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Working Process Optimization and Minimization of Production Costs*

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Preliminary note

Abstract: The economic aspects on optimization of components production is nowadays a very current issue. At the time of ongoing world economic crisis the most discussed topic in this area as well is the decreasing of the production costs. The notion of „machinability of materials“ is a complex of characteristics of the machined material which is monitored in the view of its fitness for the production in a certain way of machining. When cutting conditions and tool durability optimizing, it is necessary to apply certain optimizing criterion within certain restraining conditions. The restrictions are given by technical parameters of a machine, tool, machined material, required quality of machined surface etc. The essential economic criterion is the amount of production cost.

Optimizacija radnog procesa i minimalizacija troškova proizvodnje

Prethodno priopćenje

Sažetak: Ekonomski aspekti optimizacije proizvodnje dijelova su sada vrlo aktualna tema. U vrijeme gospodarske krize vrlo diskutirano pitanje u ovom području je smanjenje troškova proizvodnje. Pojam obradivosti materijala je karakteristika obratka u smislu njegove prikladnosti za proizvodnju i odredeni način obrade materijala. Za optimizaciju uvijeta obrade i vijeka trajanija alata potrebno je primijeniti odredene optimizacijske kriterije umutar skupa ograničivajućih uvjeta. Ova ograničenja su tehnički parametri alatnih strojeva, izradka, obradena površine, potrebna kvaliteta točnosti i slično. Osnovni kriterij optimizacije je iznos troškova proizvodnje.

1. Introduction

The simple solution is not to divide general expenses into two parts i.e. joint expenses of a department and costs of a workplace but leave it as the average value of hourly overhead lump sum designed on the basis of share of total of all overhead costs within a department and total department capacity. It is a simple solution that can be appropriate as the first stage of transition from a calculation through an extra charge to a calculation with the usage of the hourly overhead lump sum method.

By this simplification the influence of individual factors is covered and their impact is not clear in the total calculation.

Symbols

T_{optN}	- is optimal serviceability of a machine from the point of production costs, [min]	k_c	- increment shift time, (usually 1, 11-1,15)
N_{nT}	- cost to a machine related to a device serviceability,[€]	τ_{As}	- machine time, [min.]
τ_{vn}	- time to exchange of a device per [min]	O_s	- costs is the write-off of a machine,[€. h^{-1}]
N_{vmn}	- are cost to exchange of a device per, [€]	C_s	- a machine price, [€]
N_{sm}	- are cost to one minute machine labor,[€. $\min^{-1}$]	C_E	- electricity price (middle value of long-term average or educated guess), [$€/h^{-1}$]
k_r	- constant	Z_s	- machine operational life in years
m	- empiric constant from the Taylor´s relation	CFS_{EFPL}	- machine time fund planned in hours per year and shift

Symbols

v_c	- cutting speed	SM	- shift
N_c	- costs on machine work, [€]	k_{us}	- reparation index and machine maintenance index
N_v	- secondary work costs, [€]	k_{vs}	- index of time-utilization of a machine
N_{vn}	- costs to device exchange, [€]	k_1	- and q are constants
N	- production costs to calculate an operational section,[€]	F_u	- costs is chucking power influencing the jaw,[N]
N_s	- costs to exchange or offset of a worn-out device related to the operational section, [€]	k_n	- constant
N_n	- costs to machines related to the operational section, [€]	D_u	- tightening average,[mm]
N_m	- costs to exchange or offset of a worn-out device related to the operational section, [€]		**Greek letters**
N_{sm}	- are costs to one minute machine labor, [€. $\min^{-1}$]	μ	- Rubbing index between a jaw and a work-piece
N_{hs}	- hourly costs to machine operation, [€. h^{-1}]	τ_{vn}	- time to exchange of a device per [min]
M_0	- operator´s wages including social and health insurance,[€. h^{-1}]	τ_{As}	- machine time, [min.]
RNS_{pl}	- planned operational costs of a department, [%]		**Subscripts**

2. Optimal serviceability of a Machine from the Point of production Costs

Essential matters for the working process optimization are a solid analysis of on what the value of expense units depends. It is determining just because the information enables to manage the working process effectively.

