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Improvement of Precision Management of Rolling Profiles on Medium-Section Mills

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The problem of stabilization of the average thickness profiles for medium-section mill to reduce the gage by the choice of a rational mode of the automatic control system under conditions of incomplete information

Keywords: SECTIONAL BAR, UNEVEN GAUGE, THICKNESS STABILIZATION, CONTROL IN THE PERTURBATION, DEAD ZONE, SIMULATION OF SYSTEM, SYSTEM EFFICIENCY

Problem Statement

The problem of stabilizing the thickness of the complex profiles on the medium-section mill 550 of PJSC "Evraz DMZ named after Petrovsky" is considered. The effect of a large number of random disturbances on the thickness of the sections, including those which cannot be measured, in the conditions of changing of parameters of the object describes the rolling process as transient one which is subjected to random shocks. The lack of a priori information on the qualitative and quantitative relationships between the parameters of the process leads to the necessity to develop and improve algorithms for the identification and management, providing the construction of the process model on the basis of minimal volume of this information and the creation the effective management system on this basis.

Status of the Issue on the Research Topic

The reasons of uneven gauge of section bar can be the temperature instability of the billets from feed to feed as well as by the length of the strip, the wear of the rolls, the change of chemical composition of the metal from smelting to smelting, etc [1]. The improvement of accuracy of rolling is an important task, which largely determines the specific consumption of the metal, cost, reliability, equipment weight, etc.

It is known that the deviation of stripe thickness during the rolling Is determined by the equation of Golovin-Sims:

$$h = S_0 + \frac{P}{M_K}, \qquad (1)$$

where ΔS_0 is the change of the gap between the rolls in the mill; ΔP is the change of the roll pressure; $M_к$ is mill hardness.

According to the right-hand side of equation (1), there are three causes of thickness deviation from the set point: changing of the gap of unloaded rolls; fluctuations of the rolling force; changing of the stiffness of the mill. The change of the rolling force is the most difficult to describe; it is a complex function and depends on many random factors, the most important of which is the temperature fluctuation of stripes [2].

Automatic control systems of rolling dimensions adjustment have different structures and designs, but they all involve the use of such control methods or combinations as:

- the control of the roll gap (or other parameter) by the deviation of output parameter with its direct measurement;
- the control of the deviation of the output parameter with its measurement by Golovin-Sims method;
- the control of the main disturbances.

The method of management of deviation involves either accurate measurement of the size of a large transport delay, or the use of the method of indirect measurements with low accuracy. The control of the deflection by Golovin-Sims method leads to low efficiency of stabilization systems due to the large static error of control. [3] Using the method of control by disturbance the control goes with the advance, which increases the system efficiency, but it depends, firstly, on the closeness of the connection of controlled disturbances and the initial value and, secondly, on the accuracy of estimates of coefficients of transmission of control circuits.

It is known from the study [4] that the technological process management systems should be the systems of control by disturbances, as rigorous solution of the problem of invariance in the system of adjustment by deviation in general case is not possible. However, the completely invariant systems may be established based on a combined control method. But the main economic effect can be obtained by compensating the disturbances.

Directly experimental study of the functioning of the automatic stabilization system of medium thickness (ASSMT) often requires excessively large costs and time expenditures, and sometimes is impossible in principle. Thus, for example, an experimental study of the functioning of the automatic system is impossible as long as the system is not created. Meanwhile, it is necessary even at the design stage of the system to explore all of its basic properties, in particular the efficiency of its functioning in different modes taking into account all the random disturbances effecting on it.

The study of the functioning of automatic systems for existing rolling mill causes difficulties, so it is advisable to resort to statistical modeling. The rolling mill can be classified to the class of linear models as at the adjusted production the disturbances vary in a narrow range.

The Formulation of the Purposes of the Article

The purpose of this study is to investigate the ASSMT in order to choose rational modes of its operation and achieve maximum efficiency.

The Main Part

Given the stochastic nature of the rolling process, one should use the mathematical apparatus of the theory of probability and mathematical statistics during the analysis of variation in thickness. As an indication of the accuracy of rolling it is convenient to take the dispersivity of deviation of the dimensions of the finished profile. Then, the ratio of thickness dispersion compensated at control to the dispersion of the latter at the absence of control should be used as an indicator of efficiency (ASSMT) [5].

$$\alpha = D_k / D, \qquad (2)$$

where the compensated dispersion is $D_k = D - D_a$, i.e. the difference between the dispersion without the control D and dispersion under control D_a.

