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Mechanics

Modernization of Metalworking Machines

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Abstract. In modern mechanical engineering, along with advanced methods for material distribution and dosing, the traditional method of mechanical processing of materials remains an urgent issue. The performance of these operations is ensured by turning and milling machines. In Georgia, a significant number of machine tools manufactured in the former Soviet Union are still operation, However, their efficiency is very low- both in terms of their ability to achieve the desired complex geometric parameters in metal processing, due to the shortage of experienced operators with special skills. Their involvement in the metalworking processes limits the production capacity, and the high remuneration requirement for a highly qualified operator increases manufacturing costs. The presented study introduces effective methods and mathematical models of modernization. Modern 3D design modeling was also employed using modern software tools, which allowed us to minimize possible permissible errors during the implementation process. *© 2025 Bull. Natl. Acad. Sci. Georg.*

Keywords: metal, cut, machines, modernization

Introduction

In modern mechanical engineering, along with advanced methods for material distribution and dosing, the traditional mechanical processing of materials remains an urgent issue. Turning and milling operations constitute a large percentage of operations included in this method. This figure is significantly higher in individual production and in the field of equipment repair. The performance of these operations is ensured by turning and milling machines. The publication presents an approach to improving the efficiency of machines through modernization and software enhancement.

A significant number of machine tools manufactured in the former Soviet Union still exist in Georgia. However their efficiency is very low. This is due, to their limited ability to accept the desired complex geometric parameters in metal processing, and on the one hand, and the other to the shortage of experienced operators with special skills. Their involving in the metalworking processes limits the capabilities of the enterprise, and the high remuneration requirement for a highly qualified operators increases the cost of manufactured products.

Taking into account the above factors, a researcher team from the Georgian Technical University conducted a market survey, studying the cost of existing analogue equipment, on the basis of which the team developed a project proposal to increase the efficiency of old equipment, The project was implemented with the funding of the Shota Rustaveli Georgian National Science Foundation.

During the development of new equipment, project submitters were required to provide an economic assessment of the decisions made, and technical parameters and system structural schemes must be linked to the selected technical options. Economic efficiency calculations are based on the ratio of the costs incurred to implement the decision and the effect obtained after its implementation.

During the analysis of design, technological and organizational solutions, along with solving optimization problems, comparative economic calculations were carried out, which showed us how effective this or that option was. Comparative economic efficiency analysis was carried out in terms of cost, natural, basic and additional indicators.

Method

The following general indicators of comparative efficiency are adopted: reduced costs, comparative economic efficiency coefficient, the payback period for additional capital investments, annual comparative economic efficiency coefficient, which is the ratio of the difference in the cost of S' annual production output to the difference in capital K' costs of comparable options (Bissekersky & Popov, 1975). The payback period of additional capital inves-

tments shows the time during which additional capital investments are economically repaid by a more capital-intensive option, which is achieved at a lower cost of production. Its value is the reciprocal of the coefficient of relative economic efficiency.

$$E = (S_1^{'} - S_2^{'}) / (K_2^{'} - K_1^{'}). \quad (1)$$

$$T = (K_2^{'} - K_1^{'}) / (S_1^{'} - S_2^{'}). \quad (2)$$

If $E \geq E_H$ (where E_H – normative coefficient of relative economic efficiency of additional capital investments) or $T_0 \leq T_H$ (where $T_H = 1/E_H$, then additional capital investments are effective.

