DETERMINATION OF CONDITIONS ENSURING COST PRICE REDUCTION OF MACHINERY

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A new theoretical method which is used to define conditions of reducing the machinery cost price has been proposed. This method is based on functional interconnection between the major heads of expenditure. It has been analytically proved that the machining cost price, depending on production efficiency has its extremum (minimum) specified by the cutting tool wear rate. This fact made it possible to determine the optimal conditions of machining according to the criterion of the least cost price. By means of diamond grinding new conditions necessary for machining cost price reducing have been determined. They are maintenance of the optimal cutting relief of grinding wheel working face, that ensures its fast cutting capability and increase in product efficiency. The influence of dimensionless coefficient that determines the dulling degree of a single-point diamond on machining cost price has been demonstrated. Knowing this coefficient, it is possible to compare different variants of grinding in a scientifically grounded way and choose the best one according to the criterion of the least machining cost price.

Key words: machining cost price, the prime machining process time, diamond grinding, tooling price.

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ВИЗНАЧЕННЯ УМОВ ЗМЕНШЕННЯ СОБІВАРТОСТІ ВИГОТОВЛЕННЯ ДЕТАЛЕЙ МАШИН

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Запропоновано новий теоретичний підхід до визначення умов зменшення собівартості механічної обробки деталей машин, заснований на встановленні функціональних взаємозв’язків між основними статтями витрат. Аналітично встановлено, що собівартість обробки залежно від продуктивності обробки має екстремум (мінімум), обумовлений ступенем зношування різального інструмента. Це дозволило визначити оптимальні умови механічної обробки за критерієм найменшої собівартості. На прикладі алмазного шліфування аналітично визначено основні умови зменшення собівартості обробки, які полягають у підтримці на робочій поверхні шліфувального круга оптимального ріжучого рельєфу, що забезпечує високу ріжучу здатність круга й підвищення продуктивності обробки. Доведено переважний вплив безрозмірного коефіцієнта, що визначає ступінь затуплення алмазного зерна, на собівартість обробки. Знання цього коефіцієнта дозволяє науково обґрунтовано підійти до порівняння різних варіантів шліфування й вибору найкращого за критерієм найменшої собівартості обробки.

Ключові слова: собівартість обробки, основний технологічний час обробки, алмазне шліфування, ціна інструмента.

ОПРЕДЕЛЕНИЕ УСЛОВИЙ УМЕНЬШЕНИЯ СЕБЕСТОИМОСТИ ИЗГОТОВЛЕНИЯ ДЕТАЛЕЙ МАШИН

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Предложен новый теоретический подход к определению условий уменьшения себестоимости механической обработки деталей машин, основанный на установлении функциональных взаимосвязей между основными статьями затрат. Аналитически установлено, что себестоимость обработки в зависимости от производительности обработки имеет экстремум (минимум), обусловленный степенью износа режущего инструмента. Это позволило определить оптимальные условия механической обработки по критерию наименьшей себестоимости. На примере алмазного шлифования аналитически определены основные условия уменьшения себестоимости обработки, состоящие в поддержании на рабочей поверхности шлифовального круга оптимального режущего рельефа, обеспечивающего высокую режущую способность круга и повышение производительности обработки. Доказано преобладающее влияние безразмерного коэффициента, определяющего степень затупления алмазного зерна, на себестоимость обработки. Знание этого коэффициента позволяет научно обоснованно подойти к сравнению различных вариантов шлифования и выбору наилучшего по критерию наименьшей себестоимости обработки.

Ключевые слова: себестоимость обработки, основное технологическое время обработки, алмазное шлифование, цена инструмента.

