THE TRANSPORT PROVIDING OF WORKS OF THE MULTI-FLOOR FLEXIBLE PRODUCTION LINE

The Problem of a transport providing of the flexible productive line operate the sections of that with buffer stocks are located consistently on the different floors of the building are considered in the article. The rational routes of the workpieces and finished products, non-stationary buffer stocks in the form of trolleys, connecting the sections of the line and the main stock are offered. The concordance of the vertical transport carrying capacity and of the performance of the multi-floor flexible productive line sections is executed. The time cycle operation and the required number of the freight elevators, the amount of the stock trolleys taking into account the performance and location on the floors of the line sections are determined. It provides the conditions for effective operations of the multi-floor flexible production line and servicing, the vertical transport.

INTRODUCTION

The small-floor factories are characterized by a large extent of the production areas and their communication in urban areas, intense freight traffic on municipal streets and highways, and, as a result of it, by considerable economic losses. Therefore, in the large cities there is a tendency to increase the specific volume of high-rise and multi-floor buildings, including the manufacturing buildings, in the total volume of construction in connection with the need to save of the land areas, suitable for the agricultural use [1, 2]. This trend is one of the constituents of the general trend of manufacturing development related to the structural changes in all sectors of the industry due to the emergence of new production technologies and processes, a qualitative change of the labor resources, modern methods of management, and more efficient use of natural resources [3]. 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 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 megalopolis [3, 4].

A basic factor retentive the wide use of the multi-floor factories in an urban environment is constrained with the use of bulky technological equipment with the high levels of the energy consumption and of the assembly laboriousness mainly in the conditions of factory manufacturer. The decision of the problem is related to creation of the module, facilitated and easily collected technological equipment, for example, of frame constructions [5], the delivery of which the customer is made only in the disassembled state. The decline of the performance of the facilitated technological 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 megalopolis conditions [5].

The most difficult problems arise up at the use of the flexible production lines (FPLs) in the multi-floor due to its possible extension. In this case, the FPL 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 [6]. The fragmentation of the FPL 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 FPLs is related to the increase in the share of small-sized products in the total volume of products for mass consumption. The advantage of the FPL sections located on different floors of the building and producing small-sized products is the presence of relatively large backlogs in the buffer stocks, which reduces the impact of the technological equipment downtime on the line performance. The disadvantages of the use of the FPLs in the multi-floor buildings is a more difficult organization of the transport provision of its work, related to the necessity of the freight elevators application.

The efficiency of the transport system of the multi-floor manufacturing depends on the synchrony of its work with of the FPL sections, the main stock and the other subdivisions, participating in the production process. Therefore, it’s expedient to define the conditions of the transport providing of the FPL sections work taking into account their performance and location in the multi-floor building.

The aim of the article is a transport providing of the FPL sections work, located consistently on the different floors of the multi-floor building and served by the stock trolleys and freight elevators.

1. THE CONCORDANCE OF THE FPL PERFORMANCE AND CARRYING CAPACITY OF THE TRANSPORT SYSTEM

On Fig. 1 the two possible charts of the transport providing of the FPL sections work, located on the different floors of the building, taking into account the location of the first and the last F-th sections are presented. The difference between the transport providing charts of the FPL work is the focus of the technological process direction. In the first case the technological process direction is from down to top, and in second case - from top to down. Therefore, on the first chart (Fig. 1, a) the first and the last F-th sections are located accordingly on the lower and overhead Fmax floors of the building, and on the second chart (Fig. 1, b) - accordingly on the overhead Fmax and lower
floors. FPL consists of module technological equipment 1, on the basis of that on every floor of the building are formed the sections from the first to F-th. At the beginning and end of each section are located for two stock trolleys 2, which consistently are moved by the freight elevators 3 from the workpieces main stock 4 that are located on the ground floor of the building, on the first section and further to the subsequent sections. After the end of the process of manufacturing the product in a stock trolley is moved, if necessary, through the freight elevator 3 in the metrological laboratory 5 located on the lower floors of the building (as a rule, are not above the first floor) and then to the main stock 4 of the finished products. For providing of the FPL smooth operation on every section is set the scoreboard, which indicate the time remaining until the arrival of the freight elevator on the floor.

Both charts of the transport providing of the FPL sections work have an equal time of cycle in theory. Therefore, for the choice of the rational chart of the transport providing of FPL sections work are examined their advantages and disadvantages. Advantages of the first chart of the transport providing of the FPL work (Fig. 1, a) as compared to the second chart (Fig. 1, b):

1. It is faster loading of the FPL sections at the initial stage of its work with frequent changes of the manufactured products.