It is obvious that this parameter can theoretically take the values within the limits from zero (if $D = D_a$) to one (if $D_a = 0$).

The study [1] shows that in the total range of dispersion of values of the strip thickness 50-60% is occupied by field of fluctuations of medium thickness, and 40-50% is occupied by longitudinal thickness variation.

The rolling mill can be classified to the class of linear models as at the adjusted production the disturbances vary in a narrow range. This class of models is relatively simple in terms of identification. The description of the mill with such a model is based on the assumption that in the limited intervals of both spatial and temporal, the conditions of stationarity and linearity are executed. In addition, the construction of more complex models does not significantly increase the efficiency due to interference influence [3].

In accordance with (1) and taking into account the study [2], the mill stand model can be represented as shown on Figure 1.

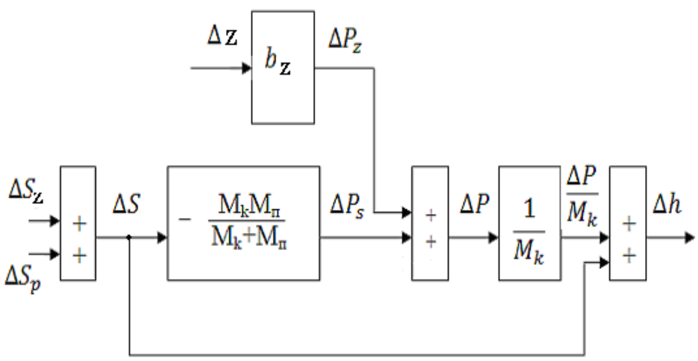

Figure 1. Roll mill stand model: M_K – stand stiffness; M_n – strip stiffness; b_Z – coefficient determining the change of roll pressure ΔP_Z under the effect of disturbances ΔZ; ΔP_S – the change of roll pressure caused by total change of roll gap ΔS, including adjusting effect ΔS_P and change of the gap ΔS_Z due to the wear and offset of rolls; Δh – profile thickness deviation

Let us consider the model of the object taking into account only one main disturbance, i.e. the change of semi-finished rolled stocks temperature. Its model can be represented as following:

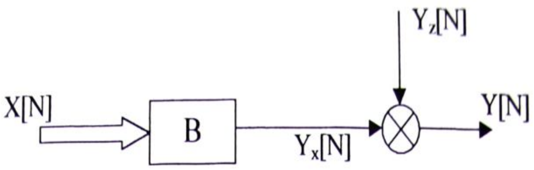

Figure 2. The model of uneven gauge formation

In this case, the total thickness of the dispersion is

$$\sigma_y^2 = \sigma_{y_x}^2 + \sigma_{y_z}^2 = b^2\sigma_x^2 + \sigma_{y_z}^2, \quad (4)$$

where $\sigma_{y_x}^2$ is the dispersion caused by controlled disturbances; $\sigma_{y_z}^2$ is the dispersion of the output caused by interferences.

The estimation of correlation coefficient is as follows:

$$r = \sqrt{1 - \sigma_{y_z}^2 / \sigma_y^2} = \sqrt{1 - \sigma_{y_z}^2 / (b^2\sigma_x^2 + \sigma_{y_z}^2)}. \quad (5)$$

Thus the dispersion of the interference is

$$\sigma_{y_z}^2 = b^2\sigma_x^2 \left(1 - \hat{r}^2\right) / \hat{r}^2. \quad (6)$$

The model and the results of simulation modeling of operation of stabilization subsystem of medium thickness of rolling with regard to the mill 550 of PJSC "Evraz DMZ named after Petrovsky" in the package Matlab/Simulink are shown on Figures 3, 4 respectively.

