Evaluation of technological risks in the work of rolling equipment

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Abstract. The approach to serviceability evaluation of the system rolling stand – rolling accessories is considered. The criteria defining the upper and lower levels of the considered system operability are proposed. Practical use of the developed provisions can be illustrated by rolling a circle with diameter 12, 14 mm and accessories No. 12, No. 14 in the conditions of a continuous small-section mill 250-1 of JSC “EVRAZ ZSMK” section-rolling shop. The received graphic data allow problem gaps to be revealed and the differentiated monitoring of the considered system to be organized.

1. Introduction

Forming rolls and their accessories form a single interconnected complex in the rolling mill, the performance and quality of the products being largely dependent on the precise operation of its work. In connection with this, when adjusting and operating the rolling mill-accessory system, it is necessary to take into account the forming conditions in the deformation center of the operating rolling stand. Ignoring the potential of the deformation center often leads to incidents in the system under consideration [1]. Guided by the conception under consideration about the inextricable link between the deformation center and the roll accessories, a technique for assessing the degree of technological risks in the system forming rolls – accessories was developed.

2. Methods of research

In practical implementation of the developed procedure, the first step determines the magnitude of the longitudinal force provided by the friction force reserve of the operating stand, taking into account the deformation conditions and design features of the gauge, and is compared with values corresponding to the system operability criteria [2 - 4]. To determine the performance criteria of the system forming rolls – accessories, we consider two limiting cases: the first one – the longitudinal force resulting from the incidents is so great that it can lead to breakage of the details of the roller accessories, the second one – the roller accessories must perform a large set of operations (holding the bar in the given position, correction before and after the center of deformation, tapering with twisting, etc.), which requires a considerable amount of longitudinal force, which can not provide a reserve of frictional forces in the deformation center of the stand, which leads to bar sticking. The considered situations characterize the upper and lower limits of the system operability.
The upper limit is limited by the strength of the parts of the roller accessories, the most important of which is the reinforcing bar, the lower limit is the magnitude of the longitudinal force required for the accessories to perform the functions assigned to it. Comparing the values of the longitudinal forces corresponding to the upper and lower level of the system’s operability with the amount of effort that the friction force reserve can provide in the deformation area of the serviced stand, the degree of technological risk of the system is estimated.

Dependencies were obtained to determine the upper limit of operability, based on the strength of the reinforcing bar.

For the case of placing the tested gauge in the strictly defined place on the body of roll:

$$Q_{ad} = \left[ \sigma \right] \left( \frac{6(l_m - a_{max})a_{max}}{l_mB_mh_m^2} \right)^2 + 3 \left( \frac{d_m a_{max}}{l_m \alpha_m \eta_m b_m h_m^2} \right)^2,$$

where $l_m$ – the length of the reinforcing bar, mm; $b_m, h_m$ – respectively, the width and height of the bar ($b_m > h_m$), mm; $d_m$ – distance from the rolling line to the reinforcing bar, mm; $a_{max}$ – the maximum distance from the force application to one of the supports, mm; $\left[ \sigma \right]$ – allowable tension, MPa; $\alpha_m, \eta_m$ – correction factors, depending on the ratio of the sides $b_m/h_m$.

When rolling one workpiece for the case of cutting on the rolls of the same gauges:

$$Q_{ad} = \left[ \sigma \right] \left( \frac{1.5l_m}{b_m h_m^2} \right)^2 + 3 \left( \frac{d_m}{2 \alpha_m \eta_m b_m h_m^2} \right)^2,$$

When rolling into two blanks with the same gauges on the body of roll:

$$Q_{ad} = \left[ \sigma \right] \left( \frac{6l_m - B_m - b_{clamp}}{2} \frac{B_m + b_{clamp}}{2} \right)^2 + 1.5l_m^2 \left( \frac{l_mB_mh_m^2}{b_m h_m^2} \right)^2 + 3 \left( \frac{2d_m \left( l_m - B_m - b_{clamp} \right) + d_ml_m^2}{2l_m \alpha_m \eta_m b_m h_m^2} \right)^2,$$

where $b_{clamp}$ – the clamps width at the edge of the body of roll, mm.

The lower level of the operability evaluation of the system rolling stand – roller accessories can be determined on the basis of the tasks solved by the roller accessories during operation.

Roller accessories solves the following main tasks [5]:

1) workpiece supply in a strictly fixed position to a certain gauge and metal removal from the gauge;
2) retention of the workpiece in the required position, in the roll throat during rolling, preventing stalling, providing the given direction of motion after rolling;
3) correction of the roll;
4) workpiece tapering;
5) small plastic deformation of individual thickened parts of the rolling.
All the operations listed above require a certain amount of longitudinal force, which determines the lower level of performance in the system rolling stand – roller accessories. Let us consider how to determine the values of the longitudinal force necessary to perform the tasks of the roll accessories.

The component of longitudinal force ensuring the prevention of stalling, twisting \((Q_t)\), can be determined by the formula:

\[ Q_t = M_{pk} \Theta_c, \]  

where \(M_{pk}\) – the torque necessary for twisting, N·m; \(\Theta_c\) – the relative angle of twisting while keeping from stalling, rad.

