Scientific Journals
of the Maritime University of Szczecin

Zeszyty Naukowe
Akademii Morskiej w Szczecinie

2018, 55 (127), 73–78
ISSN 1733-8670 (Printed)
ISSN 2392-0378 (Online)
DOI: 10.17402/303

Received: 28.05.2018
Accepted: 20.08.2018
Published: 17.09.2018

Modular loading units for facilitating multi-floor manufacturing and city logistics

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Key words: multi-floor manufacturing, flexible logistic, freight elevator, modular loading unit, collapsible container, innovative concept

Abstract

The objective of this article is to present an innovative concept of modular reconfigurable trolleys for multi-floor manufacturing that increases the efficiency of the production processes, transport and logistics. The characteristics of the original concept of modular load units for reconfigurable trolleys are presented, with their technical and technological description and assembly. This article culminates with the synthetic analysis of the effectiveness of the proposed solution. The applications contain a description of the possibilities of further implementation and development of the technology under investigation.

Introduction

The trend of developing huge cities is associated with the growth of population density due to the increase in the altitude of residential, office, manufacturing and warehouse buildings, as well as an increase in traffic in the city line. The development of underground transport communications contributes to the unloading of ground traffic, but it does not completely solve the transport problem of a huge city. Intensive traffic in such cities is associated with ensuring the livelihoods of the population, various institutions and enterprises (Fujita & Thisse, 2013). The trends of society is the development in the field of urbanization, which is associated with providing green manufacturing, with the development of a concept of effective work in the megalopolis and of the factories in the urban environment; with efficient logistics and mobility, improvement of the transport communications; with creation of innovative products for a huge city (Westkämper, 2014; Wiendahl, Reichardt & Nyhuis, 2015; Dzhuguryan & Jóźwiak, 2016c). Under these conditions, the multi-floor manufacturing buildings and multi-floor warehouses in residential areas of huge cities are developed.

An important task is to ensure the efficient operation of the multi-floor manufacturing or multi-floor warehouse in the timely delivery and shipment of various freights necessary for its operation. The purpose of the article is to present an innovative concept of reconfigurable trolleys facilitating shipment of freights inside the multi-floor manufacturing or multi-floor warehouse. The trolleys are understood as in-house logistics units, which can be easily combined into larger cargo units to be transported by road trailers that increase the efficiency of flexible logistic processes.

Trends in the development of manufacturing in a huge city

One of the main components of urban traffic is the delivery of the labor population to workplaces and, after the end of work, to residence places. The division of the city into industrial zones and sleeping areas has led to a significant increase in the traffic of the labor part of the population. The notion of "rush hour" has appeared – the time when residents of sleeping areas go to work in the industrial part of the city in the morning and return to their residence places in the evening. This approach was associated with the provision of environmentally friendly residential areas, but it did not solve the environmental and transport problems of fast-growing huge cities (Veršinin, 2007; Dorofeev et al., 2009). With the growth of people's living standards, it became obvious that the ecological problems of huge cities cannot be solved only by creating environmentally friendly residential areas. Thus, the significance of zoning factors of the huge city has receded into the background, and the main factors were the reengineering of industrial infrastructure and the organization of efficient urban transport (Westkämper, 2014).

Obviously, the closer the workplace is located to the residence place, the less time and money spent on travel to the workplaces. Therefore, the solution of the transport problem in the huge cities is possible due to the location of multi-floor offices, manufacturing and warehouse buildings directly in the residential areas. Today, multi-floor manufacturing in residential areas of huge cities has become possible due to the emergence of new environmentally friendly technologies. Such manufacturing technologies can be used even in living quarters. In this case, the most optimal variant of multi-floor manufacturing is the combination of residential and industrial buildings according to the type of workhouses (Dzhuguryan & Jóźwiak, 2016b).

