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SPECIFIC APPROACH TO ASSESSMENT OF TECHNOLOGIES FOR MULTI-FLOOR MANUFACTURING SYSTEM

The application of multi-floor manufacturing in huge cities is related to the rational use of urban areas and the solution of traffic problems. Technology assessment is a vital part of decision process in manufacturing which allows the enterprise to select manufacturing processes and technological equipment taking into account of technical, economic, environmental, social and other factors. This paper presents the specific approach to the assessment of technologies in the enterprises, represented as a system of multi-floor cellular manufacturing connected by a common vertical transport system which including passenger and freight elevators. A model for technology assessment and selection taking into account the carrying capacity of vertical transport system and the number of floors of cellular manufacturing system is proposed.

INTRODUCTION

Contemporary urbanization is characterized by the growth of population density of cities and the increase in the share of high-rise and multi-floor buildings, including the manufacturing buildings, in the total volume of construction [1]. This trend is one of the constituents of the general trend of huge cities and manufacturing development related to the structural changes in all sectors of the industry due to the emergence of new technologies and processes, a qualitative change of the labor resources, modern methods of management, and more efficient use of natural resources. Of particular note are the trends of the society development in the field of urbanization, which are associated with providing of a green manufacturing, with a development of the concept of effective work of the factories in the urban environment of the huge cities [2]. The multi-floor manufacturing factories as a good neighbors in an urban environment are associated with the creation of innovative products for the huge cities, the emergence of new information and production and management technologies, quality change of labor resources, improving transportation communications and logistics, more efficient use of natural resources [2, 3]. In the future the requirements to the technical equipment that are intended for multi-floor manufacturing in huge cities, can meet health standards of household appliances.

Multi-floor manufacturing is located in the lower part of the high-rise building and represents virtual enterprises connected or unconnected with each other by the production network and engaged in the manufacture of products components, their assembly and packaging [3]. The virtual enterprises are contained the flexible production cells or/and flexible production lines. The most difficult problems arise up at the use of the flexible production lines in the multi-floor due to its possible extension. In this case, the flexible production line is divided into sections which are consistently located on different floors of the building. The sections of the line are connected to each other by a transportation system, including the buffer stocks and freight elevators, in accordance with the sequence of the implementation of the technological process, quality control of products and warehousing. The amount of the technological equipment of the line sections depends on their possibilities of a differentiation and concentration of the operations taking into account the chosen of the methods and sequences of the products manufacturing. The fragmentation of the flexible production lines on the relatively independent sections allows to locate it in the multi-floor building without increasing of its built-up area. The ability to use of the multi-floor buildings for layout of the flexible production lines is related to the increase in the share of small-sized products in the total volume of products for mass consumption [4].

An important aspect of the efficient operation of the multi-floor manufacturing is used the technology assessment for analyzing and comparing production possibilities to support decisions on introducing new manufacturing technologies. A specific approach to assessment and select of new technologies for the multi-floor manufacturing is harmonization of manufacturing equipment performance with the capacity of vertical transport system of the building.

The purpose of this paper is to describe a specific approach to assessment and select of new technological equipment for multi-floor manufacturing.

1. A SPECIFIC APPROACH TO ASSESSMENT OF TECHNOLOGIES FOR MULTI-FLOOR MANUFACTURING SYSTEM

The high-rise building is divided into two or more parts. Manufacturing enterprises are located in the lower part of the building, and the service enterprises and administrative apartments are situated in overhead part. The layout of the technological equipment of the enterprises in multi-floor manufacturing depends on many factors, among that basic are the type and weight of the products, and also the applied technological process. As an example on Fig. 1 the charts of the technological equipment layout are presented in multi-floor manufacturing. Multi-floor manufacturing includes the technological equipment 1, freight elevators 2, and trolleys 3. Delivery of the components, tools and consumables for the technological equipment, loading and unloading of products and wastes from it is carried out by freight elevators and trolleys. Filled trolleys with products or wastes are shipped on the main storage (ground floor) [3, 5].

A basic factor retentive the wide use of the multi-floor factories in an urban environment is constrained with the use of bulky and overall dimensions of the technological equipment with the high levels of the energy consumption and of the assembly laboriousness mainly in the conditions of factory-manufacturer. The solution of the problem is related to creation of the facilitated and easily collected technological equipment of modular design, for example, of frame constructions [6], the delivery of which to the customer from the manufacturer is carried out only in the 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 is provided efficiency of the multi-floor productions operate in the huge cities conditions [4].