First of all we are going to define the terms "**decision**" and "**strategy**". Under the term "decision" we are going to understand the determination of values of input parameters in the given stage of controlled process. Under the term "**strategy of decision**" we are going to understand the sequence of the step-by-step decisions. Strategy which satisfies the conditions of the preset defined criterion of optimization will be defined as the **optimal strategy**. [4]

It is possible to present the relation for optimal durability as

$$T_{optN} = \frac{(N_{nT} + \tau_{vn} N_{vmn})}{N_{sm}} k_r (m-1) \quad (1)$$

Where:

T_{optN} is optimal serviceability of a machine from the point of production costs, [min]

N_{nT} - cost to a machine related to a device serviceability,[€]

τ_{vn} - time to exchange of a device per [*min*]

N_{vmn} - are cost to exchange of a device per, [€]

N_{sm} - are cost to one minute machine labor,[€. $\min^{-1}$]

k_r - constant

m - empiric constant from the Taylor´s relation

Determination of optimal serviceability does not depend on cutting conditions, but leads to simplification of cutting conditions optimization. After that, it relates usage of gradual way of optimal cutting conditions setting. The procedure does not lead to optimal values.

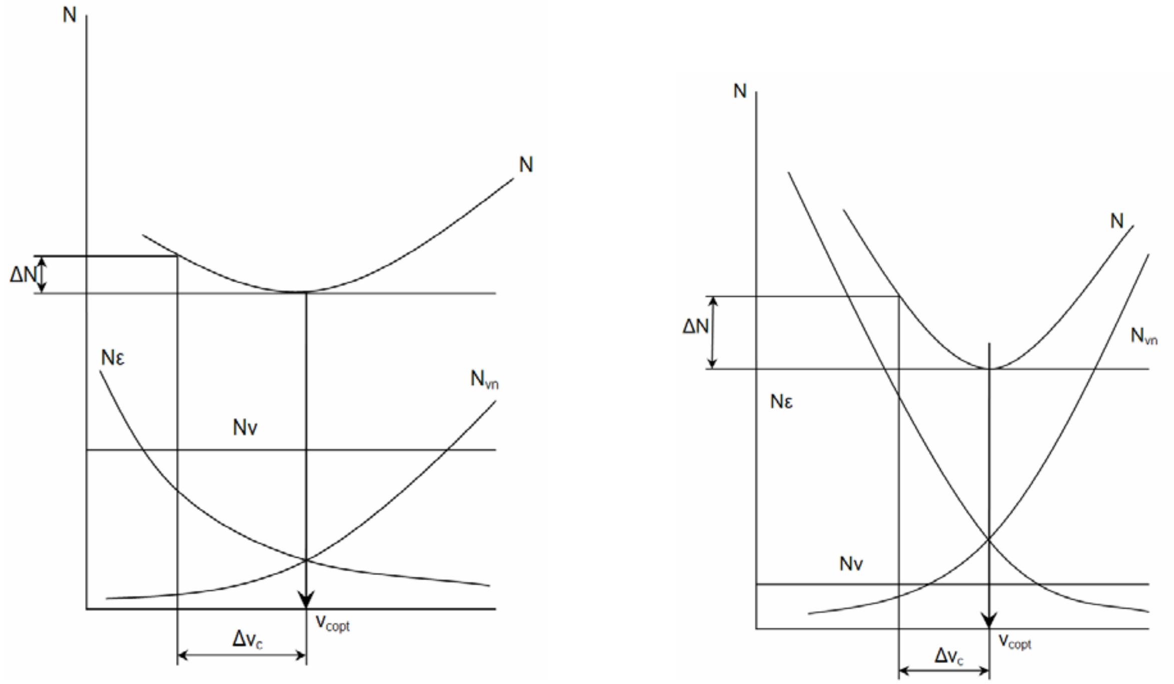
Optimization of cutting conditions is always realized according to a optimization criterion within a restriction (restrictive conditions given by production conditions).

Working process is always limited by a certain group of restrictive conditions. It is possible to formulate these conditions mathematically as inequations. The exception is the complex Taylor´s relation that is an equation.

Using more expensive production installation the costs raise more rapidly. They reach minimum at higher cutting speed than when utilizing usual machines.

Disobedience to this relation leads to sharp rise of production costs when machining using the CNC machines. The basic cost development scheme is in the fig. 1.1.

In market mechanism it is required to produce a product in such economic conditions so that its sale price be acceptable and attractive. To start thinking about a production process it is necessary to get an idea about its cost structure.



Conventional machining
Konvencionalna obrada

CNC machining
CNC obradni

Figure. 1.1. Dependence of *N* production costs and their components on cutting speed v_c . N_c – costs on machine work, N_v – secondary work costs, N_{vn} – costs to device exchange.