2. In the early sections of the FPL usually are performed roughing operations, accompanied with the enhanceable loading and therefore requires, on the one hand, more durable, heavy technological equipment, and on the other - more frequent removal of waste products, such as chips. Therefore, the first chart of the transport providing of the FPL work, in these cases, is allowed the more rationally distribution of load on the bearing structure of the building and reduced the time of the waste disposal.

3. In the early sections of the FPL usually are happened overflow of the buffer stocks [6], which contributes to the accumulation of the workpieces on the lower floors and therefore, the more rational distribution of load on the bearing structure of the building.

The disadvantage of the first chart of the transport providing of the FPL work is work heavy condition of the freight elevators operation.

The modern manufacturing is characterized the small allowances for machining, the highly reliable, facilitated technological equipment, which allows to neutralize the advantages of the first chart of the transport providing of the FPL sections work. In this case it is expedient to recommend for practical application the second chart of the transport providing of the multi-floor FPL work, shown in Fig. 1, b.

The performance of the FPL on the stage of her planning taking into account the chosen the technological equipment, methods and sequence of the machining, technological bases and tools, differentiations of the technological process and concentration of the operations is determined with the following expression:

$$Q_p = \frac{K_T}{3600} \left( K_{T1} + K_{T3} q / (F + 1) \right)$$  \hspace{1cm} (1)

$$K_T = 1 / t_p$$  \hspace{1cm} (2)

where: $Q_0$ – the performance of the FPL, pcs/h; $K_T$ – the technological performance of the FPL, pcs/s; $q$ – the number of machine tools modules in all sections of the FPL; $F$ – the number of the building floors, on which the sections of the FPL are located; $t_p$ – the time spent on work passes the FPL, i.e. directly on the product manufacturing, for example, the time cutting, stamping, etc., $t_i$ – time of idling of the FPL sections at implementation of all cycle of the finished product manufacturing (losses of cycle time of the FPL, for example, supply and drainage of tools, feed material, etc.), $t_s$ – losses of outside cycle time of the FPL, $s$ [6].

The weight and volume performance of the FPL are defined with the following expressions:

$$G_w = W_p Q_p$$  \hspace{1cm} (3)

$$G_v = V_p Q_p$$  \hspace{1cm} (4)

where: $G_w$ – the weight performance of the FPL, N/h; $G_v$ – the volume performance of the FPL, m³/h; $W_p$, $V_p$ – the weight of the finished product, N; $W_c$ – the volume of the finished product, m³.

The time of the cycle components of the freight elevator operation for the first chart (Fig. 1, a) of the transport providing of the FPL work are determined with the following expressions:

$$T_G = h(F_{max} - F + 1 + w_c) / v$$  \hspace{1cm} (5)

$$T_p = h(F - 1)(1 + w_c) / v$$  \hspace{1cm} (6)

$$G_w = W_p Q_p$$  \hspace{1cm} (7)

$$w_c = (t_R + t_L + t_R) / t_w$$  \hspace{1cm} (8)

$$t_w = h / v$$  \hspace{1cm} (9)

where: $T_G$ – the time of delivery of the workpieces by freight elevator from the ground floor to the first section of the FPL, which are located on the floor ($F_{max} - F - 1$)-th, $s$; $T_p$ – the time of successive delivery of the workpieces by the freight elevator from the first section to the last section of the FPL, $s$; $T_o$ – the time of delivery of the finished products by the from the last section of the FPL to the ground floor, $s$; $t_R$ – time of uniform movement of the freight elevator between floors, $s$; $t_L$ – losses of time from an acceleration and deceleration at the beginning and at the end of the freight elevator motion, $s$; $t_k$ – the time of the stock trolleys loading in the freight elevator, $s$; $W_c$ – the weight of the finished product, $m$; $V_c$ – the volume of the finished product, $m$.

The time of the cycle components of the freight elevator operation for the second chart (Fig. 1, b) of the transport providing of the FPL work are determined with the following expressions:

$$T_p = h(F - 1)(1 + w_c) / v$$  \hspace{1cm} (10)

$$T_p = h(F - 1)(1 + w_c) / v$$  \hspace{1cm} (11)

where: $T_G$ – the time of delivery of the workpieces by freight elevator from the ground floor to the first section of the FPL, which are located on the floor $F_{max}$, $s$; $T_o$ – the time of delivery of the finished product by the from the last section of the FPL to the ground floor, $s$.

