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Methods to Decrease Longitudinal Gage Interference of Strips

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The methods to decrease longitudinal gage interference of strips under hot rolling are considered. Implementation of these methods does not require significant material expenses.

Keywords: STRIP, LONGITUDINAL GAGE INTERFERENCE, HOT ROLLING, REDUCTION, REDUCTION MILL

Introduction

The following methods are applied to decrease longitudinal gage interference of strips at hot rolling: acceleration of mill from the leading to trailing end of the strip, use of coil box before finishing train, application of preliminary hydraulic adjusting of reduction mill, additional reduction of trailing end of the strip, which does not require heavy material expenses for implementation [1, 2].

At present, it is possible to reduce gage interference on broad-strip mills with a traditional rolling-mill practice by means of additional reduction of trailing end by screw-down structures in the intermediate or all stands of finishing mill group [2]. As shown in calculations [3], to eliminate completely the gage interference on trailing end of strip 2x1250 mm, as applied to hot rolling broad-strip mill 1680, it is necessary to ensure actual additional reduction in stands No. 5-9 within the limits of $\sum \Delta h_d = 3.2$ mm (**Figure 1**).

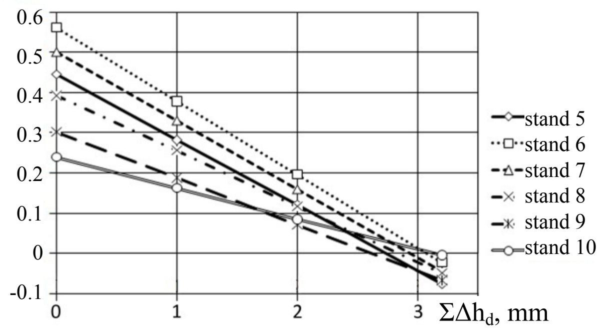

Figure 1. Longitudinal gage interference depending on additional reduction of trailing end for the strip 2×1250 mm in stands No. 5-9 of finishing group for hot rolling broad-strip mill 1680

High response time and insufficient rate of screw-down structures disallow this. Besides, at this additional reduction, the roll force and wear of screw-down structure parts increase.

Results and Discussion

Two methods to reduce a thickness of trailing end at hot rolling considered below expand performance capabilities of rolling mill in the area of precise strip making due to:

- change of roll gap and strip gage by means of adjusting anti-bend force of work rolls;
- temperature increase of trailing end of intermediate strip by limitation (elimination) of water supply on the rolls (strip).

The work rolls are subjected to force action of equilibrating devices or hydraulic bend devices through the necks during the wide strip steel rolling. This effect loads the rolls and stand additionally up to

$$P_Q = P + Q \qquad \text{(Eq.1)}$$

where P – the force in deformation zone; Q – the overall force of rolls anti-bend (or the force due to hydrobalance of the rolls).

The stand columns are elongated additionally and the roll gap and strip gage increase under the force Q action. Change of force Q value along the length of the strip being rolled allows, to certain extent, affecting its gage. Therefore, when rolling a thickened trailing end of the strip, elimination of load Q by switching off a hydraulic system of a bend (counterbalance) of the rolls ensures decrease in strip gage due to shortening of reduction mill columns and accomplishment of additional plastic deformation of metal being rolled.

Strip gage increment at the change of force acting on the rolls can be calculated through expressions (1, 2) or expression (3). Taking into account additional force Q, it will be as follows:

$$\delta h_{\mathrm{i}} = \left[\left(P_i + \mathrm{Q}_i\right) - \left(P_{\mathrm{n}} + \mathrm{Q}_{\mathrm{n}}\right)\right] / \left(M_{st} + \delta M_{si}\right), \quad \text{(Eq.2)}$$

$$\delta M_{si} = M_{si} - M_{\mathrm{sn}};\ M_{si} = \varphi_i \cdot P_i / \Delta h_i, \quad \text{(Eq.3)}$$

$$\varphi_{\mathrm{i}} = \left(0{,}57 + 0{,}62\varepsilon_{\mathrm{i}}\right)\left[1 + 0{,}023\left(\mathrm{R_i}/\mathrm{H_i}\right)^{0.5}\right], \quad \text{(Eq.4)}$$

where R_n – the minimum roll force at the minimum (nominal) strip gage; P_i – the roll force on a thickened part; M_{st} – the modulus of stand rigidity; M_{sn} – the modulus of rigidity for nominal strip gage; M_{si} – the modulus of rigidity on a thickened (or another) strip length; Δh_i – the actual reduction in thickness; ε_i – the reduction of cross-sectional area; f_i – the friction coefficient; R – the radius of rolls; H_i - the initial strip gage; φ_i – the coefficient considering the effect of deformation geometrical parameters and friction coefficient.

