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A Study of Material Handling Equipment Selection Process in industry

Mr. Ganesh Baburao Kadam[1], Mr. Girish Bandu Dhadge[2], Mr. Jatin A. Thale[3], Mr. Tushar Dattatray Bhopi[4], Mr. Sharadchandra V Kantute[5]
Students, Department of Mechanical Engineeering[1,2,3,4]
Lecturer, Department of Mechanical Engineeering[5]
Bharati Vidyapeeth Institute of Technology, Navi Mumbai, Maharashtra, India
ganeshkadam3011@gmail.com[1], girish12890@gmail.com[2], jatinthale0051@gmail.com[3], tusharbhopi007@gmail.com[4]

I. INTRODUCTION

This document provides an overview of different material handling equipment. It is intended to familiarize readers with the various material handling technologies and provide some general guidelines for selecting a particular technology for a particular application. Thus, its role is primarily informational or educational and not as a mechanism for detailed design of a specific system for a particular application.

II. GENERAL CONSIDERATIONS

When deciding what material handling equipment to use, it is important to take into account the general characteristics of the equipment types available in the market. Then, the decision maker should determine which equipment matches better to the required application. In this sense, Dunning [84] provided the following general guide for some big equipment categories that can be helpful in this decision. Static Storage Systems

Static storage systems include storage racks, block stacking systems, mezzanines and shelf and drawer storage. The common feature of static storage systems is that loads remain stationary or "static" in their storage locations until removed from the system. Static storage systems are more likely to be associated with low turnover inventories where manual storage and retrieval is a cost effective mode of operation. In this section, only selection guidelines for storage racks, mezzanines, shelf and drawer storage are discussed since block stacking does not require mechanical structures. Block stacking generally deals with lane storage of pallets or other unit loads stacked directly on top of each other in high volume, low turnover applications. Generally, block stacking provides a low cost, high density storage alternative when loads are stackable and not susceptible to crushing. In some cases, pallet stacking frames can be used for block stacking of unstable or fragile loads. Pallet stacking frames are discussed in more detail in a later section.

III. INDUSTRIAL STEEL STORAGE RACKS

Several characteristics influence the type of unit load storage rack appropriate in a given application. These include unit load specifications, selectivity requirements, throughput requirements, the material handling equipment used, and the building configuration. Unit load specifications refer to the load dimensions, the weight, and the type, condition and volume of pallets stored. Selectivity requirements refer to the number of stock picking locations that must be immediately available. This factor directly influences the depth of storage lanes as well as the picking speed. Throughput requirements refer to the number of storage positions maintained, the time frame of load movement through the system, inventory control policies and load dispatching rules. Material handling equipment directly influences the type of rack selected since factors such as turning radius, aisle width, lifting capacities, and reach capabilities determine the ability of handling equipment to interface with a given rack system. Building configuration refers to ceiling height, floor condition, structural features and other facility characteristics that influence the selection of a rack system. Pallet rack design alternatives include standard selective pallet rack, double deep rack, bridge across rack, drive in and drive through racks, gravity flow racks, push back racks, and cantilever racks. Standard selective pallet rack is the most common alternative which allows 100% selectivity for high picking efficiency. Double deep racks are similar to standard selective pallet

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IV. Shelving and Drawer Storage

The major factors driving the design of a shelving and drawer storage system include the types of products stored, the type of storage equipment used, the material handling system involved, the characteristics of the facility and the applicable government regulations and building codes. The design process involves analysis of the dimensions and weigh to stored items and the determination of how each item is to be stocked, e.g., individual items, packages, cartons, pallets, rolls, drums, etc. Inventory levels, the form of material issues, transactions throughput, and the number of stock keeping units must then be determined. This is followed by creation of a drawing of the front elevation of the storage units and notation of the specific items to be stored in each. Typically, this involves the development of several alternative storage layouts. Consideration of seismic requirements and government regulations may also influence the design of a shelf and drawer storage unit.

