INFLUENCE OF AUTOMATIZATION LEVEL OF PRODUCTION EQUIPMENT ON THE CAPACITY OF INTERNAL TRANSPORT

VPLYV STUPŇA AUTOMATIZÁCIE VÝROBNÉHO ZARIADENIA NA KAPACITU VNÚTORNEJ DOPRAVY

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Abstract

The paper reviews the influence of automatization level of production equipment on the capacity of transport equipment which is supplying it. The definition of interdependence allows more optimum projecting of both the transport and production process, as well as easier control of production process. In this paper there is shown one of the possible models for calculating the capacity of the transport device (fork-lifter).

Článok je venovaný vplyvu stupňa automatizácie výrobného zariadenia na kapacitu dopravného zariadenia, ktoré ho obsluhuje. Definícia vzájomnej závislosti umožňuje lepšie projektovať oba, výrobný aj dopravný proces, ako aj riadenie výrobného procesu. V tomto príspevku je ukázaný jeden z možných modelov pre výpočet kapacity dopravného zariadenia (vysokozdvižného vozíka).

Key words

automatization level, internal transport, capacity

stupeň automatizácie, dopravav nútorná, kapacita

Introduction

The costs of internal transport make a very important part of total production costs. Therefore it is necessary to pay attention when projecting not only of transport systems and selection of particular types of transport devices, but it is necessary during making the technological project to resolve also the system of internal transport. When projecting and organizing the internal transport care has to be taken about economic issues, productivity and profitability of the chosen transport. Any decision on the application of transport devices should be well analyzed, because it can cause greater cost than expected. Modern devices, for its complexity, sometimes have great maintenance costs. But well selected devices and well conducted organization of work in transport and manipulation, respecting prescribed working and technological routines, can very much contribute more economical and more productive production.

In projecting transport systems of internal transport there is a large number of alternatives which can satisfy our need for connection of production process, transport and load manipulation, but only one of those solutions is most economical, most productive, in one word, the optimum. The task of designer is to find that optimum an most economical transport system.

Automatization level of the production equipment

Automatization of the production equipment i.e. of production system has the task:

- to reduce physical effort of a man,
- to increase productivity,
- to increase product quality,
- to increase economical efficiency.

As a measure of automatization for production equipment - machine, production process i.e. production system most frequently is used one measure named: level of automatization. The automatization level represents the relation of the number of automatizated functions to total number of functions and can be determined by means of the formula [Ivković, Rac, 1995.]:

$$A^0 = A_f / A_u, \tag{1}$$

where:

A^0 - Automatization level,

A^f - Number of automatizated functions,

A_u - Total number of functions.

Since nowadays is present a great number of different production equipment having available quite considerable variety of construction and technological characteristics it is therefore very difficult to make comparisons between them. In order to determine the number of automated functions and their comparing the sorting of their single characteristics can be done in different ways. One of them, neither the only one nor the final, is as the following [Živković, D., 1998.]:

1. Type of the equipment drive: manual, mechanical.
2. Method of managing the machine cycle: manual, manual-mechanical, automatized, numerical controlled, adaptive control, computer aided.
3. Way of workpiece changing: manual, manual-mechanical, automatized, without human assistance.
4. Way of clamping for workpiece: manual, manual-mechanical, automatized, without human assistance.
5. Number of working axes: one, two, three, four ($4x90^o$), four($1x360^o$), more than four.
6. Way of checking for machine piece: manual, manual-mechanical, automatized, without human assistance.
7. Way of cutting tool change: manual, automatized.
8. Way of adjustment and correction for tool in relation to machine: manual, by pattern, automatic adjustment and correction.
9. Sawdust removal: manual, manual-mechanical, automatized
10. Number of working spindles: one spindle, two spindles, more than two spindles
11. Transport of workpiece from machine to machine: manual, manual-mechanical, automatized, automated (without human assistance).

By using of listed eleven criterions with forty one parameter it can be estimated the level of automatization for production equipment. The automatization level of one machining system, that means automatization level of the production equipment is determined by the following function [Živković, D., 1998.]:

$$A^0=f\,(\,K_1 - K_{11}\,;\,P_1 - P_{42}\,) \tag{2}$$

The minimal automatization level refers to the production equipment with manual machining and the maximum automatization level to the computer integrated production equipment with automatic designing of product, technology and planning (CIM).