In market economy conditions the question of machine details cost price decrease becomes extremely important, as long as it is connected with competitive machine-building production. As we know, it is possible to decrease the cost of machine details production using the up-to-date, efficient, highly-performing and energy-efficient technologies, equipment and tools, which provide the increase in labor production. However, there arises an intractable problem of optimal route-operational technology determination to produce the specific detail according to the criterion of the least cost price. Traditionally, this task is settled through structurally-oriented optimization with the use of empirical dependence for machining cost price calculation. For this purpose the technologist or planning engineer, grounding on his experience, intuitively comes up with several variants of workflow, describes them mathematically and chooses the most efficient one according to the cost price criterion. However, this method gives no guarantee in choosing the optimal variant as it may not be one of the examined variants [1; 2].

To choose the optimal method of machining in a scientifically grounded way the theoretical (analytical) approach to set the task of structurally-parametric optimization should be taken. This approach adds up to analytical description of machining cost price and determination of conditions for its decrease [3; 4]. This makes it possible to use the potential of hi-tech equipment and tools to the utmost extent.

The aimof the work is to provide theoretical basis for conditions that enable to decrease machine details cost price and develop practical recommendations for increasing the economic efficiency of manufacturing.

Taking into account three main items of expenses, the cost price C is calculated according to the scheme below:

$$C = n_1 \cdot t_H \cdot S_1 \cdot k + n_2 \cdot C_o + S_2 \cdot W \cdot t_H, \qquad (1)$$

where n_1 and n_2 stand for the number of machined details and supplied tools, pcs;

$t_H = Z \cdot t_0$ is the time allowance necessary to machine one detail, h;

t_0 is the prime process time necessary to machine one detail, h;

Z is the coefficient that reflects the amount of idle time in machining one detail towards the prime time (Z > 1);

S_1 is the worker's tariff rate, UAH/h;

k is the coefficient, that includes all possible charges (taxes) imposed upon the worker's salary;

C_o is the cost of one tool, UAH;

S_2 is the cost of an energy unit, UAH;

W is the supplied power of the manufacturing process, W.

The equation (1) includes 3 main heads of expenditure connected with the worker's salary, cost of the tools, and energy supplied while working at the lathe.

As follows from the equation, it is possible to decrease the machining cost price through decreasing the parameters t_H, n_2, C_o, W. It is common knowledge that parameters t_H and n_2 are connected with each other through the machining conditions (i.e. cutting conditions, tools characteristics etc.). That is why it is necessary to know the functional relations between t_H and n_2 parameters, calculated in an analytical or empirical way, to ground the ways for decreasing the cost price of machining conditions C. These relations are not usually taken into account within the process of calculation, but for certain variants for quite specific values of t_H, and n_2. As a result, specific decisions, which are usually taken, leave much to be desired. In order to get the optimal general solution it is important to know functional relations between the first and the second summand of the equation (1), neglecting the third one because of its infinitesimality. In other words, it is necessary to subordinate the economic formula of machining cost price C to the technological regularity in the form of functional relation between t_H and n_2, i.e. to unite economic and technologic knowledge. This attitude provides completely new possibilities to design technological and preparation manufacturing process.

For example, in the given equation substituting the formula for the used instruments take-off n_2 expressed in terms of t_H, results in machining cost price C extremum (minimum) and optimal values of the t_H and n_2 parameters. This enables to compare various technological machining schemes for different equipment, and cutting conditions, cutter characteristics, ground the conditions necessary for the decrease in t_H, n_2, and C_o parameters on the equal basis (This can be fulfilled through use of the wear-resistant coating of the tools, hi-tech machining, new tools design etc.).

The above-mentioned fact helps to determine the optimum machining parameters by the criterion of the least cost price in respect of diamond grinding, which is one of the most effective methods used to improve quality and production efficiency as well as decrease production expenses.