Slika 1.1. Ovisnost troškova proizvodnje i njihov utjecaj na brzinu rezanja v_c . N_c - troškovi stroja rada, N_v - trošak pomoćnih rada N_{vn} - trošak zamjene alata

3. Mathematical Formulation of Production Costs

We attempt to describe the criteria for minimum production costs. We shall consider only the costs items that are dependent on cutting conditions. Consequently, total costs may be given by the relation [8,9] :

$$N_c = N_s + N_n + N_m \qquad (2)$$

where:

N – production costs to calculate an operational section,[€],

N_s - costs to machine labor per an operational section, [€],

N_n – costs to machines related to the operational section, [€],

N_m - costs to exchange or offset of a worn-out device related to the operational section, [€],

Individual cost units may be formulated as follows:

For labor costs of a machine holds:

$$N_s = \tau_{As}\left[k_c \frac{M_o}{60}\left|1+\frac{RNS_{pl}}{100}\right| + \frac{N_{hs}}{60}\right] = \tau_{AS} N_{sm} \qquad (3)$$

Where:

N_{sm} are costs to one minute machine labor, [€. $\min^{-1}$],

N_{hs} – hourly costs to machine operation, [€. h^{-1}],

M_o – operator´s wages including social and health insurance,[€. h^{-1}],

RNS_{pl} – planned operational costs of a department, [%]

k_c - increment shift time, (usually 1, 11-1,15),

τ_{As} – machine time, [min.]
Hourly costs to machine operation may be formulated:

$$N_{hs} = O_s k_{us} + C_E \tag{4}$$

$$O_s = \frac{C_s}{Z_s CFS_{EFPL}.SM.k_{vs}} \tag{5}$$

Where:
O_s – is the write-off of a machine,[€. h^{-1}],
C_s – a machine price, [€],
C_E – electricity price (middle value of long-term average or educated guess), [$€/h^{-1}$],
Z_s – machine operational life in years,
CFS_{EFPL} – machine time fund planned in hours per year and shift,
SM – shift,
k_{us} – reparation index and machine maintenance index,
k_{vs} - index of time-utilization of a machine.

Optimization of cutting conditions is convenient to realize by a complex calculation whose outputs are optimal values of cutting conditions and durability of a cutting wedge. According to complexity it is necessary to use a computer with appropriate software.

Restrictive conditions are given by a working machine (its performance, cut-off twisting moment of retentive unit, cut-off size of cutting power elements, range of twists and offsets), a device (cutting material, geometry, surface roughness), material of a work-piece, cutting environment, requested qualitative parameters. [7,8,9]

For complex optimization calculation of cutting conditions mostly linear parametric programming was used. The mathematical apparatus comes out of linear or linearized restricting conditions. In connection with the development of production technology the utilization of non-linearized restricting conditions arose. It related for example continuous, non-linearized restricting conditions from the point of twisting moment (twist of a work-piece in a chucking device) and a bending moment (extraction of a work-piece one-sidely attached in a chucking device) by machines with high rotational frequency.

Apart from the continuous non-linearized restricting conditions more and more non-continuous restricting conditions occur. Before all, it relates different characteristic of working machines performance. Mathematical methods of cutting conditions optimization with these restricting conditions lead to interval optimization tasks.

For example, two restricting non-linearized conditions are mentioned.

For linear process of performance characteristic for performance holds the following line-equation:

$$P_e = k_l\, n + q_1 \tag{6}$$

Where:
k_1 and q are constants.

For the process of performance it is possible to derive for example for turning operation a restricting condition as follows:

$$a_p^{x_{pc}} f^{y_{pc}} n - \frac{10^3 60 k_1 \eta}{k_{Fc}\pi D} n \le \frac{10^3 60 q_1 \eta}{k_{Fc}\pi D} \tag{7}$$

At chucking devices at high rotational frequency under influence of centrifugal force opening of jaws and lowering of chucking power occurs. Even if the chucking devices are constructed specially to restrict the occurrence, at these devices it is possible to come out of the assumption that the decrease of chucking power is given by centrifugal power on jaws, at one jaw it is possible to think about dependence of chucking power *Fu* on rotational frequency n as follows:

$$F_u = F_{uo} - k_n n^n \tag{8}$$

Where:
F_u is chucking power influencing the jaw,[N],
F_{uo} - chucking power influencing the jaw, yet : n=0, [N],
k_n - constant

The k_n constant can be drawn from the details of a manufacturer as the decrease of chucking power at maximum rotational frequency of a spindle.

