Advanced Logistic Systems – Theory and Practice, Vol. 18, No. 1 (2024), pp. 75-90.
https://doi.org/10.32971/als.2024.008

MOBILE HANDLING UNITS IN ADVANCED MATERIAL HANDLING SYSTEMS

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Abstract: *To fulfil the increasing requirements of the social and economic environments, the equipment used in material handling processes have to be developed. The machines fitted exactly to certain manufacturing procedures some decades ago, cannot be found in the advanced version, they role are acted by other, earlier rarely used computer-controlled devices. The traditional method for the material handling is the using of mobile handling units, where the goods are moving on the machines, so the characteristics of the transportation are based on the parameters of the handling equipment. Suited to the new requirements, the structure and operation of the mobile handling units are changing but their application have similar conditions. There are many handling machines belonging to this category, this paper gives an overview about their most popular variations and their usability in advanced material handling systems.*

Key words: *advanced material handling machines, handling units, individual transport*

1. INTRODUCTION

Nowadays, the industrial systems are continuously developing, suited to the increasing requirements of the social and economic environments. Thanks for this factor, technical solutions and devices applied in production and service processes are also changing and evolving. This is also true for the equipment used in material handling processes.

The traditional method for the material handling is the using of mobile handling units, where the goods are moving on the machines, so the characteristics of the transportation are based on the parameters of the handling equipment. Suited to the new requirements, the structure and operation of the mobile handling units are changing but their application have similar conditions.

There are many handling machines belonging to this category, this paper gives an overview about their most popular variations and their usability in advanced material handling systems.

2. EQUIPMENT TYPES USED IN MATERIAL HANDLING SYSTEMS

During material handling processes, different goods are moving among technology or other objects locating in given places, to fulfil the requirements of any production, service or consumer systems [1]. There are many material handling machines in industrial and economic processes [2], which are significantly different each other, at first sight. However, we look deeper into their detailed structure and functional operation, many similarity can be found, which enables to put them into different types. In the aspect of the main structure and principal operation characteristics, 15-20 main types can be defined (e. g. cranes). The cause of the uncertainty is that some subtypes are taken as individual types into account by

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different experts (e. g. travelling and jib cranes). A possible structure of material handling device types was defined in [1].

Important question during the material handling process is how the moving of the goods can be realized? The answer is the goods handling method, which principally determines the operation and structure of all handling equipment. There are only four goods handling methods applied in material handling [1]:

- mobile handling units,
- fixed loading arms,
- transport channels,
- moving by towing elements.

The above mentioned methods were described in [1], this paper focuses only the role of mobile handling units in advanced material handling systems.

3. MOBILE HANDLING UNITS

The traditional method for the material handling is the using of **mobile handling units**, where the goods are moving on the machines [3] (Fig. 1). In this case, the handling characteristics of the goods determined by the machine (speed, acceleration, route, etc.). Typical mobile handling units are the lifter trucks, pallet cars, running hoists, travelling cranes, monorails, rack-stackers, etc.

Figure 1. Example for mobile handling unit. Source: [4]

The mobile device can be moved at ground level or at different heights above the ground level, the movement can be bounded or unbounded. An important characteristic is the driving force of the movement, which is usually a drive motor located on the device or a separate traction device (Fig. 2). In the case of traction, a distinction is made between traction unit movement (e.g. tow truck) and towing element transport (e.g. transport trolley of a two-track conveyor). In the case of traction, freight wagons are used to place the goods, from which we can also form multi-wagon trains.

The most important advantages of mobile handling units are universal applicability and simple operation. Thanks to their operational characteristics, we can use them for transport (transportation units), loading (loading units) and storage (storage units) tasks. In the case of loading units, the mobile device must also have a gripping (possibly lifting) option (e.g. forklift).

