Automated Production Lines

Automated production lines are typically used for high production of parts that require multiple processing operations. The production line itself consists of geographically dispersed workstations within the plant, which are connected by a mechanized work transport system that ferries parts from one workstation to another in a pre-defined production sequence. In cases where machining operations, such as drilling, milling, and similar rotating cutter processes, are performed at particular workstations, the more accurate term to use is transfer line, or transfer machine. Other potential automated production line applications include: robotic spot-welding, sheet-metal press-working, and electroplating of metals.

KEYPOINT Automated production lines consist of distributed workstations connected by a mechanized work transport system that moves the parts from one workstation to another as they enter the system.

END KEYPOINT

Automated production lines are usually expensive to implement, and—as examples of fixed automation—their layout is relatively hard to change once built into the production plant's infrastructure. The following are the conditions that normally suit the used of automated production lines: BULLETLIST High product demand, requiring high production quantities Stable product design, as automated production lines cannot accommodate frequent design changes Long product life—typically several years Multiple operations, involving the use of a number of workstations ENDLIST

KEYPOINT The conditions that determine the use of automated production lines include: high product demand; stable product design; long product life; and multiple operations.

END KEYPOINT

Once these conditions are met, the following benefits are usually seen to accrue from using automated production lines: NUMLIST Low amount of direct labour Low product cost High production rate Minimal work-in-progress and production lead time Minimal use of factory floor space ENDLIST In this unit a general overview of automated production lines is offered, which examines the fundamentals of automated lines (i.e. system configuration, workpart transfer mechanisms, storage buffers, and control of the production line), as well as the applications of production lines for machining systems and system design considerations. This is followed by an analysis of transfer lines, both with no internal parts storage, and with internal storage buffers. 13.2 Learning Objectives After completing this unit, and the assigned reading and exercises supplied, you should be able to: BULLET LIST Define the concept of automated production lines Specify the components of automated production Outline the system configurations used in automated production Explain the types of transfer mechanism that may be used for workpart transfer Describe the Geneva mechanism Outline how storage buffers may be deployed in automated production lines List the basic control functions that can be distinguished in the operation of an automatic transfer machine Explain the concept of a transfer line Outline the approaches that may be used for system design List the three areas that can be considered for analysis in connection with transfer lines Specify common metrics used to assess transfer lines with no internal parts storage Explain how storage buffers affect transfer line downtime Specify the factors involved in considering the overall line efficiency for a twostage transfer line ENDLIST 13.3 Fundamentals of Automated Production Lines An automated production line has multiple workstations that are automated and linked together by a work handling system that transfers parts from one station to the next, as in Figure 13.1. Starting—un-processed—parts enter the automated production line and undergo a system of automated processing at various workstations along the fixed production line; the parts are passed from workstation to workstation by means of a mechanized work transport system, until the completely processed parts pass out of the automated production line after the last process occurs to the part at the final workstation in the system. Fig General configuration of an automated production line

KEYPOINT In automated production un-processed parts enter the production line and undergo a system of automated processing at various workstations along the fixed production line, with parts being moved from one workstation to the next by means of a mechanized work transport system, until the last process occurs to the part at the final workstation in the system, at which point the part exits the automated production line.

END KEYPOINT

The line may also include inspection stations to perform intermediate quality checks on parts in the system, as well as a number of manually-operated workstations that accomplish tasks that have not been automated owing to reasons of economy or difficulty. Each station performs a different operation, so all the operations are required to complete one work unit; this means that the parts' route through the production line is fixed and cannot be changed. Multiple parts are processed simultaneously, with one part undergoing processing at each workstation in the system. This means, in the simplest automated production lines, that the number of parts in the system is found to be equal to the number of workstations that the system has; however, in more complicated configurations, provision may have been made for some form of part storage, so this calculation may not be accurate where buffering is manifest.

KEYPOINT The automated production may consist of, besides automated workstations, manual workstations and inspection stations.

END KEYPOINT

The automated production line operates in cycles with the slowest workstation processing time setting the pace for the whole line. Each cycle consists of the processing time plus the time taken to transfer parts from one workstation to the next. Certain layouts of transfer lines may allow the use of pallet fixtures for part handling (see Unit 8), the description of which has seen the emergence of the term palletized transfer lines to describe these. The alternative method of workpart location is simply to index the parts themselves from station to station; this is described as a free transfer line, and is less expensive than the palletized transfer line as pallet fixtures do not have to be custom-designed for the work transport system. However, certain workpart geometries mandate the use of pallets and pallet fixtures, in which case a system of returning them to the front of the line must be devised.

KEYPOINT For transfer line layouts either palletized transfer lines (that use pallets and pallet fixtures) or free transfer lines (that use no special fixtures or workpart holders) may be favoured.

END KEYPOINT

System Configurations A number of system configurations for the automated production line exist; System configurations for the automated production line Configuration Description In-line Consists of a sequence of workstations in a straight-line arrangement. Common for machining big work pieces, such as automotive engine blocks, engine heads, and transmission cases. Can accommodate a large number of workstations, and buffer storage can also be planned for the configuration. Segmented in-line: L-shaped layout U-shaped layout Consists of two or more straight-line transfer sections, where the segments are usually perpendicular to each other. Layout designs include the L-shaped layout, the U-shaped layout, and the Rectangular layout. Reasons for favouring segmented in-line over in-line configurations include: floor space considerations; reorientation of workparts to present different surfaces for machining in different line segments; the swift return of workholding fixtures (in the rectangular arrangement). Rectangular layout Rotary Consists of a circular worktable around which workparts are fixed to workholders. The worktable rotates to move each workpart, in turn, into each automated workstation which is located around the circumference of the worktable. The worktable is often called a dial, and the equipment is referred to as a dial indexing machine, or simply, indexing machine. Commonly limited to smaller workparts and relatively few workstations, and they cannot readily accommodate buffer storage capacity. However they require less floor space, and are generally less expensive than other configurations.