In this section, in-plant industrial trucks and dock equipment are discussed. This category includes electric rider trucks, electric narrow aisle trucks, electric hand pallet trucks, cushion tire internal combustion trucks, and pneumatic tire internal combustion trucks. These trucks are used for moving either mixed or uniform loads intermittently over various paths. While these paths can be somewhat random at the discretion of the driver, the paths are restricted to suitable indoor or outdoor surfaces. Industrial trucks provide not only a means of transporting materials, but also provide a means of accurate lifting and stacking. Appropriate tooling for the truck permits users to lift not only pallets, but a wide array of specialized loads. For example, rolls of carpet are easily moved via industrial truck by replacing standard forks with a single tube. The dock equipment discussed in this section includes dock levelers and truck restraining devices. Both of these equipment types support the use of industrial trucks for loading/unloading.

V. Powered Trucks

Industrial electric motor trucks can be found in almost any manufacturing plant, loading dock, or warehouse. Although they are made by a variety of manufacturers for diverse purposes, including some highly specialized applications, they can be classified into five general groups using Industrial Truck Association guidelines: electric rider trucks, electric narrow aisle trucks, electric hand pallet trucks, cushion tire internal combustion trucks, and pneumatic tire internal combustion trucks. Electric rider trucks are general purpose trucks and are used primarily indoors. These trucks can lift up to 6 tons andup to 18 feet in height. Electric narrow aisle trucks are used in narrow aisle applications. These trucks are used primarily for storage/retrieval in applications similar to AS/RS functions. They can easily lift loads from 2,000 to 4,500 pounds to heights of 40 feet. Narrow aisle trucks can be further subdivided into standard trucks, high lift straddle trucks, side loaders, swing mast trucks, and convertible turret/stock pickers. The names of these devices are indicative of their function. Electric hand pallet trucks are generally used for indoor applications and can handle loads up to 4 tons. These trucks are perfect for situations in which material is to be moved from one location to another without the need for lifting more than a few inches. For example, this type of truck is commonly used in grocery stores to move pallet loads of cans or boxes to a display location within the store. An added convenience is that the operator can move among customers in the store safely and without obstructed views. Internal combustion trucks add the advantage of outdoor use. They can lift 2,000 to 15,000 pounds with some specialty trucks lifting up to 50 tons. They can lift up to 20 feet in height and can operate on gasoline, LP-gas, or diesel fuel.

5.1 Non-Powered Trucks

In this section, non-powered hand trucks and non-powered pallet trucks are discussed. These trucks provide low cost material handling alternatives for some applications. They are best suited for moving lightweight loads over relatively short distances.

5.2 Non-Powered Hand Trucks

Non-powered hand trucks are used in many situations. They are inexpensively manufactured for diverse and specific applications. Common construction materials include aluminum/magnesium, steel, and wood. Because these trucks are so inexpensive, it makes sense to design them for specific material handling functions. In this way, it is possible to increase the cube utilization within the truck for material handling optimization. Aluminum or magnesium trucks generally carry 300-500 pounds of material, while steel or wooden trucks can be used to carry approximately 1000 pounds to 2000 pounds,

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respectively. The trucks range in weight from as little as 20 pounds for aluminum trucks to as much as 125 pounds for wooden trucks.

5.3 Non-Powered Hand Pallet Trucks

These trucks are designed to carry unit loads on pallets from one location to another, generally in indoor settings. Because unit loads can be quite heavy, the distances transported using this type of equipment is generally short. In many settings, hand pallet trucks are used to supplement motorized truck fleets. They are extremely efficient for transporting unit loads short distances when high lifting is not required. They can be used to position materials very precisely. Generally speaking, non-powered hand trucks cannot be used to lift more than 8,000-10,000 pounds and cannot lift a unit load to a height more than 8 inches. For heavy duty applications, steel wheels are required while lighter duty applications require only nylon or polyurethane construction. These trucks can range in weight from 200 to 400 pounds.

5.4 Dock Equipment

In this section, dock leveling equipment and truck restraining devices are discussed. Both are necessary components to ensure safe and efficient use of industrial trucks.