From the point of maximum acceptable rotational moment for 3-jaw chucking device is applicable:

$$M_{k\max} = 3F_u \mu \frac{D_u}{2} \tag{9}$$

Where:
D_u – tightening average,[mm],
μ Rubbing index between a jaw and a work-piece,

After substitution and modification there are restrictive conditions as follows:

$$a^{yFc} f^{yFc} + \frac{3\mu D_u k_n}{k_{Fc}} n^2 \le \frac{3\mu D_u F_{uo}}{k_{Fc} D} \tag{10}$$

It is clear that for general optimization of cutting conditions it is important to use different mathematical apparatus from linear programming or linear parametric programming. It mainly relates the analytic methods implicit in the analysis of possible solutions; the gradient method, geometric modeling or it is also possible to use suitable optimizing software.

Win present, with regard to stochastics of cutting process it is possible to deal with optimization with the output of machine serviceability with confidence interval. The input then does not have to be the Taylor´s complex relation but the table of combinations: serviceability, cutting speed, displacement, depth of cut. It is important to emphasize on the fact that concrete data that relate given company must be brought into the optimizing software as results from preceding analysis. The results of optimizing procedures at production of the same component in various companies lead to different values of cutting conditions and to different production costs.[3,4,9]

The important part from the point of reliability of working process presents it monitoring. The table no. 1.1. introduces main subjects of eventual monitoring.

Table 1.1. Main subjects of eventual monitoring
Tablica 1. 1. Ključni parametri za moguće praćenje

	Time is critical	Time is not critical
Working machine	CNC managing collision	Precision Thermal dilatation
Cutting machine	Destruction of cutting edge Onset of a machine	Deterioration of cutting gusset Presence of a machine Setting of a machine
Work-piece	Parameters of a work-piece Shape of a work-piece Roughness of working surface	Measures of a raw product Working material Surface integrity
Cutting process	Oscillation Cutting power, oscillation moment Performance Chip shaping	Cutting environment

4 . Conclusion

From the point of optimization of machine serviceability and cutting conditions, the most important part is machine monitoring. It means the monitoring of serviceability that has certain dispersion for concrete working conditions. Afterwards, the optimization performs for center of dispersion and exchange of individual machines is determined by the monitoring device. In the case of working without work-monitoring of a cutting machine the constant c_v is determined with high level of security. Next, it is possible to monitor total deterioration of a machine or of parts of a cutting edge as well. Monitoring of cutting process is realized by appropriate sensors whose outputs are processed using appropriate logic.

5. Referencces

Cited references [1 - 9] in the article text.

REFERENCES

[1] BERGELIS, A. : Impact of collaborative manufacturing engineering on production variety and efficiency. *10th International Conference: New Ways in Manufacturing Technologies, 2010*, Prešov, pp. 95-102, ISBN 978-80-553-0441-0

[2] HIRANO, H. : *5 Pillars of the visual workplace.* Productivity Press, Portland, Oregon, 1998.

[3] HOSHI, T. : High productivity machining research in Japan. *Journal of Applied Metal*, *Working* 4 (3), 1986, pp. 226-237

[4] HRUBINA, K.., SEBEJ, P. : Methods of artificial intelligence for solution of selected tasks of technological processes optimisation In: *Manufacturing engineering*. Vol. 7, no. 4 (2008), pp. 64-67. - ISSN 1335-7972

[5] LUXHOJ, J, T., RISS, J, O., THORSTEINSSON, U. : Trends and perspectives in industrial Maitenance Management. *Journal of Manufacturing Systems* vol. 16, 6/1997

[6] MÁDL, J. : Computer – Aided determination of machining conditions. Science Report CEEPUS, Kielce 2010, pp.97-103. ISBN 978-83-88906-56-5

[7] MÁDL, J., KVASNIČKA,J. : Optimalizace obráběcího procesu. Praha, ČVUT, 1998, 168

[8] VASILKO, K., BOKUČAVA, G.: *Technológia automatizovanej strojárskej výroby (The Technologie of Automatization of Manufacturing Production*) Bratislava, ALFA, 1991, 275 s., ISBN 80-05-00806-6

[9] VASILKO, K.: Analysis of the Impact of Cutting on Machining Process, Manufacturing Engineering, issue 1, year IX, 2010, pp 5-9