Working at home is a new stage in the production relations development connected with the emergence of information technology. In everyday life, the concept of "freelancer", is filled with a new meaning. Today's freelancer is a free self-employee, who works from a remote location, typically from home, and has a flexible self-enforced work schedule. Before the information society, this type of profession was typically reserved for carpenters, tailors, locksmiths and others. The products of this category of workers were materialized, i.e. pieces of furniture, shoes, clothing and metal products. With the development of information technology and the advent of the Internet, the field of freelancers activity has expanded: "music, writing, acting, computer programming, web design, translating and illustrating, film and video production, logistic, and other forms of piece work which some cultural theorists consider as central to the cognitive-cultural economy" (Scholz, 2013). The products of the freelancer's work have become virtual, non-materialized (digital) goods. These products are transmitted to consumers in digital format through various information networks, mainly the Internet. The following terms are used: offshore outsourcing, online outsourcing, crowdsourcing, e-lancing, virtual assistant and other, which relate to various activities of freelancers (Scholz, 2013). The emergence of this category of "home workers" allows to partially unload the traffic of urban highways, as the implementation of orders and the transfer of virtual goods and services did not require the use of vehicles.

The subsequent development of the information society has led to the improvement of traditional production technologies and the emergence of new additive technologies that significantly expand manufacturing possibilities (Westkämper, 2014). A basic factor retentive for the wide use of multi-floor factories in an urban environment is constrained with the use of bulky and overall dimensions of the technological equipment with high levels of energy consumption and the assembly laboriousness mainly in the conditions of factory-manufacturer. The solution to the problem is related to the creation of facilitated and easily collectable technological equipment of modular design, for example, frame construction (Dzhuguryan, 2012), the delivery of which, from the manufacturer to the customer, is carried out only in a disassembled state. The decline of the performance of the facilitated manufacturing equipment is compensated by mass character of its application, and the rational use of the urban areas and transport communications has provided efficiency of multi-floor productions that operate in the huge cities conditions (Dzhuguryan & Jóźwiak, 2016a).

The specific approach to assessment and select of technologies for multi-floor manufacturing is related with the technological, economic, environmental and social requirements. Obviously, the selection of technological equipment relates to the satisfaction of the demand of the population of a huge city in goods for home, study and office work: clothes, shoes, furniture, lamps, household and information technology, simulators, stationery and eats. It is also possible to manufacture components of small-sized products by outsourcing to larger companies located in the previously formed industrial areas of a huge city. The overwhelming number of such goods can be produced in conditions of multi-floor manufacturing, which relates to the tendency of miniaturization of finished products and their modules and the possibility of using technological equipment with smaller overall dimensions and weight.

An important criteria for the selection of technological equipment are the form and type of organization of multi-floor manufacturing (Westkämper, 2006; Czajka, Krot & Kuliberda, 2011; Papakostas et al., 2012; Dzhuguryan & Jóźwiak, 2016a, 2016c; Spath, 2017). The most common form and type of organization of multi-floor manufacturing are; cellular technological process (Czajka, Krot & Kuliberda, 2011) and dynamic manufacturing network (Papakostas et al., 2012). One of the main criteria for the selection of manufacturing equipment is the modular principle of their design. The technical criteria such as weight, overall dimensions of the modules of technological equipment can assess the possibility of delivery modules at different levels of the building process with their subsequent assembling, produce rapid re-engineering, recycling and utilization. Also, the criteria of weight, overall dimensions and dynamic characteristics of the technological equipment can assess the possibility of its placement on the selected floor of the building considering the available manufacturing areas and the bearing capacity of the building structure. An important criterion for the selection technological equipment is the harmonization of its performance with the throughput of freight elevators considering the number of floors of the manufacturing part of the building (Dzhuguryan & Jóźwiak, 2017). The implementation of the requirement of harmonization of its performance with the throughput of the freight elevators is related to their use in multi-floor manufacturing of reconfigurable trolleys with modular loading units for the delivery of materials, components and finished products to the destination both inside and outside the production building. The reconfigurable trolleys can also be used for the transportation of freights in multi-floor warehouses serving the multi-floor manufacturing buildings in a residential area of a huge city.