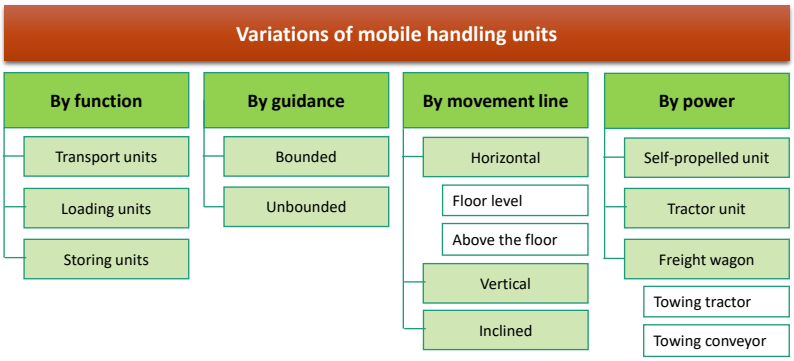

Figure 2. Versions of mobile handling units

Disadvantages include the expensive design and building (mainly self-propelled machines) and the complexity of the system due to the use of large number of unique devices (operational disturbances may occur) [5].

4. MOBILE HANDLING UNITS IN ADVANCED LOGISTIC SYSTEMS

Many mobile handling units are used in industrial practice, but in advanced material handling systems the following versions have outstanding importance:

- transport trucks,
- loader trucks,
- traveling cranes,
- suspended railway carriages,
- conveyor transport trolleys,
- warehouse racking machines.

4.1. Transport trucks

The main task of transport trucks is to move goods between two destinations and usually do not have equipment for picking up and putting down the goods, which is usually done by an external material handling device (loader). In terms of their structure, they are among the simplest material handling equipment, since in order to implement the transport function, in addition to the elements ensuring mobility (undercarriage, engine, etc.), only one transport surface for placing the goods is required. Certain types of transport trucks are capable of simpler picking up of goods (e.g. pallet trucks), or for simpler putting down (e.g. tiltable transport surface), but they cannot perform real lifting tasks [6].

The typical application field of transport trucks is the movement within the production area, in the case of bulk materials, the plant area can be several square kilometres (e.g. open-pit mines), in such cases the quantities of transported goods and the transport distances are also much higher (up to 100-ton vehicles).

The most important versions of transport trucks are shown in Figure 3, the most commonly used types are hand trucks, platform trucks and transport trains from towing tractor and freight wagons. Self-emptying ones and types with simple goods handling (special pick-up and drop-off) can be divided into separate categories.

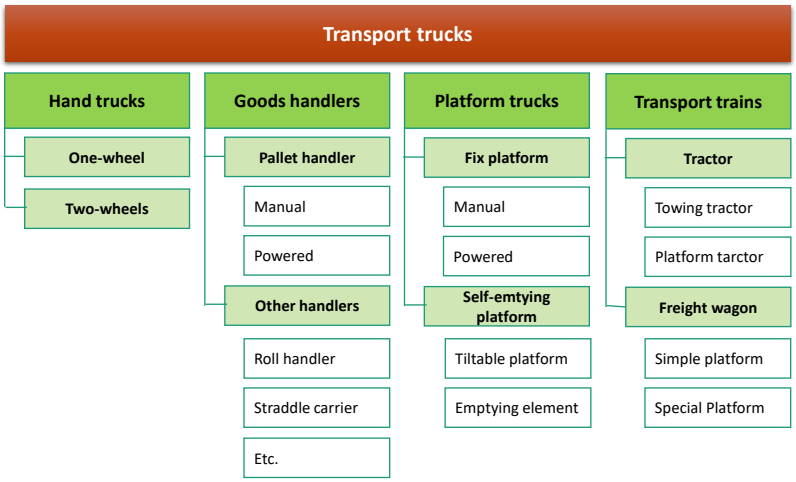

Figure 3. Versions of transport cars

Task of **goods handler trucks** are basically to transport goods, but they are capable of independently picking up and putting down a specific type of goods with the help of a built-in special lifting device. Its best-known version is the pallet truck, which is used exclusively for moving pallets of different sizes (see Fig. 1). A special version of this machine type is the straddle carrier, which is a version used for a long time, mainly for large goods, or for transporting containers (Figure 4). Nowadays, this device is occurring in more and more places at container terminals.

