UNIT 4 AUTOMATED STORAGE/RETRIEVAL SYSTEMS

Structure

4.1 INTRODUCTION

Imagine any plant/manufacturing sector without cluttered aisles, excess inventory, lost or damaged products, inaccurate records, endless searching, climbing, bending and frustration. Imagine a highly profitable operation that adds value and decreases expense.

AS/RS are means to high density hands free buffering of materials in distribution and manufacturing environments. AS/RS is a complete system designed to transport, stage/store, retrieve, and report on every item in any industrial inventory with up-to-the minute accuracy.

Objectives

After studying this unit, you should be able to understand the

- AS/RS in a computer-integrated manufacturing system, and
- design aspects of AS/RS.

4.2 FUNCTIONS OF STORAGE SYSTEM AND DEFINITION OF AS/RS

An automated storage/retrieval system (AS/RS) can be defined as a storage system under which a defined degree of automation is to be implemented to ensure precision accuracy and speed in performing storage and retrieval operations. These automated storage and mechanized systems eliminate human intervention in performing basic sets of operations that includes :

- Removal of an item from a storage location automatically
- Transferring the above item to a specific processing or interface point
- After receiving an item from a processing or interface point, it is automatically stored at a predetermined location.

A list of possible objectives that a company may want to achieve by installing an automated storage system is presented in Table 4.1.

Table 4.1 : Objectives for Installing an Automated Storage System in a Factory

Increasing the storage capacity
Increasing the stock rotation
Utilization of maximum floor space
Recovering the space for manufacturing facilities
Customer service to be improved
Control over inventories to be improved
Ensuring safety in storage function
Increasing the labour productivity in storage function
Reducing labour cost in storage operation
Reducing pilferage and improving security

Source : Based on list in reference [4]

4.3 AS/RS COMPONENTS AND TERMINOLOGY

An AS/RS consists of one or more storage aisles that are serviced by a storage/retrieval (S/R) machine. The stored materials are held by storage racks of aisles. The S/R machines are used to deliver and retrieve materials in and out of inventory. There are one or more input/output stations in each AS/RS aisle for delivering the material into the storage system or moving it out of the system. In AS/RS terminology, the input/output stations are called pickup-and-deposit (P&D) stations.

The components indicated in Figure 4.1 are briefly explained below.