Modular loading units for transported freight

Figure 1 shows an example of a multi-floor cellular manufacturing scheme. Multi-floor manufacturing includes the flexible production cells 1 with the technological equipment 2 and 3 accordingly for the manufacturing of components and products; freight elevators 4, reconfigurable trolleys 5, 6, 7, 8, 9, accordingly with the components, finished products, defective components, and waste. The flexible production cells are equipped with areas for incoming inspection 10 and adjustment 11 of the component; auxiliary assembly features 12; output control 13, repair and adjustment 14, packing and loading 15 of finished products. Building for manufacturing contains: the main storage 16 and 17 for tools and supplies on each floor, administrative and sanitary facilities 18, stair grounds and passenger elevators 19 and sound-absorbing barrier 20 (Dzhuguryan & Jóźwiak, 2016a).

Delivery of the components, tools and consumables to each flexible production cells, shipping of products and wastes from which it is carried out by freight elevators and reconfigurable trolleys. The supply of cellular manufacturing by reconfigurable trolleys is most effective using the "Kanban Cards" (Sodkomkham & Chutima, 2016) method. The trolleys after loading can be moved on the floor along the routes shown in Figure 1. Filled trolleys with finished products or wastes are shipped to the main storage. The receiver control and the formation of components complete for assembly, including packaging, are carried out in the main storage of the cellular manufacturing, which is located on the ground floor (floor number 0) of the building. On the underground floor there is parking, serving and the main storage (Dzhuguryan & Jóźwiak, 2016a).

The reconfigurable trolley consists of two types of unified modular frames fulfilling the value of the load-carrying structure (Figure 2a) and the functional structure (Figure 2b). The load-carrying structure of the modular frames ensures the stiffness and strength of the trolley, which enhances the strength of the structure in the most loaded places. The functional structure of the modular frames is providing the necessary strength and rigidity of the trolley along with the possibility of convenient access to the transported freights at the loading and unloading stage (Wiśnicki & Dzhuguryan, 2018).

Four standard sizes with overall dimensions of the both types' modular frames are proposed: 700×1500 mm, 500×1500 mm, 700×900 mm and 500×900 mm. The selection of the modular frames standard size is depended on the transported freights, their overall dimensions and standard size of the freight elevators. The load-carrying and functional structure of the modular frames can form various configurations of the trolleys and collapsible loading units depending on the type of transported freights (bulk, liquid, packed) and their parameters. The choice of a rational scheme for bolted connections of the modular loading units is determined based on the analysis of the trolley and the collapsible container structures for stresses and strains, considering the transported freight.