An important advantage of goods handler trucks is that they can be easily automated and well integrated into automatic service systems due to the simple handling method.

Figure 4. Straddle carrier. Source: [7]

The classic versions of transport trucks are **platform trucks**, which only have a transport surface and are not suitable for picking up goods. Their task is exclusively to move goods between two objects. In some types, it is possible to automatically deposit bulk goods using a tiltable platform or an emptying element.

Platform tucks are the most important devices in advanced industrial processes, because they can be easily transformed to automated guided vehicles (AGV), which in generally use

a fixed transport platform [8], where the goods are loaded and unloaded by an external automatic loading machine (e.g. robot) or a continuously operating transfer/receiving device (e.g. roller track - special transport surface) (Fig 5).

Figure 5. AGV transfer. Source [9]

A question that often arises when using pallet trucks is the possibility of combining transport tasks that occur in the same or linked relationships. Application of **trailers and tractors** can give answer to this question. In addition to the fact that trailers make it possible to connect different shipments, individual trailers are also a solution for storing the goods left on them. Since trailers do not have a drive, they are significantly cheaper than powered ones, so you can buy more of them and the lack of vehicles tied up for storage is not a problem [10]. Today, the use of trains consisting of a towing tractor and several trailers (e.g. milkrun assemblies) is the most dynamically developing field in advanced industrial material handling systems (Fig. 6).

Figure 6. Milkrun train. Source: [11]

4.2. Loader trucks

Loader trucks are used for the vertical positioning and placement of goods with the help of a gripping structure, as well as short-term horizontal movement [6]. Their primary task is the piece goods, or the loading of bulk materials between two objects (material handling,

technology, or service), which in all cases requires some kind of gripping device, or lifting equipment.

The most important versions of them are shown in Figure 7, the most commonly used types are pallet loaders, forklifts and articulated loaders. Many different versions are used in advanced industrial systems, primarily with manual operation.

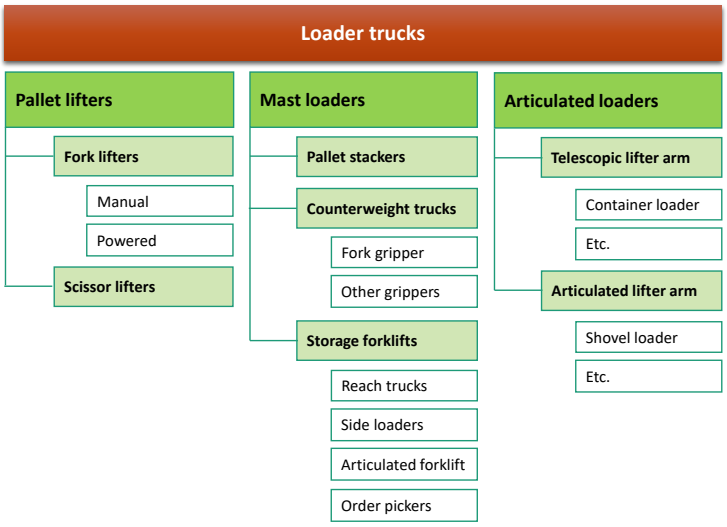

Figure 7. Versions of lifter trucks

The simplest forklifts belong to the **pallet lifters**, which are basically capable of moving and lifting pallets to a small extent (0.5-0.7 m), mainly for manual sorting, inspection or picking purposes (Fig. 8/a). Their most important advantage is that the goods can be raised to a comfortable height for manual manipulation, and in some cases they can also be used for loading (with suitable transport surfaces).

a) Pallet lifter. Source: [12] *b) Pallet stacker. Source: [13]*

Figure 8. Pallet handlers

Pallet stackers can primarily be used for short-term movement and loading of pallets in the production area or in the warehouse (Fig. 8/b). Compared to counterbalanced trucks, stacker trucks are much smaller, lighter and significantly easier to maneuver, but the fork design limits the vehicle's applicability.