KEYPOINT A number of system configurations for the automated production line exist; these include: in-line configurations; segmented in-line configurations (for example, Lshaped layouts, U-shaped layouts, and Rectangular layouts); and rotary configurations.

END KEYPOINT

Sometimes a mix of the above configurations may be favoured in particular cases. For example in Figure 13.2; here is illustrated two transfer lines that perform metal machining operations on a rear truck axle. The first line consists of a segmented in-line configuration, in the rectangular layout; the second line is in the conventional in-line configuration. There also exists a number of buffer storage locations within the configuration, particularly from one transfer line to the next. Figure 13.2: Two machining transfer lines

KEYPOINT A mix of the automated production line configurations may be favoured in certain manufacturing environments.

END KEYPOINT

Workpart Transfer Mechanisms The function of the workpart transfer system is to move parts between stations on the production line, a function performed by means of transfer mechanisms that are either synchronous or asynchronous. Synchronous transfer is the traditional method of moving parts within a production system, but asynchronous transfer has the following advantages: BULLETLIST Greater flexibility Fewer pallet fixtures needed Easy to rearrange or expand the production system ENDLIST These advantages must be offset by a higher first cost, and the fact that asynchronous transfer is hard to regulate accurately as moving parts pass between station workheads.

KEYPOINT Transfer mechanisms in the workpart transfer system may be synchronous or asynchronous.

END KEYPOINT

Here we examine two types of workpart transfer mechanism: linear transport systems for in-line systems (with synchronous and asynchronous transfer); and rotary indexing mechanisms for dial indexing machines (with synchronous transfer only). Linear Transfer Systems Types of linear transfer systems used for workpart transfer include powered roller conveyors, belt conveyors, chain driven conveyors, and cart-on-track conveyors previously described in unit 8. The typical installation of a conveyor system for workpart transfer is depicted . Work carriers attached to the conveyor ensure that workparts are transferred in a synchronous fashion from one workstation to the next, while the 'over-and-under' design of the conveyor belt ensures a continuous supply of empty carriers for reloading. The belt conveyor can also be used for asynchronous transfer of parts by using friction between the belt and the part to move parts between stations. Parts are stopped in their forward motion by means of pop-up pins, or other stopping mechanisms.: Side view of chain or belt conveyor deploying work carriers, used for linear workpart transfer Cart-on-track conveyors provide asynchronous movement of parts, and are designed to position their carts within about ±0.12mm, which is adequate for many processing operations. Other mechanisms for locating carts may also be used, such as pin-in-hole devices and detente devices. Linear transfer lines also come in the form of walking beam transfer systems, where parts are moved synchronously by means of a transfer beam that lifts parts from their respective stations and transfers them one position ahead. Parts are lowered into specially-designed 'nests' that position them for processing at the next station, then the transfer beam retracts to make ready for the next transfer cycle. This action sequence is illustrated in Figure 13.4. Figure 13.4: Operation of the walking beam system

KEYPOINT Linear transfer systems used for workpart transfer include powered roller conveyors, belt conveyors, chain driven conveyors, and cart-on-track conveyors, as well as the walking beam transfer system.

END KEYPOINT

Rotary Indexing Mechanisms Several mechanisms can be used to generate the type of rotary power required by rotary indexing machines. Two of these are the Geneva mechanism, and the cam drive. The Geneva mechanism (see Figure 13.5) uses a continuously rotating driver to index the table through a partial rotation. Figure 13.5: Six-slotted Geneva mechanism If the driven member has six slots for a six station dial indexing table, each turn of the driver results in a 1/6th rotation of the worktable, or 60o . The driver only causes motion of the table through a portion of its own rotation. The operation of the mechanism may be shown by reference to Figure 13.6, which shows the rotation of Geneva mechanism with four slots. Figure 13.6: The operation of a four-slot Geneva mechanism For a six-slotted Geneva, which we focus upon here, 120 o of driver rotation is used to index the table, with the remaining 240 o being dwell time for the table, during which the processing operation must be completed on the work unit. In general: s n 360 $\theta =$ where Θ is the angle of rotation of the worktable during indexing (degrees of rotation); and ns is the number of slots in the Geneva. The angle of driver rotation during indexing is 2 Θ, and the angle of driver rotation during the dwell time is given by: $360 - 2\theta$ The number of slots of the Geneva mechanism determines the number of workstation positions around the periphery of the rotary index machine. Geneva mechanisms with four, five, six, or eight slots are common. Given the rotational speed of the driver, we can determine total cycle time as: N Tc 1 $=$ where Tc is the cycle time; and N is the rotational speed of the driver. Of the total cycle time, the dwell time, or available service time per cycle, this is determined by: N Ts 360 180 $+\theta =$ where Ts is the available service or processing time or dwell time. The indexing time is determined by: N Tr 360 180 $-\theta =$ where Tr is the indexing (or repositioning) time.