The specific approach to assessment and select of technologies for multi-floor manufacturing is related with weight distributions of technological equipment on the floor and the selection of the optimal performance of the technological equipment taking into account the throughput of elevators.

The weight (gross) distributions of the technological equipment on the floors will be given in a kind:

$$W_{Q.F} = \vartheta_W W_{Q.1}/F, \quad (1)$$

where: W_n, W_1 – the maximum weight (gross) of the technological equipment accordingly on the F-th floor and on the ground floor of the multi-floor manufacturing, kN; ϑ_W – the coefficients of the distribution of the weight and volume of the technological equipment, the values of that depend on dynamic descriptions of the technological equipment and strength of the building structure; F – the number of floor of the manufacturing part of the building.

The performance of the new technological equipment taking into account the throughput of freight elevators are defined:

$$G_{W(V).n} \le \left[\varepsilon\left(Q_{W(V)} - \lambda L_{W(V)}\right)/T_R\right] - \sum_{j=1}^{k-1} G_{W\{V\}.j}, \quad (2)$$

where: $G_{W.n}$, $G_{W.j}$ – the weight performance of the new technological equipment and the existing technological equipment on the floor, N/h; $G_{V.n}$, $G_{V.j}$ – the volume performance of the new technological equipment and the existing technological equipment on the floor, m^3/h; Q_W – the rated load of freight elevator, N; Q_V – the nominal volume capacity of the freight elevator, m^3; L_W – the weight of the trolley, N; L_V – the volume, occupied the trolley, m^3; T_R – round trip time, h; ε – the number of the freight elevators, pcs; λ – the number of the trolleys in the freight elevator, pcs.

The analytical approach is the T_{RT} of the freight elevator is determined by CIBSE Guide D and is defined with the following expression [7]:

$$T_R = 2Ht_V + (S+1)t_S + \lambda t_\lambda; \quad (3)$$

$$T_R = 2Ht_V + St_S + \lambda t_\lambda \text{ when } S>>1, \quad (4)$$

where:

$$H = F - \sum_{I=1}^{F-1} (i/F)^\lambda; \quad (5)$$

$$S = F - F((F-1)/F)^\lambda; \quad (6)$$

$$t_V = f/v; \quad (7)$$

$$t_S = t_{f.1} + t_O + t_C - t_V; \quad (8)$$

f – the interfloor distance, m; v – the rate speed of the freight elevator, m/s; t_S– the stopping time, s; t_S – the trolley loading/ unloading time, s; $t_{f.1}$– the single floor flight time representing the time of acceleration and deceleration, s; t_o– the door opening time, s; t_C – the door closing time, s; H – the highest reversal of the typical round trip; S – the expected number of stops of the trip.