Equation (4) for coefficient φ_i is obtained from graphical interrelations [1]. The effect of anti-bend force was estimated by theory for strip (2x1250 mm) rolling as applied to hot rolling broad-strip mill 1680 for finishing train No. 5-10. In practice, the forces of hydraulic bend of the rolls within the limits of Q ≤ 0.2 P are applied to adjust the roll gap. Hot roll force was calculated by means of modelling [4, 5], and strip gage increment (longitudinal gage interference) was calculated by iteration method using equations (2) – (4) [3]. Force Q in stands No. 5-10 was changed within the limits Q_i=(0–0.2)P (n_Q=0–0.2). Partial results of theoretical investigations are presented in **Table 1** and **Figure 2**. Section 2 in **Table 1** corresponds to leading end with minimum gage being rolled with front and back tension, and section 4 – to trailing end that has lower temperature and is rolled with no back tension [3]. Section 2 is rolled at force $R_n=P_2$ and at anti-bend force $Q=Q_2=n_{Qn}P_n$ (n_{Qn}=0.2). According to this condition, for gage interference calculation on section 4, we accept anti-bend forces to be equal to $Q_i=n_{Qi}P_i$ (n_{Qi}=0; 0.05; 0.1; 0.15; 0.2). Thus, for Q_n=const at the maximum value of Q_i (n_{Qi}) and, accordingly, at the maximum elastic tension of reduction mill columns we obtain the maximum strip gage increment on section 4. So, for stand No. 5 at $Q_n=0.2P_n$ (n_{Q2}=0.2) and n_{Q4}=0.2 strip gage increment on section 4 in stand No.5 was δh_i=0.496 mm against δh_i=0 on section 2 (**Table 1**). Elimination of anti-bend force of work rolls at rolling of section 4 (n_{Q4}=0) ensures almost complete elimination of longitudinal gage interference (strip gage increment on section 4) δh_i=0.057 mm (decrease ~ 90 %). In stand No. 10, strip gage increment is eliminated completely (from δh_i=0.292 to δh_i=–0.017 mm) (**Table 2**). According to the calculations, for accepted deformation mode the change of anti-bend force by n_{Q4}=0.01 results in strip gage change by δh_i=0.013-0.024 mm. Smaller value is related to the finishing stand No. 10 where the roll force is less (**Figure 2**).

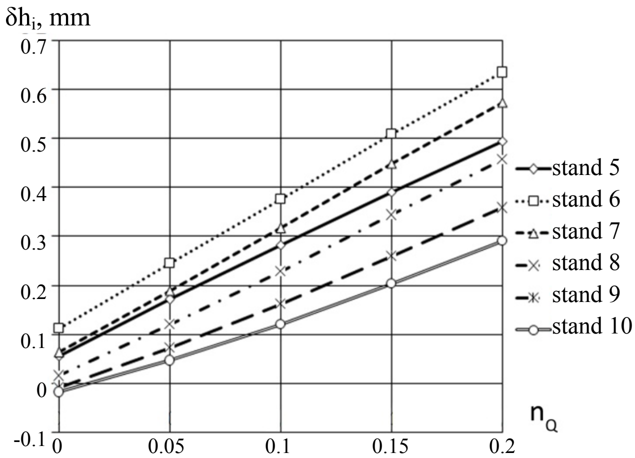

Figure 2. Change of longitudinal gage interference of strip 2×1250 mm at changing value of anti-bend force of work rolls

When strip rolling with equal values $Q_n=Q_i=0.2P$, the strip gage increment δh_i on section 4 occurs due to lower temperature of metal and lack of back tension as compared to section 2 (**Tables 1, 2**).