Based on such classified characteristics of the production equipment it can be made the evaluation of the automatization of their functions and, at extreme case, it can be determined even the automatization level of the production equipment [Ivković, Rac, 1995].

The automatization level is one relative measure of the automatization which shows the development phase of managing information to which all changes are automated. For example: the automation level would be as follows: for a radial drill 0,12 for a radial drill with a circular table 0,15, for a horizontal drilling and milling machine 0,17, for a machining centre 0,48.

Capacity

The objective in determining the capacity and its control is the determination of production capability of the observed technical system, i.e. observed machine, machine group, production lines or the entire factory. An accurately determined capacity and its efficiency coefficient are the basics for determination of management policy. On the basis of an accurately determined capacity optimum organization of work, development and use of capacity are projected, and also the basis for monitoring the dynamics of production cost.

The word capacity originates from the latin word "CAPACITAS" which originates from the word "CAPAX" which means capable, willing, able. The summary time interval of work of a technical system is the basis for the measuring of its capacity. The capacity of a technical system represents its capability to accomplish certain operations within a determined time span. The capacity of a technical system in most cases is being defined for a time period of a year, although it can be any period of time. Besides time, the capacitycan also be expressed in natural units and conditional units.

Methods for determination of capacity of technical systems are various, but always with the same objective: to achieve as realistic as possible analysis of capacity in order to get minimum costs of production and a maximum of profit. If we pay according attention to optimum use of time and if production and losses of working time are analyzed, it will show if there is possibility to increase production and decrease cost through better organization of labor.

When planning and determining capacity, and for easier monitoring and influencing the production process in the given time and space, we can define the operation of technical systems through the following terms (type of capacity):

IN-BUILT CAPACITY (*Ku*). In-built capacity of a technical system is a capacity which can give maximum work (production) according to constructive characteristics of the technical system. In-built capacity is calculated on basis of the total sum of hours within the observed period of time and can be calculated on basis of the formula:

$$Ku = 24\ Bd\ , \tag{3}$$

where is:

Bd - Observed period of time in days. If we observe the period of one year, which is the usual observation period, then is Bd = 365 days and the in-built capacity is:
Ku = 24 x 365 = 8760 h/year.

THEORETICAL CAPACITY (Kt). Theoretical capacity of a technical system is the capability of a technical system to execute a certain number of operations, to work, without interruption, a planned amount of hours. Theoretical capacity can be determined by the following formula:

$$Kt = Brd \times Ns \times Tns\ , \tag{4}$$

where is:

Brd = Bd - Bp	- Number of working days within the observed period of time expressed in days.
Bp	- Number of holidays, non-working days (saturdays, sundays and official holidays) within the observed period of time expressed in days.
Ns	- Number of work shifts within a single working day
Tns	- Number of working hours within a work shift.

POSSIBLE CAPACITY (Km). The operation of a technical system is influenced by many external factors which affect the work of a technical system and cause numerous halts and significant losses of working hours. The possible capacity of a technical system includes all these factors and losses of working hours caused by technological, organizational and economical working conditions. Possible capacity can be determined by the following formula:

$$Km = Kt \times F\ , \tag{5}$$

where is:
F - Working reliability of a technical system, which includes all possible defects caused by technological, organizational and economical working conditions, i.e. reliability factors are:

$$F = Kt \times F_M \times F_P \times F_A \times F_m \times F_O \times F_{VS}, \tag{6}$$

where:
F_M - Factor of a machine includes all time losses due to not expected defects of the machine.
F_P - Factor of the worker includes all time losses due to absence of the worker.
F_A - Factor of the tools includes all time losses due to tools.
F_m - Factor of material includes all time losses due to bad quality of material.
F_O - Factor of production organization includes all time losses due to bad organization of work.
F_{VS} - Factor of superior powers includes all time losses due to superior powers.

Previous analysis of in-built capacity, theoretical capacity, possible capacity shows that there exists the following relation:

$$Ku > Kt > Km . \tag{7}$$

The objective of determining the efficiency of the capacity of production equipment is to achieve a valuation of capacity as realistic as possible in order to get minimum production cost. If we pay according attention to optimal use of time and if production and losses of working time are analyzed, it will show if there is possibility to increase production and decrease cost through better organization of labor. If we activate the production capacities not used currently, decreasing avoidable losses the efficiency of possible capacity of production equipment can be increased significantly and the production can be more economical.