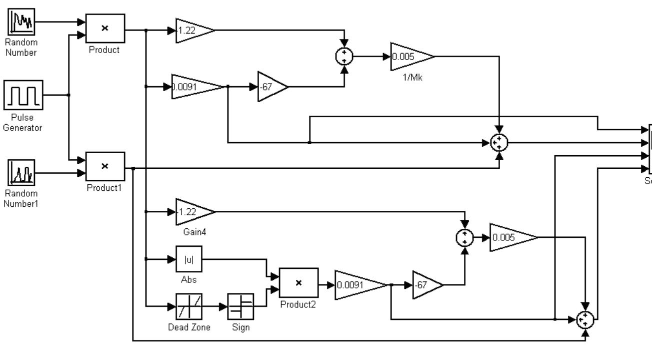

Figure 3. The model of ASSMT

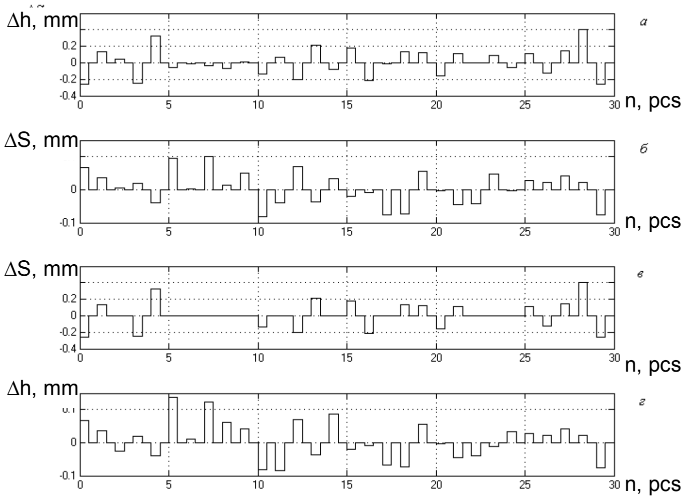

Figure 4. The results of modelling of the control of medium thickness profile control by temperature: a – controlling effect; b—deviation of rolling thickness (without the neutral zone); c – controlling effect (with neutral zone equal to 10 °C); d – deviation of rolling thickness

On the basis of prior information, one can select the range of variation of controlled disturbances which do not affect the output significantly, since the level of interference is comparable to the influence of a controlled variable, i.e select a neutral zone. While selecting this zone one must take into account the relationship of management efficiency with the statistical characteristics of the controlled variables.

To determine the probability of appearing a normally distributed random variable within the interval $(-\varepsilon, \varepsilon)$ the Laplace function was used:

$$\varphi(u) = \frac{1}{\sqrt{2\pi}} \int_0^u e^{-\frac{t^2}{2}} dt, \quad (7)$$

for which the tables were made up [6]. (In this case $t = (\theta - m_\theta)/\delta_\theta$).

From the Laplace function the formula for symmetric interval may be represented as

$$P(|\Delta\theta| < \varepsilon) = 2\varphi\left(\frac{\varepsilon}{\sigma_\theta}\right). \quad (8)$$

According to the formula (8) $\varepsilon = h\delta_\theta$, $h = 0.2,\ 0.4, ...2,$ and using Laplace functions table [6], the dependence of the possibility of appearing the temperature deviations $P(|\Delta\theta| < \varepsilon)$ within the set interval was found (Figure 5).

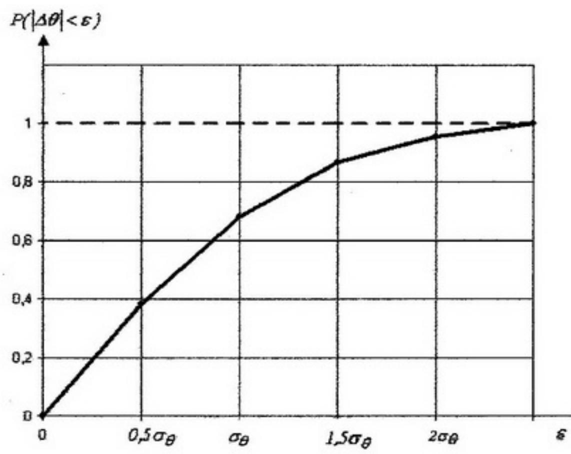

Figure 5. The dependence of $P(|\Delta\theta| < \varepsilon) = f(\varepsilon)$

Then, by varying the size of the dead zone by temperature ($\delta\theta$), the dispersion of the output thickness was estimated. Thus its dependence on the magnitude of the dead zone was calculated, as shown in Fig. 6.

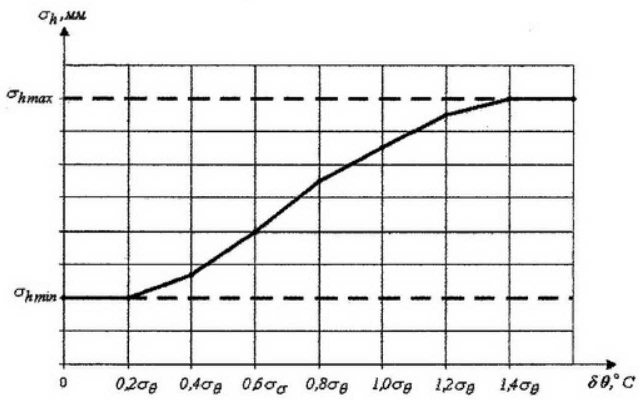

Figure 6. Theoretical dependence of the root mean square deviation from the magnitude of the dead zone

When adjusting the thickness of the rolling in the conditions of interferences, the drive of jack screws is actuated even at a slight deviation of any disturbance. Thus, it is operating almost continuously in start-braking mode, the screw-down mechanisms are worn, and the effect from compensation of minor disturbances is small.

