Improvement of Technological Process Efficiency in Rolling Mills

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Annotation. Increasing requirements for the quality of sheet metal products, especially their dimensional precision, make it necessary to enhance rolling technologies, develop computer-aided systems for process parameters, and introduce improved designs of deformation equipment. Reduced accuracy in many rolled products negatively impacts not only metallurgical processing operations but also leads to poorer technical and economic performance of the final products.

Key words: Technical progress, technical and economic indicators of rolled products, Mathematical modeling, Calculation algorithm, Mathematical models of the rolling process have been solved.

In this context, it became necessary to develop algorithms for determining optimal rolling regimes that ensure the production of strips with the required quality while maintaining equipment productivity. A key feature of the proposed approach is the application of the stochastic automata method as a tool for identifying the extremum of the objective function.Enhancing metal forming processes, particularly rolling, relies on both theoretical analysis and experimental investigation of plastic deformation behavior.

Accordingly, the creation of rolling regimes that improve sheet accuracy—based on mathematical models incorporating real values of metal deformation resistance and actual deformation conditions—as well as the design of new devices for additional strip calibration, is of significant importance.

The increasing demands placed on the quality of sheet metal products, especially regarding dimensional precision, call for advancements in rolling technologies, the development of computer-aided systems for process parameter design, and the introduction of improved deformation unit designs.

The method differs from those currently used in calculating optimal rolling conditions in that it does not require simplification of mathematical models, additivity of the objective function, and linearity of constraints.

To achieve the set goal, the following tasks were solved during the work:

* creation of a laboratory software and hardware complex for studying the process of rolling copper and brass;

* study of force parameters on an operating rolling mill and determination of possible fluctuations in rolling forces;

* study of the influence of contact friction on the rolling forces of metals and alloys of a specific chemical composition;

Mathematical models of the rolling process used in algorithms for calculating optimal modes must satisfy the conflicting requirements of simplicity and high accuracy of calculations. Such accuracy can be ensured only if the influence of the design parameters of the mill, the features of the distribution of elastic deformations of the working rolls along their length at the point of contact with the rolled strip and the influence of the random nature of the change in the parameters of the rolled product are taken into account.

The developed models for calculating the thickness variation of the rolling strip satisfy the specified requirements. Thus, in the model for calculating the longitudinal thickness variation , in addition to the main factors, the combined effect of the roll and winder beating in the thickness variation , the model for calculating the transverse thickness variation, in contrast to the existing ones, takes into account the nature of the distribution of radial flattening along the length of the bridge of their contact with the rolled strip and the effect of random changes in the transverse thickness variation of the rolled blank. The assessment of product quality and the change in parameters characterizing quality must be expressed through clear statistical criteria. This can be achieved most fully using methods of correlation-spectral analysis.

Regression equations have been obtained that relate the values of resistance to deformation of copper and brass with hardness indices, making it possible to expand the areas of application of non-destructive testing methods for mechanical properties of rolled products. One of the most universal methods of search optimization is the method of automata optimization. The emergence of ideas of automata optimization is associated with the creation of automatic control systems (robots) capable of replacing humans, so the first works on the theory of automata were devoted to modeling biological systems. The goal of the research is to build not only automata optimization systems, but also control systems composed of groups of automata.