5.5 Dock Levelers

In this section, devices that equalize the height of the rear of a trailer to the dock's height are discussed. Powered applications make use of electric or LP-gas motors and can have a load capacity from 2,000 to 30,000 pounds. Non-powered dock levelers can be used when the difference between dock and trailer height is less severe. If the difference between the dock and the trailer is less than approximately four inches, non-powered dock levelers can be used with a wide variety of industrial truck types, including hand pallet jacks. Even so, the length of the leveler would likely need to be approximately 12 feet in length to produce an acceptable grade for hand trucks. Using gas or electric lift trucks, a leveler of less than 3 feet would be acceptable. Electric pallet jacks are feasible for height differentials up to 10 inches, electric lift trucks are feasible for height differentials up to 12 inches, and gas lift trucks are feasible for differentials up to 18 inches, provided that the leveler is of sufficient length, say 12 feet.

Height differentials are not the only factors to be considered when selecting a leveler. Other less obvious considerations include truck tailgate differences, the degree of loading/unloading activity, the speed of operation required, and various personnel factors. Also of interest are environmental factors such as heat & cold retention and the corrosiveness of the applications. Certainly, designers should also decide about the level of desirable investment given the status of the building in terms of leasing versus owning the property.

5.6 Truck Restraining Devices

Truck restraining devices include wheel chocks, trailer constraints, and automatic chock devices. Their function is to prevent the trailer from moving during loading or unloading, or to prevent the truck from leaving the dock until authorized to do so from a safety viewpoint. Wheel chocks are very inexpensive and very effective and they are OSHA approved safety devices. They are used in applications from warehousing to airports. In fact, wheel chocking is one of the first activities performed when an airplane arrives at a terminal building. Even for huge aircraft, chocking is a cost effective way to achieve passenger safety. Chocks are generally made of laminated or molded rubber or wood and are wedged under tires. Although cost effective, chocks can have some disadvantages. For example, they are easily forgotten or lost, they require labor for correct placement, they reduce productivity of dock attendants by adding an extra step to vehicle arrivals and departures, and they can be ineffective in bad weather or on some surfaces.

Trailer restraints are permanent fixtures holding the trailer at the dock using the ICC (Interstate Commerce Commission) bar. Designs range from manual and low cost to automatic and high cost. Automatic chock devices perform the same function as trailer restraints, but do not rely on the trailer's ICC bar to secure the trailer to the dock. These devices are stored in the driveway and raise to hold the wheels in place. Both are extremely effective in terms of ensuring that the vehicle remains in place until unsecured. Factors to consider when selecting any restraining device include the following. They should have clearly visible hooking devices. They should provide constant engagement. They should support clear communications and should be durable. Components should be designed for their environment in terms of rust and corrosion

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and should be sealed against dirt. Furthermore, they should be easy to maintain and should allow for integration opportunities with other systems such as alarm systems or production/shipment supervisory programs.

5.7 Fixed Path Conveying

Fixed path conveyances are advantageous for periodic and continuous transport of material between locations in warehouses and factories. They are also used to accumulate goods, store packages, change elevations, and provide a continuous work surface on which progressive assembly or processing can be performed [25]. Consider the factors below when developing conveying systems:

5.8 Gravity Conveyors

These conveyors are the simplest and usually least expensive. They are useful where material is moved for short distances and movement requirements are simple. Three common types are chutes, skate wheels, and rollers. They are often used in conjunction with powered systems.

5.9 Horizontal Powered Conveyors

These are used to move material over moderate to long distances.

Live Roller

This type of conveyor is used for a variety of applications, loads, and environments [34]; but they are typically used for 30-50 lb.ft loads in warehouses. They can provide brief periods of product accumulation or dwell points [27]. Live rollers can handle up to 10,000 lbs and can carry irregular shaped containers. Live rollers are classified by their drive method, listed below. Some disadvantages are:

1. Higher cost due to construction materials.
2. Product slippage on rollers requires frequent tracking updates and diverter timing.
3. Products cannot negotiate inclines over 7 degrees without manual assistance.
4. Power surges when accumulating on driving rollers; disrupting product spacing.