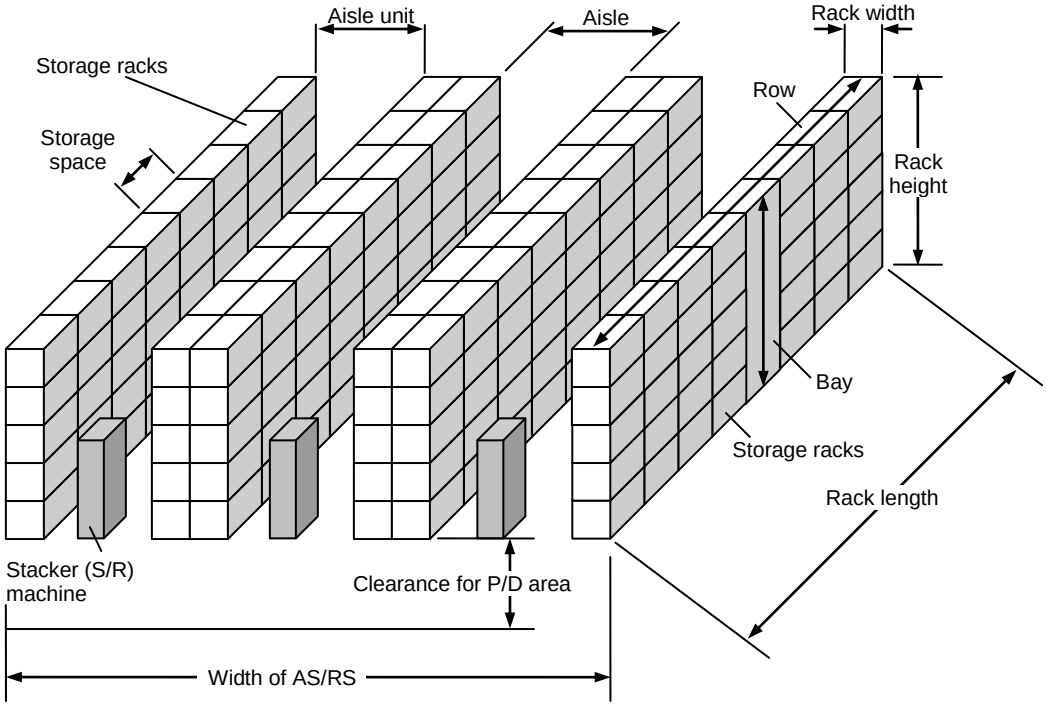

Figure 4.1 : Generic Structure of as AS/RS

Storage Space

It is the three-dimensional space in the storage racks used to store a single load unit of material.

Storage Racks

This structural entity comprises storage locations, bays and rows.

Bay

It is the height of the storage rack from floor to the ceiling.

Row

It is a series of bays placed side by side.

Aisle

It is the spacing between two rows for the machine operations of AS/RS.

Aisle Unit

It encompasses aisle space and racks adjacent to an aisle.

Storage Structure

It is the rack framework, made of fabricated steel that supports the loads contained in the AS/RS and is used to store inventory items.

Storage/Retrieval Machine

It is used to move items in and out of inventory. An S/R machine is capable of both horizontal and vertical movement. A rail system along the floor guides the machine and a parallel rail at the top of the storage structure is used to maintain its alignment.

Storage Modules

These are the unit load containers used to hold the inventory items. These include pallets, steel wire baskets and containers, pans and special drawers. These modules are generally made to a standard base size capable of being stored in the structure and moved by the S/R machines.

Pickup and Deposit (P/D) Stations

P/D stations are where inventory are transferred into and out of the AS/RS. They are generally located at the end of the aisles to facilitate easy access by the S/R machines from the external material-handling system. The location and number of P/D stations depends upon the origination point of incoming loads and the destination of output loads.

SAQ 1

(a) What are the basic operations of an automated storage/retrieval system (AS/RS)?

(b) Briefly explain about the components of AS/RS?

(c) What are the objectives for installing an automated storage system in a factory?

4.4 TYPES OF AS/RS

Several important categories of AS/RS can be distinguished based on certain features and applications. The following are the principle types :

Unit Load AS/RS

The unit load AS/RS is used to store and retrieve loads that are palletized or stored in standard-sized containers. The system is computer controlled. The S/R machines are automated and designed to handle the unit load containers. Usually, a mechanical clamp mechanism on the S/R machine handles the load. However, there are other mechanisms such as a vacuum or a magnet-based mechanism for handling sheet metal. The loads are generally over 500 lb per unit. The unit load system is the generic AS/RS.

Mini Load AS/RS

This system is designed to handle small loads such as individual parts, tools, and supplies that are contained in bins or drawers in the storage system. Such a system is applicable where the availability of space is limited. It also finds its use where the volume is too low for a full-scale unit load system and too high for a manual system. A mini load AS/RS is generally smaller than a unit load AS/RS and is often enclosed for security of items stored.

Deep-lane AS/RS

This is a high-density unit load storage system that is appropriate for storing large quantities of stock. The items are stored in multi deep storage with up to 10 items in a single rack, one load behind the next. Each rack is designed for flow-through, with input and output on the opposite side. Machine is used on the entry side of the rack for input load and loads are retrieved from other side by an S/R- type machine. The S/R machines are similar to unit load S/R machine except that it has specialized functions such as controlling rack-entry vehicles.