Internal transport

Shigeo Shingo [Shingo, Sh., 1986.], said something we must not forget when projecting, selecting the type and organizing internal transport:

“The use of fork lifters, transport tapes, transporters etc. … does not represent a rationalization of transport but only the rationalization of work within transport. Many do mix these two terms. Real rationalization of transport starts with the principle to mainly eliminate the need for transport, for example through more rational *layout*“.

Optimal *layout* allows [Zrnić, Đ., 1986. a, b]:

- Shortening of transport paths, and by that also the decrease of transport- manipulation operations,
- Productivity increase for both the production as well as transport-manipulation equipment,
- Decrease of the amount of material in the production process,
- Visibility of the working area, because the flow of material is close to straight movement,
- Shortening of the time cycle of production, because the number of transport- manipulation operations has decreased,
- Production costs are lower, because there is less transport-manipulation operations etc.

A once projected transport system should regularly be checked and possibilities for further rationalization reviewed. Usually, when making measures for decrease of production costs, we always start from the rationalization of production operations, trying to avoid particular operations and interventions, trying to shorten the time of a operation, decrease the percentage of rejected pieces, increase the automatization level of production equipment, but rarely reviews and analyzes internal transport. In the field of internal transport, there are huge opportunities for rationalization of production process and decreasing production costs. By rationalization of transport-manipulation operations there are achieved significantly greater economical effects with lower investments, than it is the case with rationalization of production operations.

One example of determining the capacity of transport equipment

Depending on the type of transport device we can determine its capacity. In this paper is given an example of determination of the capacity of an electric fork lifter.

Theoretical capacity (K_T) , regarding that the fork lifter can work effectively only 5 hours, after what his batteries have to be refilled, following the existing organization of work in "Zmaj", one fork lifter is used only in one shift.

$$K_T = Brd \ x \ Ns \ x \ Tns = 253 \ x \ 1 \ x \ 7{,}5 = 1900 \ h/year.$$

Possible capacity (K_M) is as follows:

$$K_M = K_T \ x \ R_R = 1900 \ x \ 0{,}81 = 1540 \ h/year.$$

An operational cycle of transport devices, a fork lifter for example, can be calculated from the term:

$$T_{CV} = \Sigma \ T_i \tag{8}$$

for a fork lifter we can suppose that "i" takes values between i =1 and i =14
where is:
T_{V1} - Time necessary for the fork lifter to reach the place of demand for manipulation and it can be determined from the term:

$$T_{V1} = T_g + (L_d / V_d) , \tag{9}$$

where is:
L_d - distance
V_d - Velocity of the empty fork lifter (V_d = 5 km/h = 1,39 m/sec. allowed velocity of a fork lifter inside the facility)
T_g - Time loss at the starting and stopping of the fork lifter (T_g= 3 sek.).
T_{V2} - Time necessary to manoeuvre the fork lifter into a suitable position to take the palette. This time value depends on the space available and approximately is equal to: T_{V2}= 10 sec.
T_{V3} - Time necessary to put down the forks of the fork lifter into a suitable position to take the palette

$$T_{V3} = T_{gS} + (L_S/V_S) , \tag{10}$$

where is:
L_S - Height of the forks when the lifter is moving (L_S= 0,16 m)
V_s -Velocity of descending of the forks of a fork lifter
T_{gS} - Time loss of descending the forks of a fork lifter (T_{gS}= 3 sec.)
T_{V4} - Time necessary to take the palette (T_{V4}=5 sec.).

T_{V5} - Time necessary for lifting the fork and palettes into a suitable position for moving the fork lifter

$$T_{V5} = T_{gP} + (L_P/V_P) , \tag{11}$$

where is:

L_p - Height to which the forks have to be lifted for the lifter to move normally (L_p =0,16 m.)

V_p - Velocity of lifting the forks with the palettes

T_{gP} - Time loss of lifting the forks of the lifter (T_{gP} =3sec.)

T_{V6} - Time necessary for the fork lifter to turn around and take a suitable position to start transport. Time mainly depends on available space, for normal conditions and an average fork lifter we can take that this value is T_{V6} =10 sec.

T_{V7} - Time necessary to carry the palette to its destination.

$$T_{V7} = T_{gO} + (L_O/V_O) , \tag{12}$$

where is:

L_O - Distance to which the palette is transported

V_O - Velocity of fork lifter with palette.

T_{gO} - Time loss at starting and stopping the fork lifter which approximately is: T_{gO} = 3 sec.