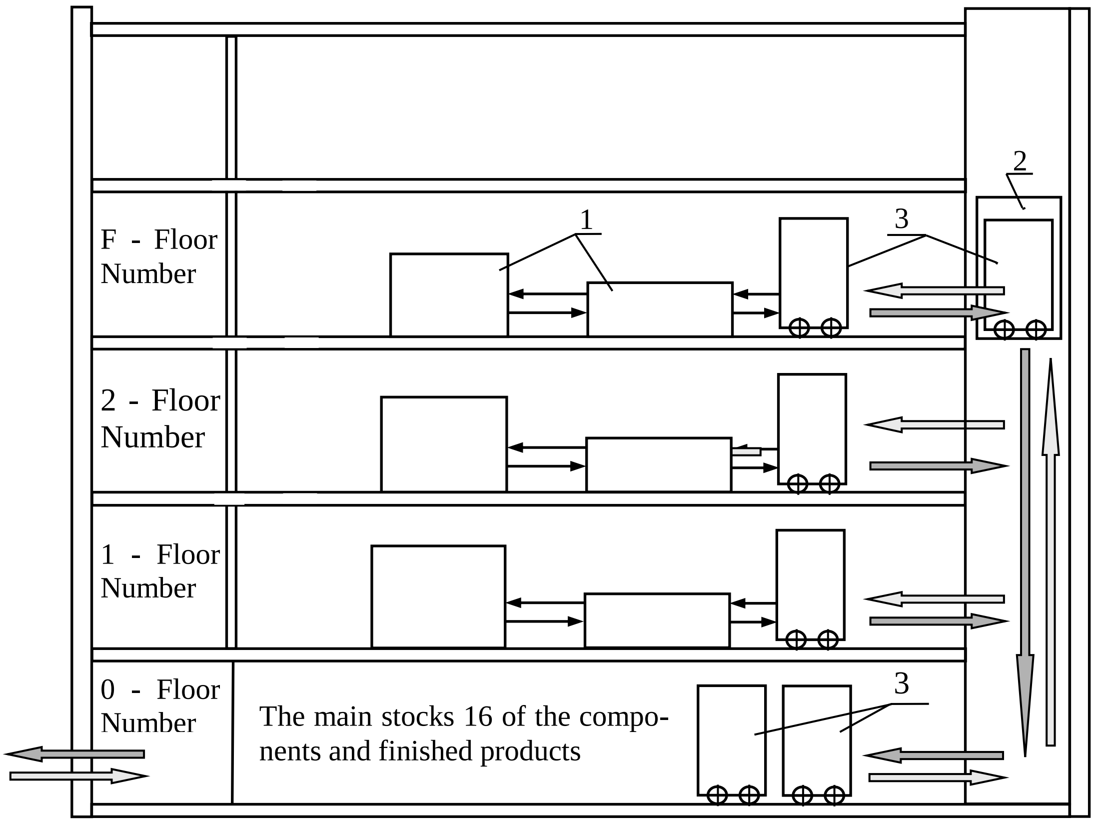

Fig. 1. Charts of the manufacturing equipment layout on the floor of the multi-floor manufacturing and technological streams

In ideal production conditions, the freight elevators consistently stop on each floor with loading and unloading the same number of the trolleys. In this case, the round trip time can be found from the following expression:

$$T_R = 2{,}78 \cdot 10^{-4} k_C f \cdot F(F+1)/v\varepsilon \approx 2{,}78 \cdot 10^{-4} k_C f \cdot F^2 \big/ v\varepsilon, \quad (9)$$

where: k_C – the coefficient of losses of time cycle of a work of the freight elevators [3].

At the stage of the technology assessment and the selection of the technological equipment on the criterion of the performance it is necessary also to take into account the number of floors of multi-floor manufacturing. The conditions for achieving the rational performance of multi-floor manufacturing equipment are defined under the following assumptions:

1. The weight (volume) performance of the manufacturing equipment on each floor is identical and equal $G_{W(V)}$.
2. On each floor there are the same number of the enterprises with production area S_P
3. Each enterprises takes the same manufacturing area of the building and work in parallel.
4. Each freight elevator has the same load Q_W (volume capacity Q_V) and occupies the same manufacturing area $S_{F.E}$ of the building.
5. The manufacturing area of each floor the is determined by the following equation:

$$S = qS_P + pS_{P.E} + mS_{S.E} + wS_{SW} + \varepsilon S_{F.E}, \quad (10)$$

where: q – the numbers of the manufacturing enterprises, ε, p, m – accordingly the numbers of the freight elevators for the multi-floor manufacturing, passenger and freight elevators of the building; w – the numbers of the stairway in the building; S – manufacturing area of each floor of the multi-floor manufacturing, m²; S_P, $S_{F.E}$ – the actual areas occupied by the each manufacturing enterprise and the freight elevator for the multi-floor manufacturing, m²; $S_{P.E}$, $S_{S.E}$ – the actual areas occupied by the passenger and freight elevators of the building, m²; S_{SW} – the actual area occupied by the stairway in the building, m².

The number of the passenger and freight elevators in the building are defined on a discrete digital simulation of the movement of elevators in a building and the passenger dynamics [7, 8, and 9]. the passenger dynamics.

The virtual area occupied by the each manufacturing enterprise is determined as:

$$S_C = \left(qS_P + pS_{P.E} + mS_{S.E} + wS_{SW}\right)/q. \quad (11)$$

As a result, the equation (10) is reduced to the well-known kind received in the article [6]:

$$S = qS_C + \varepsilon S_{F.E}. \quad (12)$$

With the above equations (9) to (12) are defined the weight (volume) of output products and which are transported by the freight elevators of the multi-floor assembly manufacturing for a round trip time [5]:

$$\varepsilon Q_{W(V)} = qT_R G_{W(V)} = \left[2{,}78 \cdot 10^{-4} k_C f\, F^2 G_{W(V)} \left(S - \varepsilon S_{F.E}\right)\right] \big/ \varepsilon S_C. \quad (13)$$