Man-on-board AS/RS

This system allows storage of items in less than unit load quantities. Human operator rides on the carriage of the S/R machine to pick up individual items from a bin or drawer. The system permits individual items to be picked directly at their storage locations. This provides an opportunity to increase system throughput. The operator can select the items and place them in a module. It is then carried by the S/R machine to the end of the aisle or to a conveyor to reach its destination.

Automated Item Retrieval System

This system is designed for retrieval of individual items or small product cartoons. The items are stored in lanes rather than bins or drawers. When an item is retrieved from the front by use of a rear-mounted pusher bar, it is delivered to the pickup station by pushing it from its lane and dropping onto a conveyor. The supply of items in each lane is periodically replenished and thus permitting first-in/first-out inventory rotation. After moving itself to the correct lane, the picking head activates the pusher mechanism to release the required number of units from storage.

SAQ 2

What are the various types of AS/RS? Briefly explain their features and applications.

4.5 DESIGN OF AN AS/RS

Several aspect of the design and operation of a storage system are discussed in the user and supplier related decisions. In this section, we examine several important factors related to layout and design of AS/RS

4.5.1 Load Sizes Determination

Load size determination is the most important element in the design of an AS/RS and is based on work flow information. The movement frequency of parts, tools, fixtures, pallets, and other supplies define the overall work flow. Work flow is determined by variety and volume of part types and the type of production system. The width, length and height of rack structure of the AS/RS aisle are related to the unit load dimensions. The dimensions of the unit loads with proper clearances provide the individual storage space dimensions and account for the size of supporting beams in the rack structure. Storing unique items of unusual and complex shape are excluded from the AS/RS design. Weight of the unit load is also considered in the structural design.

4.5.2 Calculating Individual Storage Space Dimensions

Let *l*, *b* and *h* be the length, width and height of the unit load. The length (L), width (W) and height (H) of the rack structure of the AS/RS aisle are related to the unit load dimensions and number of compartments as follows :

$$L = n_y (l + x)$$

$$W = u (b + y)$$

$$H = n_z (h + z)$$

where n_y and n_z are respectively number of load compartments along the length and height of the aisle; *x*, *y*, and *z* are allowances designed into each storage compartment to provide clearance for the unit load; *u* is storage depth in number of unit loads. All the dimensions of rack structure are in 'mm'.

The total storage capacity of one storage aisle is expressed as follows :

Capacity per aisle = $2 \times n_y \times n_z$

Constant '2' is multiplied because loads are contained on both sides of the aisle.

Example 4.1

In each aisle of an AS/RS, there are 70 storage compartments in the length direction and 10 storage compartments vertically. The dimensions of the unit load in inches (in) are 50 (length), 45 (width) and 50 (height) respectively. The allowances designed for each storage compartment are : x = 8 inch, y = 7 inch and z = 10 inch. Storage depth u in the number of unit load is 3. Determine the capacity per aisle and the dimensions of the single storage system.

Solution

(a) Capacity per aisle $= 2 \times n_y \times n_z$

$= 2 \times 70 \times 10$

$= 1400$ unit loads

(b) $L = n_y (l + x) = 70 (50 + 8) = 4060$ in

$W = u (b + y) = 3 (45 + 7) = 156$ in

$H = n_z (h + z) = 10 (50 + 10) = 5000$ in

4.5.3 Estimating Storage Spaces Number

Dedicated and randomised storage policies are used to determine the number of storage spaces in AS/RS. In dedicated storage policy, a particular set of storage slots is allocated to a specific product. Hence the sum of the maximum inventory levels for the entire products match with the number of slots required to store the product. In case of randomised storage policy, any compartment in the storage aisle is equally probable to be selected for transaction. Likewise, there is equal chance of each unit of particular product to be retrieved when a retrieval operation is performed. Thus, in a long run, maximum of the aggregate inventory level of all the products is taken into account for determining the storage space number.