The equation (1) has been transformed taking into account the following ratios:

$$t_0 = \frac{V_0}{Q}; \quad V = n_1 \cdot V_0; \quad T = \frac{h}{V_W};$$

$$V_W = \frac{Q_W}{\pi \cdot D_d \cdot B}; \quad q = \frac{Q_W \cdot \rho_a \cdot \alpha}{Q \cdot \rho_M},$$

where V_0 is the material size, which is removed from one detail, m^3 ;

Q is the production efficiency, m^3/sec;

V is the cumulative material size, which is removed from n_1 details, m^3;

h is the of wheel diamond cover thickness, m;

B, D_d is the working body width and the wheel diameter, m;

Q_W is the wheel diamond cover of the size, which is worn out per a time unit, m^3/sec;

q is specific diamond consumption, kilo/kilo;

ρ_a, ρ_M are diamond and proceeded material density, kilo/ m^3;

α is the coefficient that considers the size of diamond powder in the total wheel diamond covering size.

Neglecting the third summand in the equation (1) due to its infinitesimality, the above transformation cause the following change in the equatian:

$$C = V\left(\frac{A_1}{Q} + \frac{C_o}{V_{diamond}} \cdot \frac{\rho_M}{\rho_a \cdot \alpha} \cdot q \right)_1, \qquad (2)$$

where $V_{diamond} = B \cdot h \cdot \pi \cdot D_d$ is the wheel diamondiferous covering size, m^3;

$A_1 = S_1 \cdot Z \cdot k$.

Parameters $V_{diamond} \cdot \rho_a \cdot \alpha = m_a$ determine the weight of single-point diamonds, and the ratio $C_o / m_a = C_{01}$ defines the unit value of diamond powder mass. It has been experimentally grounded, that there is a functional linkage between the variables Q and q: $q = \beta \cdot Q^m$, where β and m are parameters established experimentally (fig. a). Considering all above-mentioned the equation (2) has been described as:

$$C = V \cdot \left(\frac{A_1}{Q} + C_{o1} \cdot \rho_M \cdot \beta \cdot Q^m \right). \qquad (3)$$

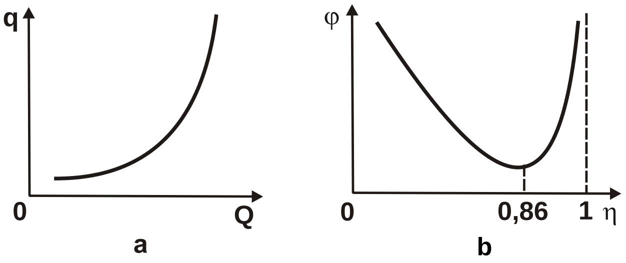

Fig. **Function of q from Q (a) and of φ from η** (b)

It is obvious that the machining cost price C under the condition of production efficiency changes alters according to extremum function. Differentiating function C by variable Q and equating the first derivative to null, we determine extremum value Q_{ex}:

$$Q_{ex} = \left(\frac{A_1}{C_{o1} \cdot \rho_M \cdot \beta \cdot m} \right)^{\frac{1}{m}}. \qquad (4)$$

Under the condition that $m \geq 2$ the second derivative C''_q in the extremum point is positive, i.e. the minimum machining cost price C.

Basing on the equation (4), it is possible to augment Q_{ex} increasing $A_1 = S_1 \cdot Z \cdot k$ and decreasing C_{01}, ρ_M, β, and m parameters. In this case the parameters C_{01}, β, and m are determined by single-point diamonds durability. Hence, the characteristics of single-point diamonds affect Q_{ex} and machining cost price ambiguously.

It is necessary to mention that optimization problem solution capabilities based on the experimentally determined equation $q = f(Q)$ are quite limited, as the equation (4) does not cover the parameters of grinding conditions and properties of the wheel and its details. Taking this into account, machining cost price may be analyzed with the help of analytical equation $q = f(Q)$ [5]:

$$q = \frac{\rho_a \cdot \alpha \cdot HV}{\rho_m \cdot c \cdot P_y \cdot a \cdot \eta^3} \cdot \sqrt{\frac{\pi \cdot tg\gamma \cdot \sigma_{comp} \cdot HV}{(1-\eta)}}, \qquad (5)$$

where σ_{comp}, HV is compression resistance and material hardness, N/m^2;

$P_y = F_y \cdot B$ determines standard pressure, N/m^2;

a is machined sample cross-sectional thickness, m;

γ is half of the grain top angle;

η is the dimensionless coefficient that correlates in the interval 0 … 1 and determines grain dulling speed (for "sharp" grain $\eta \to 0$, for dull grain $\eta \to 1$);

c is a coefficient, which characterizes grain endurance, N/m^3.