From the equation (13) we will define a rational number of freight elevators of the multi-floor manufacturing:

$$\varepsilon = F\left(\sqrt{b^2F^2 + 4ac} - bF\right) \Big/ 2a, \quad (14)$$

where:

$$a = Q_{W(V)} S_C;\ b = 2{,}78 \cdot 10^{-4} k_C f\, G_{W(V)} S_{E.F}$$

$$c = 2{,}78 \cdot 10^{-4} k_C f\, G_{W(V)} S. \quad (15)$$

Taking into account equations (9) and (14), we will find the extrema of the performance function of the multi-floor manufacturing, deciding next equation [5]:

$$\frac{d}{dF} G_{F.W(V)} = \frac{d}{dF}\left[\frac{FG_{W(V)}\left(2aS + F^2bS_\varepsilon - FS_\varepsilon\sqrt{b^2F^2 + 4ac}\right)}{2aS_C}\right] = 0. \quad (16)$$

After conversion of the equation (16) we obtain equation for calculating of the optimal production performance on each floor of the multi-floor manufacturing:

$$G_{W(V).O} = 4800 \cdot v \cdot Q_{W(V)} S_C S \big/ k_C f\, F^2 S_{F.E}^2, \quad (17)$$

where: $G_{W.O}$ – the optimal weight performance of the technological equipment on each floor of the multi-floor manufacturing, N/h; $G_{V.O}$ – the optimal volume performance of the technological equipment on each floor of the multi-floor manufacturing, m³/h.

The optimal weight performance of the new technological equipment on the floor of the multi-floor manufacturing are defined:

$$G_{W(V).O.n} \le G_{W(V).O} - \sum_{j=1}^{k-1} G_{W\{V\}.j}. \quad (18)$$

where: $G_{W.O.n}$ – the optimal weight performance of the new technological equipment on each floor of the multi-floor manufacturing, N/h; $G_{V.O.n}$ – the optimal volume performance of the new technological equipment on each floor of the multi-floor manufacturing, m³/h.

CONCLUSION

The decision criteria in the technology assessment process for multi-floor manufacturing are covered the technological, economic, environmental and social requirements. We have proposed the additional criteria for the technology assessment for the multi-floor manufacturing that can be attributed to technical requirements. However, the proposed technical criteria also are effected by the economic, ecological and social aspects of sustainability assessment process.

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 are allowed to assess the possibility of delivery modules in different levels of the building with their subsequent assembling. Block-modular principle of the technological equipment also is allowed to produce the rapid re-engineering, recycling and utilization. Also, the criteria as the weight and overall dimensions of the technological equipment are allowed to assess the possibility of its placement on the selected floor of the building taking into account 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 taking into account the number of floors of the manufacturing part of the building.

The proposed criteria for technology assessment can be used to support the development a general model for sustainability assessment process for multi-floor manufacturing in an urban environment of huge cities.

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Szczególne podejście do oceny technologii w systemie produkcji wielopoziomowej

Kryteria decyzyjne w procesie oceny technologii dla produkcji wielopiętrowej są uwzględnione w wymaganiach technologicznych, ekonomicznych, środowiskowych i społecznych. Zaproponowaliśmy dodatkowe kryteria oceny technologii dla produkcji wielopiętrowej, którą można przypisać wymaganiom technicznym. Proponowane kryteria techniczne są również realizowane przez ekonomiczne, ekologiczne i społeczne aspekty procesu oceny zrównoważonego rozwoju.

Jednym z głównych kryteriów wyboru urządzeń produkcyjnych jest modułowa zasada ich projektowania. Kryteria techniczne, takie jak ciężar, całkowite wymiary modułów wyposażenia technologicznego, umożliwiają ocenę modułów dostawy na różnych poziomach budynku przy ich późniejszym montażu. Modułowa technologia blokowa urządzeń technologicznych pozwala również na szybki re-engineering, recykling i wykorzystanie. Również kryteria dotyczące wagi i wymiarów urządzeń technologicznych są dopuszczalne do oceny możliwości umieszczenia ich na wybranym piętrze budynku z uwzględnieniem dostępnych powierzchni produkcyjnych i nośności konstrukcji budynku. Ważnym kryterium wyboru sprzętu technologicznego jest harmonizacja osiągów z przepustowością wind ciężarowych, uwzględniając ilość podłóg części produkcyjnej budynku.

Proponowane kryteria oceny technologii mogą być wykorzystane do wspierania opracowania ogólnego modelu oceny procesu zrównoważonego rozwoju w odniesieniu do produkcji wielopiętrowej w środowisku miejskim wielkich miast.

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