T_{V8} - Time necessary to manoeuvre the fork lifter so that the palette could be positioned into a suitable disposal position, where the average time for an average fork lifter is: T_{V8} = 10 sec.

T_{V9} - Time necessary to drop the forks with the palette into a suitable position for unloading.

$$T_{V9} = T_{gPS} + (L_{PS}/V_{PS}) , \tag{13}$$

where is:

L_{PS} - Height of the forks when the lifter is moving, which normally is around L_{PS}=0,16 m.

V_{PS} - Velocity of descending the forks

T_{gPS} - Time loss when descending the forks of a lifter; the average value is: T_{gPS}=3 sec.

T_{V10} - Time necessary to disposition the palette; the average value is: T_{V10}=5 sec.

T_{V11} - Time necessary for lifting empty forks of a lifter into a position suitable for moving of the lifter, which can be determined from the formula:

$$T_{V11} = T_{PP} + (L_{PP}/V_{PP}) , \tag{14}$$

where is:

L_{PP} - Height of the forks when the lifter is moving

V_{PP} - Velocity of lifting the forks

T_{PP} - Time loss when lifting the forks of a lifter; the average value is : T_{PP} = 3 sec.

T_{V12} - Time necessary for the fork lifter to turn around and take a suitable position to start moving. Time mainly depends on available space, for normal conditions and an average fork lifter we can take that this value is: $T_{V12} = T_{V6}$ = 10 sek.

T_{V13} - Time necessary for the lifter to take the starting position or a new task. We can assume $T_{V13} = T_{V1}$, i.e.:

$$T_{V13} = T_g + (L_d / V_d) , \tag{15}$$

where is:

L_d - Distance

V_d - Velocity of an empty fork lifter

T_g - Time loss at starting and stopping the fork lifter (T_g = 3 sec.)

T_{V14} - Unexpected time losses which exist in the transport cycle, and are not included in the previous analysis of the operation time of the fork lifter and we can assume that this time to be added is approximately 10 % of total time of the transport cycle.

On the basis of this average time of manipulation of the transport device, i.e. time of the operation cycle we can determine the intensity of manipulation (average value) within a unit of time:

$$\mu = 1 / T_{SV}, \tag{16}$$

where is:
μ - average number of units which a transport devices manipulates within a unit of time.

Defintion of interdependence of capacity of transport equipment and automatization level

With the help of the previously shown analysis of the transport cycle of a transport device (fork lifter) and on the example of the combine factory "Zmaj"-Beograd, for manipulation of production equipment with according automatization level, we get possible capacities which are shown in table 1.

Table 1

Automatization level of prod. equipment	Average time of transport cycle (min)	Possible capacity of transport device (pieces/year)
0,12	1,80	616.000
0,15	0,60	1,848.000
0,17	0,45	2,464.000
0,48	0,45	2.464.000

We can approximate the relation of possible capacity of a transport device and the automatization level of production equipment by the curve:

$$y^2 = a + b \ln x / x^2 , \tag{17}$$

where is: $a = 7{,}260699\ e^{+12}$; $b = 4{,}6421795\ e^{+10}$.

We see that there is a relation between the automatization level of production equipment and the capacity of transport equipment. The relation is stronger in the part where the automatization level of production equipment is achieved by integration of single production operations, while in the case of automation of the control/monitoring part of production equipment this relation is noy so strong.