According to the equation given above specific diamond consumption q obeys the extremum function (fig. b), where $\varphi = \eta^{-3} \cdot (1-\eta)^{-0,5}$. In case of η = 0 and η = 1 specific diamond consumption goes to infinity. The minimum of the function φ is reached when η = 0,86. Production efficiency is determined by the equation [5]:

$$Q = \frac{2 \cdot V_d \cdot F_y \cdot (1-\eta)}{\pi \cdot tg\gamma \cdot HV}. \qquad (6)$$

If $\eta \to 1$ (i.e. when grinding with dull grains), Q goes to null (Q → 0). The equations (5) and (6) are substituted into (3):

$$C = V \left[\frac{\pi \cdot tg\gamma \cdot HV \cdot A_1}{2 \cdot V_d \cdot F_y \cdot (1-\eta)} + \frac{C_{o1} \cdot \rho_a \cdot \alpha \cdot HV}{c \cdot P_y \cdot a \cdot \eta^3} \cdot \sqrt{\frac{\pi \cdot tg\gamma \cdot \sigma_{comp} \cdot HV}{(1-\eta)}} \right] \cdot \qquad (7)$$

When the coefficient η increases, the same happens to the first summand, but the second one decreases (considering only the left part of the function $\varphi - \eta$.

If η = 0 the second summand goes to infinity. Hence, while η is increasing the machining cost price C will initially, decrease from infinity to some definite level (minimum C), and then increase. Machining cost price minimum is reached when η < 0,86. The first derivative of the machining cost price C upon η has been taken to determine the extremum value η and the obtained formula equates with null:

$$\frac{(3 - 3{,}5 \cdot \eta) \cdot (1-\eta)^{0,5}}{\eta^4} = \frac{A_1 \cdot c}{2 \cdot V_d \cdot C_{o1} \cdot \rho_{a \cdot \alpha \cdot B}} \cdot \sqrt{\frac{\pi \cdot tg\gamma}{\sigma_{comp} \cdot HV}}. \qquad (8)$$

The equation (9) includes two variables F_y and V_d. With their increase C_{min} definitely decreases (in case η = const), and the product efficiency raises. Hence, the decrease in machining cost price C_{min} is caused by the increase in productivity Q. But the decrease in C_{min} and increase in Q are limited. The obtained results of the research have been used at the leading machine-building enterprises of Ukraine to upgrade the technological details machining process on the basis of highly-effective diamond grinding use.

Summing up the results of the research, the following conclusions have been made:

1. The work deals with the new theoretical method of determining the conditions that enable to decrease in the details machining cost price. The method is based on finding functional linkages between the major expenditure heads, that are connected with the worker's salary, tools value and energy supplied while working at the lathe.

2. According to the performed calculations, machining cost price, depending on the efficiency, has its

extremum (minium), which is conditioned by the tool wear rate. This enabled to determine the optimum machining conditions by the criterion of the least productivity.

3. In terms of diamond grinding there the new condition necessary for machining cost price reduction has been determined. It is maintenance of the grinding wheel working face optimal cutting relief, that ensures its fast cutting capability and increase in production efficiency.

Taking into account the prevailing influence of dimensionless coefficient η on the machining cost price C, it is necessary to find experimentally the value of this coefficient for different grinding wheels in the given research. This will enable to compare different types of grinding in the scientifically-grounded way and choose the best one by the criterion of the least machining cost price.

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