The best-known loader truck is the **forklift**, which can be classified as a counterbalanced truck (Fig. 9). The most universal type of forklift, it is mainly used for loading goods on pallets and is usually used within the plant area. It is one of the most common material handling devices in non-automated industrial service systems, but its automation is a complicated task mainly due to the unbound track.

Figure 9. Toyota forklift. Source: [14]

Limited corridor-sized industrial or under warehouse conditions [15], the use of counterbalanced forklifts can be difficult due to the significant length dimension (forklift length plus the size of the goods). To improve this, the **reach trucks** was developed, in which the front axle of the truck was shifted in front of the center of gravity of the goods, which reduced the size of the necessary counterweight, so the length of the truck became significantly shorter, in addition to increasing stability (Fig. 10/a). In its more advanced versions, a pusher structure enables the moving of the lifting column or the fork horizontally.

Another typical warehouse solution is the use of **side loader forklifts**, which requires even less service area and mainly occurs in warehouses with narrow aisles (Fig. 10/b). Here, the lifting column and the gripping structure are turned at a right angle, so that their size does not exceed the width of the truck in the default position. You can usually meet these forklifts when handling in high-rise warehouses, where, compared to warehouse stackers, the most important advantage is independent service from the aisle. Some versions of side loader forklifts can also be used effectively for loading long goods (e.g. pipes, steel bars).

The so-called **articulated forklifts**, with which goods are picked up or it can be laid both frontally and laterally (Fig. 10/c). In the beginning, the rotation of the lifting column and the fork structure was solved with a swivel stand mounted on the forklift, in the advanced versions the column structure rotates together with the front axle. Their application typically occurs in warehouse handling systems, but it can also be beneficial elsewhere.

a) Reach truck. Source: [16]

b) Side loader. Source: [17]

c) Articulated forklift. Source: [18]

Figure 10. Storage load-lifters

Order picking is the activity when different goods (with different properties) are placed in a specific unit load building device for the purpose of unit formation. During picking in the storage area, the goods are collected between the warehouse aisles, with the help of special **order picking trucks**, which raise the person performing the picking and the collection unit to the level of the goods for the duration of the operation (Fig. 11).

Fig. 11. Order picker forklift. Source: [19]

In contrast to forklifts with a lifting column, where the movement is only in the vertical direction, when lifting arm is used, the goods also move in the horizontal direction, which enables the manipulation of the unit. In the case of loading piece goods, this horizontal movement basically serves the positioning of the goods in a specific area (e.g. loading surface), for which a telescopic lifting device with a lever is usually used, with a gripping device matching the goods, e.g. in case of **container loading trucks** (Fig. 12/a).

Traditional application field of trucks with articulated lifter arm is the loading of bulk materials, where the design of the arm is adapted to the loading characteristics [20]. The **shovel loader** (Fig. 12/b) is the most common bulk material loading truck, usually with a single-lever lifting mechanism and a special container (bucket) for separating the material. In addition to loading, front-end loaders can also be used for earthworks (e.g. soil leveling), their advanced versions can be multi-functional, for example equipped with a grab arm or with a replaceable gripping mechanism.

a) Container loader. Source: [21] *b) Shovel loader. Source: [22]*

Fig. 12. Articulated loaders

There is a growing demand for **automatic loader trucks** in industry, but forklifts are much more difficult to automate than platform trucks. Driverless loading trucks are always equipped with gripping and lifting equipment, therefore all three operations (grabbing, lifting and moving) must be solved automatically, which requires significantly more elements (e.g. sensors) and tasks (checking, coordination of movements, etc.) as in the case of transport trucks.

4.3. Traveling cranes

Cranes are loading devices operating above ground level, which, by a combination of vertical lifting and horizontal movement, can move bulk materials or units between different vertical and horizontal points [23].

The traveling crane is a linearly moving lifting device, moving on tracks above ground level, which performs loading tasks with the help of the gripping device connected to it. These cranes use only linear movements to move goods horizontally. All types of overhead cranes contain a mobile moving unit (hoist) on which the lifting device (usually a rope drum) is placed. The running hoist moves along a specific track or on a mobile bridge structure.