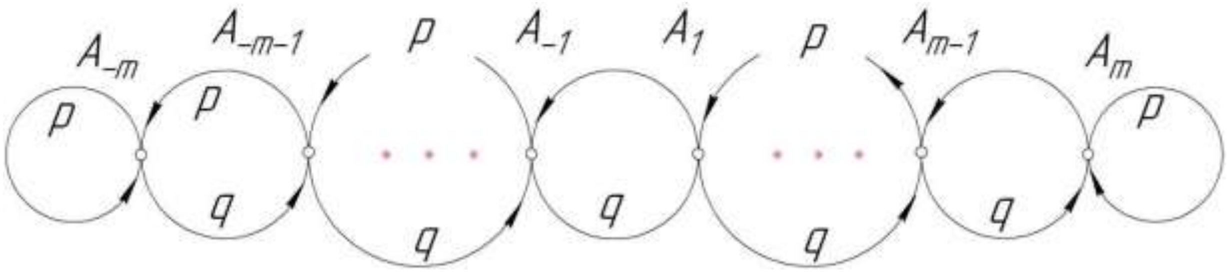

Fig.1.1. Graph of the Tsetlin machine

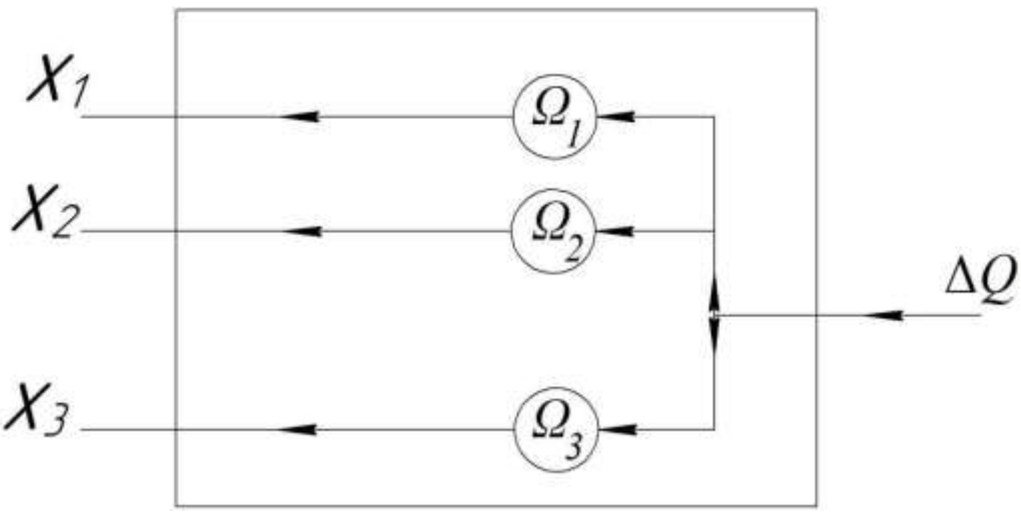

Fig.1.2. Structural diagram of the automaton optimizer

The optimization method is based on the M. L. Tsetlin automaton, which is the simplest element with an internal state that changes under the influence of the external environment in accordance with primitive reactions such as "yes-no", "acceptable-unacceptable", "pleasure-displeasure". Tsetlin's automaton has a memory depth of m and changes internal states in accordance with the graph (Fig. 1.1). The left states of the automaton correspond to negative actions of the automaton, the right ones - positive. The change of states of the automaton occurs according to the direction of the arrows: solid - with a positive reaction of the automaton to the state of the environment and dotted - with a negative reaction. If the automaton is stochastic, then the change of states occurs with a probability p with a positive reaction and a probability $q < p$ in case of a negative reaction.

An automaton optimizer composed of stochastic automata acquires the ability to search for the extremum of functions . both simple and with ravines and several extrema. Studies of the search efficiency of such an optimizer have shown that it decreases with an increase in the dimension of the objective function, while the accuracy of the optimal search increases with an increase in the memory depth of the automata. The dependence of the actual time spent on the optimal search on the memory depth depends on the number of variables and increases significantly only when $n \geq 5$. The spread of the search increases with a decrease in the probability p and is not limited when $p > 0.5$. This phenomenon allows, by increasing or decreasing the probability from 1.0 to 0.5 in accordance with the a priori

dissatisfaction or satisfaction of the search, to search for a global minimum in the presence of several local ones.

The ability of the stochastic automaton optimizer to find a minimum is not impaired even when random errors occur in determining the values of the objective function. In this case, interference filtering is achieved due to the presence of memory in the automata.

The stochastic automaton optimizer is capable of solving complex problems: such as optimizing dynamic objects, stabilizing an unstable object, and finding the optimal structure of a slot machine.

The stochastic automaton optimizer has significant advantages over other optimal search methods. Firstly, due to the parallel operation of the automata, the optimal search time is reduced several times. Secondly, the reliability of the automaton method is much higher than that of existing optimization methods, since individual failures in the operation of the automata are equivalent to some change in the probability *p* and do not change anything in the search procedure. Thirdly, the automaton optimizer works well under conditions of nonlinearity of the constraints on the non-additivity of the objective function, which is a significant difficulty when using the linear and dynamic programming methods currently used to calculate optimal rolling modes.

Much attention is paid to the development of algorithms for calculating optimal rolling modes, especially after equipping mills with automatic control systems.

The main essence of the algorithms for optimizing rolling modes is the choice of the objective function and the mathematical apparatus for finding its extremum. In the overwhelming majority of existing works, the additive criterion is adopted as the objective function - the rolling cycle time, and the dynamic programming method is adopted as the optimization apparatus. However, this method, being a powerful optimization tool, has a number of shortcomings, consisting, firstly, of the difficulty of approaching multidimensional problems, and secondly, of fulfilling the conditions of additivity of the absurd function and linearity of the constraints. These conditions of the dynamic programming method force us to simplify the objective function, taking into account either the rolling time or the energy costs for rolling.

In the work, the method of conjugate with the method of penalty functions is used as a mathematical apparatus of optimization. However, the method of conjugate requires the convexity of the objective function, its algorithm is complex near nonlinear boundaries and requires more search time. In other studies, the method of a mathematical model of the process is used, which, naturally, affects the decrease in the accuracy of calculations. In addition, like the method of dynamic programming, linear programming requires linearity of restrictions.

Methods of optimal control theory can be applied to solve problems of optimizing motion that is described by partial differential equations. Such problems are called distributed parameter problems.

When developing OMD technology, it is often necessary to solve the problem of distributing deformations by passes during rolling, by draws during drawing, in order to ensure maximum productivity while satisfying a number of restrictions that

ensure obtaining high-quality products. Let us solve one of these optimization problems.

The problem of optimal distribution of deformations between dies of multiple wires of a drawing machine with sliding turned out to be a problem of convex programming. It has a single optimum point, which can be found by a direct method by some minimization.

Let's try to find those objects of blooming, the optimization of which can be implemented. Apparently, that part of the technology, which is connected with mechanical movement of the processed metal and tool, can be the object of consideration for the purpose of optimization. Almost all movement of the technology is connected with mechanical movement. The exception is heating of metal before rolling in wells and cleaning of rolled products after rolling on fire cleaning machines, in these cases optimization is possible.

Conclusions

Fundamental knowledge of rolling is essential for practical use in the design of processing technologies for non-ferrous metals and alloys. The provided equations for evaluating deformation and energy-force parameters are applied in determining reduction schedules for sheets, strips, and tapes. The key energy-force characteristics of rolling that must be assessed when selecting a rolling mill are rolling force and torque.

During cold rolling of thin sheets and strips made of hard alloys, elastic deformation (flattening) of both the rolls and the strip occurs, while lateral spreading can be neglected. The efficiency of the rolling process is determined by mill productivity, material yield, and the quality of the final rolled product.

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