Live Roller Accumulation Conveyors

These conveyors are used to regulate the flow of products into downstream operations by providing a temporary buffer for excess products. Selection criteria depends on specific applications. Proper product alignment is required when using accumulation conveyors. Various releases are available, depending on conveyor speed. Three types of powered accumulation conveyors are [29]:

1. Zero-pressure. The line pressure (horizontal pressure between products) is eliminated.
2. Non-contact. Products are always separated from each other.
3. Minimum pressure. Some line pressure is allowed (2 to 3% of total net load).

Slider Bed/Roller Bed Conveyors

The slider bed consists of a moving belt operated across a steel support bed. The roller bed is a belt supported by rollers. The slider bed is the least expensive powered conveyor, but handles less loading than the roller bed. Roller beds require more power than live rollers. Belt conveyors offer stable support, are used for heavy loads, and can be operated at high speeds. The belt conveyors maintain product spacing to allow excellent material tracking. These conveyors are also used for inclines and declines of up to 30 degrees (and can be combined in a single conveyor). Belt conveyors are not used to accumulate. products, but they can start and stop and they can be used to meter products at the exit of an accumulator conveyor.

Roller Curves and Belt Turn Conveyors

Curves and turns are used to change the direction of material flow. Roller curves are less expensive than belt curves and they are the most common. They can be self powered or slave driven. Belt curves are used to maintain product orientation and spacing. The flat surface also allows handling of smaller, irregular sized products.

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Powered Overhead Conveyors

Powered overhead conveyors are used when system flexibility is desired or floor space is congested [24] because material flow paths are easily established and altered and obstructions are minimized, enhancing freedom of movement. Additionally, drives and other equipment are offered some protection from the environment on the floor. Below are selection guidelines from the literature for powered overhead conveyors [24]:

Vertical Conveyors

Vertical conveyors are used to lift or lower heavy loads between various levels in intermittent-flow operations and where horizontal space is limited. Of the two vertical types, the reciprocating is simpler, but the continuous supports a higher flow rate.

Variable Path Conveying

This group of material handling devices is used to transport material over a variety of routes through a facility. Typically, a system consists of a number of discrete carriers which are capable of independent movement. Two main types of systems will be considered: automated guided vehicles and monorails. A third type of delivery mechanism, pneumatic tube system, will be described for specialized applications, such as moving bulk solids.

VI. AUTOMATIC GUIDED VEHICLES (AGV)

Automatic guided vehicle is a vehicle equipped with automatic guidance equipment that is capable of following prescribed guide paths, either physical or residing in software, to transport material between various points in a system. Some advantages of these systems include[3]:

1. Most AGVs load and unload automatically.
2. They can transport materials of many different sizes and shapes.
3. They efficiently interface with other equipment, thereby, providing physical integration.
4. They are well suited to operate under computer control, allowing the control system to know the location of all materials at all times.

There are several different ways to classify vehicles. The following two tables show a summary of the different types of vehicles and the different options for the main vehicle characteristic

6.1 Monorails

Monorails are self-powered vehicles riding on an overhead track. These systems provide flexible transport of material without using valuable floor space. They are being used increasingly in the automation of fabrication, finishing, and assembly operations; but usually these systems are used in batch operations[Some advantages associated with this type of equipment are

1. They are capable of higher speeds than other transportation options (up to 500 fpm on straight runs). Therefore, they can be used to make deliveries on demand.
2. High speed and low cost tracks compared to overhead conveyors.
3. Queuing capability.
4. Could have bi-directional carriers.
5. Easy interfacing with other equipment.
6. They provide quiet running and clean carriers that are individually powered and controlled.
7. They also provide greater flexibility for expansion and layout changes.

6.2 Dynamic Storage Systems

High-Density Dynamic Storage Systems

These systems provide high-density storage for a variety of product types. They are often referred to as flow delivery systems or flow racks because of the way products are stored and retrieved from the systems. These systems can be broadly classified into three different types.