The anti-bend force for work rolls is created by hydraulic system that supplies oil under cylinder plungers in chocks of the rolls. The maximum pressure of oil is q=30 MPa. Having four plungers with diameter d=105 mm, the maximum anti-bend force will be equal to Q=0.104 MN. At acting roll forces (**Table 1**), this anti-bend force appears to be insufficient to reduce longitudinal gage interference effectively. Intensification of roll neck force Q is ensured by effect of wedge type devices [6], which allow reaching the values of Q≥0.2P.

There is no additional wear of screw-down structure parts and electric power consumption drops at strip gage control by hydrobend. Under real conditions of rolling, it is reasonable to control strip gage in the first stands of finishing train by means of additional reduction by screw-down structures, and in the last two-three stands – by device for work rolls hydrobend. As middle stock moves from roughing train, heat content of metal decreases on a delay table when hydrodescaling after a scale breaker and at rolls cooling by water in the finishing train.

Table 1. Deformation parameters of strip 2x1250 mm from incoming billet H = 20 mm at the various values of anti-bend force on section 4. Stand 5

Parameter	Section 2 at $n_{Q2} = 0.2$	Section 4				
		$n_{Q4} = 0$	$n_{Q4} = 0.05$	$n_{Q4} = 0.1$	$n_{Q4} = 0.15$	$n_{Q4} = 0.2$
H, mm	20.0	20.0	20.0	20.0	20.0	20.0
h, mm	13.000	13.057	13.172	13.283	13.392	13.496
Δh, mm	7.000	6.943	6.828	6.717	6.608	6.504
ε	0.350	0.347	0.341	0.336	0.330	0.325
v, m/s	1.44	1.44	1.44	1.44	1.44	1.44
t_{av}, °C	946	872	873	873	873	873
f	0.366	0.380	0.379	0.378	0.377	0.376
u, s^{-1}	10.8	10.8	10.7	10.6	10.5	10.4
l, mm	47.41	47.40	47.01	46.62	46.24	45.87
p_{av}, MPa	257.0	313.0	309.3	305.7	302.5	299.2
P, MN	15.23	18.55	18.17	17.82	17.49	17.15
M_s, MN/mm	1.87	2.29	2.27	2.25	2.24	2.22
δh, mm	0.000	0.057	0.172	0.283	0.392	0.496

Table 2. Deformation parameters of strip 2x1250 mm from incoming billet H = 20 mm at the various values of anti-bend force on section 4. Stand 10

Parameter	Section 2 at $n_{Q2} = 0.2$	Section 4				
		$n_{Q4} = 0$	$n_{Q4} = 0.05$	$n_{Q4} = 0.1$	$n_{Q4} = 0.15$	$n_{Q4} = 0.2$
H, mm	20.0	20.0	20.0	20.0	20.0	20.0
h, mm	13.000	13.057	13.172	13.283	13.392	13.496
Δh, mm	7.000	6.943	6.828	6.717	6.608	6.504
ε	0.350	0.347	0.341	0.336	0.330	0.325
v, m/s	1.44	1.44	1.44	1.44	1.44	1.44
t_{av}, °C	946	872	873	873	873	873
f	0.366	0.380	0.379	0.378	0.377	0.376
u, s^{-1}	10.8	10.8	10.7	10.6	10.5	10.4
l, mm	47.41	47.40	47.01	46.62	46.24	45.87
p_{av}, MPa	257.0	313.0	309.3	305.7	302.5	299.2
P, MN	15.23	18.55	18.17	17.82	17.49	17.15
M_s, MN/mm	1.87	2.29	2.27	2.25	2.24	2.22
δh, mm	0.000	0.057	0.172	0.283	0.392	0.496

Thus, according to investigation data on continuous mill 1700 [2], fall in metal temperature in stand No.10 by one degree induces increase of strip gage by 0.004-0.007 mm.

The temperature of trailing end of the stock, when entering the first stand of finishing train, is by 40-80°C less than that of leading end. When the stock enters the finishing train, the temperature gradient along the length of the stock drops and is 10-30°C. The temperature difference lengthwise the stock results in increase of finished strip gage on the trailing end. This is promoted also by the absence of trailing end tension during rolling in the finishing train.