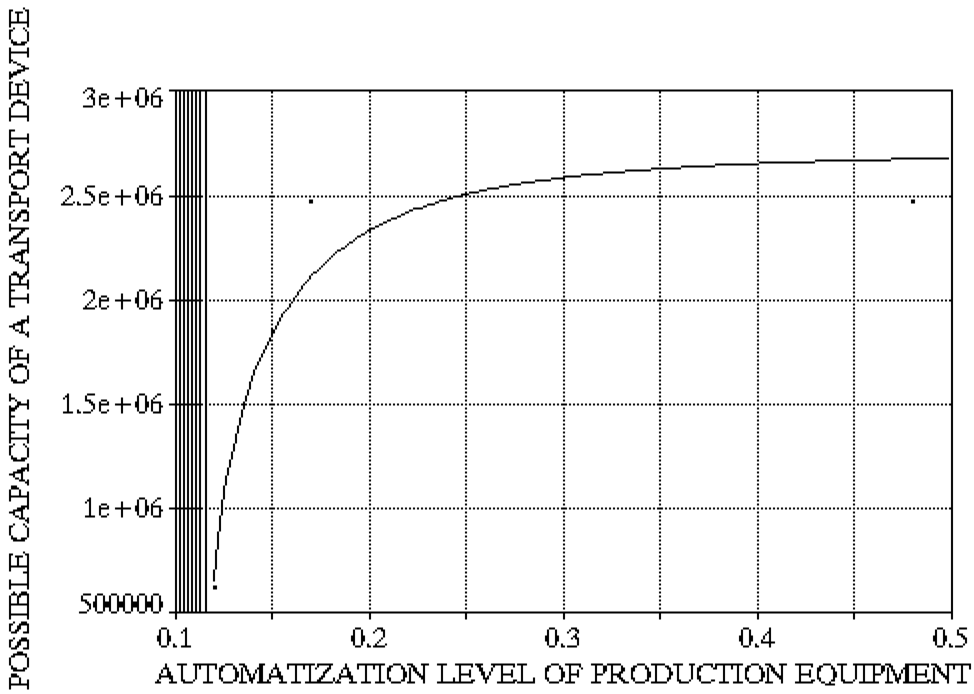

Figure 1. *Relation of possible capacity of a transport device and the automatization level of production equipment*

Conclusion

From the research shown, and in the framework of modern projecting methods for production and transport systems and optimization of their characteristics, one can see that there exists a certain level of dependence of internal transport on the automatization level of production equipment, and that this dependence is not strong. The dependence of internal transport from the automatization level of production equipment shows in the part where the automatization level is based on grouping single production operations. Where the automatization level of production equipment is based on the automatization of control/monitoring operations, that dependence is negligible. The definition of the relation between automatization level of production equipment and possible capacity of internal transport, allows more efficient use of the capacity of internal transport equipment and optimum selection of necessary production and transport equipment, whereby production costs can be cut significantly.

References:

[1] BROWNE, J., DUBAIS, D. Classification on flexible manufacturing systems. In *The Magazin FMS*, 1984, pp.114-117.

[2] DAŠIĆ, P. *Statistička obrada eksperimentalnih podataka, Knjiga 1: Jednofaktorna regresiona analiza. Monografija*. Kruševac, 2003, 250 s.

[3] GROOVER, M. *Automation, production systems and computer integrated manufacturing*. New Jersey, Englewood Cliffs, Prentice-hall. INC, 1987.

[4] IVKOVIĆ, B., RAC A. *Revitalizacija obradnih sistema - mogući prilaz u industriji prerade metala*. Beograd, 1995.

[5] MELLICHAMP M. J., KWON O-JOUNG, WAHAB, A. FMS designer: an expert system for flexible manufacturing system design. In *International Jurnal of Production Research*, 1990, Vol. 28, Number 11, pp. 2013-2024.
[6] NILSSON, N. Fiagarma-fully integrated garment manufacture an extension of the concept of flexible manufacturing system. In*, Proceedinss of the 2nd European Conference on Automated Manufacturing*. Birminghampp, 1983, 189-211.
[7] EGBELU, J. P. Machining and material flow system design for minimum cost production. In *International Jurnal of Production Researsh*, 1990, Vol. 28, Number 2, pp. 353- 368.
[8] ZRNIĆ, Đ. The influence of the transportation system modelling to the system elements performances and development of their construction. In *Scientific Meetings of the Serbian Academy of Sciences and Arts*, 1996, Vol. LXXXIII. Department of Technical Sciences, Book 2, pp. 573-586.
[9] ZRNIĆ, Đ. Some problems of material handling system design. In *XIV International conference on material handling and warehousing*. Belgrade: Ed. by Đ. Zrnić, Faculty of Mechanical Engineering University of Belgrade- Material Handling Institute Belgrade, 1996, pp 1.27-1.40.
[10] ZRNIĆ, Đ. Some problems of modelling the complex material flow system. In *Manufacturing systems: Modeling, Management and Control*. Vienna, Ed. by P. Kopacek, Pergamon (Elseviev Science),1997, pp 429-434.
[11] ŽIVKOVIĆ, D. Dependence analyze for some parameters of transport system in dependence on automatization level of equipment being superintended. In *XV ECPD International Conference on Material Handling and Warehousing*. Belgrade, 1998, pp 2.7-2.11.
[12] ČINGO, Š. *Nova japanska proizvodna filozofija.* Beograd: Jugoslovenski zavod za produktivnost rada, 1986.