The time $T_p$ of successive delivery of the workpieces by the freight elevator from the first section to the last section of the FPL in the both charts are identically.

The time $T_c$ of cycle of the freight elevator operation for both charts of the transport providing of the FPL work are determined with the following expression:

$$T_c = k_c (T_o + T_p + T_0) / 3600 = k_c h (2F_{max} + W_c + Fw_c) / 3600 v$$  \hspace{1cm} (12)
where: $T_C$ – time of cycle of the freight elevator work, $h$; $k_c$ – the coefficient of outside cycle losses of the freight elevator operation, the values of that are in limits $k_c = 1.05 - 1.6$.

The values of the coefficient $k_c$ is depends on the frequency of breakdowns of freight elevators, removal of production waste, the use of the metrological laboratories for quality control of products, availability of spare freight elevator in the building, etc.

The estimated demand for the freight elevators, providing of the FPL sections work, are defined with the following expressions:

$$
\varepsilon = \frac{w_b G_P T_C}{(Q_W - \lambda L_W)}
$$

(13)

$$
\varepsilon = \frac{w_b G_P T_C}{(Q_V - \lambda L_V)}
$$

(14)

where: $\varepsilon$ – the estimated demand for the freight elevators, providing of the FPL sections work, pcs.; $w_b$ – the reserve coefficient; $Q_W$ – 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 stock trolley, N; $L_V$ – the volume, occupied the stock trolley, m$^3$; $\lambda$ – the number of the stock trolleys in the freight elevator, pcs.

From the expressions (14) and (15) are chose the highest value of the parameter $\varepsilon$, and is rounded off to the highest integer. If the thus obtained integral value $\varepsilon$ is slightly different from the calculation should provide a freight elevator reserve on the cases to downtime of basic freight elevators due to performing maintenance or their breakdowns.

The estimated demand for the buffer stock trolleys, providing of the FPL sections work, are defined with the following expression:

$$
n = 4F + 2\varepsilon + m
$$

(15)

where: $n$ – the estimated demand for the buffer stock trolleys, pcs; $m$ – the number of parallel working metrology laboratories, pcs.

CONCLUSION

The proposed transport maintenance of multi-floor FPL allows:

1. The efficiency of multi-floor manufacturing to be increased at the expense of the rational organization of technological streams, providing of rhythmic works of the FPL sections, the trolleys application for the transportation of workpieces, finished products and wastes.

2. The concordance of the vertical transport carrying capacity and of the performance of the multi-floor flexible productive line sections taking into account the proposed charts of a transport providing of work of FPL sections to be executed.

3. The time cycle operation and the required number of the freight elevators, the amount of the stock trolleys taking into account the performance and location on the floors of the line sections, and also the technical characteristics of freight elevators to be determined.

REFERENCES


W artykule zaprezentowano problemy transportowe elastycznej linii produkcyjnej podzielonej na sekcje, które korzystają z zapasów buforowych znajdujących się na różnych piętrach budynku. Zaproponowano rozwiązania w postaci racjonalnych dróg przepływu półwyrobów i wyrobów gotowych, niestacjonarnych zapasów buforowych umieszczonych na wózkach, łączących odcinki linii produkcyjnej z głównymi magazynami. Skierowano nośność transportu pionowego z elastycznymi odcinkami linii produkcyjnych. Uwzględniono czas trwania operacji, wymaganą liczbę wind towarowych oraz liczbę wózków z uwzględnieniem charakterystyki i lokalizacji umieszczonych na poszczególnych piętrach odcinków linii produkcyjnej. Zaproponowano warunki dla skutecznego działania elastycznej linii produkcyjnej multi-piętrowej oraz serwisowania pojazdów, transportu pionowego.

Autorzy:

prof. dr hab. inż. Tygran Dzhuguryan – Akademia Morska w Szczecinie, Wydział Inżynierii-Ekonomiczny Transportu, Instytut Inżynierii Transportu, Zakład Inżynierii Produkcji, e-mail: t.dzhuguryan@am.szczecin.pl
dr hab. inż. Zofia Józwiak – Akademia Morska w Szczecinie, Wydział Inżynierii-Ekonomiczny Transportu, Instytut Inżynierii Transportu, Zakład Technologii Transportu Zintegrowanego i Ochrony Środowiska, e-mail: zofia.jozwiak@interia.pl
**Fig. 1.** Charts of the transport providing of works the multi-floor FPL: 1 – the module technological equipment, 2 – the stock trolleys, 3 – the freight elevators, 4 – the main stocks of the workpieces and finished products, 5 – metrological laboratory