The areas of application of traveling cranes are basically related to handling of a production area, and their greatest advantages occur when moving large quantities of goods. Most traveling cranes can be used to move both piece goods and bulk materials (using a suitable gripping device). Over time, certain types of traveling cranes have become suitable for off-site service (e.g. gentry cranes) in terms of their structure, and have even specialized for certain tasks (e.g. outdoor storage). Its variations are shown in Fig. 13, the most important difference between each type is the location of the track, which can be suspended, running at ground level, or a combination of the two. Most of the versions are a bridge structure solution, the only exception to this is the running hoist. In modern material handling systems, you can mainly encounter traveling hoists, bridge cranes and gantry cranes.

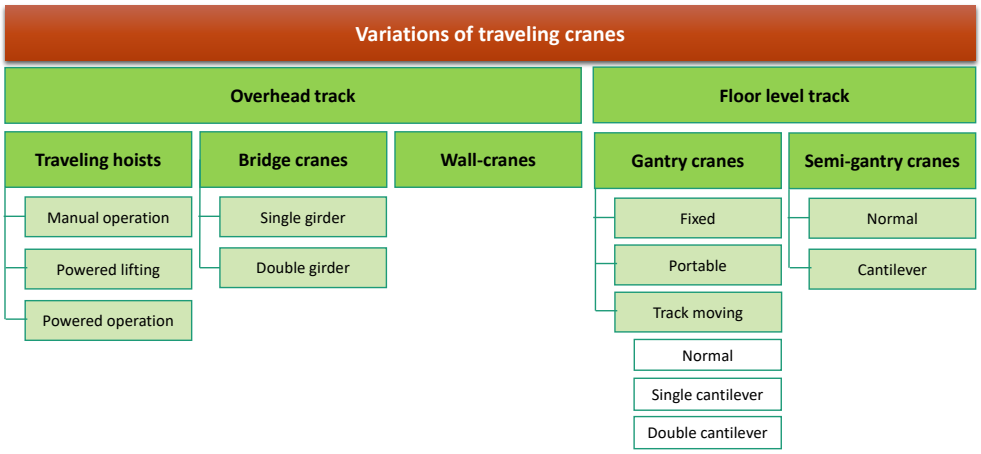

Figure 13. Versions of traveling cranes

The **traveling hoists** is a simple trolley structure, on which a lifting device is attached and suspended on a track, it is moved in the horizontal direction manually or with an electric drive. In terms of its design, it can have 2, 4, 6, or 8 wheels (depending on the load), the track control is automatic due to the placement of the wheels on both sides. The crane track usually consists of homogeneous steel beams, which can be straight or curved. The lifting device can be a rope drum or chain wheel, in the case of the latter, manual lifting is also possible (chain winch). It is typically used to lift and move unit goods, usually with a crane hook. In the case of smaller loads, manual movement is also possible (using a traction chain), but it is usually moved by electric drive through a suspended switch panel, with a pedestrian solution (Fig. 14).

It can also be used in advanced industrial systems, especially where lifting heavier goods is not a regular task and arises in different places. An important feature of this cranes is the location of the runway, because they are only suitable for servicing objects directly below the runway.

In the case of **bridge cranes**, the lifting hoist is placed on a bridge structure, which moves on a pair of tracks above ground level fixed to the hall structure or support columns (Fig. 15). Since both the bridge structure and the track are straight, and are perpendicular to each other, so the goods can reach any point of the area bounded by the pair of rails by moving the trolley and the crane bridge simultaneously. In terms of its variants, the most

important aspects are the load of the crane and the bridged span (the distance between the pair of rails). The smallest bridge cranes with one main girder and suspended trolley are used for smaller loads. For heavier goods, a more robust structure and usually double girder design with an overrunning hoist is used.

Figure 14. Demag traveling hoist. Source: [24]

In advanced manufacturing plants, the overhead crane is the most frequently used loading device for lifting heavy goods. The upper access and movement of the goods does not interfere with ground-level traffic, and objects located anywhere in the space under the crane can be quickly accessed.