The indicators included in the formula K' and S' can be used both in the form of total capital investments per unit of production and in the form of cost of production per unit of production. Capital investments K represent capital investments K' made in connection with the annual N_Γ output of production (in kind or value terms) (Bissekersky & Popov, 1975; Vavilov & Vertolat, 1964).

$$K = K^{'} / E_\Gamma. \quad (3)$$

An important indicator of relative economic efficiency is reduced costs, which are the sum of current expenses (cost) and capital investments reduced to the same dimension, corresponding to normative efficiency indicators.

$$B_{np.i} = S_i^{'} + E_H K_i^{'} B_{np.i} = S_i^{'} + E_H K_i^{'}, \quad (4)$$

where $B_{np.i}$ – the estimated costs for one year are, $S_i^{'}$ current contributions by option, $K_i^{'}$ – capital contributions to production funds under the same option, $B_{np.i}$ reduced costs calculated over the statutory payback period. To find optimal solutions, criteria of relative economic efficiency are used when analyzing constructive, technological and organizational solutions. The selection of the criterion is related to the nature of engineering solutions, but the main criterion of the relative efficiency of options is the reduced costs. When determining the most effective option for a technical solution, it is necessary to select a starting base for comparison, which involves calculations of relative economic efficiency based on the calculation of capital investments and current expenses (cost).

The decision to create and introduce new equipment is made on the basis of calculating annual economic efficiency. The annual economic effect of new equipment is the total savings of all production resources (living labor materials, capital inputs) that the production economy receives as a result of the production and use of new equipment and which is ultimately reflected in the growth of the gross domestic product. The analysis of the annual economic effect is based on the comparison of the reduced costs of the basic and new options, taking into account the comparison condition according to the volume of products produced, quality parameters, time factor, etc.

$$Э_Г = [(S_1 + E_H K_1) - (S_2 + E_H K_2)] N_{G2}, \quad (5)$$

where S_1, S_2 is the cost of annual N_{G2}, output of a product is the cost of the base and new technologies, K_1, K_2 – the total capital investment for the same output of the product is the cost of a unit of output of the product under S_1, S_2 – the base and new technologies, and K the specific capital investment is the cost of the options (Matkarimov, 2021; Mchedlishvili et al., 2016; Vavilov & Vertolat, 1964).

The subsequent task of optimizing the selection of synthesizable parameters is transformed into solving z_m the problem of single-parameter selection of the required parameter size in a dialog mode, which ultimately reduces to selecting the required size of all search parameters.Among the parametric synthesis methods, one of the most important is the synthesis method according to given transient processes. The method of synthesis of control systems using imaginary frequency characteristics (Mchedlishvili et al., 2008).

We obtain $f(t)$ the imaginary frequency characteristic of the function in the argument expression $F(p) = f(t)$, p is the order of the Laplace operator $p = \delta$ by assigning subjective meanings, where δ is considered as an imaginary frequency $w = j\delta$.

The method of approximate determination of originals is based on the characteristics of imaginary frequencies and the condition of proximity to the originals.

Approximating characteristics of imaginary frequencies are generally obtained by using the following types of expressions containing uncertainties and coefficients:

$$F^0(P) = \frac{b_0 + b_1 p}{a_0 + a_1 p + a} \quad F^0(P) = \frac{b}{a_0 + a}. \quad (6,7)$$

These characteristics should primarily take into account the thresholds $F^0(o)$ and $F^0(\infty)$ values of the characteristics. In the synthesis method, the coefficients are given a_i and b_i we find the coefficients of the adjustable coordinate. The coefficients of the adjustable coordinate image are given and we find the $F(P)$ coefficients of the adjustable coordinate image (Bissekersky & Popov, 1975; Matkarimov, 2021; Mchedlishvili et al., 2016).

The general synthesizable and desired coordinate representations can be written as follows:

$$F(p, \sigma_j) = \frac{M(p) + \sum_{j=1}^{S} \sigma_j M_J(p)}{N(p) + \sum_{j=1}^{S} \sigma_j N_J(p)} = x(t)$$

$$\text{and } F^0(p) = \frac{M^0(p)}{N^0(p)} = X^0(t) \quad (8,9)$$

where M, N^0 and N are p and σ_j – polynomials and represent. Synthesized coefficients (parameters). Integral approach to processes $(P, \sigma_j) \cong F^0(p)$.