In order to evaluate the relationship of the number of inclusions of jack screws drive with the magnitude of the dead zone it is necessary to determine the probability of presence in the interval which is symmetrical relating to expectation function $(\alpha = m_\theta - \varepsilon;\ \beta = m_\theta + \varepsilon)$. Since the control is performed in deviations from the current average value of the temperature, then the expectation function of the disturbance equals zero, and thus, it is necessary to determine probability of the appearing in the interval $(-\varepsilon \div \varepsilon)$.

The expression for the normal one-dimensional density of distribution of temperature can be written as

$$f(\theta) = \frac{1}{\sigma_\theta\sqrt{2\pi}} e^{-\frac{(\theta - m_\theta)^2}{2\sigma_\theta^2}}, \quad (9)$$

or, taking into account $T_\theta = 0$,

$$f(\theta) = \frac{1}{\sigma_\theta\sqrt{2\pi}} e^{-\frac{\theta^2}{2\sigma^2}}, \quad (10)$$

The analysis of Fig. 6 shows that the implementation of the dead zone $\delta\theta = 15 \div 20^\circ C$ has almost no effect on the dispersion of output thickness at the control system operation. Analyzing the results of the simulation (*see Fig. 5*), we see that at the implementation of the dead zone about 40% of production is rolled at nominal roll gap, i.e. jackscrews drive is not actuated. This significantly diminishes the wear of screw-down mechanism and reduces the consumption of electric energy consumed by the system.

Conclusions

The studies have shown that the automatic control system of medium thickness of rolling reduces its dispersion by 35-65%.

The statistical modeling of the functioning of the control system of average rolling thickness showed that the implementation of the dead zone reduces the wear of screw-down mechanism and reduces power consumption, virtually without reducing the effectiveness of management, and the comparison of experimental and theoretical results showed their correspondence.

In the future, it is advisable to investigate the behavior of the system under the influence as a perturbation not only the semi-finished rolled stock temperature, but also its thickness.

References

1. A.P. Chekmaryov, V.I. Boyko, G.S. *Shcherbina. Issledovaniye stana 550 kak ob'yekta avtomatizatsii i sintez sistemy avtomaticheskogo regulirovaniya tolshchiny prokata.//ASU tekhnologicheskimi protsessami v prokatnom proizvodstve.* – Kyiv: Tekhníka, 1975. - P. 61–65.*

2. A.N. Chernyshev, G.S. Shcherbina, N.I. Beda. *Eksperimental'noye issledovaniye vliyaniya temperaturnogo rezhima na razmery fasonnykh profiley prokata // Metallurgicheskaya i gornorudnaya promyshlennost'.* – 1977. - № 4. - P. 16-19.*

3. V.N. Korotchenko, G.S. Shcherbina, V.V. Kirsanov. *Stabilizatsiya razmerov prokata i trub v*

usloviyakh otsutstviya polnoy informatsii // Teoreticheskiye problemy prokatnogo proizvodstva. - Dnepropetrovsk: 2000. - P. 343-345.*

4. N.S. Raybman. *Osnovy upravleniya tekhnologicheskimi protsessami / Glavnaya redaktsiya fiziko-matematicheskoy literatury.* - Moscow: Nauka, 1978. - 440 p.*

5. V.N. Danchenko, A.Ē. Chernyshev, E.Ē. Panyushkin. *Issledovaniye tochnosti trub TPA-140 zavoda im. Lenina.* - Dnepropetrovsk, 1981. - 16 p.*

6. V.S. Pugachyov. *Teoriya veroyatnosti i matematicheskaya statistika.* - Moscow: Nauka, 1979. - 497 p.*

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Повышение эффективности управления точностью прокатки профилей на среднесортных станах

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Рассмотрена задача стабилизации средней толщины профилей на среднесортном стане с целью снижения разнотолщинности за счет выбора рационального режима работы автоматической системы регулирования в условиях неполной информации.