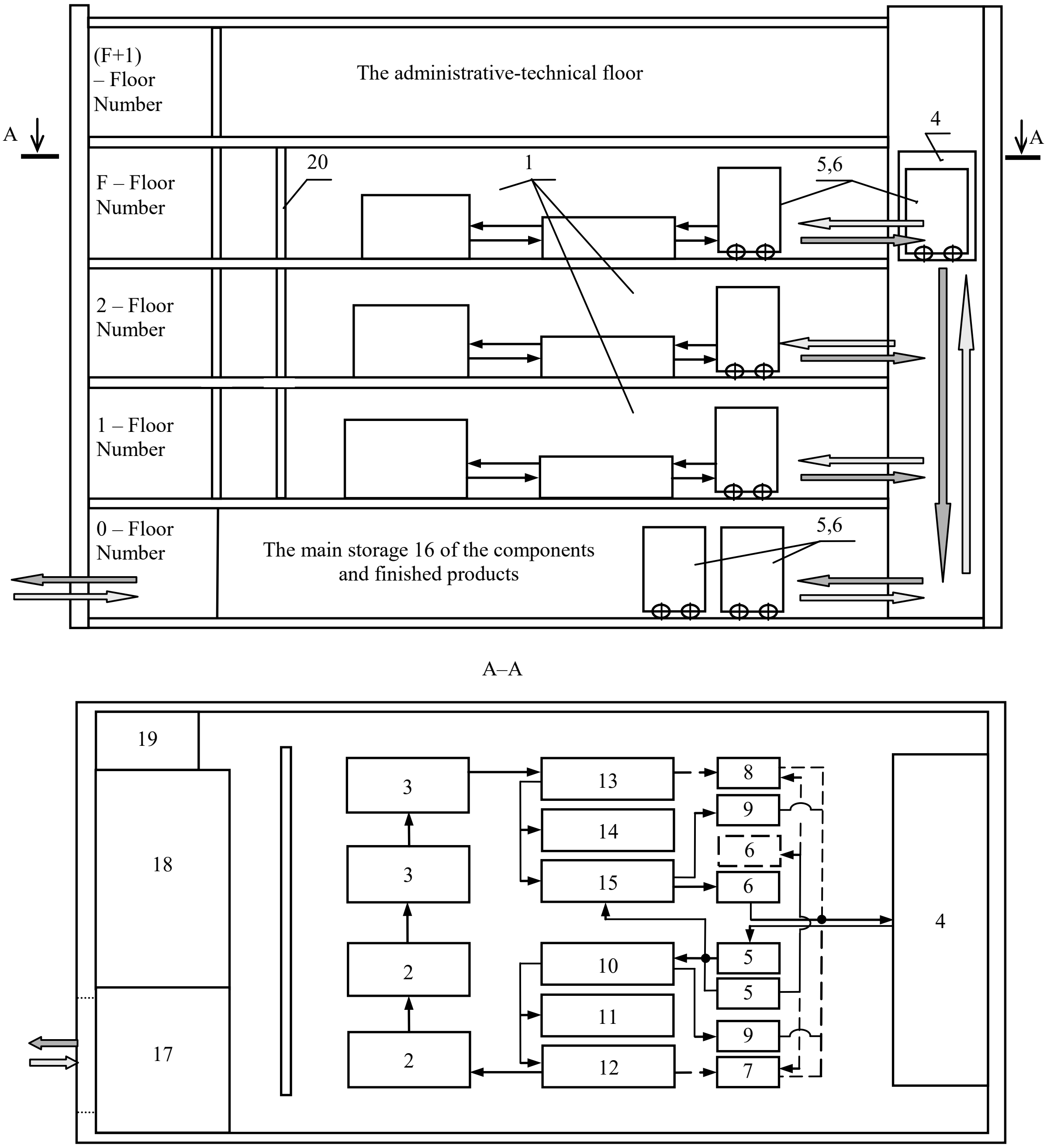

Figure 1. Scheme of the multi-floor cellular manufacturing and technological streams: ── basic technological streams, – – – auxiliary technological streams

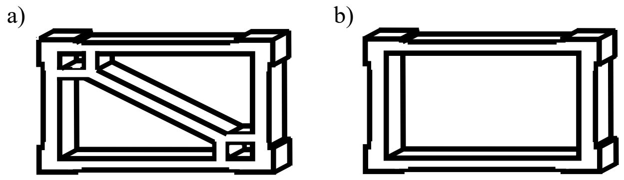

Figure 2. The construction of modular frames with load-carrying structure (a) and with functional structure (b) (Wiśnicki & Dzhuguryan, 2018)

The base of the reconfigurable trolley is made of a modular loading unit with a load-carrying structure on which four wheels are mounted. Depending on the transported freights and the parameters of the freight elevator, the reconfigurable trolley can have one (Figure 3a) or two (Figure 3b) rows of load-carrying and functional modules and one (Figure 3a), two (Figure 3c) or four (Figure 3d) bases connected to each other.