Figure 15. Konecranes bridge crane. Source: [25]

A special version of bridge cranes is the **wall-crane**, which is used when it is not possible to place a pair of rails. These cranes can move along a wall with the help of a pair of rails placed on the wall. They are typically used in cases where the distance between the hall walls is too large, or it is not possible to place intermediate columns, but it is important to reach all points of the area accessible by the console. An important feature of this type of crane is that it can also be installed on the outside of the hall walls.

The **gantry cranes** consist of a bridge structure standing on a pair of rails placed at ground level, linearly moving legs, and a hoist that runs on it, equipped with a mandatory lifting device. Since it is more complicated and more expensive to create a track above ground level outdoors (there are no hall walls or columns), it is easier to place the rails on the ground and install legs on the crane bridge. In terms of its variants, the most important factor is the possibility of a cantilever design. Since the crane track is not attached to the hall wall, the bridge structure can extend beyond the area bounded by the legs (Fig. 16). The operating principle of the gantry crane can be used not only for loading large loads, but also for smaller, occasional lifting tasks. The solution to this is small mobile cranes, which can be easily moved to the place of lifting in the form of stands rolling on rubber wheels.

Figure 16. Konecranes gantry crane. Source: [26]

In advanced industrial systems, gantry cranes are primarily used in outdoor storage areas, handling bulk materials and large unit loads (e.g. containers), or it occurs at various terminals, often in the form of automatically operating cranes.

In their structure, the features of bridge cranes and gantry cranes are combined with **semi-gantry cranes**, which consist of a bridge structure with feet on one side, moving on a steel rail at ground level and a rail above ground level fixed to the hall structure or supporting columns.

Automated traveling cranes are an important area of the automated material handling in advanced industrial systems. In the aspect of the automation, the movement of the cranes is easily realized by automatic elements, but the lifting and the gripping of unit goods can cause hard problems [27].

Cranes usually use cable hoist to lift goods. Because the cable is flexible, goods swing during the motion of the crane. Swinging of the goods influences the positioning during

handling processes (increase the loading times). This phenomenon cause problems for the automated operation. Important task to reduce the swinging of the goods for the effective operation. Avoiding or reducing of the swinging of the goods, different lifting solutions can be applied: oscillation reducing solutions, guiding elements, scissor mechanism, etc.

Traditional gripper for cranes is the hook, which can be used only for manual control of unit goods. For the substitution of hooks, several automated gripper solutions can be applied, their most important characteristics are: they have to suite to the handled unit, they have to operate separately, they have limited applicability (only certain unit types), etc.

4.4. Suspended railway carriages and conveyor transport trolleys

In the case of **suspended rail tracks**, material movement is carried out by a transport unit (monorail trolley) with an independent drive moving on a fixed track located above the ground level [6]. The movement can take place on any spatial track, it provides the opportunity to connect several separate track sections, or also for the creation of storage tracks. Self-propelled trolleys are most often used, but there are also assemblies that move several trailers. The cars are usually electrically driven, can be stopped at any point on the track, and can be moved in two directions if necessary (Fig. 17).

Figure 17. Mecalux monorail system. Source: [28]

Its typical areas of application are the individual movement of piece goods and the movement of large goods between workplaces and their handling at workplaces (the goods are not removed from the cart). Automated versions are most often applied in advanced material handling systems, which can also be used in complex service systems with the automatic operation of the switching system.

In terms of their operational characteristics, similar mobile transport devices are the **carriages of double-track conveyors**, in which the operation is not carried out by an independent drive, but by means of a connecting traction element [6]. These structures are usually smaller, so they can be used primarily for the continuous movement of smaller goods moved in large quantities. There are also low-track versions, in which the car usually moves on the ground.