The effect of temperature gradient Δt_5 between sections 2 and 4 of the middle stock on the gage increment δh_i (as applied to hot rolling broad-strip mill 1680) is shown in **Figure 3**. Calculations of rolling temperature mode and roll force are carried out by means of modeling [4, 5], and change of gage increment at $Q_i=Q_{н}=0$ - by Equations (2) - (4) [3]. It follows from **Figure 3** that strip gage increment has a linear dependence on temperature gradient Δt_5 (Δt_5 is a temperature gradient between sections 2 and 4 of the middle stock before stand No. 5), which corresponds to theoretical calculations [2].

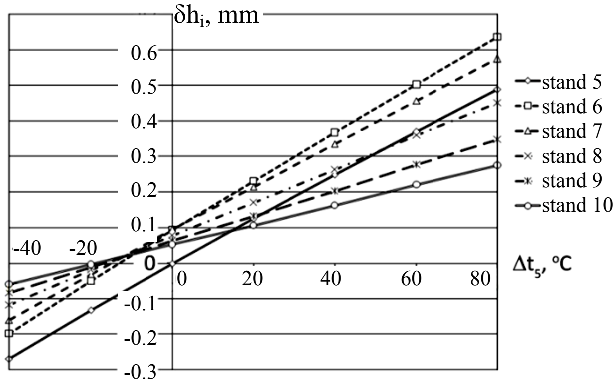

Figure 3. Change of longitudinal gage interference of strip 2x1250 mm in the finishing train of hot rolling broad-strip mill 1680 depending on temperature gradient between sections 2 and 4 of the middle stock before stand No. 5

According to calculations (**Figure 3**), at Δt_5=60°C the strip gage increment after stand No. 5 is δh_i=0.37 mm, and after stand No.10 – δh_i = 0.221 mm. The drop of strip temperature in stand No. 10 by one degree leads to increase of strip gage by $\delta h_i \approx 0.0037$ mm which is less than in the experiments [2].

Increase of strip gage increment at Δt_5=0 in stands No. 6-10 is caused by congenital gage interference and change of temperature mode of rolling.

One of the methods to decline gage increment along the length of strip (longitudinal gage interference) is to decrease the temperature gradient between leading and trailing ends of the middle stock (strip). It can be achieved by differentiated water supply along the length of strip. For example, when rolling a trailing end of middle stock 4-6 m long, without water feed on its surface the temperature of this section of the stock raises by 15-25°C. As a result, the longitudinal gage interference decreases by δh_i=0.05-0.07 mm after stand No. 10. When a trailing end of the strip is in the finishing train, water-off will ensure raise of strip temperature and additional decrease of longitudinal gage interference. In that case, with decrease of strip gage, the temperature increment on its trailing end will increase and efficiency of this method application will be greater from the first stand of finishing train to the last one. Before next strip delivery in the finishing train, water feed in hydrodescaling and in roll cooling collecting channels is reactivated.

Conclusions

The methods to decrease longitudinal gage interference of strips under hot rolling are considered. Implementation of these methods does not require significant material expenses.

References

1. M. Meerovich, A. I. Gertsev, V. S. Gorelik, E. J. Klassen. *Precision Increase of Sheet Products,* Metallurgiya, Moscow, 1969, 264 p.*
2. K. N. Tkalich, Yu. V. Konovalov. *Precise Rolling of Thin Strips,* Metallurgiya, Moscow, 1972, 176 p.*
3. V. A. Nikolaev, D. A. Matyushenko. *Metal i Litye Ukrainy*, 2007, No. 8, pp. 20-22.*
4. V. A. Nikolaev *Rolling Theory,* Zaporizhzhya State Engineering Academy, Zaporizhzhya, 2007, 228 p.*
5. V. A. Nikolaev. *Izvestiya Vuzov. Chernaya Metallurgiya*, 2005, No. 11, pp. 24-29.*
6. V. A. Nikolaev. *Izvestiya Vuzov. Chernaya Metallurgiya*, 2006, No. 7, pp. 35-38.*

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Оперативные способы снижения продольной разнотолщинности полос

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Предложены и теоретически обоснованы способы снижения продольной разнотолщинности полос при горячей прокатке, реализация которых не требует значительных материальных затрат.