Upon receipt of the reconfigurable trolleys in the main storage, they can be combined in large cargo units, with the use of quick-release clamps. Such a new integrated loading unit can be as large as 20-feet ISO container or intermodal swap-body. What's more it can be easily collapsed when needed, e.g. when it returns empty after delivery. Loading

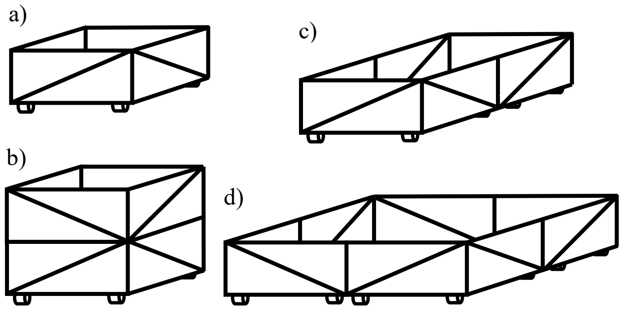

Figure 3. Schemes of the reconfigurable trolleys assembled from modular frames

and unloading of the integrated cargo unit can be carried out with an overhead crane, forklift or other loading machines. The usage of self-loading trailers or ACTS (Abroll-Container-Transport-System) technology is also possible. It is more convenient to consecutively load each trolley into the truck through its open side wall and then fasten them in a single container unit with quick-release clamps.

Loading of the reconfigurable trolley into a truck is made considering the sequence of their unloading when delivering the freight to the recipient. This makes it possible to implement a flexible logistics process in the multi-floor manufacturing or the multi-floor warehouse. Figure 4 shows the schemes of assembling of the integrated containers formed for reconfigurable trolleys (Wiśnicki & Dzhuguryan, 2018).

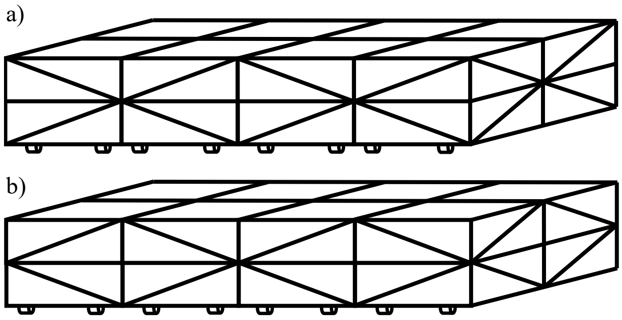

Figure 4. Schemes of assembling the integrated containers from the trolleys

The choice of material for the module frames and the technology of their manufacture depends on the weight of the transported freight, the overall dimensions of the reconfigurable trolleys and, on their basis, collapsible container. The module frame of reconfigurable trolleys can be manufactured from light metal alloys, for example, aluminum alloys, as well as from plastics or carbon plastics. A large standard sized metal module frame is expedient to manufacture, according to method of casting, and for the manufacturing of a small standard sizes module frame it is possible to use additive technologies.

Application of reconfigurable trolleys and integrated loading units in the multi-floor manufacturing or warehousing and transport allows to achieve the benefits in the form of increased security and reduced logistics costs. A loading unit is understood in this case, as the consolidated packaging adapted to mechanization of internal and external transport processes. The condition for benefiting is the appropriate choice of units, to meet the matching requirements for cargo carried as well as means of transport and handling equipment. A chosen loading unit should have sufficient cargo capacity, considering its volume and weight, should be resistant to the transportation forces. The most common choice is the standard units: containers (ISO standard) or swap bodies (CEN standard), which allows transloading between different modes of transport (Wiśnicki, 2006; Chwesiuk, Kotowska, & Wiśnicki, 2008; Rzeczycki & Wiśnicki, 2016; Wiśnicki & Dyrda, 2016; Wiśnicki & Dzhuguryan, 2018).

Conclusions

The use of the modular frame units for assembling of reconfigurable trolleys and, on this basis, the formation of collapsible containers can reduce the time and costs of their design, installation, dismantling, re-equipment and disposal, simplifying the transportation of the modular loading units to the assembling place of the trolleys in multi-floor manufacturing or multi-floor warehouses. The process of assembling the trolleys and, on their basis, of collapsible container does not require special equipment and can be carried out to the allocated assembly areas, or on any free areas in the warehousing or manufacturing location. This contributes to the formation of flexible logistics processes in the organization of transport and warehouse systems by increasing the efficiency of creating or re-equipping the required types, overall dimensions and configurations of trolleys and, on this basis, the formation of collapsible containers.

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