4.5.4 Estimation of AS/RS Throughput and the Number of S/R Machines

System throughput is defined as hourly rate of S/R transactions (number of loads stored and number of loads retrieved) that an automated storage system can perform. A dual command cycle is used to increase the throughput, since it reduces travel time per transaction. Following are the factors that influence system throughput :

- Velocity of S/R machine
- Single and dual command cycles
- System utilization per hour
- Arrangement of stored items
- Speed of AS/RS control system
- Speed and efficiency of the material handling equipments

The number of S/R machines can be determined as follows :

$$\text{Number of S/R machines} = \frac{\text{System Throughput}}{\text{S/R machine capacity in cycles per hour}}$$

4.5.5 Estimating the Size Parameters of the Storage and Retrieval System

System length, width and height are vital to estimate the size of AS/RS. For this purpose, it is required to determine following parameters:

(i) **Number of Rows and the Number of Bays in Each Row of a System**

Number of S/R machines used to store and retrieve materials depends primarily on the system throughput and the cycle time. S/R machines are used for one or more aisles. Each aisle has two rows. Therefore, the number of rows in case of one S/R machine per aisle is :

Number of rows in the system = 2 × Number of S/R machines in the system.

$$\text{Number of Bays} = \frac{\text{Number of storage space required}}{\text{Number of rows per S/R machine} \times \text{Number of S/R machines} \times \text{Number of storage spaces per system height}}$$

$$\text{Number of storage spaces per system height} = \frac{\text{System height desired}}{\text{Storage space height}}$$

The variation in the desired system height is in between 30 to 90 ft.

(ii) **Estimation of Bay Width, System Width, Rack Length, System Length, Bay Depth and Aisle Unit**

The length of a single storage space is added to the centre-to-centre rack support width to calculate bay width. Thus we get,

Bay width = Length of storage space + Centre-to-centre rack support width

$= l + x + x_1$

where x_1 is the centre-to-centre rack support width

Rack length = bay width × number of bays

System length = rack length + clearance for (*S/R machine run-out + P/D area*)

Bay depth = width of the individual storage space + bay side support allowance

$= u\,(b + z) + x_2$

where x_2 is the bay side support allowance.

$$\boxed{\textit{Aisle unit} = \textit{Aisle width} + (2 \times \textit{Bay depth})}$$

$$\boxed{\textit{System width} = \textit{Aisle unit} \times \textit{Desired number of aisle}}$$

SAQ 3

(a) What are the various factors that influence system throughput?

(b) Differentiate between dedicated storage policy and randomized storage policy.

Example 4.2

The single command cycle system of a XYZ Inc. has cycle time per operation as 2 minutes. Expected system throughput for the corporation is 360 operations per hour. Number of storage space per system height is 15 and total number of storage spaces using a randomized policy is 9000. Assuming storage and retrieval operation take same time, determine :

(i) Number of S/R machines;

(ii) Number of rows; and

(iii) Number of bays in each rows.

Solution

(i) Number of S/R machines $= \dfrac{\text{System Throughput}}{\text{S/R machine capacity in cycles per hour}}$

$$= \frac{360}{2 \times 60 \text{ cycles/h}} = 3$$

(ii) Number of rows in the system = 2 × Number of S/R machines in the system

$= 2 \times 3 = 6$

(iii)

$$\text{Number of Bays} = \frac{\text{Number of storage space required}}{\text{Number of rows per S/R machine} \times \text{Number of S/R machines} \times \text{Number of storage spaces per system height}}$$

$$= \frac{9000}{2 \times 3 \times 15} = 100$$

4.5.6 Determination of Single- and Dual-command Cycle Times for Unit Load AS/RS

Single-command Cycle

It performs either storage or a retrieval operation. There are certain steps that are followed in storage or retrieval cycle to determine the cycle time. In case of storage cycle, machine picks up a load, travels to the storage location, deposits the load, and returns empty to the P/D station. Similarly, in a retrieval cycle, the S/R machine begins at the P/D station and travels empty to the retrieval location. Thereafter, it picks up the load, travels to the P/D station, and deposits the load.

