleration curve, resulting in a low peak dynamic torque and fairly low mean torque. The cam can be designed to give a wide range of stops per revolution of the index plate, and the indexing is inherently accurate. A further advantage is that it always has at least two indexing pins in contact with the cam.

Figure 2.11 shows the acceleration patterns of the modified trapezoidal, sine, and modified sine cams and the Geneva mechanism for the complete index of a four-stop unit. It can be seen that the modified trapezoidal form gives the best pattern for the smoothest operation and lowest peaking. The sine and modified sine both give smooth acceleration, but the peak torque is increased, whereas with the Geneva mechanism, the slight initial shock loading and the peaking at the reversal of the acceleration are clearly evident.

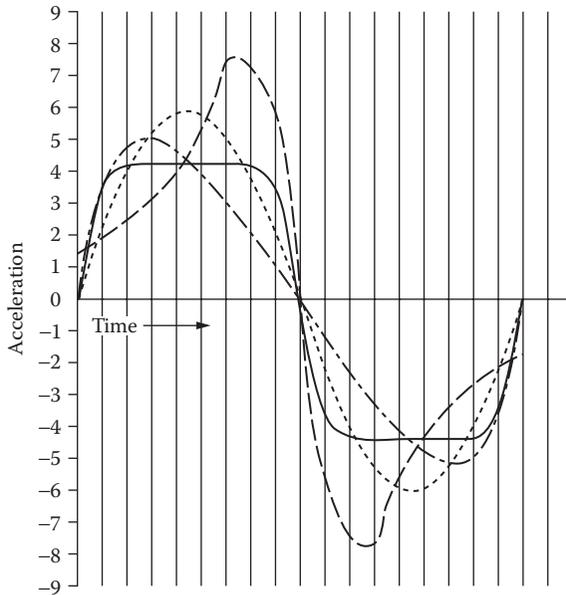


FIGURE 2.11 Comparison of acceleration curves for a Geneva mechanism and various designs of crossover cams: modified trapezoidal, — ; four-stop Geneva, - - - ; modified sine, - · - · - ; sine, ····. (Adapted from Huby, E., *Assembly Machine Transfer Systems*, paper presented at the Conference on Mechanized Assembly, July 1966, Royal College of Advanced Technology, Salford, England. With permission.)

2.4 OPERATOR-PACED FREE-TRANSFER MACHINE

With all the transfer systems described earlier, it is usual for the cycle of operations to occur at a fixed rate, and any manual operations involved must keep pace; this is referred to as *machine pacing*. Machines are available, however, for which a new cycle of operations can be initiated only when signals indicating that all the previous operations have been completed are received. This is referred to as *operator pacing*.

One basic characteristic common to all the systems described is that a breakdown of any individual workhead will stop the whole machine, and production will cease until the fault has been rectified. One type of in-line intermittent operator-paced machine, known as a *free-transfer or nonsynchronous machine* (Figure 2.12), does not have this limitation. In this design, the spacing of the workstations is such that buffer stocks of assemblies can accumulate between adjacent stations. Each workhead or operator works independently, and the assembly process is initiated by the arrival of a work carrier at the station. The first operation is to lift the work carrier clear of the conveyor and clamp it in position. After the assembly operation has been completed, the work carrier is released and transferred to the next station by the conveyor, provided that a vacant space

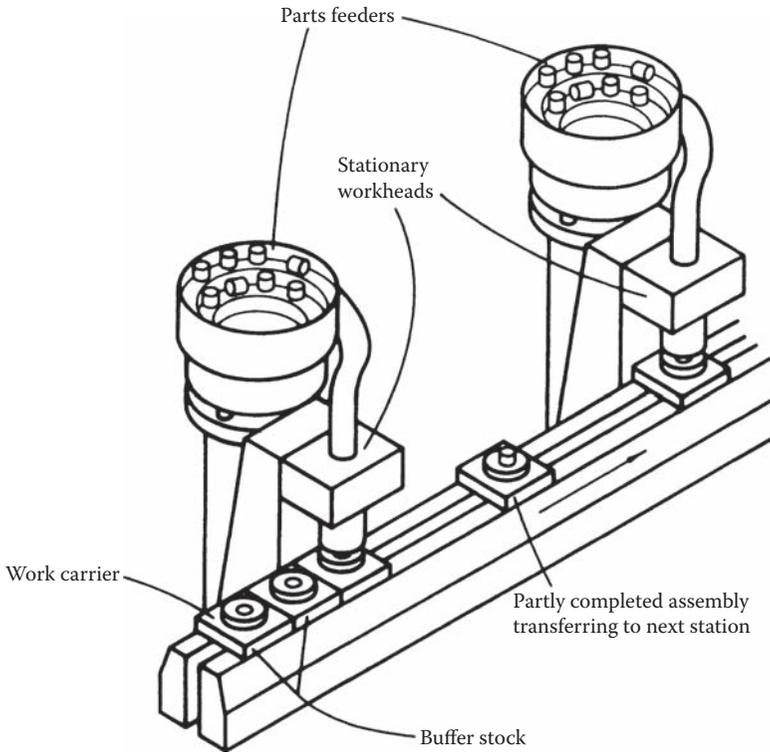


FIGURE 2.12 In-line free-transfer or nonsynchronous machine.

is available. Thus, on a free-transfer machine, a fault at any one station will not necessarily prevent the other stations from working. It will be seen later that this can be an important factor when considering the economics of various transfer machines for automatic assembly.

REFERENCES

1. Huby, E., Assembly Machine Transfer Systems, paper presented at the Conference on Mechanized Assembly, July 1966, Royal College of Advanced Technology, Salford, England.