In expanded form, it reduces to the following dependenci

$$M^0(p) \sum_{j=1}^{n} \sigma_j N_J(p) - N^0(p) \sum_{j=1}^{n} \sigma_j M_J(p) =$$
$$= N^0(p) M(p) M^0(p) N(p) \quad (10)$$

According to the obtained image, we write the conditional equations for $p = \delta_V$ the approximation node l. Then the conditional equations are multiplied by the weighted coefficients $\lambda_V(\delta_V)$.

Functionals built on the derivatives of nonlinear rings are used as a mathematical tool to approximate the processes of nonlinear systems to desired processes Φ_g.

$$\Phi_g = \int_0^{\Gamma_g} \Phi_g^2 [\bar{x}_i(t); \bar{\varepsilon}(t)] \text{ at}, \quad (11)$$

where, $\bar{\varepsilon}(t)$ and $\bar{x}_i(t)$ are the desired functions, the time interval over which the integral approximation processes are realized.

Material

According to the modernization scheme, the drives, electrical circuit, and feed (X, Y, Z) mechanisms of the metalworking machine tools were replaced. They were equipped with a CAD/CAM system. A 3D model, working drawings, and the technological process for their manufacture were developed for modernization.

Conclusion

Using the above methods, we selected the modernization options for both machines and the modernization cost for each of themwere as follows: the amount spent on the modernization of the lathe model 1E61MT required 21000 GEL, while the the milling machine model 6T10 required 16600 GEL.

According to the obtained data, a Chinese-made analogue of the lathe 1E61MT with an automated system TX600-8 costs 48000 USD , excluding purchase tax, while the Chinese automated analogue of the milling machine 6T10, model XH7124, costs 10600 USD plus 15000 USD in purchase costs, totaling of 25600 USD.

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მექანიკა

ლითონდამამუშავებელი ჩარხების მოდერნიზაცია

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** სატრანსპორტო სისტემებისა და მექანიკის ინჟინერიის ფაკულტეტი, საქართველოს ტექნიკური უნივერსიტეტი, თბილისი, საქართველო*

(წარმოდგენილია აკადემიის წევრის ე. მეძმარიაშვილის მიერ)

თანამედროვე მანქანათმშენებლობაში, მასალების დაყოფა დოზირებაში შემავალ თანამედროვე მეთოდებთან ერთად, კვლავ აქტუალურ საკითხად რჩება ტრადიციული მეთოდით მასალების მექანიკური დამუშავება. აღნიშნულ მეთოდში შემავალი ოპერაციების დიდი პროცენტული მაჩვენებელი მოდის სახარატო და საფრეზო ოპერაციებზე. საქართველოში ჯერ კიდევ შემორჩენილია ყოფილი საბჭოთა კავშირის წარმოების ჩარხების სოლიდური რაოდენობა, რომელთა ეფექტურობა ძალზედ მცირეა, ერთი მხრივ, ლითონის დამუშავების სასურველი,

რთული გეომეტრიული პარამეტრების მიღების შესაძლებლობებისა და, ასევე განსაკუთრებული უნარების მქონე გამოცდილი ოპერატორების მხრივ. მათი საწარმოო პროცესში ჩართვა ზღუდავს საწარმოს შესაძლებლობებს, ხოლო მაღალკვალიფიციური ოპერატორის მაღალი ანაზღაურების მოთხოვნა ზრდის წარმოებული პროდუქციის თვითღირებულებას. წარმოდგენილ პუბლიკაციაში მოცემულია მოდერნიზაციის ის ეფექტური გზები, მეთოდები და მათემატიკური მოდელები, რომელთა გამოყენებით წარიმართა პროცესი ცალკეული კვანძებისა და დეტალების დამზადების დროს. ასევე გამოყენებული იყო პროექტირების 3D მოდელირება თანამედროვე პროგრამის გამოყენებით, რამაც შესაძლო დასაშვები ხარვეზების მინიმალურ დონეზე შემცირების საშუალება მოგვცა პროცესის დროს.

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