4.5. Warehouse racking machines

The task of the warehouse handling equipment is to serve the storage structures (e.g. warehouse racks) and carry out the loading, unloading and transfer operations as efficiently as possible. In unit goods warehouses, depending on the volume of service tasks, various material handling machines with intermittent operation are used (forklifts, cranes, etc.). Some types (e.g. side-loaders, push column forklifts) were developed specifically for storage [15].

Large size or in the case of warehouses with high service needs, **rack-stacker machines** are usually used (Fig. 18.), which are material handling machines with intermittent operation for moving unit goods in warehouses (at high heights). The corridor direction, or vertical movement can be easily solved (linear movements), special structures are used to grip the goods, the structure of which is adapted to the characteristics of the goods to be handled. The rack service machines only move goods within the aisle, the transport of outgoing goods is carried out by separate equipment (e.g. roller conveyor system). In advanced warehouse systems, automated racking machines are usually used, which can quickly and accurately move the goods placed in the warehouse units (pallets, boxes, etc.).

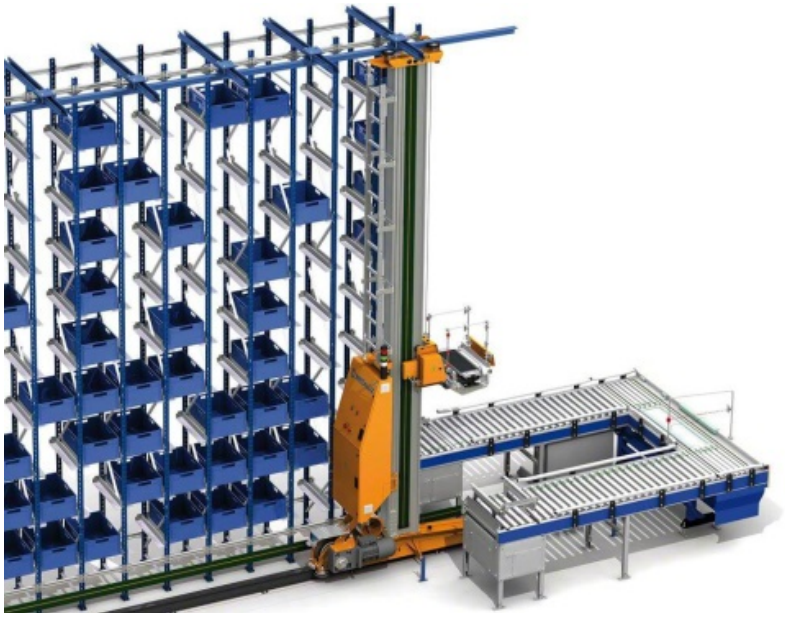

Figure 18. Rack stracker crane. Source: [29]

A new concept for the implementation of automated storage is the application of separate, mobile handling units (integrated gripping and moving elements) placed on each shelf level within the aisles (Fig. 19). **Aisle-bound mobile units** only move goods horizontally between the storage areas and an elevator, which moves the goods vertically. The most important difference compared to large rack-stacker machines is the small size of the carts, easier maintenance and expandability.

Figure 19. Schaefer shelving system. Source: [30]

5. SUMMARY

To fulfil the increasing requirements of the social and economic environments, the equipment used in material handling processes have to be developed. The machines fitted exactly to certain manufacturing procedures some decades ago, cannot be found in the advanced version, they role are acted by other, earlier rarely used computer-controlled devices. The traditional method for the material handling is the using of mobile handling units, where the goods are moving on the machines, so the characteristics of the transportation are based on the parameters of the handling equipment. Suited to the new requirements, the structure and operation of the mobile handling units are changing but their application have similar conditions.

There are many handling machines belonging to this category, this paper gives an overview about their most popular variations and their usability in advanced material handling systems.

As a statement we can say that the automated solutions (AGV, automated crane and monorail trolley systems, etc.) are applied in many areas, but the simpler, cheaper and more flexible manual and manually operated machines (hand trucks, pallet trucks, etc.) are also can be found among the applications in the advanced industrial systems.

Next phase of this research will be the uncovering of the special parameters and application advantages of these machines, which can show the development directions of the mobile handling units.

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