The component of the longitudinal force needed to straighten the front or rear ends \((Q_0)\), can be found:

\[ Q_0 = \frac{W_{pl,b} \sigma_s}{x_e \left(1 - \frac{x_e}{l_b}\right)} \mu_b, \]  

where \(W_{pl,b}\) – the moment of resistance under plastic bending, mm\(^3\); \(x_e\) – the distance from the front end of the wiring to the point where the force is applied when straightening, mm; \(l_e\) – length of the wiring, mm; \(\mu_b\) – the coefficient of friction between the bar and the wiring.

The component of the longitudinal force required for plastic deformation \((Q_d)\) of individual thickened parts of the workpiece in the roller accessories:

\[ Q_d = \sigma_s b_0 h_0 \ln \lambda, \]  

where \(\sigma_s\) – the deformation resistance, MPa; \(b_0, h_0\) – respectively, the width and thickness of the bar before entering the rolling stand, mm; \(\lambda\) – the stretching ratio of the thickened parts of the workpiece.

The longitudinal force necessary for the tapering \((Q_k)\) can be determined by the formula:

\[ Q_k = \frac{M_{p,k} \varphi_{cap} l_b}{l_0 l_1}, \]  

where \(M_{p,k}\) – the twisting moment, n·m; \(\varphi_{cap}\) – the full angle of tapering, rad; \(l_b\) – distance between the axes of work rolls and tapering rolls, mm; \(l_0\) – the distance between adjacent stands, mm; \(l_1\) – the value of the capture arc during tapering, mm.

The value of the longitudinal force necessary for the operation of the roller accessories \((Q_n)\) can be determined as the sum of all components by the following general formula:

\[ Q_n = Q_s + Q_t + Q_0 + Q_d + Q_k. \]  

The above formula is general and for each specific pass it should be specified taking into account the features of rolling and the problems solved by the roll accessories.

The condition of trouble-free operation of the system rolling stand – roller accessories can be formulated as an inequality:

\[ Q_{rad} \geq Q_4 \geq Q_n, \]  

where \(Q_{rad}\) – the minimum level of performance in the system rolling stand – roller accessories.
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where \( Q_1 \) is the longitudinal force provided by the friction reserve, MPa.

Carrying out the above inequality ensures the trouble-free operation of the system. Exceeding the indicated limits creates a situation of technological risk, in which the failure of the system is very probable. The possible technological risk for non-fulfilment of inequality (9) is controlled, so if \( Q > Q_1 \), then this situation can be corrected by increasing the degree of deformation in the serviced stand by redistributing the drawing through the passes or reducing the load on the roller accessories when the gauge is changed. In the case where \( Q > Q_{ad} \), the situation can be corrected by redistributing the drawing coefficients in the stands, reinforcing the elements structure of the roller accessories in multistrand rolling with some time overlap.

3. Results and discussion

Method for assessing the system performance rolling stand – rolling accessories is developed using MS Excel application with results interpretation in a graphical form, which is very convenient for analysis. The developed methodology and this software application allow the range of products of the mill to be visually analyzed and problem gaps to be identified from the point of view of the system operation reliability rolling stand – rolling accessories.

The possibilities of the developed technique will be considered using the example of analyzing the working gauges of circles with a diameter of 12, 14 mm and accessories No. 12, No. 14 rolled on a continuous small-section mill 250-1 of a long product rolling mill at JSC “EVRAZ ZSMK”. Calculations were carried out using the above dependencies, the magnitude of the longitudinal force provided by the friction force reserve according to the data of [6] is shown in figure 1. The graph shows the upper and lower limits of the system operability under consideration.

All stands in which the magnitude of the longitudinal force is comparable with the allowable value or exceeds the indicated limits are high risk stands in the system rolling stand – rolling accessories, and require additional attention during the installation of the accessories and during operation. As it follows from figure 1, when rolling circles with a diameter of 12, 14 mm, accessories No. 12, No. 14 on a continuous small-section mill 250-1 of a long product rolling mill at JSC “EVRAZ ZSMK” at an incident on one line in the first stand, the magnitude of the longitudinal force exceeds the permissible value, obtained based on the strength of the reinforcing bar, with the simultaneous incident on two lines in stands from A to 5, the same pattern is observed that must be taken into account when setting and operating the accessories.

![Figure 1. Evaluation of the system performance rolling stand – roller accessories, for rolling circles 12, 14 mm and accessories No. 12, No. 14 on the continuous small-section mill 250-1 of a sort-rolling shop at JSC “EVRAZ ZSMK”.](image-url)
In all passes of the considered example the magnitude of the longitudinal force, necessary for the accessories to perform their functions, is less than the longitudinal force that can provide the reserve forces of friction in the deformation center of the serviced cage, which guarantees the normal operation of the accessory.

4. Conclusion
A new technique for assessing technological risks in the operation of rolling equipment is proposed, which makes it possible to identify potentially hazardous passes and to organize a differentiated monitoring of the system operation rolling stand – roller accessories, to perform sound calculations of details of the roller accessories, to evaluate and correct the gauges in terms of reducing the number of possible incidents.

References
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