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High-Rise, Served by a Guide Truck

Stacking heights to 40 feet. Narrow aisle, high-lift, or turret truck can be used under rail or wire guidance. Somewhat tighter tolerances that on conventional selective pallet racks.

Storage/Retrieval (S/R) Machine

High degree of inventory control in large-volume, high-throughput applications. Operations frequently automated under computer control. Exacting tolerances on racks and floors. Storage heights can reach 75 feet or more.

High Density

Loads confined to specific lanes under automated control. Traveling carrier or retrieval mechanism removes loads on first-in, first-out basis. High-rise configurations can be used.

Horizontal and Vertical Carousels

Horizontal and vertical carousels are usually incorporated into automated material handling operations [76]. These systems have movable racks or shelves that hold parts. The entire set of racks/shelves is rotated to bring the needed item to a pick position for retrieval (or a empty slot to the pick position for storage). Picking and placing is done manually or automatically. The manual weight limit is 35 to 40 lb. Typically, automatic extraction weight limit ranges from light loads to about 100 lb. The storage systems can be used for many applications, including maintenance parts, tooling, dies, WIP, buffer storage, warehousing, and distribution. The advantages associated in the use of carousels are

1. They are low cost, stand-alone, and modular storage systems.
2. Both versions are available in a wide assortment of heights, lengths, and capacities.
3. Automated or manual extraction methods are available for adding or removing stored products.

VII. AUTOMATED STORAGE AND RETRIEVAL SYSTEM (AS/RS)

AS/RS are commonly applied in two types of operations: warehousing or distribution and plant automation. These systems are typically high-rise systems capable of storing pallets, totes, drums, or other similar types of unit loads. The systems may be single aisle or large, multi-aisle systems. The storage/retrieval machine is automated and capable of moving at high speeds within the captive aisle. Occasionally, multiple aisles will be equipped with a transfer mechanism so that one S/R machine can serve multiple aisles. These systems provide good inventory control as well as protection from damage and pilferege. These systems are typically used in conjunction with other automated material handling devices, such as automated guided vehicles. Some of the system advantages typically cited for AS/R systems are:

1. The equipment enables reduced inventory levels through tightened control measures
2. Space requirements are reduced with high-rise, high-density storage techniques
3. Their ability to operate almost unattended If the load or products can be identified automatically by their size or shape or by a code that can be read automatically, then the storage system can operate unattended.
4. Capability to interface automatically with a number of different types of conveyors andother transportation equipment

Lifting, Leveling, and Work Positioning Systems

In this section, lifting, leveling and work positioning systems are discussed. This category of equipment includes stationary systems, overhead mobile cranes, gantry cranes, stacker cranes, hoists, and balancers. The focus of this section will be primarily on cranes and hoists because they are the most widely used equipment for lifting, leveling, and work positioning. Stationary systems include fixed devices such as the jib crane which is a fixed crane with a cantilevered bridge supported from a stationary vertical support. Overhead mobile cranes are traveling cranes with a movable bridge running on the top surface of rails of an overhead fixed runway structure. They carry a movable or fixed hoisting mechanism.

Gantry cranes are traveling cranes similar to the overhead mobile crane, except that the bridge carrying the hoisting mechanism is rigidly supported on two or more legs running on fixed rails or other runways. A stacker crane is a crane adapted to piling or stacking bulk materials. It could include a fixed or pivotally mounted boom. A hoist can be defined broadly as any mechanism for lifting or lowering loads.

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Cranes

In this section, five different types of cranes are discussed: single girder bridge cranes, double girder bridge cranes, single girder gantry cranes, jib cranes, and overhead stacker cranes. The discussion includes characteristics of these crane types in terms of maximum span, maximum lifting capacity, maximum height, maximum bridge, trolley and hoist speeds, and the type of use for which they are suitable.

Electric Hoists

Industrial hoists are widely used for lifting. They are generally inexpensive and reliable. They increase the safety associated with lifting and enable the movement of much larger unit loads than would be possible with many other economical lifting options. An electric hoist can be defined as a suspended machinery unit using wire rope or chain for vertical lifting or lowering of freely suspended unguided loads. Because the primary reason cited for hoist failure is the failure to consider the duty environment of the hoist, it is useful to consider duty factors in the hoist selection process.

pallets, industrial metal and plastic containers, palletizers and load stabilizing systems.