Dual-command Cycle

Cycle time is determined in case of dual-command cycle when it starts its operation with the S/R machine at the P/D station. The machine picks up the load and travel to the storage location to put down the load. Thereafter, the machine travels to the retrieval location to recover the load. Finally, it travels back to the P/D station to deposit the load.

Bozer and White (1984) derived an expression for cycle time based on following assumptions :

- Randomised storage of loads in the AS/RS
- Horizontal and vertical velocities of the S/R machines are constant
- Rack openings are of single-size
- P/D station is located at the base and at the end of the aisle
- Simultaneous horizontal and vertical travel of S/R machine

The storage space dimensions help to determine the length (L_1) and height (H_1) of an AS/RS aisle and it is given as follows :

$$L_1 = n\,(l + x)$$

$$H_1 = m\,(h + z)$$

where n and m are the number of bays and storage spaces per system height.

Time required travelling full horizontal length and vertical height of an aisle is given by

$$T_h = \frac{L_1}{V_h} \quad \text{and} \quad T_v = \frac{H_1}{V_v}$$

where V_h and V_v are the average horizontal and vertical speeds of S/R machines.

For single-command cycle, cycle time is given as :

$$T_{sc} = T\left(\frac{M^2}{3} + 1\right) + 2T_{pd}$$

For dual-command cycle, cycle time is :

$$T_{dc} = \frac{T}{30}\,(40 + 15M^2 - M^3) + 4T_{pd}$$

where T_{sc} = single-command cycle time,

T_{dc} = dual-command cycle time,

$T = \max (T_h, T_v)$,

$M = \min (T_h / T, T_v / T)$,

T_{pd} = time to perform either a pick up or deposit,

T_h = time taken to traverse full horizontal aisle distance, and

T_v = time taken to traverse full vertical aisle distance.

4.5.7 Estimating the Utilization of S/R Machines

The performance evaluation of an automated storage and retrieval system is based on the percentage utilization of S/R machines.

Suppose there are *N* number of S/R machines in the system and each aisle is served by one S/R machine. Then the number of transaction per S/R machine per hour is

$$N_t = \frac{ST}{N}$$

where *ST* is the system throughput for an AS/RS.

System throughput depends on the relative numbers of single and dual command cycles performed by the system. Let α be the number of single command cycles performed per hour, and β be the number of dual command cycles per hour, at a specified or assumed utilization level.

Then an equation can be formulated for the amount of time spent in performing single command and dual command cycles each hour and is given as :

$$\alpha T_{sc} + \beta T_{dc}$$

SAQ 4

Differentiate between Single- and Dual-command Cycle Times for unit load AS/RS.

4.6 SUMMARY

In this unit, we have dealt with the automated storage and retrieval system used in industries to handle, store and retrieve materials with precision, accuracy and speed under defined degree of automation. The objective of installing an Automated Storage System in a factory or warehouse is to increase storage capacity, floor space utilization, labour productivity in storage operations, stock rotations etc. An AS/R system are custom-planned for each individual application, and they range in complexity from relatively small mechanized systems that are controlled manually to very large computer-controlled systems that are fully integrated with factory and warehouse operations. In this unit, we have attempted to cover some basic aspects related to Automated Storage and Retrieval System.

4.7 KEY WORDS

AS/RS : An Automated Storage and Retrieval System consists of one or more storage aisles that are serviced by a storage/retrieval (S/R).

S/R Machines : It is used to move items in and out of inventory. An S/R machine is capable of both horizontal and vertical movement.

P/D Stations : P/D stations are where inventory are transferred into and out of the AS/RS.

4.8 ANSWERS TO SAQS

Refer the preceding text for all the Answers to SAQs.

FURTHER READINGS

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