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Analytical Model for the Wide-Strip Rolling Mills Working Rolls Wear-Out Failures

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Abstract

The paper proposes a mathematical model for the gradual shape deterioration of wide-strip rolling mills working rolls active generatrixes subject to wear within the working zone during tandem rolling strips of a specified gauge. While modeling, the authors have determined the theoretical dependency needed to estimate the mean life of working rolls according to the transverse strip gauge interference criterion. Gauge interference of tandem-rolled strip transverse section shall be derived from the sum of the values of current shape of upper and lower working rolls active generatrixes, which are calculated based on strip width. In its turn, an active section of each roll shall be calculated for every following strip as a difference between the current roll radius values at the crown middle and that above/below the strip edge, while the shape deterioration rate of active roll generatrixes shall be defined by the difference between the roll wear rates in these sections. To estimate the rate of roll wear during rolling every following strip of the specified gauge, the base dependency of the structure-energy concept describing wear of stationary tribocouplings is used, which has been obtained by simultaneous solution of fundamental equations of molecule-mechanical and structure-energy friction theories. The moment of working roll failure (expected life) is determined based on the condition of achieving the nominal limit by gauge interference of a current strip.

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Keywords: Failure model; Working rolls; Wear; Transverse gauge interference; Durability; Criterion; Life; Energetic and mechanical approach.

1. Problem statement

The most important task of the theory and practice of flat rolled product manufacture is the issue of forecasting durability of working rolls according to the criterion of limit shape deterioration of their active generatrix due to

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non-uniform wear of crown surface in the working zone. As changes of a current roll shape may be described for the specified rolling schedule with mathematical methods, transverse shape of each strip may be controlled as well as the instant of roll failure (their life) may be forecast based on the time of exceeding the specified value by the transverse gauge interference of the next strip.

Engineering estimate of the roll life according to the known gauge enables their change scheduling, forecasting the mill production output, calculating material removal at redressing, roll consumption and their annual demand as well as analyzing possible methods for increase of their durability and roll product quality

The authors could not find any analytic solutions proposed in the literature. In this connection, they would like to offer a variant of physical and analytical model of working roll failures based on the criterion of transverse shape accuracy degradation at strip rolling.

2. Model of generating working roll failures

The design life of working rolls of any finishing stand at the sheet mill may be determined for an estimated rolling sequence of the j th strip batches with due regard to their shape accuracy and based on the general methodological approach to assessment of parameter reliability of process facilities [1] and corresponding theory of forecasting safety margin and durability of machine parts [2-6].

If in compliance with the above theory, the value of transverse gauge interference of the j th (-nd) strip $\delta_{h\,j}$ is taken as an index of working roll state that undergoes changes at its rolling, the prerequisite of their performance shall be the following inequality in this case:

$$\delta_{h\,j} < \delta_{h\,j*} \tag{1}$$

where $\delta_{h\,j*}$ - the limit of the j th (-nd) strip gauge interference calculated for each stand according to COST requirements to this rolled product size.

The value $\delta_{h\,j}$ of transverse gauge interference of each j th (-nd) strip shall be determined by the sum of values of current shapes of active generatrixes of the upper $\Delta^{u}_{p\,j}$ and lower $\Delta^{d}_{p\,j}$ working rolls that were calculated based on the crown width rater than its length:

$$\delta_{h\,j} = \Delta^{u}_{p\,j} + \Delta^{d}_{p\,j} = \left(\sum_{j=1}^{j*}\Delta^{u}_{p\,(j-1)} + \dot{\Delta}^{u}_{p\,j}\cdot t_j\right) + \left(\sum_{j=1}^{j*}\Delta^{d}_{p\,(j-1)} + \dot{\Delta}^{d}_{p\,j}\cdot t_j\right), \tag{2}$$

where $\dot{\Delta}^{u}_{p\,j}$, $\dot{\Delta}^{d}_{p\,j}$ - rates of changing values of current shape of the upper and lower working roll during rolling the j th (-nd) strip according to its width ($j = 1,2,3,...j*$, $j*$ - the number of the batch at rolling which prerequisite (1) is violated);

$\Delta^{u}_{p\,(j-1)} = \dot{\Delta}^{u}_{p\,(j-1)}\cdot t_{j-1}$ and $\Delta^{d}_{p\,(j-1)} = \dot{\Delta}^{d}_{p\,(j-1)}\cdot t_{j-1}$ - values of shapes of active generatrixes of the upper and lower working rolls after rolling the ($j-1$) -th/-nd strip recalculated for the width of j -th/-nd strip. If $j = 1$, the values $\Delta^{e}_{p\,0}$ and $\Delta^{u}_{p\,0}$ represent shapes of active generatrixes of the upper and lower working rolls according to the width of the first rolled strip $B_{j=1}$. They are obtained when an initial grinding shape is imposed by its distortions from roll temperature and force as well as anti-crossbreak corresponding to conditions of rolling the first ($j = 1$) strip. Thermal profile at cold and hot sheet rolling may be estimated with the known methods of E.A. Garber [7, 8], while roll shape deterioration from roll force and anti-crossback is to be assessed according to methods of V.M. Salganik [9];

$t_j = G_j\cdot/(\rho_j\cdot b_j\cdot h_j\cdot V_{n\,j})$ - time of rolling the j -th/nd strip with G_j weight, $b_j\times h_j$ cross section and ρ_j material density; $V_{n\,j}$ - rate of rolling the j -th/nd strip.