Pallets

Pallets are probably the most common platform for moving unit loads. Perhaps the most obvious area of concern associated with the use of pallets today involves cost and quality tradeoffs. Poor quality pallets annually cost industry billions of dollars in the form of product damage, lost productivity, and damaged handling. A key decision affecting the overall life cycle cost of pallets is the materials used in their manufacture which can include wood, pressed wood fiber, corrugated fiberboard, plastic or metal. More wooden pallets are sold each year than any other type due to the versatility, low cost, biodegradability and recyclability of this material. Pressed wood fiber is a combination of wood fibers and organic resins which eliminates the need for nails and enables the molding of pallets into more space efficient designs. Disposable, corrugated fiberboard pallets can be made of recycled paper materials and provide a light weight, low cost alternative for one way shipping when loads do not need to be stored outdoors. Durable plastic and metal pallets may provide the low cost alternative over the full pallet life cycle despite their high initial cost. Both of these materials are recyclable, can be sanitized for clean applications, and can be used in the most demanding applications. The table in this section summarizes some of the tradeoffs associated with different materials used for the manufacture of pallets and the typical applications associated with each.

Industrial Metal Containers and Plastic Containers

Selecting a container is an integral part of the design and planning of any parts handling and storage system. The key attribute of importance to system designers is the degree of protection afforded from environmental hazards such as rough handling, moisture, temperature variation and other influences. Additional important features include accessibility for manual or automated part retrieval, stack ability/nestability, and the difficulty associated with handling the container itself. These factors drive the design of the container with common variations which include pans, hopper front storage bins, modular containers, tote boxes, wire containers, corrugated metal containers, wood boxes and wirebound boxes. Pans provide shallow, open storage space that is ideal for odd shaped, durable parts which can be transferred through simple dumping. Hopper front storage bins are ideal for organizing and storing small to medium sized parts where easy access is important. Modular containers, particularly useful for sorting and organizing small parts, are typically used in conjunction with standard racks or shelving. Tote boxes provide an efficient container alternative when strength for heavier loads and stackability are important. Wire and corrugated metal containers provide stackability and selectivity in unit loads that are usually compatible with standard handling equipment and pallet racks. Collapsible wire containers provide the additional advantage of efficiency in storage and shipping when empty. Application notes and design factors applicable to these types of containers are summarized in the first table in this section. The selection of the material to use in making containers is also an important consideration. Possibilities include plastic, metal, wood, corrugated, fiberboard and various combinations of these materials. The costs and benefits of these various materials for the manufacture of containers are summarized in the second table included in this section.

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Palletizers

Palletizing involves the consolidation of individual products into unit loads. It usually takes the form of stacking layers of cartons, cases or bags onto pallets in a predetermined pattern. Factors to consider in selecting a palletizing system include product characteristics, pallet specifications, location information, upstream sources of products being palletized and throughput requirements. Examples of product characteristics include the physical envelope, weight, special features and handling requirements of the product. Examples of pallet specifications include the design of the pallet and the mix of pallet sizes and quality levels included in the application. Location information refers to the available floor space, headroom, and proximity to other operations. There are three major types of palletizers which include vacuum head, row stripping and robotic palletizers. Vacuum head palletizers use pneumatically powered suction cups to grip layers of products and place them on pallets. Row stripping palletizers first form a row of products. After this, a pusher transfers the row to the machine's makeup area in order to fill another row of a layer of products. When the layer is complete, the machine deposits it onto a pallet or another layer. Robotic palletizers can use a cartesian, articulated arm or gantry design. Cartesian palletizers feature a mast and a cross arm which maneuver products through four axis movement.

Articulated arm models also offer four axis movement but use an arm with waist, shoulder, elbow and wrist joints instead of a cartesian table. Gantry palletizers mate a robotic arm to a gantry. The table in this section compares the key application attributes of the three major types of palletizers.